Perceptual Control Theory

An Overview of the Third Grand Theory in Psychology

Introductions, Readings, and Resources

Dag Forssell, Editor

This book

Perceptual Control Theory :
An Overview of the Third Grand Theory in Psychology
Introductions, Readings, and Resources

is available as a free PDF download from the publisher's website, www.livingcontrolsystems.com, as well as the free online libraries www.archive.org and www.z-lib.org, which will help ensure that this book and others on the subject of ***Perceptual Control Theory, PCT,*** will be available to students for many decades to come.

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8. Psychology—Research—Methodology. 9. Management.
10. Education. 11. Evolutionary epistemology.
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I. Title.
II. Title: An Overview of the Third Grand Theory in Psychology

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The Thinker image courtesy of the Baltimore Museum of Art

Prior (2008-2014) editions title:
Perceptual Control Theory: Science & Applications – A Book of Readings

Updated, expanded and rearranged.
New subtitle, new ISBN numbers, new publication date.
May, 2016

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- Benchmark Publications and Bill Powers for selections from *Behavior: The Control of Perception*, *Making Sense of Behavior,* and *Living Control Systems* I, II and III.
- Bill Powers, Tom Bourbon, Jim Soldani, Tim Carey, Rick Marken, Bruce Nevin, and Fred Nickols for papers they have written about PCT.
- Kiddy World Promotions B.V. and Frans Plooij for selections from *The Wonder Weeks.*
- Routledge and Tim Carey for selections from *Principles-based Counselling and Psychotherapy*.
- Rick Marken for selections from *Doing Research on Purpose*.
- Bartley Madden for selections from *Reconstructing Your Worldview*.
- Shelley Roy for selections from *A People Primer: The Nature of Living Systems*.
- Australian Academic Press Group, Rick Marken and Tim Carey for selections from *Controlling PEOPLE.*

I am pleased to include selections from books published by Living Control Systems Publishing.

A heartfelt thanks to Bruce Nevin for help editing and clarifying text throughout.

Hayward, California
Dag Forssell

About the cover:

Rodin's *The Thinker* is associated with the René Descartes' philosophical statement:

I think—therefore I am.

Once you understand PCT, you realize that control is the fundamental process of life. All living organisms control as long as they live and when control ceases, life ceases. Control and living are inexorably intertwined. Thus:

I control—therefore I live—therefore I control—therefore I live...

The subject matter of this book

This book is all about a scientific revolution in progress. A perspective:

A revolution occurred in the engineering sciences

In 1927, Harold Stephen Black, an American electrical engineer, revolutionized the field of applied electronics by inventing the negative feedback amplifier, a control device. Some consider his invention to be the most important breakthrough of the twentieth century in the field of electronics because of its wide application.[1]

Today, we are surrounded by control devices that are doing work humans used to perform. One application most everyone is familiar with is the cruise control in your car. Here, instead of the driver monitoring the speed of the car and speeding up or slowing down as needed, a negative feedback control circuit compares the speed of the car to the speed set by the driver, and the moment they differ moves the accelerator as needed.

The problem this book addresses

Engineers understand how control works and now build capable robots, but most people (including psychologists) have only a very general sense that we control and do not yet understand this fundamental, very simple phenomenon that is ubiquitous in nature. As a result, people all around the world, in all walks of life, of all persuasions, scientists and lay people alike, are profoundly ignorant of how living organisms—and that includes people—actually function. We all suffer the consequences of this ignorance—in our personal lives, on the job, in our society and all over the world. Dr. Tim Carey has called this our greatest global challenge.[2]

A scientific revolution in the life sciences is on the way

Understanding the phenomenon of control provides an explanation for the way living organisms behave, what behavior is, how it works, and what it accomplishes. This understanding has been developed by William T. Powers in great detail for 60 years. Powers' work, which applies the theory of control to the field of psychology, is now called Perceptual Control Theory, PCT. It lays a foundation for psychology and related life sciences to become natural sciences rather than merely descriptive arts.

All control systems control their perceptions, not their behavior or actions (output). Living organisms behave in order to perceive that which they want to experience. Behavior/action is automatic—what it needs to be under the circumstances to make perceptions match internal specifications, wants. This is why behavior is the wrong thing to study. Behavior/action is not what life is about; it is about perceiving/experiencing that which you want to experience. This instant as well as in the long run.

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1 For more, see **https://en.wikipedia.org/wiki/Harold_Stephen_Black**.

2 See **www.tinyurl.com/GreatestGlobalChallenge**.

Blue text signifies links you can click on to move around in this book.

Comments on PCT

- PCT is an innovation that destroys [social science] expertise on a massive scale[1]
- There is one clear message that we have to send to the life sciences concerned with behavior, which in one way or another means all of them. It is that all the behavioral sciences have been pursuing an illusion during their whole history, the behavioral illusion. They have been misled by the actions that organisms use for generating effects that are of importance to them into thinking that those actions are the effects of importance.[2]
- Bill Powers is one of the clearest and most original thinkers in the history of psychology. For decades he has explored with persistence and ingenuity the profound implications of the simple idea that biological organisms are control systems. His background in engineering allowed him to avoid many of the traps that have victimized even the best psychologists of the past. I believe his contributions will stand the test of time.[3]
- I will disagree in serious ways with most of the widely accepted psychological theories you encounter in popular literature, in textbooks (of whatever discipline), and in the halls of academe. I will agree with the other theories at some points, but the underlying assumptions of the theory here (Perceptual Control Theory) are not those you will find either printed or implied on many of the pages printed about psychology. In that sense, this book is disputatious. I do not, by the way, claim that those other authors and lecturers are immoral or mentally deficient. I claim only that they are wrong.[4]
- Bill Powers' work in the 20th century will prove to be as important for the life sciences as Charles Darwin's work in the 19th century. By the time this notion has become common knowledge, historians of science will be very happy with this correspondence between two giants.[5]
- The best way to prove that the explanation actually explains something is to cast it as a working simulation, turn it on, and let it operate by the rules you have put in it. If you can't do that, then you don't have a model *or* an explanation. All you have is more or less persuasive rhetoric.[6]

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1 Summary by Mats Lundqvist, Director of the Chalmers University of Technology School of Entrepreneurship, while discussing Mats' reading of the PCT literature. Original Swedish: "PCT är en massivt kompetensförstörande innovation".

2 Bill Powers in a post to collaborators working on what became the paper *A Model for Understanding the Mechanisms and Phenomena of Control.*

3 Comment on *Dialogue Concerning the Two Chief Approaches to a Science of Life* by Henry Yin, Professor of Psychology & Neuroscience at Duke University.

4 Philip J. Runkel in his Preface to *People as Living Things; The Psychology of Perceptual Control.*

5 Comment on *Dialogue Concerning the Two Chief Approaches to a Science of Life* by Dr. Frans X. Plooij, author of *The Wonder Weeks*, Arnhem, The Netherlands.

6 From Bill Powers' Preface in *Living Control Systems* (1989) (page xvi).

Preface to the 2016 edition

This Book of Readings provides an overview of Perceptual Control Theory (PCT), with selections from the extensive literature of the field and pointers to tutorial programs and other resources. It has been called "The PCT Handbook". I hope this edition lives up to that designation—that you find it inspiring and useful.

The first book of readings was issued in 2008. The changes to this 2016 edition with a new cover, subtitle, ISBN numbers, and publication date are as follows:

Papers. New to this section are *The Domain of PCT, Evaluating PCT, The Future of PCT, A PCTer's Lament,* and *A Consultant's Lament*.

Books. Several entries have been added. Note that while this parenting book does not explain PCT, *The Wonder Weeks* shows when levels of perception develop in infants. The selections from *Management and Leadership* have been changed to provide a complete illustrated explanation for the Rubber Band Experiment.

Reviews. This new section features reviews of PCT books, including such gems as the original 1973 review of *Behavior: The Control of Perception*. All are available as pdf files at www.pctresources.com/Other/Reviews.html.

Focus on demonstrations. PCT is a generative science. This sets it apart from contemporary social sciences, where "modeling" is just a word and no functional explanations can be offered. Functional demonstrations of many kinds are possible.

Resources at websites. The list of websites, archives and presentations has been updated. Visit iapct.org for the most current list of resources and announcements.

Papers on-line. One of the papers in this new section is *Perceptual Control Theory and its Application*, which includes a discussion of some common but incorrect objections to PCT voiced by some of the most prominent psychologists of today. The ignorance, distortions, and misunderstandings reviewed here are possible only because the fields of psychology and social science do not require an understanding of the natural sciences. Most of these papers can be downloaded from www.pctresources.com/Other/Online.html.

Focus on MOL. This new section presents resources focusing on the Method of Levels (MOL), an application of PCT to psychotherapy.

Focus on management. An important application of PCT is better management practices. These flow naturally from an understanding of our levels of perception.

Note: As with previous editions, if you downloaded this e-book from www.livingcontrolsystems.com, you are welcome to pass it on, but you may not post it on any website without permission. You can purchase a printed copy from your favorite Internet bookstore, or ask your local bookstore to order a copy for you.

Dag Forssell, Hayward, CA. May, 2016

The frontispiece below is an excerpt from a loving tribute to Bill Powers.
For the full letter see **www.iapct.org/files/RunkelTribute.pdf**

. . . .

You did not invent the loop. It existed in a few mechanical devices in antiquity, and came to engineering fruition when electrical devices became common. Some psychologists even wrote about "feedback." But the manner in which living organisms make use of the feedback loop—or I could say the manner in which the feedback loop enabled living creatures to come into being—that insight is yours alone. That insight by itself should be sufficient to put you down on the pages of the history books as the founder of the science of psychology. I am sure you know that I am not, in that sentence, speaking in hyperbole, but in the straightforward, common meanings of the words.

In a decade or two, I think, historians of psychology will be naming the year 1960 (when your two articles appeared in *Perceptual and Motor Skills*) as the beginning of the modern era. Maybe the historians will call it the Great Divide. The period before 1960 will be treated much as historians of chemistry treat the period before Lavoisier brought quantification to that science.

. . . .

Philip J. Runkel, October 13, 1999

Papers

Books

Papers shown here (and many more) are posted individually at www.livingcontrolsystems.com

Blue text signifies links you can click on to move around in this book.

Books

Reviews

Behavior: The Control of Perception
Reviews from Science 1974, the jacket, the second edition, the Chinese edition and the web

Making Sense of Behavior: The Meaning of Control
Reviews from the web

Living Control Systems: Selected Papers of William T. Powers

Living Control Systems II: Selected Papers of William T. Powers

Living Control Systems III: The Fact of Control
Reviews from Nature, the book, and the web

Dialogue Concerning the Two Chief Approaches to a Science of Life
Comments on the book and the science

People as Living Things: The Psychology of Perceptual Control
Reviews by Len Lansky and from the web

Casting Nets and Testing Specimens: Two Grand Methods of Psychology
Reviews from the web

Controlling PEOPLE: The Paradoxical Nature of Being Human
Reviews by Bruce Nevin and Fred Nickols

The Wonder Weeks: ... help him turn his 10 ... phases into magical leaps forward
Reviews from the book. See Amazon for 500+ reviews

The Method of Levels: How to do Psychotherapy Without Getting in the Way
Reviews by Warren Mansell and from the web

Principles-Based Counselling and Psychotherapy: A Method Of Levels Approach
Reviews by Bruce Nevin and from the book

A Transdiagnostic Approach to CBT using Method of Levels Therapy
Reviews from the book and from the web

Control in the Classroom: An Adventure in Learning and Achievement
Reviews from the book and from the web

Management and Leadership: Insight for Effective Practice
Review from the web

Reconstructing Your Worldview: ..Four Core Beliefs ... Solve ... Business Problems
Reviews by Bruce Nevin and from the book

Without Miracles: Universal Selection Theory and the Second Darwinian Revolution
Reviews from Nature, the Library Journal, the book, Piero Scaruffi, and the web

The Things We Do: Using the Lessons of Bernard and Darwin ...
Reviews from the book, Piero Scaruffi, and the web

Mind Readings: Experimental Studies of Purpose
Reviews from the web

More Mind Readings: Methods and Models in the Study of Purpose

Doing Research on Purpose: A Control Theory Approach to Experimental Psychology
Review by Bruce Nevin

The Dilemma of Enquiry and Learning

Ways of Learning and Knowing: The Epistemology of Education

The Death of Jeffrey Stapleton: Exploring the Way Lawyers Think

Introduction to Modern Psychology: The Control-Theory View

A People Primer: The Nature of Living Systems
Reviews from the book

Papers

Books

Focus on demonstrations

Perceptual Control Theory can be demonstrated in compelling ways, such as movement of your arms, legs and eyes; computer tutorials and simulations, robots and bugs operating in computer programs, and functioning robots all implementing the PCT hierarchy—layers of interacting control systems.

Papers

Books

Tutorials and simulations

www.livingcontrolsystems.com/demos/tutor_pct.html
This web page features demos and simulations for DOS and Windows. Be sure to read the first pdf, *Running PCT Demos*, and note the need for emulation software to run DOS programs with recent versions of Windows. With a Windows XP computer, you can run DOS programs directly.

www.pct-labs.com/
Adam Matić's demo programs for your browser are Java versions of Powers' original DOS programs shown above, with more conversions to come.

www.mindreadings.com/demos.htm
This web page features Rick Marken's demo programs for your browser. Here are 19 interactive demos. The Baseball Catch Simulation is documented in *Doing Research on Purpose*, page 97. The Spreadsheet Simulation of a Hierarchy of Control Systems (a download) demonstrates the counter-intuitive phenomenon that the same few lower-level control systems can satisfy divergent higher level control systems at the same time. See also *Mind Readings,* page 133.

Books focusing on demonstrations

Living Control Systems III (the entire book)
People as Living Things (chapters 6, 7, 8, 9, 13, and 18. Note page 211)
Introduction to Modern Psychology (page 21)
Management and Leadership (pages 51 ff and 27 ff – in this volume)
Dialogue Concerning the Two Chief Approaches... (page xxvii, right column)

Papers in this volume where demonstrations and robots are discussed

BYTE Articles—The Nature of Robots
Running PCT Programs

Special issue of Closed Loop

Portable PCT Demonstrations. Volume 3, Number 2, Spring 1993.
http://www.pctresources.com/Journals/Files/Closed_Loop/

Websites featuring robots

Robots implemented in software and hardware
Rupert Young: **www.perceptualrobots.com/**
Richard Kennaway **www2.cmp.uea.ac.uk/~jrk/**
For Kennaway's site, note ***Perceptual control theory and robotics*** as well as ***Real-time procedural humanoid animation***, also an application of PCT

YouTube video featuring robots based on PCT

Rupert Young: **www.tinyurl.com/RupertRobots**
Adam Matić **www.tinyurl.com/AdamRobots**

Resources at websites

Websites

www.iapct.org

This is the official site for Perceptual Control Theory and the Control Systems Group. Click on LINKS to view a list of PCT-related websites. Check for news of events and additional publications.

As of May 2016, some 18 dedicated sites, blogs, discussion groups, and partial sites are listed here.

CSG-net archive

www.pctresources.com/CSGnet

This web page provides both software and data that enables you to read CSGnet from the beginning in 1990. Some important conversations are excerpted as "Selected threads".

Archive of PCT journals

www.pctresources.com/Journals

PCT journals deal with Bateson, cybernetics and PCT.

Papers

Reviews of PCT books and Papers on-line, pdf files

Books

www.pctresources.com/Other

Listed under *Reviews* and posted as pdf files at this location.

What students are saying about PCT

www.pctweb.org/whatis/students.html

Opinions by students who were exposed to PCT from the very beginning of their undergraduate education.

Teaching a New Generation about Psychology

www.tinyurl.com/TEDxPsychBlunders

A TEDx talk at Burnley College by Warren Mansell shows how to correct five blunders that have become generally accepted in psychology.

Papers on-line

The Origins and Future of Control Theory in Psychology
Paper explains that PCT is the third Grand Theory in psychology, with the first two being the behaviorist and cognitive theories.
psycnet.apa.org/journals/gpr/19/4/425/

Perceptual Control Theory and its Application
PCT—Necessity, Engineering, Hierarchy, Reorganization, Objections
www.researchgate.net/publication/220107835

Understanding Collective Control Processes
Pointing the way to a new approach in sociology. A chapter in *Purpose, Meaning, and Action: Control Systems Theories in Sociology.*
www.researchgate.net/publication/235344131

An Embodied Grammar Of Words
Integrating the science of PCT and the science of language
www.zelligharris.org/Embodied.grammar.pdf

Restoring Purpose in Behavior
Challenging the standard paradigm in neuroscience and psychology. A chapter in *Computational and Robotic Models of the Hierarchical Organization of Behavior.*
www.researchgate.net/publication/277721485

How Basal Ganglia Outputs Generate Behavior
The "Basal Ganglia" control Transition perceptions. This explains symptoms of Parkinson's disease and generates testable predictions.
www.hindawi.com/journals/aneu/2014/768313/ article
www.hindawi.com/journals/aneu/2015/504073/ correction

A Biopsychosocial Model Based On Negative Feedback And Control
A review article; Frontiers in Human Neuroscience
www.tinyurl.com/biopsychosocial-model

Models and Their Worlds
Comparing the behavior of different conceptual models
www.tinyurl.com/LivingThings page 137
or Closed Loop Vol 3 #1 at www.tinyurl.com/PCTjournals

A Model of Kinesthetically and Visually Controlled Arm Movement
Detailed info on the "Little Man" computer program
www.tinyurl.com/LittleManPaper
See also www.tinyurl.com/PCTsimulations and scroll down to "Little Man"

Man-Machine Interface Design
Perceptual control and layered protocols: fundamental concepts & grammar
1) www.researchgate.net/publication/223302270
2) www.researchgate.net/publication/220108447

PDFs of some of these articles posted at www.pctresources.com/Other.

Papers

Books

Focus on MOL

The Method of Levels (MOL) is an application of PCT which benefits people directly and which for the first time makes psychotherapy coherent and rational. It is based on the hierarchical structure of PCT.

Dr. Timothy Carey was first to use MOL exclusively in his clinical practice. While working for Scotland's National Health Service from 2002 to 2007, he used this approach exclusively with primary care patients. Tim, together with colleagues who had learned MOL from him, reduced the waiting list from 15 months when he arrived to less than one month five years later. Tim Carey, Warren Mansell and Sara Tai now provide training workshops in MOL for clinicians and conduct research projects investigating different aspects of MOL with postgraduate research students.

Website

Tim Carey's MOL website: **www.methodoflevels.com.au/**

Books focusing on or illustrating the Method of Levels

Living Control Systems II, the chapter on An Experiment with Levels
Making Sense of Behavior, the chapter on Inner Conflict
The Method of Levels
Principles-Based Counselling and Psychotherapy
A Transdiagnostic Approach to CBT
Control in the Classroom

Papers
Books

Papers in this volume where MOL is discussed

Reorganization and MOL
A Model for Understanding the Mechanisms and Phenomena of Control
About The Method of Levels

Special issue on PCT and MOL

Ten papers on the theory, research and practice of PCT and MOL.
The Cognitive Behavioural Therapist, Volume 2, Issue 3, Sep 2009.
www.tinyurl.com/PCTandMOL

Science and Practice of Transdiagnostic CBT: A PCT Approach

International Journal of Cognitive Therapy, 7(4), 2014
www.researchgate.net/publication/273802155

Enabling Flexible Control

Warren Mansell's May Davidson Award Lecture – DCP 2011
www.tinyurl.com/FlexibleControl

Article in Elsevier's *Clinical Psychology Review:*

An integrative mechanistic account of psychological distress, therapeutic change and recovery: The Perceptual Control Theory approach
www.tinyurl.com/IntegrativeAccount

The Take Control Course: Conceptual Rationale for the Development of a Transdiagnostic Group for Common Mental Health Problems

Review article: Frontiers in Psychology, 10 February 2016
www.researchgate.net/publication/293824259

Focus on management

An understanding of Hierarchical PCT and MOL provides insight for personal introspection as well as for dealing with others. As reported in *Effective Personnel Management,* Jim Soldani managed well by "getting into the other person's world". Jim asked questions that brought out higher levels in his associates' perceptual hierarchies, thus gaining insight into their understanding, circumstances, and desires. Jim tells me that in many interactions his questioning—and associates trusting him with thougtful answers—would uncover internal conflicts, such as an associate wanting a promotion, but being uncomfortable with the idea of confronting others to resolve problems which could hinder performance. Jim was able to help/coach associates to resolve their conflicting desires and become more productive members of the team. Understanding PCT and the hierarchy of levels can make management and work in organizations more rewarding for managers and associates alike.

Books focusing on management

Management and Leadership: Insight for Effective Practice
People as Living Things, Part VII, The Social Order
Reconstructing Your Worldview ... Four core beliefs...

Papers in this volume where management is discussed

Effective Personnel Management
How I Applied PCT to Get Results
A consultant's lament

An interesting website

Fred Nickols has written several papers, doing his best to introduce PCT to managers in plain language. Check out the links at his website.
www.nickols.us/controltheory.html

Papers
Books

Ten Minutes — An Introduction to PCT

In November 1991, Bill Powers graciously accepted my invitation to fly from Durango to Los Angeles to attend my first one-day program introducing what we now call Perceptual Control Theory, PCT. He also graciously abstained from too much detailed critique of my performance. The next morning, before I took him back to the airport, Bill sat down to compose what he thought might be a more effective introductory summary of what PCT is all about. Here is what he wrote. The original is reproduced on the following page.

Dag Forssell

10 minutes

1. *There have been two paradigms in the behavioral sciences since 1600 AD. One was the idea that events impinging on organisms make them behave as they do. The other, which was invented in the 1930s, is control theory. We are going to explore the second of these paradigms.*
2. *Control theory explains how organisms ~~can~~ control what happens to them. This means all organisms from the amoeba to ~~mankind~~ Humankind. It explains why one organism can't control another without physical violence. It explains why people deprived of any major part of their ability to control soon become disfunctional, lose interest in life, pine away, and die. It explains why it is so hard for groups of people to work together even on something they all agree is important. It explains what a goal is, how goals relate to behavior, how behavior affects perceptions, how perceptions define the reality in which we live and move and have our being. Control theory is the first ~~scien~~ scientific theory that can handle all these phenomena within a single testable concept of how living systems work.*

Bill Powers

Papers

Books

Papers

Books

10 minutes

(1)

1. There have been two paradigms in the behavioral sciences since 1600 AD. One was the idea that events impinging on organisms make them behave as they do. The other, which was invented in the 1930s, is control theory. We are going to explore the second of these paradigms.

2. Control theory explains how organisms ~~can~~ control what happens to them. This means all organisms from the amoeba to ~~mankind~~ humankind. It explains why one organism can't control another without physical violence. It explains why people deprived of any major part of their ability to control soon become disfunctional, lose interest in life, pine away, and die. It explains why is is so hard for groups of people to work together even on something they all agree is important. It explains what a goal is, how goals relate to behavior, how behavior affects perceptions, how perceptions define the reality in which we live and move and have our being. Control theory is the first ~~seen~~ scientific theory that can handle all these phenomena within a single testable concept of how living systems work.

Bill Powers

NOV 3, 1991.

The Domain of Perceptual Control Theory (PCT)

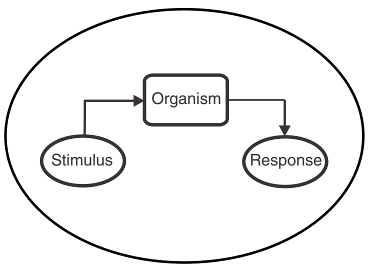
Exploring the significance of PCT without explaining it

Bill Powers always sought more effective ways to explain PCT. One way was to place PCT between *Behaviorism* and *Cognitive Psychology*, because from the outside controlling looks like stimulus-response, and from the inside controlling is experienced as thinking and acting. The summary illustrations below portray these relationships. For overview as well as in-depth explanations of PCT, see several papers and books at PCT websites.

Papers

Books

Behaviorism



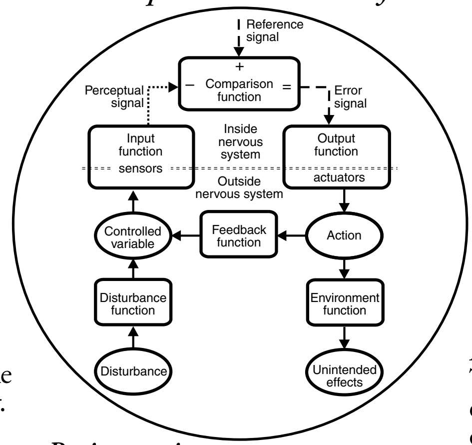
Basic premise
Stimuli in the environment make the organism respond with ***output***.

Pro
- Intuitively obvious—we can see how changes in the environment make people and animals react.
- Long tradition—350+ years.
- Embedded in our culture
- ***Everybody*** knows this is true.

Con
- Scientific method for inanimate objects misapplied to living things.[1]
- Denies existence of purposes, goals.
- Diverse actions are counted as the 'same response'.
- False/misleading explanations and terminology.

Prospects for the future
None. A natural science cannot be built on a descriptive, non-functional, mistaken paradigm.

Perceptual Control Theory



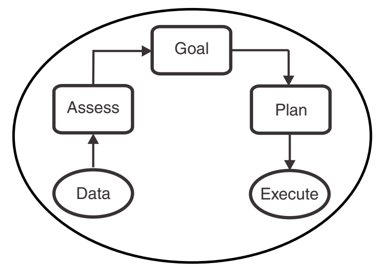
Basic premise
Living organisms are systems of control systems, which use their actions to control their sensed perceptual ***input***.

Pro
- Scientific method for control systems correctly applied to living things.
- Long development—1952+.
- Explanations of purposes, conflicts, cooperation, etc. make sense.
- Interactive demonstrations and computer simulations compelling.
- All functional elements explicitly defined and quantifiable.
- Models behavior of individuals.[2]
- PCT principles help explain life.

Con
- Far from intuitively obvious—has to be demonstrated, studied.
- Cannot be integrated into any prevalent school of psychology.
- Shows that current psychologies are fundamentally mistaken.

Prospects for the future
Bright. PCT lays a foundation for psychology and the life sciences to become natural sciences.

Cognitive Psychology



Basic premise
The brain evaluates data from the environment, creates a plan based on goals and computes commands to muscle fibers, creating ***output***.

Pro
- Intuitively obvious—we sense that we think and act.
- Long tradition—1950s+.
- Currently dominant.
- Embedded in our culture
- ***Everybody*** knows this is true.

Con
- Scientific method for inanimate objects misapplied to living things.[1]
- Physically impossible for the brain to specify muscle action.
- Assess–goal–plan: Contrary to common assumptions, the brain does ***not*** processes symbols the way a digital computer does.
- Poorly defined elements.
- False/misleading explanations and terminology.

Prospects for the future
None. A natural science cannot be built on false assumptions, vague definitions, and non-functional word-pictures.

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1 The scientific method as used in ***output***-focused psychologies relates an Independent and a Dependent variable. See *The Experimental Method is Crippling Psychology*.

2 For theories & modeling, see *Experience, Reality, and HPCT*.

It matters little which of the great multitude of psychological theories you have come to believe in. You act to experience what you want to experience and keep it that way by resisting disturbances, always have, always will.
- You ***are*** a system of control systems. Once you understand, all the old explanations crumble. If you want to understand how we function—what behavior is, how it works, and what it accomplishes—PCT is the only game in town.
- With PCT, you gain a new perspective on conflict and how to resolve it, relationships, management, feelings...

Over...

The Domain of PCT, continued. About scientific revolutions—and one most people know about.

While this comparison focuses on psychology, the insight PCT offers reaches far beyond psychology and the social sciences.

- When scientists who study living things are ignorant of how control works, they cannot recognize control in action. This affects research in biology, neurology and more. Engineers have understood how control works since 1927.
- The basic function is simple: Control is comparing what should be with what is and acting to eliminate any difference.
- Life is control "all the way down". For example, control is essential for flawless replication and repair of DNA across millions of generations. Control is necessary to guide the growth of any organism. Control is ubiquitous in nature. Have a look at Bill Powers' essay *The origins of purpose: the first metasystem transitions* at site in footer.

Explore without explaining

If you just heard about PCT you might ask what is the big deal, but not want to study the function/workings of a control system, much less a hierarchical system of same.

This short paper is meant to outline the pros and cons of PCT compared to current psychologies.[1]

The idea of PCT rendering contemporary psychologies obsolete may seem preposterous.

About Scientific Revolutions

Scientific revolutions[2] are rare but significant. Examples include how the discovery of Oxygen rendered the chemical science of Phlogiston obsolete, the rise and decline of the caloric theory, and the atomic-molecular theory. These and more are described in the *Harvard Case Histories in Experimental Science*, edited by James Bryant Conant, then president of Harvard, for students majoring in the humanities or social sciences.[3]

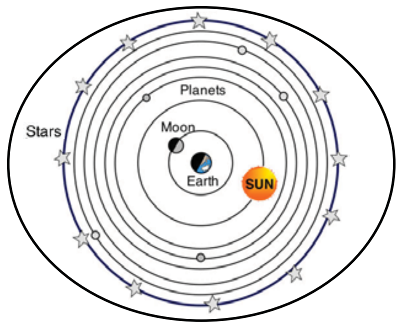
PCT lays a foundation for psychology to become a natural science, not merely an art. Once you understand how you function, you can change your life and relationships for the better. Welcome to the PCT revolution!

1 For qualitative differences, see *Descriptive versus generative scientific theories*.

2 The seminal work on scientific revolutions is *The Structure of Scientific Revolutions* by Thomas S. Kuhn.

3 Download from pctresources.com under Public.

Earth-centered astronomy
Ptolemy
Almagest (150 AD)
Originating in antiquity



As of the late 1500s...

Basic premise

The earth is the immovable object at the center of the universe, with all heavenly bodies revolving around it.

Pro

- Intuitively obvious—anyone who looks at the heavens can see this.
- Long tradition—1,200+ years.
- Mathematical projections can predict solar eclipses.
- Embedded in our culture.
- ***Everybody*** knows this is true.

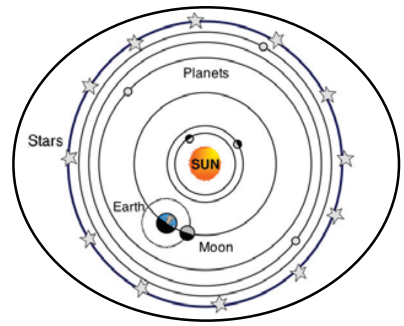
Con

- Physically impossible (But people could not know that in the 1500s.)
- False/misleading explanations and terminology.

Prospects for the future

None. A natural science cannot be built on non-functional, non-quantifiable descriptions of appearances.

Sun-centered astronomy
Copernicus
On the Revolution of the Heavenly Spheres (1543 AD)



As of the early 1600s and today

Basic premise

The sun is the center of the solar system, with planets moving around it. The earth revolves on its axis. Stars appear stationary, because they are very far away.

Pro

- A physically correct explanation.
- Explanations make sense.
- Space travel possible.

Con

- Far from intuitively obvious—the functioning model has to be taught.
- Shows that Ptolemy is fundamentally mistaken.

Prospects for the future

Bright. Lays a foundation for astronomy to become a natural science, not a descriptive, non-functional art.

Dag Forssell, 2015

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It matters little whether you believe the sun is carried by the gods in a carriage across the sky, that the earth is flat, or the center of the universe. The earth spins on its axis, always has, always will. Once you understand, all the old explanations crumble. If you want to engage in space travel, sun-centered astronomy is the only game in town.

Descriptive vs. Generative Scientific Theories

by Dag Forssell 2004
Note on page 3 added 2010

The spectacular progress we have seen in the physical sciences in the last 400 years, compared to previous millennia, is largely due to a historic shift from descriptive science to generative science.

By a generative theory we mean a postulated organization of functional components with well defined, quantified interactions. Operating by itself as a model or in simulation, this organization generates action which validates or disproves the particular theory. Other terms used to describe the two kinds of theory are Empirical versus Fundamental, where empirical means derived from data using correlations or statistics (without any understanding of underlying reasons) and fundamental means derived from basic ideas, or laws of nature.

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This comparison of descriptive and generative science in the fields of astronomy and psychology illustrates the well-known scientific revolution in astronomy and suggests that a similar upheaval is overdue in psychology and related fields.

The starting point for the modern era of physical science was the Copernican idea of a Sun-centered universe. Copernicus's model was adopted and promoted by Galileo, who among other things carried out meticulous studies of acceleration, thereby establishing the basic methods of modern physical science. The model of the solar system was later refined by Kepler and the laws of nature that govern it defined by Newton, completing the conversion of astronomy from descriptive to generative. Replacing the previous descriptive, "cut-and-try" approach to physical science, this sequence of developments laid the foundation for our contemporary, generative, physical and engineering sciences.

As new theories have been proposed and tested in the physical sciences, numerous scientific revolutions have followed, but as Thomas Kuhn explains in *The Structure of Scientific Revolutions*, textbooks don't usually explain or even mention previous concepts, so students are left with the impression that science is a matter of accumulating facts, where of course all new facts must fit previous facts. Not so. Numerous upheavals have taken place in physical science in the last 400 years.

DESCRIPTIVE ASTRONOMY

Concept
Formalized by Greek astronomer Ptolemy (approx. 87–150 AD) in one of the world's oldest scientific works, the *Almagest*, the basic concept was that the Earth was an immovable object at the center of the universe. The idea that the Sun and all the other heavenly bodies rise in the East and revolve around the Earth seemed obvious and was accepted by scientists and lay people alike.

Study
You study the description of each heavenly path and master the tools of this science—the geometry and mathematics of circles and epicycles.

Description and interpretation
Descriptions assume that we experience reality directly through our exquisite senses—in living color and stereophonic sound. What we observe in the heavens is what is going on.

Prediction and testing
You predict future positions by projecting forward from current observations, using the descriptive mathematical tools. Because of the great regularity of the heavenly movements, such projections were very accurate. Lunar eclipses could be forecast years in advance. Ptolemy's descriptive model must be said to have been quite successful.

Limitations and complications
Ptolemy's descriptive mathematics provided no explanation for the phases of the moon or planets. About eighty epicycles (read fudge-factors) were defined by Ptolemy to make the basic geometric descriptions hang together.

Use
Heavenly constellations were noted, named and invested with significance by the Ancient Egyptians, from whom we have inherited Astrology. The model served as the basis for development of the calendar and was helpful for navigation at sea. The Catholic church accepted Ptolemy's circles and spheres and concluded that the planets are supported and carried by perfect crystal spheres as they revolve around the Earth.

To learn more
The University of St. Andrews web site:
http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Ptolemy.html
is one good source of information on Ptolemy.

DESCRIPTIVE PSYCHOLOGY

Concepts
Basic concepts have included sequences of stimulus and response.

Behaviorists believe the environment determines what we do. Cognitive psychologists believe the brain issues commands for particular actions.

In both cases, explanations focus on output—on particular actions. Both these beliefs are at present almost universal among scientists and nonscientists alike.

Study
You study a vast number of theories put forth by a multitude of psychologists. You master the tools of statistics, which can provide an illusion of causal relationships and thus an illusion of understanding.

Description and interpretation
Descriptions assume that we experience reality directly through our exquisite senses—in living color and stereophonic sound. What we observe and describe is objective truth.

Prediction and testing
You predict future behavior basically by saying: "I've seen this before—I'll see it again." Due to the great variety of conditions and individuals, such predictions have an extremely poor track record.

Comparison with a working model has never been required. No psychological theories have ever been disproven or discredited.

Limitations and complications
The field of psychology is extraordinarily fragmented. The focus is on behaviors, which are classified and discussed, but no functional, physical explanations are offered for even the simplest phenomena.

Use
Descriptive psychological ideas of many different kinds are used throughout our culture. They are part of our language and pervade education, politics, management etc.

People have long used unverified concepts from these descriptive sciences to feel they are explaining events.

To learn more
We live in a culture dominated by descriptive sciences of psychology. Umpteen books on various psychologies are published every year. Findings are regularly reported on the evening news.

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GENERATIVE ASTRONOMY

Origin

Polish astronomer Nicolaus Copernicus (1473–1543) proposed the Sun-centered alternative to the Earth-centered Ptolemaian model. Copernicus distributed a handwritten book called *Little Commentary* to other astronomers already in 1514. His major work *On the Revolution of the Heavenly Spheres* was published in 1543. Copernicus work (still descriptive, featuring some epicycles, but on the right track) was championed by Galileo Galilei (1564-1642), who found evidence supporting the concept, such as phases of Venus and moons of Jupiter using the newly invented telescope. Johannes Kepler (1571-1630), using observations collected by Tycho Brahe (1546-1601), found that if planetary paths were elliptical, not circular, they would fit the data—doing away with the need for epicycles. Finally, Isaac Newton (1642-1727), formulated the laws of motion and gravity, which, when operating on heavenly bodies interacting in the mechanism we call the Solar system, generate the elliptical motions observed in the heavens. The 200-year conversion of astronomy from a descriptive to a generative science was complete.

Postulates

Copernicus's *Little Commentary* states seven axioms, which suggest the structure of the universe:

1. There is no one center in the universe.
2. The Earth's center is not the center of the universe.
3. The center of the universe is near the sun.
4. The distance from the Earth to the sun is imperceptible compared with the distance to the stars.
5. The rotation of the Earth accounts for the apparent daily rotation of the stars.
6. The apparent annual cycle of movements of the sun is caused by the Earth revolving round it.
7. The apparent retrograde motion of the planets is caused by the motion of the Earth from which one observes.

GENERATIVE PSYCHOLOGY

Origin

Developed by William T. (Bill) Powers (1926–). Bill was trained by the U.S. Navy as an electronic technician to service control (servo) systems. After WW II, he obtained a B.S. degree in physics. An interest in the important subject of human affairs led him to enroll in a graduate program in psychology, but he left after one year because his proposed Masters Degree thesis, involving control by rats, was not acceptable to the Spencian psychologists then in charge. He began his development of Perceptual Control Theory (PCT) in the early 1950s by applying control engineering and natural science to the subject of psychology. His major work *Behavior: the Control of Perception* was published in 1973.

In this work, Powers proposes a structure of our nervous system, complete with mechanisms in some detail and, most important, functional interactions between the various elements and clusters of these mechanisms. The result is a coherent whole that can be tested to see if it functions in a way that rings true when compared to our observations of the real thing—human beings and animals. PCT lays a foundation for a new beginning, a new way to think about and perform research in psychology and related fields.

Postulates

Philip J. Runkel spells out postulates of Perceptual Control Theory (PCT) in *People as Living Things*, (page 57):

1. Causation in the human neural net is circular and simultaneous.
2. Action has the purpose of controlling perception. Controlling perception produces repeatable consequences by variable action.
3. A controlled perception is controlled so as to match an internal standard (reference signal). Every internal standard is unique to the individual, though two individuals can have very similar standards.

One of the deductions one can make from these postulates is that particular acts are not, in general, predictable.

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Note:

As discussed in *Big Bang* (2004) by Simon Singh, page 22 ff, and *The Structure of Scientific Revolutions* (1970, 1996) by Thomas Kuhn, page 75, Aristarchus of Samos (circa 310-230 BC), proposed a heliocentric solar system. On pages 34-35 and 68-69, *Big Bang* features informative overviews of the evidence for the earth-centered model and the sun-centered model in Aristarchus' era and as of 1610 AD, after Galileo's observations. I leave it to another student of PCT to present a similar overview of the evidence for descriptive versus generative psychology.

Generative astronomy, continued

Postulates, continued

Newton's three laws of motion and law of gravity suggest the dynamic physical states of and interactions between moving objects:

Motion:

1. Every body will remain at rest, or in a uniform state of motion, unless acted upon by a force.
2. When a force acts upon a body, it imparts an acceleration proportional to the force and inversely proportional to the mass of the body and in the direction of the force.
3. Every action has an equal and opposite reaction.

Gravity:

> Every particle attracts every other particle with a force that is proportional to the product of their masses and inversely proportional to the distance between them.

The structure and functional interactions allow the scientific model to generate action by itself. This can be compared to actual observations as well as used to predict future states of the heavens.

Study

You grasp the idea and generative model of the solar system by studying the mechanism and dynamic physical relationships between moving objects.

You realize that the concept of an Earth spinning around its axis while revolving around the Sun is counter-intuitive, but once the mechanism and the quantifiable physical interactions have been studied, it is not particularly difficult to visualize and understand.

Description and interpretation

You realize that appearances in the heavens can be very deceiving. What looks obvious to the intuitive observer may be better explained by a very different mechanism operating in ways that are not readily apparent and can only be inferred from various observations, interpreted through the framework of a proposed mechanism.

Generative psychology, continued

Postulates, continued

These postulates are summarized and amplified on page 129:

> Perceptual control theory claims that behavior controls perception—at every time, in every place, in every living thing. The theory postulates that control operates through a negative feedback loop—neurally, chemically, and both. The theory postulates the growth of layers of control both in the evolution of the species and in the development of individuals of the "higher" animals. Those are the crucial postulations of invariance in PCT. They are asserted to have been true for the single cells floating hither and thither a billion years ago, which might have had only two layers of control, and they are asserted to be true for you and me with our many layers. They are asserted for all races, nations, sexes, and indeed all categories of humans—and indeed all categories of creatures. Furthermore, if one creature is found reliably to violate any one of those postulations (and yet go on living), the theory will immediately be revised.

Study

You grasp the idea and generative model of PCT by reading the basic text, studying tutorials that explain control in detail, by experiencing physical control systems, and by studying informative simulations you can run on your own Windows computer.

You realize that the concept is counter-intuitive, but once the mechanism and the quantifiable physical interactions have been studied, it is not particularly difficult to visualize and understand.

Description and interpretation

You realize that our various sensors merely originate neural signals when "tickled" by various physical phenomena in a physical reality we as humans will never know, but certainly do our best to draw conclusions about. You realize that everything you see, hear, touch and smell is made up of neural signals in your nervous system. The sights and sounds you enjoy are fabricated by your nervous system and "displayed" in your mind. You never experience reality directly.

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Books

Generative astronomy, continued

Prediction and testing

You build a model of the Solar System, either a physical model or a simulation of the physics, implemented in a computer program. You make sure that you program functional interactions correctly with regard to the laws of nature, such as Newton's laws of motion. You predict by allowing the model to operate by itself, generating future positions. You test these predictions against the best possible observations of the motions of heavenly bodies. You expect agreement as closely as you can measure, or you modify your model.

Predictions based on contemporary astronomy routinely match observations to the limit of measurement. Rockets launched into space have found their targets.

Consequence

Copernicus's theory was not compatible with the existing, predominant Ptolemaian theory. It ultimately gave rise to a scientific revolution, which took a long time to play out. Once you understand the mechanism of the Solar system, Newton's laws of motion and gravity and accept the generative model, you reject all the explanations inherent in the old, descriptive astronomy, though not necessarily all of its observations. You may retain some of its language, such as "The Sun rises in the East." You realize that if you are interested in moving beyond the scope of simple observation, such as calculating trajectories and forces required for space travel, the old descriptive astronomy would have been utterly useless. You recognize that the physical model and mechanisms implied by the descriptive science, such as the stars revolving around the Earth in 24 hours, was not physically feasible. You recognize that accepted phenomena of the old science, such as the epicycles, planets moving in small circles as they move in big circles, were illusions.

Use

The transition from descriptive to generative physical science laid the foundation for the engineering progress we have enjoyed for the last 400 years.

Generative psychology, continued

Prediction and testing

You build a model of an organism, either a physical model or a simulation of the physics, implemented in a computer program. You make sure that you program functional interactions correctly with regard to the laws of nature, as known from physics, kinetics, neurology, etc. You predict by allowing the model to operate by itself, generating activity on its own. You test these predictions against observations of actual, living organisms operating by themselves. You expect very close agreement, or you modify your model.

Tests to date shows correlations above .95, often around .98, between the model and the actual person.

Consequence

Powers's theory is not compatible with existing, predominant psychological theories. It causes a scientific revolution, which will take a long time to play out. Once you understand the mechanism of perceptual control and recognize that control is the pervasive, defining quality of living things, you reject the basic concepts of descriptive psychologies, though not necessarily all of their observations. You have little choice but to continue using the languages of contemporary psychologies, such as "What are you doing," because that is part of our current culture and language. (PCTers might say "What are you controlling for.") You realize that if you are interested in moving beyond the scope of repeating observations, such as developing harmonious management programs or effective educational programs, descriptive psychologies have severe limitations. You realize that the physical mechanisms implied by descriptive science, such as super-computer brains issuing commands, are not feasible in a rapidly varying environment. You recognize that many widely held ideas, such as people controlling their behavior, or responding to stimuli, are illusions.

Use

PCT, seen as an overall organizing principle for living organisms, lays a foundation for a fresh review of the life sciences, promising great progress in the future.

Papers

Books

Generative astronomy, continued

Limitations
By the time the transition from an Earth-centered to a Solar-centered astronomy was complete, the evidence for the Solar system was compelling to those who looked at the evidence. However, at that time there was much detail left to be worked out, such as detailed equations that portray the movement of the moon relative to the Earth, and astronomers are still uncovering wonders of the universe. Newtonian physics has been extraordinarily successful, but we still don't have any explanation that tells us how gravity works. But we have no doubt that it does.

Willingness and ability to understand
If you were raised at an age and in a society where everybody *knew* that the Earth rests at the center of the universe, and somebody suggested the idea of a Sun-centered universe. What would you make of it?

Would you have been willing and capable of making the effort to grasp the model? Might you have found the idea strange and obviously false?

Acceptance
The basic Sun-centered model of our local universe is widely accepted today. You most likely take it for granted because you learned the concept already in kindergarten. It was not intuitively obvious, was it?

To learn more
The Internet features numerous web sites about Copernicus, Galileo, Kepler and Newton. *On the Shoulders of Giants*, edited by Stephen Hawking, (2002) features the full text of *On the Revolution of the Heavenly Spheres* by Copernicus, *Dialogues Concerning Two Sciences* by Galileo , *Harmony of the World*, book five, by Kepler, and *Principia* by Newton.
For information on the numerous scientific revolutions in the natural sciences, see Thomas Kuhn's *The Structure of Scientific Revolutions*.

Generative psychology, continued

Limitations
PCT is a natural science in its infancy. Evidence that living organisms control their perceptions is compelling to those who examine it, and this makes all the difference for our understanding of behavior. Detailed simulations show how a hierarchy of control systems can work. Some levels of control in people can be clearly demonstrated. The postulated higher levels are by no means definitive. How perception works at the various levels is unknown; thus wonders of perception remain to be uncovered. But there can be no doubt that we control our perceptions.

Willingness and ability to understand
You have been raised in a culture where everyone *knows* that we react to stimuli in our environment and control our actions. Now someone suggests that you don't react, you oppose disturbances. You don't control your actions, you control your perceptions. Your brain does not issue commands, it sets reference signals. What would you make of it?

Are you willing and capable of making the effort to grasp the model? Might you find the idea strange and obviously false?

Acceptance
The basic PCT model of how living organisms control their internal worlds will hopefully be widely accepted fifty years from now. Children most likely will take it for granted because they will learn the concept already in elementary school.

To learn more
People as Living Things; The Psychology of Perceptual Control by Philip J. Runkel introduces the theory and shows its implications for numerous aspects of human experience, thereby illustrating its significance and challenging crucial contemporary notions of how humans and human relationships can work. This is a very good place to start. The book refers to other PCT literature and points to web sites where you can download tutorials and simulations. See http://www.livingcontrolsystems.com.

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Books

Evaluating Perceptual Control Theory (PCT)

By Dag Forssell

Has it ever occurred to you to question the idea of the solar system? The idea is highly counter-intuitive and caused a scientific revolution just a few centuries back, but in today's world this idea is taught in elementary school, so you likely take it for granted.

Another idea that may seem counter-intuitive is that all living organisms are control systems. In today's world this (actually rather simple) idea is not yet widely accepted and taught in elementary school. So when you get exposed to this idea it has to fit into your existing weave of knowledge, just as you have woven everything that you have experienced and learned since infancy into your personal understanding of the world you live in.

If you have not studied contemporary psychology as taught in universities the world over, you may have a very easy time learning how control works and incorporating the PCT explanation into your weave of understandings, concluding that it amounts to common sense. Just read the literature and work with the computer simulations to get full benefit from the insight that PCT offers.

If, on the other hand, you have studied and internalized any of the multitude of theories in contemporary psychology, and if these are now important to you, integrating PCT into your personal weave of understandings may present a challenge. PCT is a very different kind of theory. See *Descriptive vs. Generative Scientific Theories*.

Evaluating PCT by reading about it

Philip J. Runkel's odyssey is perhaps the best guide on the path from conventional psychology to PCT.

Back in the summer of 1985, one year away from retirement as professor of psychology and education at the U of Oregon in Eugene, Phil sent a six page, single space letter to William T. (Bill) Powers, with questions about an article published seven years prior.

Bill replied just six days later with a nine page letter. So began a very instructive correspondence.

You can follow Phil's careful exploration, questions and emotional upheaval as he repudiated most of his professional publications and began writing his major work, *People as Living Things*. This book, 18 years in the making, is not just a detailed review and critique of contemporary psychology in light of Perceptual Control Theory, it provides much more.

In his review of this work, Len Lansky, Emeritus professor of Psychology at the U of Cincinnati, wrote:

> Runkel has written a book on Perceptual Control Theory (PCT) which is at one and the same time: a text book for graduate and undergraduate psychology; an introduction to perceptual control theory (PCT) for the general reader; a paean to William Powers and his achievement—PCT; a memoir about his (Runkel's) exposure to PCT; and an integration of the research and theoretical work on PCT for those familiar with the theory.

The entire correspondence that led to *People as Living Things* was published in 2011 as *Dialogue Concerning the Two Chief Approaches to a Science of Life*.

Bill Powers strove his entire life to give PCT to the world. In this spirit, although they are easier to read as paperbacks or hardcover, all books on PCT that I publish can be previewed at Google Books. See www.livingcontrolsystems.com: **Click here to read several titles on-line**. To help you find your way, 30+ papers and tables of contents from 20+ books, with sample chapters from most, are included in the free pdf download *Perceptual Control Theory: An Overview of the Third Grand Theory in Psychology*.

To see what *Dialogue* is about, I recommend page i, right column, page xxxiii, right column, the following page and Phil's reply Jan 8, 1986. The full letters excerpted here are printed on pages 72-75 and 85.

To sample *People as Living Things*, I suggest the Preface on page xiii, Modeling and Theories on page 97 ff, Chapter 10 on page 123 ff, Chapter 16 on page 177 ff, and about the sometimes glacial pace of adopting new insights, page 479, right column, bottom.

Bill Powers' seminal work *Behavior: The Control of Perception (B:CP)* was published in 1973. His article *Quantitative Analysis of Purposive Systems* (the one Runkel asked questions about) followed in 1978.

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A number of psychologists have published books featuring what they call control theory. Incorporating a superficial understanding of PCT into their pre-existing weave of conventional understandings, they lost the functional aspect. These efforts have hindered rather than helped the adoption of PCT. Other prominent psychologists have taken these non-functional versions as evidence that the original was flawed, and have published critiques without ever reading B:CP or any other actual PCT literature.

A huge resource for serious students of PCT is CSGnet (Control Systems Group network), an unmoderated mailing list started in August 1990 and still going strong. A complete archive is available at pctresources.com. Here you can search for discussions on numerous aspects of psychology. Bill Powers' contributions are prolific, patiently helping people through fundamental changes in their understanding.

While attempting to build a business teaching PCT in the 1991-1994 time frame, I took the time to collect numerous threads from discussions on CSGnet. See *Threads from CSGnet*. Some are funny (StarTrek.pdf, AprilFool.pdf), some metaphorical (FableOfRadio.pdf), and some discuss the distortions that present obstacles to an adoption of PCT (DevilsBibliography.pdf).

Evaluating PCT by running simulations

PCT is a theory in the mold of the 'hard' physical sciences. Because it provides a functional model, not merely a flow-chart kind of "model" as is the norm in conventional psychology, Bill Powers began in the late 1980s to write programs that demonstrate fully functional simulations of behavior. These are available for download at livingcontrolsystems.com.

Starting in the 1990s, Rick Marken, using Java, developed demonstrations that run in your browser. See http://www.mindreadings.com/.

By 2008, with the assistance of Bruce Abbott, Bill Powers created an updated series of teaching demos for Windows that are explained by and included with *Living Control Systems III: The Fact of Control.*

Fully functional models simulating the performance of human beings are unique in the realm of the life sciences. This sets PCT apart from the huge field of psychological theories, where every psychologist worth his salt offers his or her theory of some aspect of psychology.

A scientific revolution in progress

From time to time, some prominent psychologist calls for a meta-theory capable of integrating the vast multitude of theories in conventional psychology. But rejecting conventional psychology, suggesting that psychology start over (discarding a huge body and continuing flood of published books and papers) is not acceptable, so the eminent suitability of PCT for that purpose is not recognized.

As Thomas S. Kuhn explains in his seminal work *The Structure of Scientific Revolutions,* the confusion, distress, and failure throughout the community of contemporary psychology is typical of the early stages of a scientific revolution. Kuhn explains that during a revolution, people already committed to the old paradigm don't let go, while newcomers adopt the new. Therefore, a scientific revolution usually requires a generation change.

This revolution has begun but will take more time, several decades no doubt. As you evaluate and study PCT, you will discover its considerable explanatory power. You may agree that PCT lays a foundation for the science of psychology to leave its descriptive past behind and turn into a generative natural science that can take its place alongside the other natural sciences we can rely on, such as physics and chemistry.

About the future

The day will come when our children are taught in elementary school about control and how it works; that living organisms act to control what they experience without focusing on how they do it; that you cannot know what other people want to experience by watching their actions or, put another way, you cannot know what others are doing by watching what they are doing; how to resolve conflict, which as controllers we are prone to create.

When this day comes, the world will be a better place.

Please be very careful as you evaluate PCT.

Terminology is an important issue when comparing different theories. Phil Runkel discusses the different meanings of "theory" and "model" in descriptive and generative theories. Bruce Nevin expands this awareness to other fields in his paper: *The Future of PCT*.

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The Future of PCT

Bruce Nevin
Post to CSGnet October 2015

Philip Jerair Yeranosian:

> Could everyone describe what the future of PCT research is? Ok, we can have more and more people designing Rick's demos. But what's the real endgame in PCT? What's it going to look like?

Bruce Nevin:

I don't see the future of PCT as its endgame.

PCT provides a theoretical and conceptual foundation for all the sciences that investigate any aspect of living things: their behavior, the processes within them, their interactions, the social and organizational systems in which they participate, and perhaps more. Anything to do with life and living. That's an awfully big umbrella. Exploring all that comes under that umbrella will take a very long time, and I think we will continue to discover more. I say 'we' meaning us humans, or those of us who engage in this discovery; the farther developments will come after the end of this lifetime.

A very exciting development is the work that Kent McClelland is doing with collective control. He has developed the conceptual framework and he and Martin Taylor have proposed a nomenclature for the environmental stabilities that are brought about and maintained by collective control.

Stabilization of the environment is a major benefit of collective control at all scales—at small scale, cells combining to form complex multi-celled organisms and viruses evolving to mitochondria within cells, and the evolutionary path generally from pathogen to parasite to symbiote to e.g. enterome. At large scale, we are ignorant of anything beyond human social systems, and I think necessarily so for the same reason that a cell within the body necessarily does not perceive or control the same inputs that the body does. That reason, assuming such perceptions were somehow physically possible, is that pathological conflict would ensue. One or both would be unable to survive more than a generation or so because of disturbances and environmental destabilization at both levels of organization.

If we survive as a species over the next century of environmental destabilization called climate change, it will be because we learn to participate more intelligently and deliberately in the processes of developing and changing human social arrangements by collective control. I believe that the development, broad acceptance, and above all practical application of PCT is essential for this.

Equally important, in a complementary way, will be the increasing PCT sophistication of neuroscience, and the increasing PCT sophistication of its practical applications. We do not know what neuroscience research informed by PCT may disclose and make possible.

Without collective control for the common good, the applications of research in this more sophisticated neuroscience could be disastrous. Think only of technologies that have already been put into the childish hands of those whose most important CV in life is accumulation and retention of wealth and power, and in the hands of the politicians and generals who serve them. So far, these folks have known only about reward and punishment as handles for manipulating the public by influencing what perceptions they control at what references.

We will have to learn to heal the polarization that has been so assiduously cultivated for political and economic gain. This polarization exploits especially

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those whose childhood was ruled by authority and fear, reward and punishment. This experience during the years of most extensive cognitive development has physiological and cognitive consequences.

A number of studies in the past couple of decades have concerned cognitive differences between conservatives and progressives. Characteristics associated with conservatives are also associated with what used to be called the limbic system, including the amygdala: for example, a stronger preference for predictability and familiarity, a greater avoidance of cognitive dissonance, more aggressive response to uncertainty and threat, etc.

In one study in England, students who self-identified as conservatives had larger amygdalae than those who self-identified as liberals. (R. Kanai; et al. (2011-04-05). "Political Orientations Are Correlated with Brain Structure in Young Adults". Curr Biol 21 (8): 67780. doi:10.10016/j.cub.2011.03.017. PMC 3092984. PMID 21474316.) I surmise that this is a consequence of a childhood that was ruled by authority and fear, reward and punishment.

I wrote about the amygdala in a prior post. The amygdala mediates establishment of long-term memory as well as processing of emotional states (sensations in the body associated with remembered and imagined perceptions). Not least for reasons that I think are evident in sex-differentiated properties of the amygdala which I noted in a previous post, I am certain that full participation of women in the processes of developing and changing our social arrangements by collective control is essential to our survival in the face of climate change.

As is well known in principle but all too often forgotten in practice, collective control is much more difficult in an email environment, because without nonverbal communication channels superficial differences degenerate too easily into the email equivalent of chest-bumping. If we do indeed control a perception of PCT being accepted in that vastly encompassing umbrella role over so many scientific fields, as we claim to do, then as means to that end we must negotiate many conceptual and terminological prior commitments in a—dare I say it?—in a more compassionate way. Getting extricated from such commitments on the way to grasping PCT is not an easy process. Bill's correspondence with Phil Runkel is exemplary (*Dialogue Concerning the Two Chief Approaches to a Science of Life*).

A few examples of terminological commitments in other fields:

- Neuroscientists have got used to talking about feedback meaning afferent vs. feedforward meaning efferent, and their knowledge of negative feedback control may be pretty much limited to homeostasis. So we need to be careful that we understand what they mean, and that they understand what we mean.
- In the statistical methodology of IV-DV research, a controlled variable is one that is controlled by the experimenter so as to have null effect on the dependent variable DV, so we need to acknowledge their use of the term and the importance of the experimenter maintaining the integrity of the experiment while emphasizing that the focus of PCT research is on what the observed organism controls.
- To a programmer we may need to make clear that the controlled variable is not a 'control variable' regulating order of execution of program steps
- In my work with language, I have to acknowledge the 'information' of information theory (communication theory) in relation to the objective information in utterances: the latter is collectively controlled, and may be included among the means by which an individual may reduce uncertainty (one definition of the former).

When they are made explicit, terminological differences such as these are superficial, even trivial, but if they are unnoticed people talk past each other, each convinced of the other's obtuseness. Any place where we give precise PCT definitions of terms and concepts, the words we use have other meanings outside of PCT. As an example of addressing these problems of communication in a helpful and constructive way, I offer this paragraph from some recent writing by Martin Taylor (I hope with your permission, Martin):

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> When some people hear the word "control", they take it to be the opposite of "freedom", and therefore that a psychological theory based around "control" is a theory to be opposed on principle. Others may think of "self-control", a modicum of which is the core of civilized behaviour; too much self-control prevents people from seeing your true feelings and renders you untrustworthy; too little, and you thoughtlessly do things that damage other people and your physical environment.
>
> Perceptual Control is neither of those.
>
> To get a feel for what Perceptual Control is ...

Any time there's disagreement or argument, assume first that one or more words being used by one party do not mean the same as the identical words being used by the other party. You can't tell what a person is saying by just looking at their words. That's a special case of "You can't tell what a person is doing by watching what they're doing." Apply the Test. If we spend our time bickering and blowing one another out of the metaphorical water, what benefit are we for our avowed aim of seeing PCT accepted?

There are important areas of potential research and understanding which have not even been considered yet (so far as I know). So there is no question of the future of PCT being its end game. One such area which to my knowledge has been completely unexamined so far in PCT is hypnosis. The range of hypnotic phenomena, many of which are rather startling.

An example is time dilation, in which for example an artist accomplished 70 hours of slow, painstaking trial-and-error work, solving tricky problems of color and technique, producing a painting on a theme on which he had been blocked for many years—in 6 hours of clock time (paper 27 in vol. II of Milton Erickson's collected papers). The vexed question of awareness is a central element in hypnosis. What makes the difference between whose who are 'good' subjects for hypnosis and those who are not?

A few more thoughts on our political environment: PCT makes large claims. PCT neuroscience will underwrite these large claims with greater authority. Conservatives—and my impression is that they include most of those folks who hold the purse strings—respect authority. Conservative values are equivocal about the essential freedom of control systems to set their own reference values for CVs from within themselves.

On the one hand, this perception sort of jibes with the narcissistic myth of the independent individual, dear to conservative ideologies. It also jibes with a perception, commonly controlled by conservatives, that human nature is unruly, even depraved, and must be constrained and directed by institutions and authority.

On the other hand, it conflicts with the desire to control other people and make their behavior predictable ("prediction and control of behavior", the behaviorist/cognitivist marketing slogan).

If PCT social science can inform social activism with real insights and new forms of participation, this will put conservative politicians into the kind of conflict that we see in their denial of climate change. In this, of course, the politicians are defending stabilities in the environments of businesses and institutions.

The manipulations of public opinion by PR and propaganda have engendered a populist tiger, which threatens to bite them. To the extent that applications of PCT to the direction of social change are effective and gain recognition there will be attempts to make use of them to preserve those environmental stabilities that favor those whose most highly valued CVs concern the accumulation and preservation of wealth and power. It will be fascinating to see how this all plays out.

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Why Study Perceptual Control Theory?

by Dag Forssell July, 1997, revised 2003

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What's in it for you?

Are you curious why and how people do what they do? Would you like to be more effective as a parent, teacher, manager, spouse or friend—and develop more satisfying relationships in the bargain? I bet you will discover that you will gain more useful, dependable insight more quickly when you learn Perceptual Control Theory (PCT) than you possibly could any other way. You will begin to question many conclusions that you previously thought were well-established truths.

I am a mechanical engineer who came to the United States from Sweden in 1967 with my wife Christine. My curiosity about "what makes people tick" was aroused when Christine became a salesperson in 1976. I began to study sales, management, public speaking, listening skills, parenting and psychology. I thought a book or program was worthwhile as long as I found an idea or two that made sense to me and that I thought I could use.

In 1988 I came across *Behavior: The Control of Perception* by William T. Powers. I soon realized that this book outlined a new scientific approach to understanding human nature—it was not just another pop-psychology or self-help book with one or two good ideas.

As I studied PCT, I saw an entirely new way to explain what behavior is and what actions accomplish. PCT looks at behavior from the inside perspective of the behaving person, not from the outside perspective of an observer. PCT shows clearly that actions are rarely deliberate; a person is not necessarily aware of actions. Actions influence the environment (or attempt to) so that a person experiences what the person wants to experience at the time and under the circumstances.

With PCT insight, I now see actions as symptoms of wants and understandings and ask people about their wants whenever a conflict arises. In PCT-speak, this means that I ask them what the situation looks like from their inside perspective and what perceptions they are trying to control, rather than jump to conclusions about the situation based on my incomplete observations from the outside, supplemented by a generous helping of other information retrieved in real time from my personal store of understanding and memories—in other words, based on what I imagine.

I realized that I had on many occasions caused conflict with others by insisting on my interpretations and by trying to impose my wants, telling people what to do and how to do it. So now I do my best to offer information instead, information that my friends and associates can consider and make their own; information that will affect how they understand their world, change what they want—and thus change their actions.

As Christine and I began to apply this understanding in our own interactions, our already good marriage became even closer. If one of us is upset about something, we let the other know we have a strong error signal. This leads our conversation directly to a discussion of a want (the reference signal), compared to a perception or interpretation of what is (the corresponding perceptual signal). This approach eliminates the oh-so-intuitive focus on actions. It removes any accusatory tone from discussion and helps us support each other by reviewing the want—it's origins in higher-level understanding, appropriateness and selection, stored perceptions (imagination) mixing with current input, creating our current perception or interpretation of what is, actions we have tried, and unintended consequences of each other's actions. It becomes easier to make suggestions and accommodate each other's preferences. We recognize that persistent error signals cause reorganization and can be harmful, but accept the idea that error signals and reorganization are part of life.

I now put my understanding to use daily when dealing with customers—anticipating what perceptions they are controlling—and find myself getting along much better than I did earlier in my career.

My whole outlook on life has changed and I feel much more accepting and at peace with myself than I used to, all because I have gained a fundamentally different understanding.

The remarkably simple explanation developed by Bill Powers is based on both the principles and methods of successful physical science and it remains consistent with our intuition about the autonomy and complexity of human nature. Once you understand this explanation, you will find it both elegant and compelling. The explanatory mechanism introduced by PCT is testable through various experiments, so don't accept it on anyone's authority. Test it for yourself—every step of the way. You will find that PCT covers much ground and explains a great deal of our experience, but leaves many mysteries for future researchers to explore, such as consciousness, awareness, attention and memory—mysteries for which no-one has any definitive answers.

When you study PCT, bear in mind that this is not just an idea of the month, another passing fad or "The Powers Philosophy," but a simple, basic description of the marvelous mechanism that *is* a human being, always has been, and always will be. You *are* a perceptual control system, as is every living being. That is why it is important to understand how a perceptual control system works, and this is why we offer tutorials and simulations you can run on your own computer.

When you understand the mechanism described by Perceptual Control Theory and see that people always control perceptions, you can understand any new interaction by reasoning based on PCT. You no longer need to memorize advice for all possible circumstances. Social interactions in all their apparent complexity suddenly become much simpler and easier to understand. This kind of insight you cannot ever learn from descriptive science—a storytelling or "this is what you do" approach to learning.

Understanding the basic mechanism will only be the beginning of your personal transformation. As you live through new experiences, you will naturally examine them in the light of PCT. Over time, your understanding will mature and flavor your entire outlook on life.

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Why worry about explanations?

PCT offers an explanation. Why should you care about an explanation? I have heard many people say: "Don't confuse me with theory, tell me what to do!" I think that there is good reason for this doubting attitude when it comes to education that deals with social interaction. Explanations come in many flavors. Some are vacuous, some superfluous, some erroneous and some very useful indeed, providing solid understanding and structure for the way we think. Let me briefly share some thoughts on explanations and science:

Explanations are not necessary to live

Fishes, cats and people get along just fine without any explanations at all. We all learn from experience. We want something and act in various ways until we experience what we want. Then we remember what we did (or rather, what perceptions we were controlling at the time).

Some explanations amount to conversation

Explanations sometimes merely restate the problem (you can't read because you are dyslexic, where dyslexic is Greek for "can't read"), offer conversational speculation (the customer bought from you because he liked you best), or lump symptoms together in groups to define a "syndrome" which provides an illusion of scientific understanding.

Learning from experience provides little structure

Learning from experience, you deal with each situation as it occurs. As you accumulate experience, you say: "In these circumstances, do that." It takes a very long time to accumulate a variety of experiences and attempt to draw general conclusions from them. Unless you happen to hit on some very solid generalizations you will likely be surprised over and over when things don't turn out the way you expected. Your generalizations are unlikely to provide dependable structure for your thinking and guidance for new and different situations.

Many widely accepted explanations are wrong

Our language is full of references to the idea that the environment and people in it make us do and feel things. "You make me so angry!" "Look what you made me do!" "Our managers reinforce desirable behavior." "I want to make you happy." "His reaction is understandable when you know how he has been conditioned." We have all grown up with these concepts and explanations and they sure can seem valid when you look at people's actions from the outside. Nevertheless, the Stimulus-Response concept of linear causation is simply wrong, and the concept of the brain issuing detailed commands, likewise linear causation, is also wrong. Neither is physically feasible. Statistical findings, resulting from research based on these intuitively appealing concepts, are most often of very low quality.

Languages are made up of explanations

The language of a particular science at any point in time defines concepts, explanations and functional relationships in a coherent whole. The language and its concepts determines how we view and describe what we experience. When you have learned a scientific language it becomes very difficult to step outside it and see an entirely different explanation, based on different basic concepts, where words take on different meaning. What you already "know" seems "right" and different explanations seem "wrong."

In his book *Inventing Reality: Physics as language* (NY: Wiley, 1990), Bruce Gregory reviews successive languages in the physical sciences, each one replacing its predecessor. When a new, more useful, testable and demonstrably more valid language is radically different, a scientific revolution has to take place eventually, because the old explanations and concepts lose their validity when compared to the new.

Scientific revolutions happen

I changed my notions about scientific progress when I read *The Structure of Scientific Revolutions* by Thomas S. Kuhn (Univ. of Chicago Press, 1970). I had thought that scientific progress always meant adding new discoveries to an already validated body of knowledge. Now I understand that the history of science is a history with long spells (many decades or centuries) of knowledge accumulation, punctuated by intellectually violent transitions where old knowledge is superseded by new concepts that give rise to new detailed explanations. Sciences start over. I am happy to particiate in a movement that is bringing a fundamentally new, testable and very practical explanation to the life sciences.

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Good explanations make a huge difference

In-depth explanations provide structure

With a structure of in-depth explanations, such as provided by the contemporary engineering sciences, you can extrapolate from known principles and designs to completely new, never before attempted, actions and designs—yet be very confident things will work out. Such a body of in-depth explanations become a way of thinking—a systems concept in PCT language. This structures your thinking and provides a framework by which you fit additional experiences and conclusions into a coherent understanding. PCT offers a structure by which you can organize your understanding of living organisms and make sense of their behavior.

Where explanations prove correct – science can progress

The impact of correct, useful explanations is readily seen in the recent history of the physical sciences. New concepts, a new approach to measurement and a new set of physical explanations were introduced by Copernicus, Galileo, Kepler and Newton in the 1500s to 1700s, laying the foundations for modern physical science and the remarkable progress we have benefitted from during the last 300 to 400 years.

When students learn about the physical sciences today, they replicate many fundamental experiments and accept the theoretical explanations that go with them because they can see near perfect agreement between their own experience and the explanation. When engineers design devices today, they confidently expect them to work as predicted.

PCT offers a correct explanation – science can progress

When you learn about PCT today, you can replicate many fundamental experiments, run the simulations and accept the explanation that goes with them based on your own judgement, because you can see near perfect agreement between your own experience and the explanation. When you offer your friends information passed through the filter of PCT understanding, you will be offering better (and less confusing) information than they can get with today's descriptive languages and they will be able to control their perceptions better than they do now—they can be more satisfied. When you deal with people in the future, you will have greater understanding and confidence. You will be able to bring some order out of apparent chaos in your personal world.

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PCT in 11 Steps

By William T. Powers

1 Behavior as Control

Control is a process of acting on the world we perceive to make it the way we want it to be, and to keep it that way. Examples of control: standing upright; walking; steering a car; scrambling eggs; scratching an itch; knitting socks; singing a tune. Extruding a pseudopod to absorb a nanospeck of food (all organisms control, not only human beings).

The smallest organisms control by biochemical means, bigger ones by means of a nervous system. Whole organisms control; the larger ones have brains that control; most have organs that control; if they are composed of many cells, their cells control; the DNA which directs their forms and functions controls; even some molecules, certain enzymes, control by acting on the DNA to repair it when it's damaged. Control is the most basic principle of life and can be seen at every level of organization once you know what to look for.

In this series[1] we will examine the process of control to see how it works, how it explains the behavior of organisms, how we can recognize it when we see it, and how understanding it can change our theories. In the first 11 mini-chapters we will see how PCT, Perceptual Control Theory, grows out of and replaces its main theoretical predecessors.

We will start by seeing how the mainstream of behavioral science found itself in channels that led to confusions and impossibilities, and how engineers who had no interest in psychology at all managed to discover the one basic principle that could have saved the sciences of life from a 300-year search down one blind alley after another. The problem is not that the life sciences got everything wrong; it's just that they got the most important things wrong: what behavior is, how behavior works, and what behavior accomplishes.

1 Bill Powers wrote this compact series of 11 brief statements to serve as an outline for a proposed TV program. The program did not come to pass, but this is an excellent summary of PCT.

2 Behavioral Science I

Before PCT, there was behavioral science. The "behavioral" part indicates that if we're behaviorists, we're interested in what we can see organisms doing, not in what we might guess goes on inside their minds, or brains, or other insides. Others have tried guessing, but without much success.

When a person accidentally moves a bare foot too close to a fire, an observer can see the foot pull away from it. In Descartes' *Treatise on Man* (1631) he says "If the fire A is close to the foot B, the small parts of this fire, which, as you know, move very quickly, have the force to move the part of the skin of the foot that they touch, and by this means pull the small thread C, [running up the back to the brain] ... simultaneously opening the entrance of the pore d, e, where this small thread ends... the entrance of the pore or small passage d, e, being thus opened, the animal spirits in the concavity F enter the thread and are carried by it to the muscles that are used to withdraw the foot from the fire."

This sounds like an attempt to understand responses to stimuli, but 380 years later we can understand it as a description of a negative feedback control system, which we will get to before long.

If the observer happens to be the organism with the overheated foot, one more effect can be observed: it hurts. This leads to noticing that the foot is generally moved according to whether the sensed warmth is too little, too much, or just enough. The fire affects the sensed temperature of the foot in one direction; the response affects the same sensed temperature in the opposite direction. This turns out to be an exceptionally important observation. It's a pity that nobody could have analyzed it in 1631, but Newton's calculus then lay 73 years in the future. A differential equation would have explained this circle of causation that baffled philosophers of science until, 400 years later, control system engineering appeared.

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3 Behavioral Science II

Just as PCT began to get organized, a new branch of behavioral science appeared: cognitive science. The emphasis moved from externally visible variables to those experienced by each individual. Now it was permissible to explore processes inside the brain and try to analyze them, but the phenomena to be explained scientifically were still basically the way stimuli cause responses. Theoretically, stimuli from the environment were now analyzed by cognitive processes in the brain, which then would formulate plans for generating responses appropriate to the stimuli.

The main task for the brain was now to figure out what commands should be sent to the muscles to generate appropriate results, given all the information coming into the brain from outside. This required the brain to have knowledge of neural and physiological processes as well as physical processes in the external world, and entailed rapid computation of the "inverse kinematics and dynamics" of body and environment ("kinematics" = properties of linkages, " dynamics" = movements of masses). Once this plan of action was turned into the set of necessary commands, it could be executed to produce the actions and their anticipated results.

There is something wrong with this picture. Rabbie Burns observed that the best-laid plans of mice and men gang aft agley, which is true not because we are bad at analyzing and planning but because plans of *action* are always close to their expiration dates. A planned action such as turning a steering wheel might produce exactly the wrong result if another car, a second later, changes direction by only a small amount. Planning all the turns of the steering wheel needed to drive from home to work couldn't conceivably get you to work the next day, no matter how precisely executed, even if exactly the same movements worked perfectly the day before. Think about other cars, traffic lights, pedestrians, weather, road repairs.

While planning clearly does take place, it can't operate by planning actions. We plan results, not actions, and that requires a new model of behavior. Even before cognitive science appeared, that new model was under construction.

4 Understanding Purpose

The new model was born in a parallel universe. Electronics engineers of the 1930s were using their new skills at designing electromechanical systems to automate tasks formerly done only by human beings. These tasks entailed a specification for some external condition to be brought about and maintained, even though it was impossible to predict or even detect all the events that might disturb that condition. The tasks included such things as aiming guns from the deck of a rolling ship; stabilizing the temperature of a room subject to opening and closing of doors and windows at unpredictable intervals on cool or cold days; adjusting the course of a torpedo to arrive at a moving target that made propeller-noises; keeping an airplane flying through rough air at constant altitude and speed, and on course.

To build such devices the engineers had to solve some basic problems. How could a (preferably) simple electromechanical device be given a specification for some effect that didn't yet exist, to be caused by a behavior that was not yet being carried out? How could this future state be made to cause an action in present time that would lead to that state? What if the effect of the action were disturbed *while* the device was producing the action? The engineers of the 1920s and 1930s, not knowing that the behavioral sciences had declared a device of this sort to be impossible (because future effects can't bring about their own causes), kept working at this problem until they solved it. The result was a new occupation called control system engineering, and (accidentally) a new theory of just about everything that lives.

These engineers had inadvertently discovered how purposive systems work. This discovery re-opened the door to the concept of intentional behavior directed by internal mental goals (which Watson, the founder of behaviorism, called a primitive superstition). The next logical step would have been to introduce this new understanding to the behavioral sciences. However, the sciences of life already had dozens of theories, all based on the idea that purpose is just causation misunderstood. They resisted mightily and that giant leap for mankind didn't happen.

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5 Cybernetics *en Passant*

The Mexican physiologist Arturo Rosenblueth did notice the new ideas. He had been primed by studying under Walter B. Cannon, who worked to understand homeostasis, a process inside organisms that stabilizes critical variables such as nutritional state, body temperature, CO_2 level in the bloodstream, and other details of the life-support systems. Rosenblueth noticed that in the human body were many systems, behavioral systems, that appeared to work almost exactly in the way that the new artificial servomechanisms work. He communicated this discovery to Norbert Wiener, a mathematician at MIT where control engineering was rampant, and cybernetics was born.

Unfortunately, the main founders of cybernetics were not control-system engineers. They learned just enough about control systems to pattern cybernetic thinking around concepts like circular causation, but were more interested in subjects like communication, information theory, and (later) artificial intelligence and failed to carry the transformation to its ultimate conclusion.

That last step was not begun until the 1950s. That was when I learned of a recent school of thought called engineering psychology, and also started following the lead of W. Ross Ashby, a psychiatrist in the cybernetics movement who did have an understanding of control systems. With the help of R. K. Clark and R. L. MacFarland, I began to explore control systems with the idea of joining the cybernetics movement. After our first paper was published in 1960, we made overtures to psychology and cybernetics, but were put off by a general lack of interest. Clark and MacFarland went on to other things, and I kept working on PCT on my own. This led to my first book in 1973, then eventually to the formation of the interdisciplinary Control Systems Group in 1985, which in 1994 started a move toward becoming international by holding a meeting in Wales, and a few years later two meetings in Germany. The 22nd annual meeting of the CSG took place in 2006 at South China Normal University in Guangzhou, PRC, in collaboration with the Systems Society of China. PCT is part of the mainstream now. Almost.

6 A Scientific Revolution

The nature of a control system was almost understood by those who adopted behaviorism and cognitive science. There is something of each one in a control system.

The behaviorists realized, correctly, that behavior is based on perceptions that are caused by the physical events called stimuli. A driver can't keep a car on the road with both eyes closed. The kind of problem unsolved by behaviorism was how the stimuli could affect the driver's steering-responses in exactly the quantitative way needed to keep the car in its lane or steer it onto the correct exit ramp. This problem becomes worse when we realize that the driver also has to respond to *invisible* stimuli such as a crosswind. If the driver doesn't steer slightly into the wind by exactly the right amount, the car will drift into a ditch or into oncoming traffic. In general, stimuli as classes of happenings given names like "oncoming traffic" might lead to the right *consequences* of behavior ("avoiding collisions"), but are simply not the sort of thing that can produce the *quantitative amount and direction* of behavior needed.

Cognitive scientists realized, correctly, that behavior is the means an organism uses for achieving goals. An organism with a goal, they thought, must somehow figure out how to behave to achieve it. They noted, correctly, that the required behavior is not just a qualitative class of actions, but the quantitatively correct amount of action in exactly the right direction. The driver needs to perceive the environment to steer a car; the perceptions are supposedly the basis for the computations by which the organism calculates the actions that will achieve the goal. But it seems unbelievable that the driver could carry out all the repeated mental calculations required in the short time available, based on rather imprecise perceptions of what is going on out there.

In fact, neither behaviorism nor cognitive science hit on what now seems like the right explanation of behavior, though both hovered near it. The main mistake of both was to assume that the final product of brains was behavior, overcomplicated by the idea that behaviors must be exactly calculated.

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7 The Solution: PCT

Here are the main questions unanswered by previous theories. How can stimuli produce not just responses, but *specifically appropriate* responses? What is a goal, that it can lead to just the behavior that will achieve it?

To answer these questions we have to look at things like perception and action a little differently. When someone steers a car, the perception that matters is the relationship of the car to the road as seen through the windshield. All the steering behavior has to be based on that perception—but not that perception alone.

It is also necessary for the driver to know, somehow, how that picture framed by the windshield *should* look if the car is to be properly located. This picture has to exist in the same place that the perception exists: in the brain. Without getting too neurological about this, we can say that whatever form the perception takes in the brain, the image of how the car and road *should* look must be in that same form, because the perception has to be compared with that image, the *reference image* ("goal:" goals are In Here, not Out There).

The difference between the imagined reference image and the real perception tells the driver how much steering error there is. "Error" just means the difference between reference and real. If the two coincide exactly, there is no error. If there is a mismatch in one direction, the driver should steer to the right. If in the other direction, to the left. That is basic control theory.

Now the cognitive scientist wakes up and says, "Yes, but exactly how much left or right? The brain has to calculate that, doesn't it?" The answer is yes, but. Yes, if there's a big error the brain should cause the steering wheel to turn a lot or if a small error, a little. But (and now we see the beauty of classical negative feedback control theory) the brain doesn't have to compute the exact amount because it can continuously adjust the action as the error changes, making smaller and smaller approximate adjustments as the error gets smaller until there is no error. Then no more changes in steering effort occur and the car is where it belongs in the lane. No complex computations. No planning. Just one swift simple process that converges smoothly to a final condition.

8 Behavior in the Real World

A driver traveling along a straight level road sees the picture in the windshield as exactly right; he steers neither to the right nor to the left. But is that true in the real world? Riding with a driver, we see endless little movements of the steering wheel, yet we don't feel or see the car moving left or right in its lane. The driver's steering efforts seem to be having no effect.

The reason is simple once you work it out. When the car starts drifting a little to either side for any reason, the driver immediately turns the wheel the other way as much as needed to keep the drift from getting larger, then a tweak more to eliminate it. If the driver can detect changes of the car's position as small as we can detect, or smaller, then we will never see or feel anything but tiny, barely-detectable, changes in position—if any at all. But the steering efforts can be quite large, in a gusty crosswind. It really looks as if the driver is responding directly to the crosswind, but of course in a closed comfortable car there is no way to detect the crosswind, except through effects on the car that the driver is mostly preventing. The result is that the deviations of the car are kept very small, especially in comparison to what would happen if the driver *didn't* make those steering movements. This is called negative feedback control—the same thing Descartes described.

So it seems that control means keeping disturbances from having much effect. But now, suddenly, the driver is turning the wheel so the car veers entirely out of its lane, a huge steering error. We immediately see why: it's an exit ramp. But why doesn't that steering control system act immediately to counteract the error? Because the reference image has been changed (one more time: reference image, reference perception, reference condition = GOAL). In fact, the driver's brain has smoothly changed the reference image from that of a car going straight in its lane to that of a car curving off to the right and up the ramp. The control system, still keeping the perception of the car's position matching the reference image, automatically alters the steering actions so as to keep the steering error close to zero. We see that simply by smoothly altering the goal of the behavior, the driver accomplishes the required change in behavior in an extraordinarily simple way, with no complex calculations.

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9 Behavior: The Control of Perception

Behavior is the externally visible part of a process by which perceptions of various aspects of the experienced world are controlled. It is not the end-product of either the effects of stimuli or the goals sought by the organism. Behavior is simply the adjustable means by which an organism can keep its perceptions matching reference conditions. As disturbances come and go, behavior changes to have equal and opposite effects. As reference conditions vary, behavior changes to cause perceptions to vary in a matching way.

Behavior changes to cancel the effects of the disturbances on whatever the organism is controlling. The appearance is that the disturbances cause the actions, the observable behavior. But the real story is that the actions prevent the disturbances from significantly altering what the organism is concerned with: the perceptions it is controlling. This is how PCT explains the appearances that led to behaviorism.

When we make plans, the appearance is that we plan what behaviors will be needed to achieve what we want. But we can't predict what disturbances and changes in properties the environment is going to throw at us. What we can do is plan the perceived consequences we want to happen. We don't plan actions; planning successfully means planning perceptions. Higher levels in us tell lower control systems what perceptions to experience. The lower control systems adjust their actions to make their perceptions match the reference conditions they are given, and (without being told) enough more to cancel the effects of any disturbances that might be happening. This is how PCT explains the appearances that led to cognitive science. PCT does not require the brain to perform miracles of prediction and impossibly fast, complex, and accurate computations.

PCT thus encompasses the concepts of behaviorism and cognitive science, providing a single framework in which the observations of both can be understood. With one more added concept—levels of control—it expands to encompass all that human beings and perhaps all organisms experience.

10 Emotion

The control hierarchy can control perception at many levels by using actions from mild to strong, but there is something missing: feelings. This model doesn't suggest the physical feelings that accompany emotions, but one modification of the model can put feelings into relationship with the goals that go with them, to cover both the cognitive and feeling sides of emotion.

Disturbing higher control systems or changing goals causes errors that generate a cascade of changes in the reference signals passed down the hierarchy of control. We now divide this cascade into two branches. A behavioral branch goes to systems, mostly learned, that control using muscles. A somatic branch, primarily a product of evolution, goes into the amygdala, then the hypothalamus, and then the pituitary gland and autonomic nervous system which control the state of the body. This branch is where emotions supposedly originate, but in the PCT theory emotional feelings are effects, not causes.

Some control systems are inherited; most are learned. All act to adjust both the somatic systems and the action in the behavioral branch. The somatic branch adds sensations that generate the feeling component of the configurations we call emotions. Example: Either learned or innate systems can specify goals like escaping or attacking. If the perception differs from the reference, a "motivating" error signal is sent to multiple lower behavioral systems as reference signals. The effect of the error signal on the somatic branch provides the feeling part of the experience, the so-called fight-or-flight syndrome. The goals of attacking or fleeing distinguish fear from anger; the physiological states have been found to be identical in both emotions.

The feeling part of emotions often arises without any consciousness of the cause. This can happen if awareness is engaged at higher levels, and a disturbance occurs that affects lower-level control systems not currently in awareness. Those systems will react automatically by using the muscles and, according to this theory of emotion, will also adjust the physiological state of the body. The sensations arising from the physiological states will be processed level by level up the hierarchy, and when the perceptions reach a level accessible to awareness, will attract attention exactly as if they had occurred spontaneously, or had been caused from outside the body. An injection of adrenaline can be interpreted and experienced as fear *or* anger.

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11 The Hierarchy of Control

The driver keeps the car in its lane, yes. But why? To stay alive, surely, but there are more immediate reasons. The driver has a destination in mind, and wants to get there. The reference perception: *I am at the entrance to the parking lot at the mall*. The actual perception: I am on 55th street a mile from the parking lot. So keep the car moving along in its lane. When the entrance appears, change the reference: *the car is following **this** path into the lot.*

The higher system is not telling the lower one what to do but showing it what to perceive. It does so by continuously varying the reference image, not by commanding steering wheel movements. The lower system automatically corrects the effects of disturbances and little steering errors on the car's path without having to be told to do it. The higher system needs only to alter the images that the lower system is to reproduce by turning the wheel. The lower system determines when, how much, and which way to turn the wheel.

The reason for going to the mall is to buy a dress shirt. The reason for buying the dress shirt is to look good at a wedding. The reason for looking good is to please the woman you're going to marry. The reason for pleasing her is that you want to show respect for her opinions. The reason you show respect for her opinions is that you want to make the marriage as ideal as you can, and see respect as an essential principle for making a good marriage.

Each level of control sets multiple goals for the next level down to perceive; that's how any higher system controls its own perceptions. The higher system's perception is built out of the perceptions that exist, some being controlled, at lower levels. There are many control systems at each level, and more than a few levels. The only systems that act on the environment directly are those at the first level. All the rest act by adjusting the perceptual goals for lower systems. All control their own perceptions, not their actions.

Now you know the essence of Perceptual Control Theory, which replaces the basic concepts of behavior in both behaviorism and cognitive science. A revolution, in progress.

Bill Powers,
Lafayette, Colorado, October 2009

This series continues with ***Reorganization and MOL***, an overview of how control systems may come into being, change, cause internal conflict, and ways to resolve internal conflict.

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Reorganization and MOL

By William T. Powers

1 Reinforcement Theory

The most popular explanation of learning is still based on reinforcement, or the idea of reward and punishment. According to this theory, learning isn't something organisms do; it's something done to them by their environments. Evolution has given certain things in the environment the power to make us change our behavior to get them, presumably because getting them enhanced our ability to compete with other organisms, so the only organisms left are the ones whose behavior is reinforced by such things.

The theory of reinforcement says that if behavior produces a reinforcer, a consequence favorable to the organism in some way, that behavior will become more likely to occur again. But consider picking up a glass, drinking its contents, and putting it down. Repeating all that behavior exactly will not get you another drink: the glass is now empty. Your action changed the environment so you have to do something different to get the same result. If getting a drink just reinforces the same behavior, you will not get another drink.

The same problem occurs in more subtle ways. When you pick the glass up, it is 20 centimeters directly east. When you put the glass down again, it is 15 centimeters to the east. If, to pick it up again, you now repeat exactly the same changes in the joint angles of your arm and shoulder with your body in precisely the same position and orientation, you'll probably knock the glass over. In general, in order to cause a given consequence to repeat in the real world, it is almost always necessary to *change, not repeat* the behavior that produces that consequence.

Reinforcement theory, therefore, is based on a misreading of how behavior works. What we have to explain is not how the same behavior is caused to repeat, but how exactly the right changes in behavior occur to generate the same consequence as before. To get the right temperature, add hot water to the bath, or sometimes add cold water. We see organisms producing the same consequences over and over using different, even opposite behaviors.

Note: This series of 8 statements is a continuation of ***PCT in 11 Steps***, A summary of Perceptual Control Theory by Bill Powers.

2 From Reinforcement to Reorganization

A rat is left of the lever it's pressing so it moves to the right to press it. After eating the resulting pellet, it happens to be to the right of the lever so it moves left to press it again. Somehow the same kind of food pellet reinforces both directions of movement, but only the one that is needed is carried out.

This problem was actually recognized some time ago, but B. F. Skinner (who borrowed reinforcement theory from Thorndike and modified it) thought up a clever, though somewhat evasive, way around it. What is reinforced, he proposed, is not the particular lever-pressing movements, but the class of all possible movements that could perform the function of making the lever go down. He named that class "the operant."

This gives reinforcers some pretty occult powers. Not only do they increase the probability of pressing the lever, but the reinforcement from last time increases the probability of making the movements that are correct for *this present* instance of pressing, which may entail pawing the lever, sitting on it, or biting it, depending on what is happening between presses.

There is an alternative to reinforcement theory that doesn't have these problems. It was actually hinted at by Skinner. He was asked, in effect, why the rat presses the lever the very first time, before any reinforcing consequences have occurred. He explained that organisms normally "emit" unpredictably variable behavior when no reinforcements are occurring, and that is how the rat blunders into the lever the first time so the apparatus delivers a food pellet.

We can forget the part about reinforcement and just look at the variable blunders. Random variations aren't unlikely, but systematic explorations would do just as well. Suppose we guess that the initial unpredictable blunderings noted by Skinner are actually caused by a lack of whatever is rewarding to the organism. If the blunderings happen to bring some of the reinforcing thing to the rat, or vice versa, the deprivation is lessened and the blunderings slow down. As enough of the reinforcement becomes regularly available, the blunderings gradually become systematic behavior that presses the lever enough or in the right pattern to supply the missing reinforcer. The rat now provides itself efficiently all the reinforcement it wants or needs.

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3 Reorganization theory

This leads us to a different view of the way both rats and people learn. Those random variations aren't an accident: they're the only way we have for learning something new that we can't learn by reasoning things out or referring to past experience. When we're really stuck, or really ignorant like a baby or dumb like a rat, all we can do is try things at random and hope to hit on something that makes life a little better. Of course we don't always go thrashing randomly around; we do that only when something goes wrong and nothing we already know how to do works to set it right.

We can begin to put a new picture together. When something goes wrong, meaning that there is trouble with controlling some perception, some process inside us starts to induce random but gradual changes of organization into the brain. The way we perceive, the way we detect errors, the way we convert errors into reference conditions for lower-order systems, all begin to change. This naturally changes the way other people will see us behaving. If for any reason our attempt to control a perception seems to be working better, the random variations slow down or stop and any current changes keep going in the same general direction as long as control seems to be improving. When it starts to get worse again, we start the random process again, changing randomly in different directions. With some luck, this will bias the changes so we spend more time making control better than making it worse.

As control gets better, errors get smaller, and the logical thing to do would be to make the changes smaller, eventually going to zero when the error is zero, or less than some amount that doesn't bother us any more. Once the brain's organization has changed enough to restore good control, the cause of the random variations goes away and we go on controlling using the new organization—as long as it continues to work well.

The outward appearance of this reorganizing process could easily be seen to mean that something reinforces the correct behavior. Reorganization theory says no, that is a misinterpretation. What is happening is that problems cause reorganization to start, and successes slow it down or stop it, and it's the organism, not the environment, that is starting and stopping the changes. A mirror image of reinforcement; causation reversed.

4 Reorganization and conflict

Reorganization theory tells us that organisms that learn have an ability to alter their own organization as a way of modifying control systems or creating new ones when difficulties arise. In PCT, the current assumption is that reorganization is the process that generates nearly all control systems in an adult human being (or modifies rudimentary systems we inherit). There has to be some predisposition to develop certain levels of control, but the actual systems that we end up with, the hypothesis says, are built mostly by the organism's own experiences in the present-time world, and are built by the most important control system we inherit from our ancestors, the control system that builds and modifies control systems. In PCT it is called "the reorganizing system," though it is likely to consist of many subsystems in the brain, and who knows, perhaps throughout the body. Those "repair" enzymes hopping along the backbones of DNA molecules might be doing more than repairing. They might be reorganizing the molecules.

There is a lot to learn about this new way of seeing behavior and learning.

Let's say that organisms have an inherited ability to reorganize themselves when things go wrong. Control theory tells us about one thing that can go very wrong in a brain. It happens when, in the course of random reorganization, two or more control systems at one level try to control their own perceptions by sending different reference signals to the same lower-order control system. In trying to see oneself as a worthy member of the human race (level n+2), one sets the sub-goals (level n+1) of being cooperative and also, for different reasons, being competitive. It is very hard to find one behavior (at level n) that will accomplish both of these reference conditions at the same time. In fact, if you want to accomplish them simultaneously, you can't. That's a conflict.

Because these are control systems, they will produce as much output action as required to match perception to reference. The result of conflict is probably going to be a disaster. The harder one system tries to be cooperative, the harder the other tries to be competitive, and where these strivings come together to direct lower-level behavior, they will cancel each other out. The control systems might as well have been removed with a neurosurgeon's scalpel. A great block of control has been lost.

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5 Resolving inner conflict

We encounter little conflicts all the time. Stay home and relax or go out and have a good time. Chocolate or vanilla. Buy or don't buy. Turn right toward the movies or turn left toward the mall. Any time when we could do different things but not both at once, and we want to do both at once, we have a conflict. The normal result is that we very quickly reorganize and make a choice, removing the conflict. If we couldn't do that, life would be a serious mess.

Not every case where there are two mutually-exclusive choices is a conflict. When you drive to a store, on the way you repeatedly encounter possible choice-points: turn or go straight, turn left or turn right. But you already know the way to the store, and the alternatives never come up unless there's an accident or a road repair crew in the way. You've already resolved those conflicts. You just follow the sequence of left and right turns that ends up at the store and never even consider turning any other way.

But genuine choice-points, genuine conflicts, do come up, and sometimes they don't get reorganized away. Should I stay with my unfaithful wife because I love her or divorce her because I hate what she did? Tell the boss what my friend stole, or be loyal to the friend and not tell? Be a go-getter, or relax and enjoy life? To be or not to be, that is the conflict.

Persistent, chronic conflict is a debilitating state. It destroys the ability to control, because neither of two conflicting goals can be achieved; as soon as the error in one control system is reduced, the other is increased and that side pulls or pushes harder. All the effort that one system can produce is used only to cancel all the effort the other system can produce, or most of it. Most psychotherapists would agree that almost all the problems that people bring to therapy involve loss of control. Behind loss of control, we can now venture, there is most probably a persistent conflict.

Now the question is, "Why has this person's natural ability to reorganize not removed this conflict already?" Part of the answer lies in the answer to another question: "When something is wrong with one control system, causing poor control and reorganization, why doesn't reorganization change other control systems, too, even if nothing is wrong with them?" There must be some way of focusing or amplifying reorganization where it's needed.

6 Awareness and reorganization

A good answer comes not from theory but from experience. No matter what technique a psychotherapist uses—giving homework assignments, talking to chairs, rolling the eyeballs this way and that, or mindfully meditating—most would agree that problems don't get solved until the client is aware of them. It's generally accepted that awareness normally is in contact with only a rather small part of the activities going on in the brain, even control processes. This means that most of the brain is operating without awareness, even if it's still controlling all kinds of perceptions. The perceptions, however, would then just be neural signals with nobody looking at them, like (up to now) the ones you receive from the seat you're sitting in, or from your breathing. Therapists want your awareness to be focused on the problem, not elsewhere. It will be: awareness is attracted to problems.

So why should solving a problem depend on being aware of it? We can now offer a possible answer: because the main focus of reorganization follows the main focus of awareness. This is how the changes are confined to just part of the brain's organization. This is just a possibility suggested by the mobility of awareness and the apparent observed fact that change and awareness are intimately related. It's probably not a very controversial proposal.

PCT offers one additional dimension to consider: the organization into levels of control. Conflict involves at least three levels: an upper level goal using two lower control systems controlling different perceptions, and a lowest level where a single control system is receiving two incompatible reference images. Sit down, stand up. Go outside, stay inside. Text her, ignore her. The lowest system can't do both. It may come to some compromise state, but that won't do what any higher-level system needs to be done. There is a lot of difficulty at that lowest level. It wouldn't be surprising if that were where awareness goes: to the place where the conflict is being acted out.

But that isn't the place that needs to be reorganized. To reorganize at the lowest level will just change the way the conflict is being expressed. And this is where the therapist finds the client, embroiled in endlessly reorganizing the consequences of the conflict, while doing nothing to change the systems at the higher level that are causing the conflict. What the client needs is to move awareness up to where changes of organization will do some good.

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7 The Method of Levels: MOL

We have the recipe for resolving conflicts: move awareness to the level that is causing the conflict rather than the level acting it out. That's easy to say, but how do you do it?

Very probably, all successful psychotherapists manage to do it. If the ideas in PCT are right, they wouldn't be successful if they weren't doing it (beside whatever else they're doing that they think is important). What psychotherapists almost all do is to get the client talking about a problem which we would now expect to involve some kind of conflict, and by that means bring the consciousness or awareness of the client into contact with the parts of the brain where the problem is located. The image is that of a flashlight in a dark cathedral. Awareness is the place where the circle of light is, showing a pew or a stained glass window or a plaque or a dead body. All else is in darkness, though it's obviously still there. Inside the cathedral of the brain, the spot of light may be on the struggle to accomplish two incompatible things at once—but if it is there, where is whoever holds the flashlight? Somewhere else. Perhaps at a higher level. Excuse the metaphors, please; one day they will be replaced with something firmer. But that dead body does attract attention.

In the approach called the Method of Levels, there are two goals. One is to get the client talking about, aware of, the details of the problem. The other is to try to find hints about the higher system from which the client is observing, hints that are regularly dropped by the client. The flow of conversation will be interrupted by a sigh, a laugh, a long pause, or very often by some statement about the process going on, such as "This isn't getting me anywhere," or (what the therapist really likes to hear) a remark such as "It's like I'm looking down at both sides of the problem at once."

Whatever the disruption might be, the therapist asks about it, hoping to draw the client's attention up a level. If the idea about awareness and reorganization is right, that should concentrate reorganization at the new level and start changes going at the level where the conflict is being caused. It doesn't matter what the client says about the new level or what the therapist thinks about it. Simply focusing reorganization at that level is all that the method of levels requires. No diagnosis, no treatment, no advice, no interpretation, no suggestions, no homework. But ... not "no therapy."

8 Where are we? Where next?

PCT had its first beginnings in about 1953. Today it is known by hundreds, perhaps even thousands, of scientists all over the world. Some 10,000 school counselors, teachers, and administrators in the US have been through courses to learn it. The method of levels, first practiced in the US by a few counselors and licensed therapists, is now in use at the University of Canberra, Australia; Fife, Scotland; Manchester University, England; New Jersey and North Carolina and California USA; and the school system in the Northern Territories of Canada. Other places, too. Undergraduate and graduate courses on PCT and MOL are offered, with a PhD program starting up in Manchester.

But PCT is far from a finished product, just as MOL is far from a common method of therapy. New terminologies and new orientations open the way to new research possibilities; there is simply no predicting what the future holds or what PCT will look like in another 50 years. Some go so far as to say that PCT shows us the form of the first actual science of psychology, the first sign that psychology could become a science like physics and chemistry with all their rigor and unity. What will still remain useful of the older theoretical frameworks or the data they produced is undetermined as of now; it could be that with the new orientation, all the old problems will have to be drastically reframed, with as little proving to be interesting as there was of alchemy when it was replaced by chemistry. Such a revolution would, of course, create very human difficulties for those who have bought into older theories. Stubborn resistance is understandable and to be expected. There is no reason to discard the old just because it is old, but if it turns out to be no longer relevant, it will be discarded nonetheless.

Many of those involved with PCT and MOL have longed for years to see a "Center for the Study of Living Control Systems" come into being, where scholars, researchers, students, and the public could gather to develop these new ideas further and to communicate and learn them both as theories and as applications. It would be an amazing place.

Bill Powers
Lafayette, Colorado, October 2009

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Perceptual Control Theory

A Model for Understanding the Mechanisms and Phenomena of Control

Abstract

Perceptual Control Theory (PCT) provides a general theory of functioning for organisms. At the conceptual core of the theory is the observation that living things control the perceived environment by means of their behavior. Consequently, the phenomenon of control takes center stage in PCT, with the epiphenomena of behavior playing an important but supporting role. The first part of the paper explains how a negative feedback control system works. This explanation includes the basic equation from which one can see what is required for control to be possible. The second part of the paper describes demonstrations that the reader can download from the Internet and run, so as to learn the basics of control by experiencing and verifying the phenomenon directly. The third part of the paper shows the application of PCT to psychological research, learning and development, conflict, and psychotherapy. This summary of the current state of the field celebrates the 50th Anniversary of the first major publication in PCT (Powers, Clark & MacFarland, 1960).

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Key words: Nature of control, Control theory, Control of perception, Negative Feedback, Computer Models, Conflict and control

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This survey of the field of psychology was created as a collaborative project in 2010–2011.
For an email discussing this document, see page 17. Originally posted at pctweb.org in 2011.
Fig 1 redrawn for clarity, document reformatted, and email added by Dag Forssell, May 2014.

The phenomenon of control

The phenomenon of control is important in Psychology. Even a cursory glance through academic journals reveals a large number of references to the term 'control', as exemplified by E. A. Skinner (1996). Terms such as *perceived control, locus of control, cognitive control, subjective control,* and *vicarious control* speak directly to the phenomenon. If we include implicit references to control, such as self-determination, self-regulation, agency, learned helplessness, and emotion regulation, the number of references grows exponentially.

Although the importance of control in the process of living has long been recognized, this recognition is divorced from any broadly accepted formal understanding of how control works. Such a conceptual framework is essential first because without it the principles of control evade intuition, and second because, unless intuition has been adjusted to the facts of control, an encounter with a control system in action almost inevitably results in misinterpretation of what it is doing and how it works. The purpose of this paper is to present a summary of the current state of Perceptual Control Theory (PCT), which provides a conceptual framework for understanding the facts and mechanisms of control.

The phenomenon of control is familiar from the behavior of artificial devices such as the thermostat. The thermostat acts to keep a variable, room temperature, in a pre-determined state (the temperature setting of the thermostat), despite disturbances (such as changes in outside temperature and the number of people in the room) that would act to move that variable from the predetermined state. In the behavior of living organisms control is seen as purposeful or goal-oriented: the organism is seen acting to bring some variable state of the world, such as one's relationship with another person, to a pre-determined state (marriage) despite disturbances (such as disapproving parents and/ or competing suitors).

Perceptual Control Theory (PCT): A theory of control

There are three steps to learning PCT. The first, and perhaps the most difficult, is to grasp just how different this sort of organization is from cause-effect (input-output, stimulus-response, open loop) systems. The second step is to experience control systems in action—control systems inside the person who is doing the learning. And the third step is to learn to see the parallels between the abstract model and a real living system. We start by looking briefly at an abstract model of a control system that will be revisited throughout the article.

Step 1: Organization and properties of a negative feedback control system

Negative feedback control, first formalized by engineers in the 1930s, entered psychology through engineering psychology and the cybernetic movement of the 1940s and '50s (Ashby, 1952; Miller, Galanter & Pribram, 1960; Wiener, 1948;). The similarities, and important differences, between these systems and those used in PCT have been explained elsewhere (Powers, 1992). The system used in PCT will be explained here. A single isolated negative feedback control system can be represented as a two-part block diagram. One part shows variables and relationships that can be observed from outside the system-a model of the environment with which the control system interacts, including quantitative measurements of those interactions. The remainder of the model is essentially a proposal for what sorts of functions and variables might exist inside the controlling entity that would account for what we can see it doing from outside. The spirit of this model is the same as in physics and chemistry. It is a proposal for the existence of unseen entities and laws relating them-in physics the unseen entities include things like an electron, a field, or energy. The model is stated so one can use it to make predictions, and the requirement for accepting the model is that predictions be confirmed by experiment and observation to the limits of measurement. That is an ambitious goal and we do not claim more than to have set foot on that path. But that is the intent and the guiding principle behind PCT.

Figure 1 shows the 'canonical' PCT model of a single negative feedback control system[1] in relation to an environment.

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1 The full model is built from many systems like this operating in parallel and arranged in layers, a hierarchy of concurrent control in many dimensions.

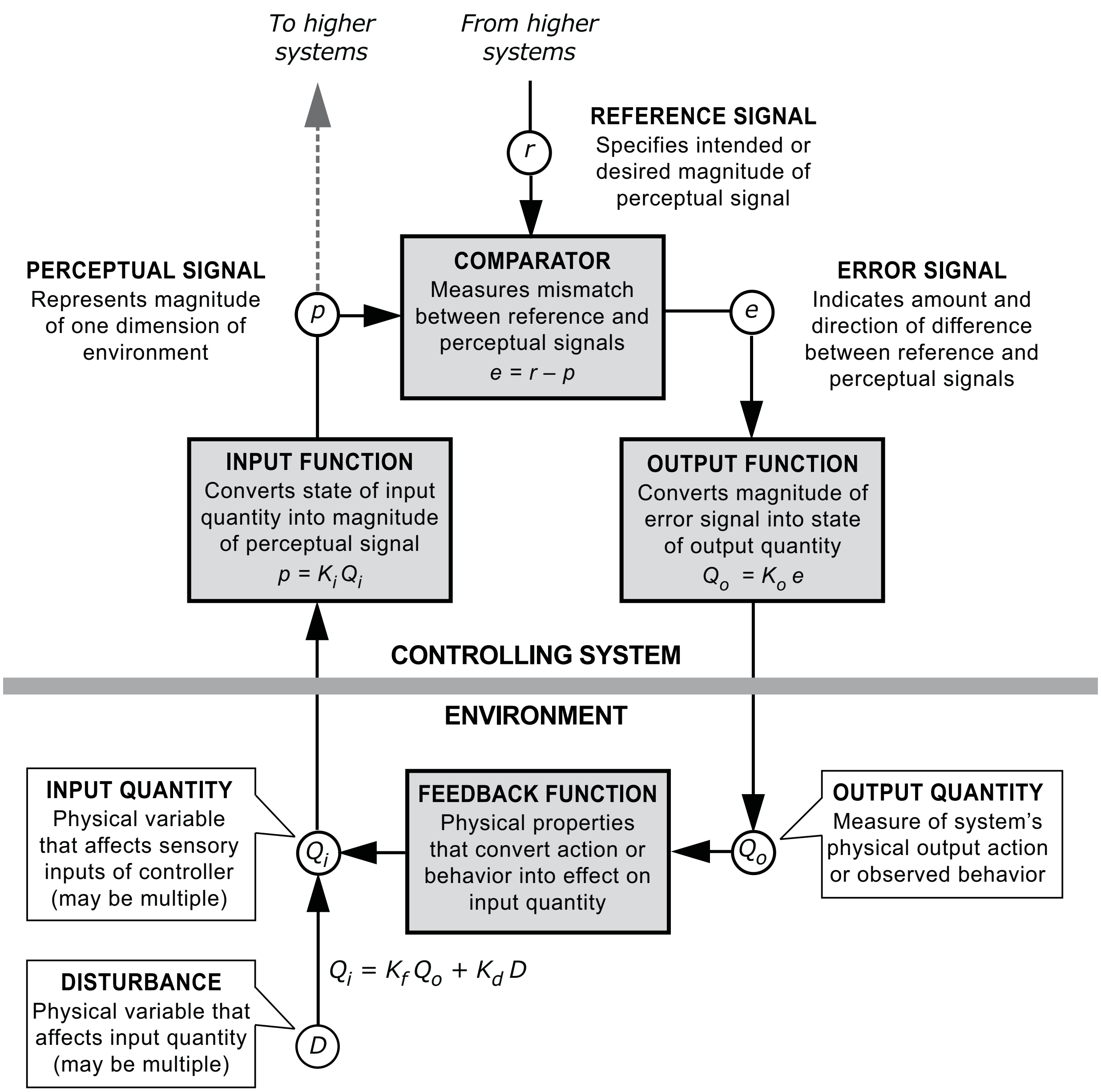

Figure 1: The basic organization of a negative feedback control system. Loop functions are shown in gray. Variables D, Q_i, *etc. are employed in the fundamental algebraic equations of negative feedback control theory, as described in the text. The reader is invited to explore the functions and relationships interactively in the Live Block demo (one of the LCS3Programs set—see the Resources section below).*

There are two independent variables, the reference signal and the disturbance. The first task is to work out the properties of this organization in its simplest form, which is the steady state attained when these two variables are held constant.

A small dose of algebra will help here. Each main component of the system is represented by an equation showing, to a first approximation, how the output of that component depends on its input in the steady state.

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Starting with the input quantity (Q_i) in Figure 1 and going around the closed loop, we represent the input-output function in each box as a simple linear equation:

(1) $p = K_i Q_i$ — input function
(2) $e = r - p$ — comparator
(3) $Q_o = K_o e$ — output function
(4) $Q_i = K_f Q_o + K_d D$ — feedback and disturbance functions

where p = perceptual signal, r = reference signal, e = error signal, Q_i = input quantity, Q_o = output quantity, D = disturbance, and K in each case (K_i, K_o, K_f, K_d) is a constant converting amount of input to amount of output at each of the indicated points in the loop. The largest increase in output occurs in the output function, where very weak neural signals are converted to as much as hundreds of pounds of muscle force.

The four numbered statements above describe how the output of each function depends on its input or inputs. In the simplest case, when the disturbance and the reference signal are constant, the whole system, if properly designed, comes into a state of balance which can be found by solving the simultaneous equations for variables of interest. Solving for the perceptual signal p by successive substitutions yields

$$p = K_i K_o K_f (r - p) + K_i K_d D$$

The product (K_i, K_o, K_f) is the 'loop gain', representing how much a signal affects itself through the feedback loop. Substituting $G = K_i K_o K_f$ to represent loop gain, we obtain

$$(5)\quad p = \frac{G}{1+G}\, r + \frac{K_i K_d D}{1+G}$$

As the loop gain becomes larger (and the addition of 1 becomes less significant), the ratio $G/(1+G)$ approaches 1 and becomes progressively less sensitive to changes in G.

The higher the loop gain, the more precisely the control system makes the value of the perceptual signal match the value of the reference signal, even with disturbances interfering.

Equation (5) is the most important equation in this theory about living control systems. If $G = \infty$, then[2] $p = r$: the reference signal determines the perceptual signal, disturbances have no effect, and large variations in loop gain have no effect on performance. If $K_f = 0$ (no feedback) then $G = 0$ and $p = K_i K_d D$. That is, the perceptual signal is determined entirely by the disturbance. When system dynamics are considered, the equations become more complex, but the steady-state equations remain true. The steady state, or very slow changes, can be understood correctly in this relatively simple way.

Knowing that Q_i is nearly constant when loop gain is high, we can use Equation 4 to see how the output action is related to disturbances. ΔD, a change in the disturbance D, results in ΔQ_o, an opposing change in the output Q_o.

$$(6)\quad K_f \Delta Q_o = -K_d \Delta D$$

A change in the disturbance results in a change in the effect of the output on Q_i that is opposite and almost equal to the effect that this change in the disturbance has on the same variable.

Thus the relationship of the response (output) to the stimulus (input) is determined primarily by the two environmental constants K_d and K_f, not by the actual input-output characteristics of the control system. This may be verified in the Live Block demo previously mentioned (see the LC3Programs link in the Resources section). We call this effect the 'behavioral illusion' because it explains how it has been possible for so long to mistake a control system for an input-output or stimulus-response system.

H.S. Black of Bell Labs, traveling to work aboard the Lackawanna Ferry on the morning of August 2, 1927, suddenly realized how negative feedback could (as outlined above) make telephone relay amplifiers almost immune to changes in vacuum-tube characteristics and erase the nonlinearities of their characteristic curves, while greatly increasing the bandwidth of uniform response (Black, 1934, 1977). High-fidelity audio amplifiers were one result, now familiar, of this insight. Another, less well known but ultimately much more important, was the development of the field of control system engineering—which, by way of cybernetics, led to PCT.

In sum, behavior is the externally visible aspect of a control process by which perceptual experiences are controlled.

We control perceived results, not behaviors or actions. Behavior is the control of perception.

2 More exactly, r is the limit of p as G approaches infinity.

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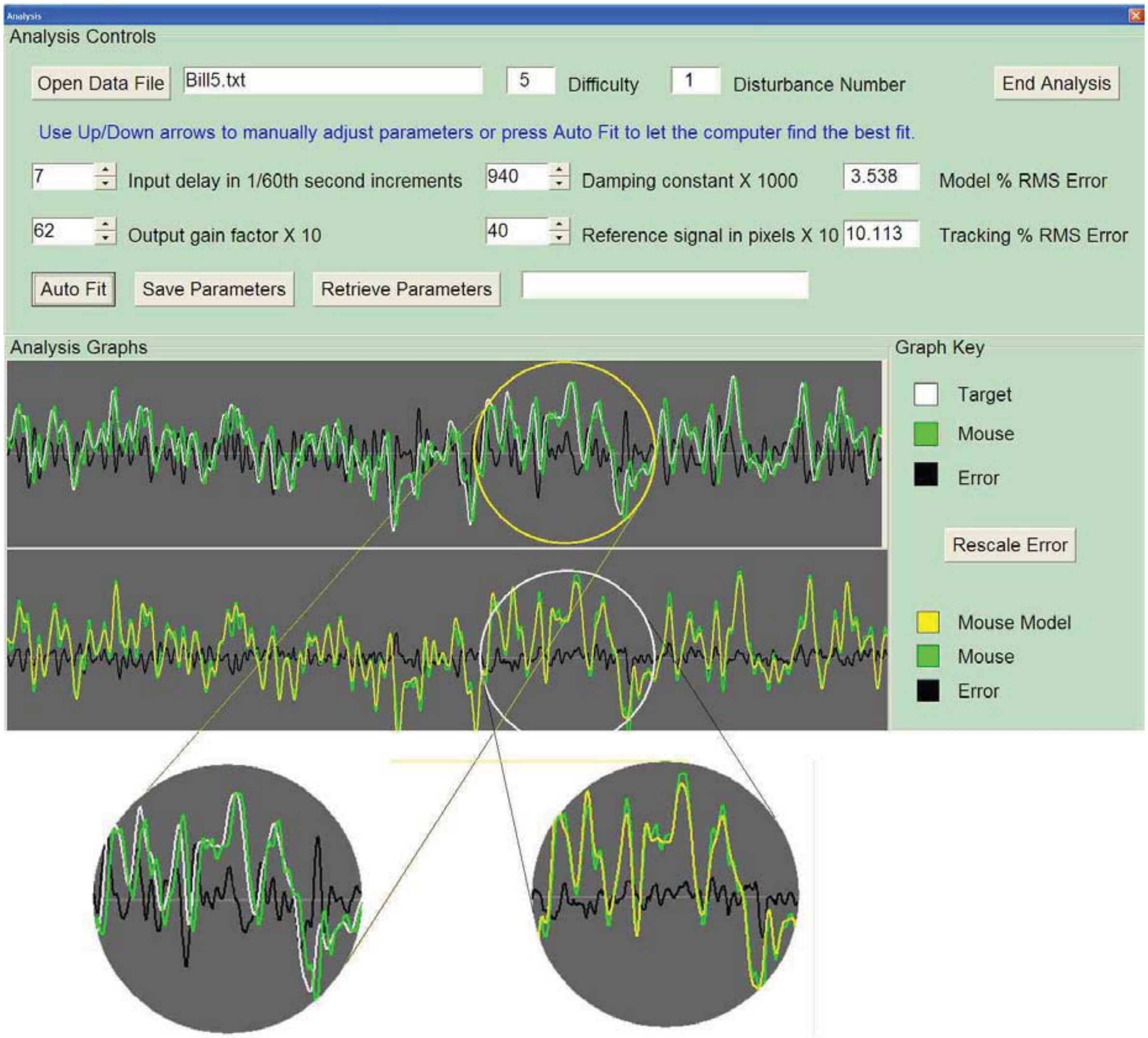

Figure 2. Analysis of human tracking run and fit of negative feedback control model to the data. Upper traces: experimental results; lower traces, match of model (yellow) to the real mouse movements (green). Expanded views taken from each trace are shown to facilitate the comparison. Note delay of human's mouse (green) behind target movements (white).

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Step 2: Demonstrations of negative feedback control

We turn now to the phenomena of control. In the Resources section at the end of this paper are some links to the Internet through which the reader can download several programs that provide interactive demonstrations of control phenomena produced by living control systems within the reader.

There are two sets of demonstrations that can be downloaded and run on a PC,[3] the Demo3 set and the LCS3Programs set. The Demo3 set is a tutorial in PCT with its own narration, which the reader may want to try right now: it will be helpful.

3 As of this writing, you must use a Windows XP emulation program to run these demos on a Macintosh.

The other, LCS3Programs, is a set of 13 demonstration programs that are part of a book (Powers, 2008) but which can be downloaded and run without the book. We highly recommend experiencing the interactive programs. The abstractions in the model will take on much more meaning when connected to direct experience of the phenomena that they describe.

The LCS3Programs set, after installation (following instructions on the download page), is started by clicking on a desktop icon with a red ball on it. The first that we will examine is called ***Demo 4-1, TrackAnalyze*** on the menu which appears at startup. Practice with it for a bit, then follow the instructions to collect data for a formal one-minute run, and then analyze it, using the ***Auto Fit*** button to find the best parameters automatically. The result of the analysis will be a window that looks like Figure 2.

The upper plot shows the target (red) and mouse (green) positions. The black trace is the point-by-point difference between them, the tracking error, which for this 1-minute run was 10% (RMS) of the range of target movement. The lower plot shows how the model's behavior compares with the person's. The error of fit of the model's behavior to the real behavior (labeled "Model % RMS Error"), is 3.6% of the target's range. Since that is less than half of the tracking error, the model must be approximating some of the tracking errors the real person made.

This model inserts a time delay between input and output, called a transport lag, which is optimized by the analysis program. The best-fit value usually comes out to about 8/60th of a second, or about 133 milliseconds (7 to 9 frames of the display screen running at 60 frames per second). With this delay fixed at zero, the 3.6% best-fit error grows to 6%, so we may conclude that the delay is real. Starting a few years after the first tracking experiments were done by engineering psychologists in the 1940s and 1950s, there have been persistent rumors that "feedback is too slow" to be used in behavioral models (e.g. Lashley, 1960), and an apparent conviction that with high loop gains feedback systems with even small delays would become violently unstable. Clearly nothing like that occurs here, either in the negative feedback control model or in the human being. A feedback model with parameters properly chosen, including delays, is exactly fast enough—neither faster nor slower than the real human behavior.

Beyond Tracking

PCT is relevant not just to tracking but to all behavior that involves control—and a careful look suggests that all behavior involves control (Carver, C.S. & Scheier, 1998; Marken, 1988; 2002; McClelland and Fararo, 2006). The loop variables seen in the tracking task can be seen in any example of everyday behavior, from eating breakfast in the morning to brushing one's teeth at night. In each of these behaviors there are controlled variables (like the distance between cursor and target in the tracking task), references for the state of these variables (corresponding to the cursor being aligned with the target), disturbances that would move these controlled variables from their reference states (corresponding to the random variations in target position) and actions that bring the controlled variables to these reference state and keep them there, protected from disturbance (as the mouse movements keep the cursor on target).

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Non-tracking demonstrations of control can be found in the LCS3Programs series. The first shows a red ball that is being disturbed in three ways: its position wanders from side to side, its shape varies from tall and thin to short and wide, and its 'north pole' changes orientation as the ball rocks upward and downward. The three disturbances causing these changes have very low correlations with each other. The participant moves a slider with the mouse, affecting all three aspects of the ball equally and simultaneously. The task is to pick one aspect and hold it constant for one minute: either the lateral position *centered*, or the shape *round*, or the orientation of the pole *pointing toward you*.

After the experimental run, three correlations are calculated among these variables for each plot. The computer indicates by a yellow highlight which of the aspects was under intentional control. It is almost never wrong. Contrary to intuition, the mouse position correlates best with the two uncontrolled aspects of the ball. Figuring out why this is true is a good test of understanding PCT.

Possibly the most surprising demonstration in terms of showing what is meant by control of perception, is ***Demo 9-1, SquareCircle.*** The participant employs the mouse to move a white dot so that it traces as accurately as possible around all four sides of a red rectangle. After the tracing is done, typing 'v' changes the view to show the path that the mouse followed. It is an almost perfect circle (Figure 3, below). The feedback function (see Figure 1) is such as to transform a mouse position relative to the radius of a reference circle into a similar position along a radius from the center of the rectangle to its periphery[4].

But participants are never aware that they are moving the mouse in a circle; they think they are moving it—with some small difficulties—in a rectangular path as shown by the white dot. This impression remains even when they know the truth.[5] Behavior is a process of controlling perceptions, not actions. The actions automatically become whatever they must be to produce the intended perceptual result[6].

Hierarchical PCT (HPCT)

There are two kinds of hierarchical control. One can be called the 'what-why-how' kind and provides a relatively atheoretical way of analyzing behavior into levels. The other is similar but involves a more general analysis. The first kind can be seen in a familiar situation.

You notice someone with a finger on a button beside a door. You ask yourself: "What is he doing?" and the answer seems simple: "He's ringing the doorbell". That is *what* the person is doing. But this is only a means to some end, which we can see if we ask *why* he is ringing the doorbell. Maybe he is visiting and wants Aunt Mary to open the door. Maybe he is promoting a candidate in an upcoming election. Maybe he is delivering pamphlets. Although the *why* is obscure to an observer (but not to the doorbell ringer), the *how* of the observed behavior is clearly "by pressing the doorbell button". However, even this *how* has its own 'what-why-how' pattern. *What* is "seeing and feeling my finger pushing the button", *why* is "to make the bell ring" and *how* is "by moving my hand and arm to the appropriate place". These possibilities illustrate the point demonstrated a few paragraphs ago: the action we see a person producing is generally different from

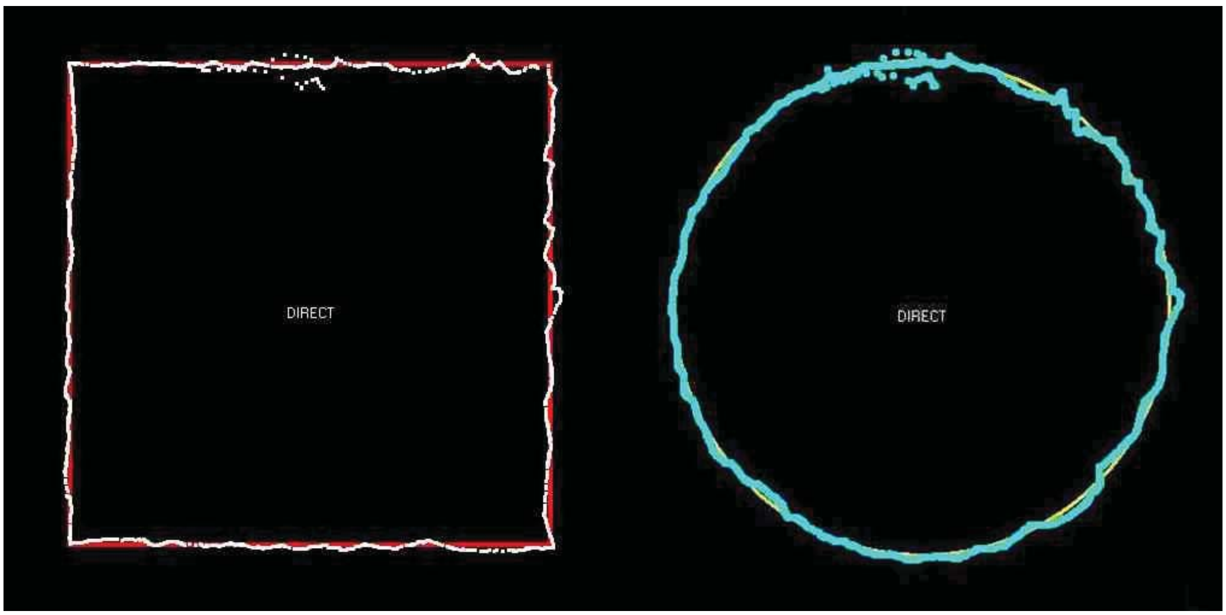

Figure 3. Participant used mouse to move white dot so as to trace red square (left). Mouse actually moved in a circle, as revealed (right) on typing 'v' after the tracing is finished.

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4 You should type a 'd' before doing the tracing, to select the simplest ('direct') form of feedback function

5 There is a similar persuasiveness of illusion in the McGurk effect, the subject of much inconclusive research since McGurk & MacDonald (1976).

6 Typing a 't' makes the reference figure, and the mouse movements, into a triangle ('c' makes it a circle). The mouse path is obvious to an onlooker in either case.

the static or dynamic controlled variable that the person is using the action to control, whether we are looking at the details or the larger picture.

There seems to be a hierarchy of goals here, but what we are seeing so far is a perceived principle, the what-why-how principle, being applied over and over to smaller and larger subdivisions of one complex overall control process. We understand the result by using our capacity to perceive logic, principles, and concepts about systematic order in the world. And those words are showing us something quite different from the what-why-how principle. We have *logic*. We have *principles.* We have a *system concept*. These are the top three levels of perception currently being proposed—tentatively—in PCT. How are those classes of perceptions related to each other? Asking those questions is how we uncover an underlying hierarchy of (proposed) *kinds* of control systems in the brain.

The Second Law of Thermodynamics, conservation of momentum, and Newton's Law of Gravitation are among the principles perceived as adding up to the system concept we call 'physics'. Likewise for different sets of principles that add up to government, economics, religion, society, self, and Mom. Peter Burke (2007) sees system concepts like these in terms of 'identity control'. To support a given system concept, one must vary the reference levels for an appropriate set of principles. To achieve a perception that a principle is present to a desired degree, it is necessary for principle-level systems to vary reference levels specifying which programs are to be perceived in progress. The language gets a little clumsy but the idea may still be understood.

The general idea is that each perceptual signal at one level in the hierarchy is a function of multiple perceptions at a lower level. Control of a perception at one level requires adjustment of reference signals sent to lower systems, which control the perceptions on which the state of the higher-level perception depends. This general organization of the hierarchy of control is the system concept that is called 'hierarchical PCT' or HPCT.

The PCT hierarchy had its beginnings in the 1950s at the lowest levels of all, currently termed *intensity*, *sensation*, and *configuration*. The need for a hierarchy showed up immediately when the spinal reflexes were first recognized as control systems. A spinal reflex (exemplified by the knee-jerk reflex) automatically resists any disturbance of its input variable. But how can the systems higher in the brain use the motor outputs if the spinal control systems automatically react against changes in limb positions or muscle lengths or tendon tensions, and so on? Do we need some elaborate and completely *ad hoc* system that turns the reflexes off when higher systems want to use the muscles, then back on?[7]

Once it is realized that a reflex fits the description in Figure 1, the answer becomes as obvious as the problem was. The simplest way a center higher in the brain can change the controlled variable (without employing violence) is to alter the reference signal. Thus we arrive at the basic principle of hierarchical control, which applies equally well at any level from the spinal reflex to cortical reflection on the state of the world. A control system at any level senses and controls a perception of the type that is supported by that level of brain or nervous system organization. It does so not by commanding the muscles to twitch, but by telling systems at the next level down how much of the perceptions that they control they are to produce. Only at the lowest level, the tendon reflex, do the control systems control their own perceptions by generating muscle forces that affect the outside world. HPCT proposes a mechanism by which specifying reference signals for the level below can turn a goal at the highest level, stage by stage, into the specific muscle actions that achieve it.

The main levels currently proposed are named the *intensity*, *sensation*, *configuration*, *transition*, *event*, *relationship*, *category*, *sequence*, *program*, *principle*, and *system concept*. There may be subdivisions within these categories. Despite having been formulated and revised and worked over for more than 50 years, they are still tentative and subject to more revisions (especially the highest current level). But under the present definitions (Powers, 1998) the basic concept is illustrated and the definitions have proven useful (e.g. van de Rijt & Plooij, 2010).

The higher levels of perception take more time than the lower to be recognized, but in the end all levels of perception are occurring at the same time.

7 At the same time that PCT was first being described, the Russian physiologist Nicolai Bernstein wrote about this problem (Bernstein, 1967).

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Because they form an integrated picture of conscious experience, sorting the experience into its constituent perceptions takes some practice. The originators of PCT took seven years to notice and formalize just five levels (Powers et al., 1960).

For experience with levels, the reader is referred to Marken's demonstrations:

mindreadings.com/ControlDemo/Levels.html
mindreadings.com/ControlDemo/HP.html

Reorganization

The eleven proposed levels of control systems within people are not all present at birth, but it is proposed that their development is well under way by the end of infancy (van de Rijt & Plooij, 2010). They are proposed to result from a change process referred to as 'reorganization', acting on pre-existing structures in the brain that, we assume, have evolved to favor the development of the various types of controlled variables. The 'Ecoli' demonstration in the LCS3Programs set enables you to experience the mechanism that PCT has adopted for the process of reorganization. Reorganization is the unifying concept used to explain how new control systems come into being and how old ones are changed.

In the first paper that led to PCT, a 'negentropy' system was proposed as the origin of reorganization (Powers et al., 1960). It was patterned after a proposal by the cyberneticist W. Ross Ashby (1952) to account for the basic kind of learning called 'trial and error.' It is the only option available to an organism before the time that systematic processes become organized. Powers et al. adopted Ashby's idea that random changes in system parameters might begin when 'intrinsic' controlled variables (Ashby's 'essential' variables) deviate from genetically specified reference levels. These changes of organization continue as long as 'intrinsic error' persists, stopping only when some control-system organization results that brings the intrinsic/essential variable close to its reference level again and keeps it there against disturbances. The processes involved act like an odd sort of control system, now called the *reorganizing system*, that controls by producing random variations of neural organization.

This is the polar opposite of the concept of reinforcement as introduced by Thorndike (1927) and elaborated by B. F. Skinner (e.g. Skinner, 1969). Under reinforcement theory, when an animal produces a behavior that has a beneficial consequence, the organism behaves that way more often. Reorganization theory says that a *lack* of something beneficial gives rise to *continuing changes* in the internal organization of control systems in the organism, changes which slow down when the latest reorganization results in behavior that reduces the deficit. When intrinsic error is reduced enough, reorganization stops and the behavioral organization then in effect persists; the organism keeps controlling the same perceptions in the same way.

PCT proposes that behavior is not what is learned. Instead, a control system is acquired or modified. The behavior that corrects intrinsic error can involve both specific actions and their exact opposites. As shown clearly in the Demo3 set of demonstrations, control can be learned and improved even when a different pattern of behavior is required every time a given control action is successfully executed. A control system, simply because of its underlying organization, automatically varies its actions as disturbances come and go, without needing any warning or any prior experience with each new pattern—one of the great advantages of negative feedback control over other kinds of control.

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B. F. Skinner defined 'the operant' as any behavior that produces a reinforcer. But because he eschewed models of what happens inside an organism, and Ashby had not yet demonstrated the principle behind reorganization, he did not realize that there was an alternative to reinforcing both a specific action and some unrelated action, even the exact opposite. A reinforcer produced by pressing down on a lever with the left paw should increase the probability of pressing the lever with the left paw, yet the next lever-press may be accomplished by pressing the lever with the right paw (or even by backing into it!). How can the reinforcement of left-paw pressing increase the probabilities of these other, quite different behaviors? Defining these different behaviors as somehow the same because they have a common consequence (lever-depression) only obscures the problem rather than solving it. In PCT we are concerned with 'how' questions about what happens inside an organism, and our very different concept of what is learned accounts for the multiplicity of means to the same end for which B. F. Skinner tried to substitute 'the operant'. The LCS3Programs set of demonstrations includes a number of demonstrations of reorganization (Powers, 2008).

Step 3: Applications to selected topics

Methodology

According to PCT, all behavior from the simplest to the most complex is organized around the control of perception. Understanding behavior means knowing what perceptions are being controlled, how they are being controlled, and why. For instance, understanding the behavior of a fielder catching a fly ball means knowing that the fielder is controlling a perception of the optical position of the ball (*what*) by moving on the field appropriately (*how*) with the ultimate goal (*why*) of keeping the approaching ball at a constant or only slowly changing vertical and horizontal angular direction from the fielder until it is caught (Marken, 2001). Behavioral research in the PCT paradigm is, therefore, aimed at discovering what variables the system is controlling, how these variables are being kept under control, and why. The *what* question is always the main focus of PCT research, and it is answered using a methodology known as *the test for the controlled variable* or simply *the test* (Powers 1973, 2005).

The test is based on the fact that a properly functioning control system acts to protect controlled perceptions from disturbances which, in the absence of control, could move these perceptions from their reference states. The test starts by inventing hypotheses about what perception might be under control. Hypotheses about controlled variables come from trying to see the behavior from the organism's perspective. For example, when a beaver is seen to be building a dam one might hypothesize, risking a far-fetched guess, that the beaver is trying to diminish the noise level of the water flow. If the loudness of that noise is a controlled variable for the beaver, the beaver will do something to bring loudness to whatever reference level the beaver sets. If the reference level is zero, then any nonzero sound intensity constitutes a disturbance. The hypothesis is tested by applying disturbances that will be resisted if the hypothesized perception is being controlled. In the beaver example, a research program was indeed carried out in which the researchers produced the sound of rushing water from a loudspeaker near the beavers (Richard, 1983). If the noise were not what is being controlled then the beavers would behave the same way with or without the noise; the disturbance would not be resisted. In fact, the beavers did resist the noise disturbance by piling mud on the source of the noise, suggesting that beavers do control (among other perceptions) the sound of rushing water, keeping that variable as close to zero as possible. It's not hard to imagine why.

The disturbance is the independent variable in the test for the controlled variable. The dependent variable is typically the state of the hypothetical controlled variable itself. So the test is conducted in the same way as in conventional behavioral research; the researcher manipulates an independent variable and measures concomitant variation in a dependent variable. But in this kind of test, observation of a predicted effect of the independent variable on the dependent variable is a negative result, because it indicates that the dependent variable is not being controlled. Conversely, if behavior cancels any effect that does start to occur then the dependent variable (the hypothetical controlled variable) is likely to be under control. If, for example, an increase in the sound of rushing water leads to actions that keep this sound at zero, it is evidence that the sound of rushing water is a controlled variable with an apparent reference of zero loudness. In this we see several ways in which research in the PCT paradigm differs from conventional research.

1. The test focuses on identifying control systems through the discovery of controlled variables. The test can apply to higher level (e.g., self-image) as well as lower level perceptual variables (Robertson et al. 1999).
2. The test focuses on the behavior of one individual at a time. This approach to research has been called 'testing specimens' to distinguish it from 'casting nets', which focuses on the study of groups (Runkel, 2007). For individual prediction accuracy, Kennaway (1997) has shown the importance of obtaining much larger correlation coefficients than those considered strong in Psychology.
3. The results of research using the test are validated using modeling techniques, like those described in Step 2, which is receiving more support in Psychology (Rodgers, 2010).

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Learning and development

We have looked at the PCT model of the reorganization system. Though it applies to other kinds of learning, such as observational learning (Bandura et al., 1966) and verbal learning, we will discuss how reorganization may be the basic phenomenon behind the two most widely accepted concepts of learning, classical conditioning and operant conditioning,

Classical conditioning

Pavlovian or classical conditioning begins, we propose, with an existing control process, either learned or inherited (a 'reflex'). Consider thermoregulation. The controlled variable is the sensed temperature in the hypothalamus. If that core temperature drops, shivering starts, and as that activity warms the bloodstream and the internal temperature receptors, the shivering eventually slows or stops. This is a basic control system, probably inherited. The controlled variable is core temperature; the disturbance is heat loss that causes the core temperature to deviate from its (inherited) reference level, and the output variable is shivering that counteracts the heat loss.

The general PCT explanation of classical conditioning starts with deviation of a critical kind of controlled variable such as core body temperature from its reference level. The initial deviation, an 'intrinsic error signal', if not immediately corrected, is detected by an hypothesized reorganizing system's comparator (it could be a distributed property of all neural control systems), which starts random changes in neural connections, perhaps similar to the synaptic changes often proposed for Hebbian learning (Hebb, 1949). Suppose that some otherwise neutral stimulus such as cold air blowing on the skin happens to precede the change in the controlled variable by a few seconds. Neuroanatomy permitting, reorganization will eventually make a connection between the neutral perceptual signal and the input function of this control system. That neutral stimulus thus produces the same perceptual signal in the control system that would be produced by a change in the controlled variable, a drop in core temperature, but does so before the critical controlled variable actually changes enough to cause reorganization to start. When the cold air starts blowing, the revised control system will now detect an error and the error will cause the same action as usual, shivering, protecting the core temperature from the disturbance—but there will be no further reorganization because the next time the cold air is experienced, shivering starts immediately and the change in the intrinsic or essential variable, the drop in core temperature, does not occur, or is much less.

If now we arrange for a tone to precede the blowing of cold air on the skin, the same thing will happen again (once more, neuroanatomy permitting): if the shivering does not entirely counteract the effect of the cold air, reorganization will continue and the tone will eventually start the shivering even sooner, further reducing or eliminating the 'intrinsic error'. Rescorla has remarked that classical conditioning phenomena can be predicted by thinking of how a scientist recognizes causality—a regular relationship between antecedent and consequent (Rescorla, 1988). The model of reorganization that predicts classical conditioning—as well as extinction—is based on *actual* relationships between antecedents and consequents. But it does not rely on cognitive processes of recognition.

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Operant conditioning

The same reorganizing process that creates the phenomena of classical conditioning can also explain operant conditioning. The main difference is that here reorganization appears to work more on the output side of the control system than the input side.

All the basic forms of operant conditioning, such as a fixed-ratio experiment, begin by restricting the organism's access to something important: food, water, or even warmth or sweetness. This is of course an error condition in some basic and presumably inherited control system. In Skinnerian terms, an animal subjected to this 'establishing condition' spontaneously 'emits' whatever behaviors have already been acquired or inherited that might lessen the deprivation.

Consider the case in which a rat is rewarded for lever-pressing by delivery of food pellets. Two different processes appear to be working here. The first one is simply an initial search for food and the narrowing of the search to any area where food was found. This is most probably an organized behavior that all rats learn, or it may be an innate behavior due to a control structure that they are born with. In the second process, the rat's accidental and then purposeful use of the lever to obtain food, it is the progressive refinement of the behavior pattern that makes it instrumental—reliable and organized to produce a specific effect in the given environment. Only the second process would require any change of internal organization.

Together, these two processes take place in what we may call the learning phase of a conditioning experiment. That phase is followed by a maintenance phase when the animal routinely uses the new technique to alleviate its hunger. The reorganizations in this kind of conditioning are primarily on the output side, where errors give rise to changes in the reference signals that are sent to this or that lower-order system that controls by means of already-organized behaviors.

Reinforcement is said to increase the probability of the behavior that produced it. This has a descriptive basis in observations during the learning phase of an experiment. Observation of what happens first in the operant cage shows, however, that it is the convergence of exploratory activities below, near, and above the lever that first increases the probability of producing the reinforcement. The PCT alternative to reinforcement theory, up to this point, is simply to say that this is normal control behavior. When the error is reduced, the tendency to go on exploring is decreased; when error is reduced enough, the exploring ceases.

Because this model leads us to expect essentially the same series of events that the theory of reinforcement suggests (albeit for different reasons), either theory accounts for the described facts for the initial learning phase. Simply having a plausible alternative to the theory of reinforcement, however, is useful in itself. It shows that reinforcement *is* a theory, not simply a description of a fact, and needs to be investigated as skeptically as any other theory.

By itself, reinforcement theory predicts that reinforcement leads to more behavior that generates more reinforcement. Considering only the basic principle of the theory, it would seem that if the rate of reinforcement increases, the behavior rate should also increase, or conversely should decrease noticeably if the rate of reinforcement decreases, and behavior should cease if the reinforcement completely stops.

It is true that complete cessation of reinforcement does result in extinction of behavior. However, changing the schedule of reinforcement to reduce the amount of reinforcement produced by the existing behavior rate does not reduce, but actually increases the amount of behavior, as the organism 'defends' its food intake, and ultimately its body weight. The behavior rate is increased just enough to maintain the reinforcement rate nearly constant. This increase in behavior rate is known as the *extinction burst*. It is not transient, as the word 'burst' suggests, but rather persists as long as behavior can maintain the desired food intake. Experiments with normal rats obtaining all their food by lever pressing (Collier *et. al*. 1986) showed that these animals maintain food intake at 20 to 25 grams per day even as the required behavior ranges from 20 presses to obtain a gram of food to 1000 presses per gram. In reinforcement theory, these observations are inexplicable; in PCT, they become easy to understand: it is behavior that maintains the reinforcement rate, not the other way around. The evidence above shows that reinforcement is actually controlled by behavior; it is simply one of many kinds of controlled input.

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But such reinterpretations do not come easily to any science. Even physics once preferred a 'luminiferous ether' to the transmission of light through a vacuum, and chemistry once preferred the emission of phlogiston to the absorption of oxygen, until experimental evidence created an intellectual crisis. PCT, we hope, brings such an intellectual crisis to the sciences of behavior.

Conflict

The way a person's control systems are organized into levels with many independent control systems at the same level makes internal conflict possible, and indeed likely. Conflict arises when one control system receives disparate reference signals from more than one system at higher levels. For that one system where the contradiction occurs there is no problem; a virtual reference signal results and behavior matches perception to it. But neither of the higher systems gets the input it was requesting and both experience chronic errors. This effectively removes both higher control systems from useful service for still-higher systems, and the conflict may escalate (depending on details of organization), each system continually increasing its effort to resist the disturbance caused by the other.

Conflict within a person can arise quite by accident. A person may have a goal of being a good person. To be a good person, one should be steadfast, both consistent and firm; also, one should be supportive of others; obliging and accommodating. Both of these sub-goals are supposedly ways of satisfying the higher goal of being a good person. But when it comes to selecting a specific way of behaving that will satisfy both goals, the contradiction arises: one can't be steadfast and obliging at the same time, or firm while being accommodating too. At the level where a specific goal is to be achieved through specific programs, there is direct conflict. To behave one way means not behaving the other way. This sounds like a simple problem, and usually it is easy to resolve through some quick and automatic reorganization. But conflict can also be a serious problem leading to chronic difficulties: stay with an abusive mate for the sake of love and the children, and at the same time—an impossibility—leave, for the sake of sanity and safety.

Conflict between persons also interferes with positive social interactions. Cooperation requires several people acting to achieve a common goal. However, the more important the goal is (in technical terms, the higher the gain around the loop), and thus the smaller the errors the participants strive to eliminate, the more likely it is that conflicts will create problems. As participants' control becomes more skillful, a smaller discrepancy between their perceptions (or their goals) suffices to set them at odds with each other.

Another problem with between-persons conflict is that each person probably experiences internal conflict as a result of holding back from doing what would actually be necessary for prevailing over others in the details of goal-seeking. The urge to violence, as newscasts of parliamentary procedures occasionally illustrate, is not always easy to resist—and when it is resisted, a person loses some of his own goal-seeking skill. Conflict, whether intra- or inter-personal, can be crippling.

Clinical practice based on PCT is finding more and more evidence that serious unresolved conflict may be one of the primary reasons for psychological problems (Carey, 2008). Attention and reorganization tend to focus on the lowest level where conflicts are played out, but a conflict can be permanently resolved only by reorganizing on the levels where the contradictory goals are set. This suggests an approach to therapy that involves deliberate shifts in the focus of attention toward higher levels of organization.

PCT based psychotherapy: the Method of Levels

Psychotherapy has focused, understandably, on pathology. PCT contributes a useful perspective in understanding psychological disorders by first providing a model of satisfactory psychological functioning. Dysfunction then is disruption of successful control (Carey 2006, Mansell 2005). Distress is the experience that results from a person's inability to control important experiences. The symptoms of distress clearly cannot be 'treated' as though they were in themselves the problem. The PCT perspective is that restoring the ability to control eliminates the source of distress. As we noted earlier, conflict has the effect of denying control to both systems that are in conflict with each other. Conflict is usually transitory. It is when conflict is unresolved and becomes chronic that the symptoms recognized as psychological disorder become apparent.

As discussed earlier, chronically unreduced error triggers reorganization. When difficulty in controlling is due to more ordinary causes (environmental disturbance, inadequate perceptual input, inappropriate means, etc.), reorganization alters the control system in some way until control is restored (where that is possible). However, when error persists because two systems are specifying different goals for the same lower-order system, the lower system is 'frozen' in a state that satisfies neither of the higher systems that are locked in conflict.

There is evidence that attention tends to focus on this conflicted lower system. The subjective experience is of being 'stuck' and not knowing why. Nearly all schools of therapy assume that change requires being aware of what is to be changed. The general principle, in PCT, is that the main locus of reorganization seems to follow awareness.[8] The difficulty is that it is futile to reorganize the 'stuck' system; it is working properly.

8 It appears that awareness is *in* one level while focused *on* those lower levels where reorganization is also focused. Subjective attitudes and interpretations are perceptions on the level that awareness is *in*; the objects observed from that level (which those attitudes and interpretations are *about*) are the lower levels of perception.

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No matter how it is changed, it still cannot satisfy two contradictory specifications of the goal it seeks; the best it can do is to seek a compromise goal, leaving both of the conflicting systems unable to achieve control. Instead of reorganizing the conflicted system at the lower level, one or both of the conflicting systems at the higher level must be changed so that they perceive differently or so that they use as means of control different lower-order variables that can be independently controlled at the same time. A shifting of attention is the key to doing this. Although reorganization is an automatic response to intrinsic error that cannot be controlled voluntarily, there is plentiful evidence that awareness can be redirected, and that this changes the focus of the reorganizing process. But the act of reorganization can be done only by the person experiencing the conflict.

The therapeutic approach that is based on the principles of PCT is called the Method of Levels (MOL; e.g. Carey, 2006; 2008). The core process is to redirect attention to the higher level control systems by recognizing 'background thoughts', bringing them into the foreground, and then being alert for more background thoughts[9] while the new foreground thoughts are explored. When the level-climbing process reaches an end state without encountering any conflicts, the need for therapy may have ended. When, however, this 'up-a-level' process bogs down, a conflict has probably surfaced, and the exploration can be turned to finding the systems responsible for generating the conflict—and away from a preoccupation with the symptoms and efforts immediately associated with the conflict.

Despite the demonstrated effectiveness of various approaches to psychotherapy there is still no generally accepted account of how these effects are achieved. In fact, it has been shown (e.g. by Wampold 2001) that psychotherapies based on quite different models of disorder can have similar effects. As a consequence, there has been an increasing call to move away from developing new techniques and strategies based on diagnosis and instead to focus on underlying common principles and mechanisms (e.g., Rosen & Davison, 2003).

9 "Background thoughts" are probably the same phenomenon described by Beck (1976) as "automatic thoughts."

The paradigm of perceptual control provides a common underlying process (conflict) and a common change mechanism (reorganization) that may provide the means to make sense of these otherwise puzzling results.

While some of the propositions about the application of PCT principles to psychotherapy remain speculative, there is also indirect but strong evidence for this approach. Problems of control (understood as control of behavior, impulses, emotions, or thoughts) are widely recognized as important in psychological functioning. Many approaches to psychotherapy use conflict formulations to explain psychological distress (Carey 2008, 2011). Many approaches also depend upon awareness in resolving problems and recognize the need to consider problems from higher levels of thinking (such as important life values or belief systems). Also consistent with the nature of reorganization is a growing body of literature that recognizes that the change involved in the resolution of psychological distress is not a linear or predictable process (e.g. Hayes 2007).

Exploring psychological disorders and their treatment from the perspective of perceptual control provides a new direction for psychotherapy researchers and practitioners. An understanding of the nature of psychological distress that is developed from a model of normal function rather than dysfunction will help to clarify the purpose and process of treatment. By distilling the important components of psychotherapy, it allows therapists to be clearer about their roles and to make their treatments more efficient, and it can provide insight into the purpose of psychotherapy. PCT, then, will have an impact on long standing debates such as the equal effectiveness of treatments versus the superiority of some treatments or the importance of specific versus common factors. PCT proposes a consistent and coherent approach that could provide a unifying focus for dealing with distress. With a unifying focus, a more consistent and coherent approach can emerge that will go a long way towards preventing the debilitating impact of psychological distress that is currently on the increase in many countries.

A guide for learning MOL therapy is provided by Carey (2006). Applying the Method of Levels does not assume blind faith in the correctness of PCT. Rather, every application is an opportunity to challenge and test the theory, as well as a chance to put

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the theory to good use. Research into MOL therapy has been started in several countries—see Bird, Mansell, and Tai (2009), Carey (in press), Goldstein and Goldstein (2005), Goldstein (2007). This research must be continued and extended in order to evaluate the theoretical expectations which are based on the concepts of negative feedback control, reorganization, redirection of awareness to higher perceptual levels, and internal conflict resolution.

Afterword

The reader of this paper may be experiencing some internal conflicts between implications of PCT and some other theory that has seemed reasonable and believable. We can only comment (not very helpfully) that most of the people now engaged in the exploration of PCT were trained in some other way of explaining and understanding the behavior of humans and other organisms. Most have used and even taught those other ideas for many years. Each person has had to work through the internal and professional conflicts involved in a sometimes wrenching change of understanding. It may be a little helpful to keep in mind that such conflicts are to be expected, and that persistence will probably resolve them. PCT suggests that this conflict is at the highest levels, principles and systems. Control of perceptions at these levels is the hardest to change, we assume because every high-level change requires many lower-level changes, the need for which may take time to become apparent.

Resources

Computer simulations

The LCS3 program set is available at:
www.billpct.org. This web page is mirrored here: livingcontrolsystems.com/billpct.html

The Demo3 program set and many other DOS and Windows demo programs are available at:
livingcontrolsystems.com/demos/tutor_pct.html

Demo programs by R. Marken run in a web browser: www.mindreadings.com/demos.htm

Reference websites

Introductions and discussions of Perceptual Control Theory can be found at several web sites. Four of the most comprehensive reference sites are:

- www.iapct.org/
- www.livingcontrolsystems.com/
- www.pctweb.org/
- www.mindreadings.com/

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Email discussing this document:

Date: Fri, 03 Jun 2011
From: Bill Powers
Subject: Re: Perspectives on Psychological Science - Decision on Manuscript ID PPS-11-099

Hello, Bruce --

On 6/3/2011, Bruce Nevin wrote (to Rick):

BN: No one has responded to your plea for help with our jointly produced "paradigm" paper. I say again that the key is audience. Bill said, and we agreed, that we were writing it for a general audience of intelligent readers of technical bent. We have not submitted it to a journal that has that readership. Instead, we have submitted it to journals addressed to a particular audience of intelligent readers with prior commitments in psychological theory. As I understand it (maybe wrongly), you offered to rewrite it for that audience. I am not surprised that this has been a discouraging task. It is much too frank a survey to get past their defenses. And it is a survey, rather than a report of previously unpublished work. Of course, the survey covers ground that is new to those readers, but editors of those psych journals assume that for something to be relevant for their readers it must naturally be on familiar ground and that therefore to be newsworthy it must be new, i.e. recent and not previously published results.

BP: I think you've made this problem very clear. I have started planning to talk at the CSG meeting in July, or at least organize a discussion, about a direct confrontation with conventional ideas, perhaps through a book to be written via Google Docs by all of us who are concerned. I wish everyone on this CC list would come to the meeting, but not all can.

When I first started writing *Making Sense of Behavior*, the title was *Starting Over*. Those who heard about that were very reluctant—that would be a little like burning bridges instead of building them. But aside from the personal contacts we make, or the writing of popular (non-scientific) works, it's starting to look as though there isn't any other choice. The bridge keeps getting burned by the people on the other side. They don't realize that we're trying to rescue them before that little island they're on is washed away by the tsunami.

So I say, let's make waves.

Best, Bill

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An Essay on the Obvious

William T. Powers January 1991
Post to CSGnet

. . . I'm reminded of a lot of the "new physics" stuff that's been going around—The Emperor's New Mind, The Quantum Self, chaos in the brain, and so on. I'd like to say this about that:

AN ESSAY ON THE OBVIOUS

I think that all attempts to apply abstract physical principles and advanced mathematical trickery to human behavior are aimed at solving a nonexistent problem. They all seem to be founded on the old idea that behavior is unpredictable, disorderly, mysterious, statistical, and mostly random. That idea has been sold by behavioral scientists to the rest of the scientific community as an excuse for their failure to find an adequate model that explains even the simplest of behaviors. As a result of buying this excuse, other scientists have spent a lot of time looking for generalizations that don't depend on orderliness in behavior; hence information theory, various other stochastic approaches, applications of thermodynamic principles, and the recent search for chaos and quantum phenomena in the workings of the brain. The general idea is that it is very hard to find any regularity or order in the behavior of organisms, so we must look beyond the obvious and search for hidden patterns and subtle principles.

But behavior IS orderly and it is orderly in obvious ways. It is orderly, however, in a way that conventional behavioral scientists have barely noticed. It is not orderly in the sense that the output forces generated by an organism follow regularly from sensory inputs or past experience. It is orderly in the sense that the CONSEQUENCES of those output forces are shaped by the organism into highly regular and reliably repeatable states and patterns. The Skinnerians came the closest to seeing this kind of order in their concept of the "operant" but they failed to see how operant behavior works; they used the wrong model.

Because of a legacy of belief in the variability of behavior, scientists have ignored the obvious and tried to look beneath the surface irregularities for hidden regularities. But we can't develop a science of life by ignoring the obvious. The regular phenomena of behavior aren't to be found in subtleties that can be uncovered only by statistical analysis or encompassed only by grand generalizations. The pay dirt is right on the surface.

The simplest regularities are visible only if you know something about elementary physics—and apply it. Think of a person standing erect. This looks like "no behavior." But the erect position is an unstable equilibrium, because the whole skeleton is balancing on ball-and-socket joints piled up one above the other. There is a highly regular relationship between deviations from the vertical and the amount of muscle force being applied to the skeleton across each joint. There is nothing statistical, chaotic, or cyclical about the operation of the control systems that keep the body vertical. They simply keep it vertical.

The same is true of every other aspect of posture control and movement control, and all the controlled consequences of those kinds of control. Just watch an ice-skater going through the school figures in competition. Watch and listen to any instrumentalist or vocalist. Watch a ballet dancer. Watch a stock-car racer. Watch a diver coming off the 10-meter platform. Watch a programmer keying in a program.

It's true that when you see certain kinds of human activity, they seem disorganized. But that is only a matter of how much you know about the outcomes that are under control. The floor of a commodities exchange looks like complete disorder to a casual bystander, but each trader is sending and receiving

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signals according to well-understood patterns and has a clear objective in mind—buy low, sell high. The confusion is all in the eye of the beholder. The beholder is bewitched by the interactions and fails to see the order in the individual actions. When you understand what the apparently chaotic gestures and shouts ACCOMPLISH for each participant, it all makes sense.

Of course we don't understand everything we see every person doing. It's easy to understand that a person is standing erect, but WHY is the person standing erect? What does that accomplish other than the result itself? We have to understand higher levels of organization to make sense of when the person stands erect and when not. We have to understand this particular person as operating under rules of military etiquette, for example, to know why this person is standing erect and another is sitting in a chair. But once we see that the erectness is being controlled as a means of preserving a higher-level form, also under control, we find order where we had seen something inexplicable. We see that an understanding of social ranking, as perceived by each person present, results in one person standing at attention while another sits at ease. Each person controls one contribution to the pattern that all perceive, in such a way as to preserve the higher-level pattern as each person desires to see it.

It seems reasonable that once we have understood the orderliness of simple acts and their immediate consequences, we should be able to go on and understand more general patterns that are preserved by the variations that remain unexplained. As we are exploring a very large and complex system, we can't expect to arrive at complete understanding just through grasping a few basic principles. We must make and test hypotheses. But if we are convinced that the right hypothesis will reveal a highly-ordered system, we will not stop until we have found it. If, on the other hand, we are convinced that such a search is futile, that chaos reigns, we will give up the moment there is the slightest difficulty and turn to statistics.

I claim that human behavior is understandable as the operation of a highly systematic and orderly system—at least up to a point. I say that it is the duty of any life scientist to find that orderliness at all discoverable levels of organization, and to keep looking for it despite all difficulties. We must explore all levels, not just the highest and not just the lowest; what we find at each level makes sense only in the context of the others.

We have a very long way to go in understanding the obvious before it will be appropriate to look for subtleties. I have no doubt that we will come across mysteries eventually, but I'm convinced that unless we first exhaust the possibilities of finding order and predictability in ordinary human behavior, we won't even recognize those mysteries when they stare us in the face. I don't think that anyone is prepared, now, to assimilate the astonishments that are in store for us once we have understood how all the levels of orderly control work in the human system.

We won't get anywhere by looking for shortcuts to the ultimate illuminations that await. Most of the esoteric phenomena of physics that are taught in school today were occurring in the 19th Century, as they always have. But who, in that century, would have recognized tunneling, or coherent radiation, or time dilatation, or shot noise? If we want to see a Second Foundation of the sciences of life, we have to begin where we are and build carefully for those who will follow us. If we succeed in trying to understand the obvious, the result will be to change what is obvious. As the nature of the obvious changes, so does science progress.

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Things I'd like to say if they wouldn't think I'm a nut

Or — Overgeneralizations that aren't that far over.

William T. Powers, 1989

When you study human beings, remember that you are a human being. You can't do anything that they can't do. You think with a human brain, experience with human senses, act on the world as human beings experience a world. Whatever you say about them is true about you. Whatever you can do, they can do.

Understanding human nature means more than having a large vocabulary. You experience the world at many levels, some lower than symbols and some higher. If you try to understand by using nothing but words, you'll miss most of the picture. What most people call "intellectual" is really just "verbal." If you always use the same terms to refer to the same idea, it's not an idea but a verbal pattern. Most important words don't mean much. Words that "everybody knows" don't mean anything. Words that are used to describe psychological phenomena are almost all informal laymen's terms that have negative scientific meaning: they imply the existence of things that don't exist, like "intelligence" or "aggressiveness" or "altruism." Or "conditioning" or "habits" or "aptitudes" or—see the literature.

Knowledge isn't what you can remember or name: it's what you can work out from scratch any time you need to, from basic principles. The behavioral sciences don't have any basic principles. None, that is, that would survive scientific testing.

Statistical findings are worse than useless. They give the illusion of knowledge. Even when they're true for a population, they're false when applied to any given person. To rely on statistics as a way of understanding how people work is to take up superstition in the name of science. It's to formalize prejudice.

When you propose an explanation of human behavior, you ought to make sure that the explanation works in its own terms: what exactly does it predict? Most explanations in the behavioral sciences consist of describing a phenomenon, saying "because," and then describing it again in slightly different words.

Perceptual control theory may have a long way to go as a theory of human nature, but it's the only theory that deals with individuals and accepts them as autonomous, thinking, aware entities. You might say that thinking about them that way is what makes control theory possible to understand. Using control theory, you don't have to ignore individuals who deviate from the average. Using control theory you can propose explanations that you can test. Using control theory you can learn that scientific understanding isn't any different from ordinary understanding. A scientist would judge that a cooling device used in regions of very low ambient temperatures would be inefficient, and you can't sell a refrigerator to an Eskimo, either.

But never forget that science bought Phlogiston for 150 years, and stimulus-response theory—so far—for 350 years. We're still crawling our way out of one system of faith into the next, still looking for dry land and solid ground. Is control theory the new faith? Not as long as you can forget everything you've memorized and reason it out for yourself.

> ***The behavioral sciences don't have any basic principles. None, that is, that would survive scientific testing.***

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PCT is Reverse Engineering

All the physical sciences can be thought of as reverse engineering

Dag Forssell 1997 rev 2003

Can't look inside: Speculate

Think of people as complex devices. They sometimes behave in ways we expect, sometimes not. No-one has been able to open them up, take a look inside and figure out how they work, but speculative, plausible-sounding "theories" abound, are widely accepted and have become engrained in our language.

Work out a way: Reverse engineer

Suppose you manufacture encapsulated products and your competitor has just introduced a very capable product of unknown design. It is difficult to figure out how the new device is designed and what is going on, because the product is made up of a great many components and you cannot take it apart without destroying it. To "reverse-engineer" it you:

1) describe what the device does (how it behaves) in some detail, and
2) suggest physical explanations. Based on these, you design and test circuits and mechanisms that perform just like the unknown product.

When your reverse-engineered design can be plugged in as a replacement for the unknown device, you can claim that you understand at least one way the unknown device might work—and you are probably quite certain of many ways it cannot work.

PCT reverse engineers living organisms. You can test the PCT model by letting it behave *by itself*, and compare the result with the behavior of the real thing—people. Since it is ourselves we reverse-engineer, we naturally require that the explanation and model we come up with feels right; that it intuitively makes sense to us when we consider how we might actually work. Simulations, experiments where the PCT model replaces people, and personal experience indicate that PCT is a valid model. PCT appears to be the first approach to explaining human behavior that holds up to critical scientific scrutiny and is worth refining.

Understanding purposeful behavior

Perceptual Control Theory (PCT) gives an intuitively satisfying explanation for purposeful human behavior, were purposeful behavior is also known as control. PCT calls our attention to the pervasive phenomenon of perceptual control and provides a summary explanation that can be presented as a single control system.

Hierarchical PCT (HPCT) outlines a hierarchical arrangement of multiple control systems—a more detailed elaboration of PCT that allows for the complexity of our experience. The distinction between PCT and HPCT is most often glossed over and the whole scheme called PCT.

PCT focuses on how we look at and experience things, and the way these perceptions are compared with experiences we want. PCT explains how thoughts become actions and feelings and why stimuli *appear* to cause responses.

PCT improves our understanding of human interpersonal behavior, including conflict, cooperation and leadership in families, education, business and society.

Applying PCT

To drive a car, it is important to know how the controls work, but it is not necessary to understand how the controls are designed in detail—you can leave that to the automotive engineers.

To apply PCT in daily life, it is important to understand the basic concept—but it is not necessary to understand all the technical details—you can leave that to the PCT engineers.

When you understand the basic concept of PCT, you will observe yourself and others and at the same time visualize the internal mechanism in action. Your understanding of the internal mechanism will give you greater ability to enjoy your ride through life and to help others enjoy theirs, too.

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The Tank That Filled Itself

By William T. Powers

Perceptual control theory (PCT) is a cross between biology and engineering. Its shallowest roots are in control theory, developed during the 1930s and 1940s by electronics engineers; and homeostasis, physiologist Claude Bernard's idea from the mid-1800s. Walter B. Cannon carried Bernard's idea further in the 1930s, and a decade later Cannon's ex-student Arturo Rosenblueth, aware of new engineering developments, told Norbert Wiener about the resemblance of control systems to behavioral systems in human beings and animals. That was the start of cybernetics, the science of "steersmanship." PCT was probably conceived when I learned something about control systems first as a navy electronics technician and then as a student physicist. It was brought to life in 1952 when I read Wiener's 1948 book.

But the tap root of PCT goes far deeper than the strata in which we find the control engineers of the 1930s, or Wiener, Rosenblueth, Cannon, and Bernard, or me as a young man of 26. It burrows through layers of engineering developments in which we find 19th-Century control systems for steering steamships, down through Watts's 18th-Century flyball governor for steam engines, through the wind-driven grain-mill speed regulators ("lift-tenters") immediately beneath, through medieval temperature controls for furnaces, down through Arabian water clocks, all the way to a Greek inventor named Ktesibios, a student of Archimedes, a contemporary of Euclid, and possibly head of the Museum of Alexandria in Egypt before the great library was burned. Ktesibios was interested in water clocks.

The road not taken: the first recorded negative feedback control system

Water clocks, in ancient Egypt, had a small tank that held water used to fill, very slowly, a larger reservoir, raising a float and moving the time pointer. To keep the smaller tank filled precisely to the right level, so the clock would keep proper time, ancient Egyptians had either to keep the tank filling fast enough that it continually overflowed, or to assign a slave to replace a much smaller amount of water as it was used by the clock. In about 250 BC, Ktesibios thought of an automatic device that would prevent wasting water and making a mess. His regulator would replace the slave, using a float in the small tank to measure the water level and a link from the float to operate a valve that would let more water in when the water level dropped. Now the tank could keep itself full without human help.

With a little poetic license, we can imagine a pre-Ktesibios water clock outside in an ancient courtyard, but equipped with the Ktesibios regulator. The regulator would respond to all kinds of disturbances in just the right way. If a flock of birds took a drink from the small tank, or if water slowly evaporated on a windy hot day, the float would fall slightly and the valve would open a bit more to compensate for the transient or continuing loss. If a rainstorm overfilled the tank or somebody tossed a stone into it, the valve would close until the clock's use of water lowered the water level, then open just enough to keep the tank at the former level. Everything this device did, the slave it replaced would have done.

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Presented July 2010 at the Control Systems Group conference in Manchester, UK

It's important to notice that neither the slave nor the regulator had to know anything about why the water level varied. They didn't have to chase away thirsty birds or people throwing stones or anticipate hot dry winds. All either one had to do was sense and affect the very thing that was supposed to be controlled, the water level. The slave sensed it by looking; the machine sensed it with a float. If the water level went below the right level, the regulator, human or mechanical, was internally connected so as to open the valve until the intended level was restored, then to adjust the valve to maintain that level. The valve was being opened or closed as a means of controlling the *sensed* or *perceived* water level, since that is all the slave or the machine knew about the actual water level. We can say that the actions were the means by which either the slave or the machine controlled a perception of water level based on the actual water level.

Here is a diagram of how the Ktesibios regulator worked, which is certainly in the running as a diagram of how the slave, if there was one, would have worked, too.

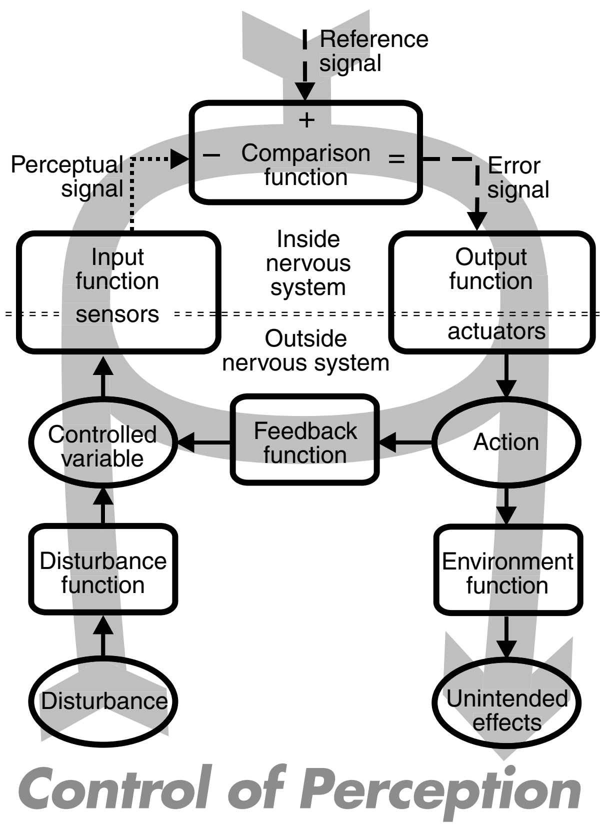

Figure 1: Basic diagram of perceptual control.
Grey overlay highlights closed-loop flow.
By Dag Forssell, 2010.

The disturbance at lower left is a bird or a stone or a rainstorm or a leak in a pipe or any of a thousand phenomena in the environment of the clock. Each of those phenomena, to act as a disturbance, would have to be connected in some way to the water level in the small tank, the controlled variable in the diagram. The "disturbance function" represents the means by which each disturbance changes the water level—removing water, displacing it to raise the level, or adding water.

The regulator proper is above the inside-outside boundary marked by double dashed lines. There is a sensor (vision or float) in an input function that converts the controlled variable into a perceptual signal, an internal representation of the water level. This signal is compared to a reference signal, which is an internal representation of the desired or intended water level. In the artificial regulator, the reference signal is simply the water level at which the valve is just barely closed—it can be changed by altering the link that connects the float to the valve. In the slave, it's a neural signal that biases the relationship between sensory input and output action, or more simply, it's a mark on the wall of the tank selected as a target for the water level.

Out of the comparison function comes a signal or an effect that is converted by the nervous system of the slave or the construction of the device into an output action. Opening or closing of the valve depends on whether the error signals too little or too much water, and the degree of opening depends on the size of the error. We are now back in the environment of the regulator. The action operates the valve, which in the diagram is called a feedback function, since it feeds an effect of the output action back to the input sensor. The action also has other effects, shown lower right, such as exciting the optic nerve of someone else watching the action, but those effects (which the observer experiences as the behavior of the regulator) have nothing important to do with this particular regulator. The effect of action that matters is the effect on the controlled variable, the same variable that the system is sensing. The water is maintained at the intended level, the "reference level," by purposive actions governed by a goal, the goal being a specification for the state of a perception that is to be created and maintained.

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The road that was taken

Psychologists and neurologists and biologists were not stupid in the first third of the 20th Century. They were simply unlucky. They did not happen to think of the arrangement Ktesibios thought of, nor were they in contact with the engineering projects in which the ideas of Ktesibios were being elaborated upon at an increasing pace. The main result was that when they saw behavior that looked as if it were goal-directed by the behaving system itself, they ran into what looked like an impossibility. If they had lived in Ktesibios' time, they would have asked how the final water level, which did not yet exist, could reach back through time and alter the water intake so as to cause that specific level to come into being. Aristotle had spoken of "final causes," which included the way the idea of a chair could cause a carpenter to shape wood so as to build one. But in 1910 nobody believed in those primitive concepts any more. The scientific consensus was that this appearance had to be an illusion, and that when we understood the brain better we would see that the slave was not intentionally regulating the water level; he was simply responding to stimuli in such a way that the change in water flow happened to compensate for whatever had caused the change in water level. As to how Ktesibios' clever little trick worked, that would be a matter for engineers, not psychologists, to investigate. It couldn't have anything to do with how the slave really worked.

Behaviorists side-stepped this problem entirely early in the 20th Century. They decided in effect that we had to leave questions like this to future generations when we would know more about how the brain works. Until then, all that a scientist could do was to observe effects of the environment on an organism, record the behavior that followed environmental stimuli, and thus elucidate the laws of behavior. It seemed obvious that if there were no stimulus inputs, there would be no behavioral outputs; that became a matter of scientific faith. Organisms could not initiate anything. Like any object made of matter, they could only respond to external forces and influences as their histories and their internal construction dictated. This was the line of thinking which, however reasonable, set behaviorism on the path to extinction.

Shortly after the 1930s when control engineering came into existence, psychologists who still wanted to explore the mind inside the organism, not just behavior, organized a new approach called cognitive psychology. Fighting the scoffing of behaviorists all the way, they tried an orderly approach to studying the internal organization behind behavior, if not in terms of mechanism then at least in terms of function. They started to make models, computer models into which they could put functions they assumed to underlie behavior, in an attempt to demonstrate artificial but intelligent behavior rather than just responses to stimuli. These psychologists knew, of course, about cybernetics and control systems because those were major topics in the 1940s and 1950s. But they didn't know enough about control systems, and tried to invent their own explanations of purposive or goal-driven behavior. Many cyberneticists joined them, but cyberneticists hadn't learned much about control systems either.

If these cognitive psychologists and the cyberneticists who joined them had lived in the time of Ktesibios, they would have explained the slave's behavior in a new way. Instead of seeing just stimuli and responses, they would have envisioned a complex set of brain functions at work. First there would be a goal, a desired state of affairs: the water is to be kept at a specific level in the small tank. The brain would have to detect incipient disturbances that could change the water level, and predict the amount by which they would raise or lower the level. Then given this number, the brain would calculate the way muscles would have to change joint angles of the limbs and fingers in order to cause the valve to open or close by the right amount and for the right length of time to replace the lost water or to let the excess water drain out into the main reservoir. With this plan of action completed, the brain would then, just as the effect of the disturbance arrived, issue the required neural signals which would operate the limbs and the hand to turn the valve one way or the other and then, if needed, back to normal.

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Perhaps cognitive psychologists would not have accepted this explanation if they had ever seen Ktesibios's regulator in operation, where obviously none of those processes was happening yet the result was exactly what was needed. But they did offer similar explanations of other behavior which are still believed by a very large number of life scientists (excluding me).

I have delayed showing the system diagrams of behavioristic and cognitive models until now so we could see them side by side.

These models are quite similar, differing mainly in their ideology. In both of them, behavior is the terminus of an input-output process. In the cognitive model, the disturbance of water level is predicted from the data, but the controlled variable is not affected until the very end, when the disturbance occurs and the planned action is actually carried out. The arrow from data to assessment actually skips past the four boxes above it so the prediction can be made before the disturbance happens. In both diagrams, the idea that a feedback effect alters the perception during the disturbance, and that the disturbance itself is not perceived at all, is simply missing.

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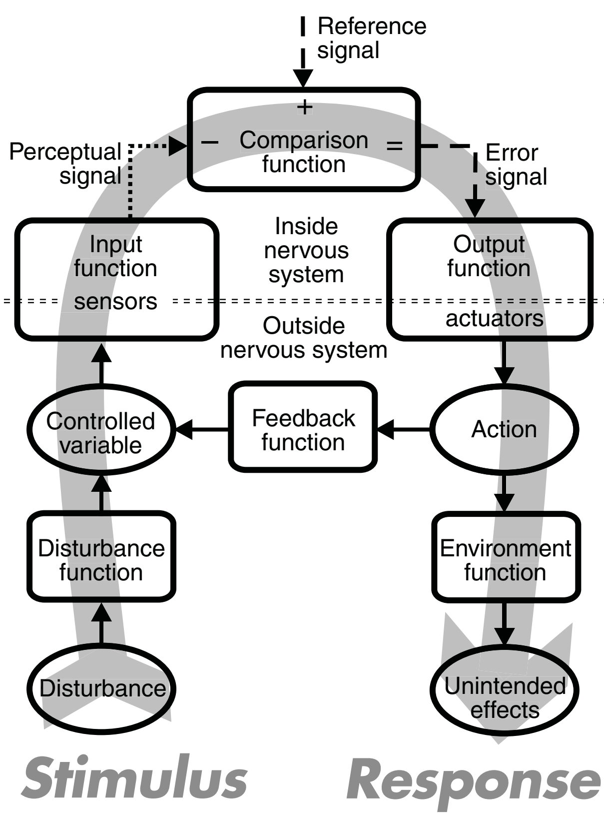

Fig. 2 Behaviorism:
Stimulus–Organism–Response

Grey overlay highlights flow in terms of the basic diagram of perceptual control

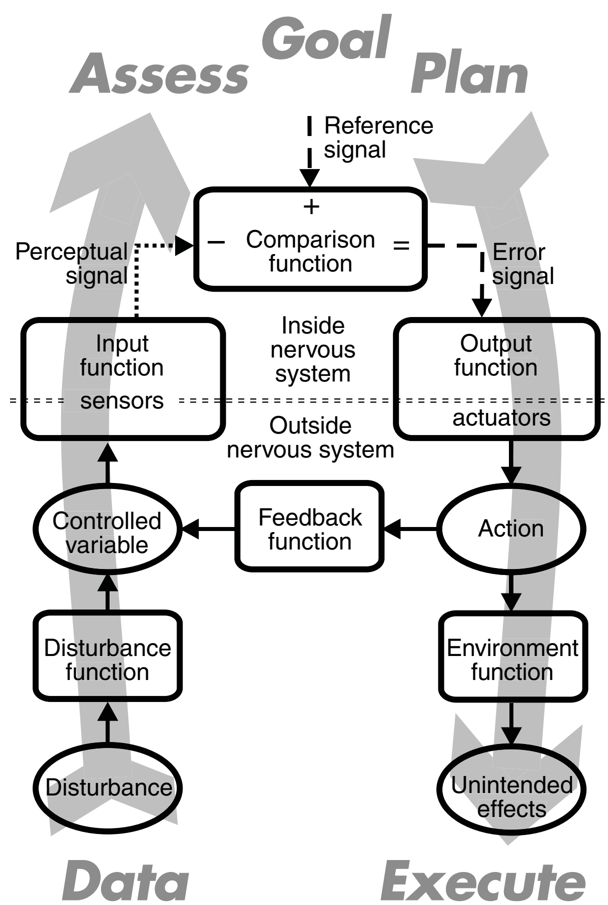

Fig. 3 Cognitive Psychology
Data–Assess–Goal–Plan–Execute

Grey overlay highlights flow in terms of the basic diagram of perceptual control

What if the first road had been taken?

Anyone who is convinced of the correctness of either Fig. 2 or Fig. 3 should by now be suffering some doubts. Both of those figures imply a kind of system which, if you tried to build it, would reveal itself to be full of complex calculations and operations. But anyone who decides to accept Fig. 1 even tentatively, just to see what the implications might be, is going to find direct contradictions of important ideas accepted by a very large number of life scientists. That sort of contradiction means either that there is something very wrong with the new idea, or that a revolution has started.

This brings the discussion into the purview of this meeting. How a therapist visualizes what is happening inside a patient or client makes a lot of difference. If Fig. 2 is imagined to be correct, the question becomes that of how to arrange the environment of the patient so as to cause more satisfactory behaviors to take place. If Fig. 3 is imagined, as is likely where a cognitive therapy is envisioned, then correcting a problem becomes one of changing assessments and predictions of the experienced world and formulating realistic plans of behavior to reach properly defined goals.

But what if Fig. 1 is accepted? What seemed to be environmental stimuli or data for analysis are now just disturbances applied to other variables that are the ones actually under control. The goals are still there for cognitive scientists to find, but now we see that they are goals for perceptions, not for actions, and that the actions are produced and varied in whatever way is made necessary by the disturbances, without any need for complex computations. Behavior is, for the behaving system, relatively uninteresting and unimportant. A person is really concerned about the perceptual consequences of behaving. The behavior that controls those consequences is itself of interest mainly when it affects other people. Clearly a different sort of therapeutic approach is needed if Fig. 1 is the right one.

Conclusions

The water level control system is not complex or hard to understand. The greatest difficulties in assimilating PCT come not from its complexity but from the conflicts between PCT and other theories learned and accepted long ago. That's the main message I want to convey here. There is no way simply to add PCT to the older theories: a choice is necessary. In both of the older views, what an organism does begins in the environment and ends with actions on the environment. Under PCT, the only reason for action is to affect a controlled input to make a perception match an internal specification, a goal state. Seeming stimuli are, in most cases, only disturbances affecting the real stimulus.

There is a conflict now in the worlds of all the life sciences. It is a conflict between the new ideas embodied in perceptual control theory, which are simply the principles that Ktesibios unknowingly put into practice 2200-odd years ago, and the old concepts of what behavior is and how it works, which were developed in the 17th through 20th centuries because theoreticians failed to rediscover what Ktesibios saw so long ago. Resolving this conflict is probably going to be a long process. Every person now pursuing PCT has felt the inner conflicts, and the resolution is far from finished. One does not dump a lifetime of learning overnight even willingly, and willingness is not an easy state to reach. I hope a few who read and hear this will find it more possible to become willing.

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Mary on PCT

Post to the Control Systems Group Network, Nov 11, 1992
From: Mary Powers

... I am getting requests for information about CSG from netters and by snail mail. The following is what I am sending out...

While the existence of control mechanisms and processes (such as feedback) in living systems is generally recognized, the implications of control organization go far beyond what is generally accepted. We believe that a fundamental characteristic of organisms is their ability to control; that they are, in fact, living control systems. To distinguish this approach from others using some version of control theory but forcing it to fit conventional approaches, we call ours Perceptual Control Theory, or PCT.

PCT requires a major shift in thinking from the traditional approach: that what is controlled is not behavior, but perception. Modeling behavior as a dependent variable, as a response to stimuli, provides no explanation for the phenomenon of achieving consistent ends through varying means, and requires an extensive use of statistics to achieve modest (to the point of meaningless) correlations. Attempts to model behavior as planned and computed output can be demonstrated to require levels of precise calculation that are unobtainable in a physical system, and impossible in a real environment that is changing from one moment to the next. The PCT model views behavior as the means by which a perceived state of affairs is brought to and maintained at a reference state. This approach provides a physically plausible explanation for the consistency of outcomes and the variability of means.

The PCT model has been used to simulate phenomena as diverse as bacterial chemotaxis, tracking a target, and behavior in crowds. In its elaborated form, a hierarchy of perceptual control systems (HPCT), it has lent itself to a computer simulation of tracking, including learning to track, and to new approaches to education, management, and psychotherapy.

Control systems are not new in the life sciences. However, numerous misapprehensions exist, passed down from what was learned about control theory by non-engineers 40 or 50 years ago without further reference to newer developments or correction of initial misunderstandings. References in the literature to the desirability of positive feedback and the assertion that systems with feedback are slower than S-R systems are simply false, and concerns about stability are unfounded.

The primary barrier to the adoption of PCT concepts is the belief—or hope—that control theory can simply be absorbed into the mainstream life sciences without disturbing the status quo. It is very hard to believe that one's training and life work, and that of one's mentors, and their mentors, must be fundamentally revised. Therefore, PCT appeals to those who feel some dissatisfaction with the status quo, or who are attracted to the idea of a generative model with broad application throughout the life sciences (plus AI and robotics). There are very few people working in PCT research. Much of its promise is still simply promise, and it meets resistance from all sides. It is frustrating but also tremendously exciting to be a part of the group who believe that they are participating in the birth of a true science of life.

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About discussions of PCT —a high-wire act?

A post to CSGnet by Mary A. Powers, November 1993

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I seem to be somewhat grumpy this morning ☹

<snip>

What I see going on here, and it's been going on for months, is people who think PCT is interesting and has its points, but who see Bill [Powers] and Tom [Bourbon] and Rick [Marken] as dancing on a high wire without a safety net. How can they possibly have such reliance on control theory that they don't need the security and comfort—and wisdom and right-thinking—of (for instance) feedforward or information theory or dynamic systems theory or whatever.

Most of this endless quibbling is between people who have lots of training and professional experience with control systems of the artificial variety, or who have approached the same issues PCT addresses, but in a different way—between those people and the three dancers on the wire. Those people have their feet on the wire, but they've got to have that net, and a safety harness, and they aren't letting go of the platform, either.

Meanwhile Bill and Tom and Rick are saying "what's with the harness and the net?" Because for years they've been out there on that "wire," and it isn't a wire at all, but solid ground. A lot of what PCT "leaves out" or "doesn't explain"—a lot of the really valuable, important stuff that PCT dismisses so arrogantly and unwisely—is harnesses and nets. Stuff that's really superfluous (and even a barrier) to understanding.

I think I'm becoming disillusioned with [CSG]net. I can look over at the bookcase and see 6 computer-paper boxes full of printouts, a sickeningly large proportion of which is quibbling of the sort that came through this morning, and Bill endlessly and patiently explaining, and explaining again, and explaining yet again—and nobody seems to be able to stop and think MY GOD, how is he able to keep these discussions going with psychologists and information theorists and control engineers and roboticists and AI types and linguists and sociologists and educators and therapists and organizational development people and bicycle designers and human factors mavens—and the answer staring all you klutzes in the face is not that he's some kind of frigging genius—pretty smart, sure—but that his ace in the hole, the ground on which he takes his stand, the source of his insights and analyses and ability to talk to people in all these "separate" fields, is PERCEPTUAL CONTROL THEORY. Simply that, no frills, none of this baggage you keep dragging in. Just a simple little unified theory of living systems which enables him to handle the complexities of all these fields. Doesn't anyone else want to try it too? The only catch is: you'll never get anywhere with PCT if you keep looking at it from where you are. You need to look at where you are from the point of view of PCT. Then maybe Bill could quit teaching kindergarten over and over again, and have some time to get some development done, and have some company doing it.

I guess I'm still grumpy ☺

Mary P.

Is PCT a religion?

A post to CSGnet by Mary A. Powers, September 1994

Is PCT a religion?

The short answer is no, but it might be worth expanding on further.

It's not a new question—it usually comes up when someone (like Rick [Marken], for example) shows that he is passionately engaged with PCT.

Having one's emotions involved in a systems concept, whatever it is, usually provokes this question, unless of course it is a religion, in which case it is sort of obvious.

But laying the blanket term "religion" on any systems concept is, I think, confusing a general concept with a particular manifestation of it.

I think systems concepts are to be characterized by the apparent fact that challenges to them arouse intense emotions, and any change is powerfully resisted.

The conventional view of a scientist is based on an assumption (a wrong one, I think) that the logic level is the highest brain function, and that therefore doing science is a very cool enterprise.

People who attend scientific meetings of any kind—linguistics, geology, astronomy, physical anthropology (to name a few in which the arguments are notably intense)—can tell you this is hardly the case. Passions run extremely high. There is far more at stake than comparing different conclusions from the same data and coming to polite arrangements to agree or disagree.

And what is all the ruckus about? A belief, a faith, in a systems concept (such as PCT). There's nothing wrong with that; it's the source of motivation to continue exploring it (and endure considerable personal setbacks and sacrifices to do so).

Just like a religion, you might say. Yes, they are at the same mental level. But science has different rules (or should) from religion. Religion says "don't ask, believe," and values the strength of that faith against anything that might contradict it. Science, presumably, says "challenge it, test it, try to find something wrong with it, try to come up with something better."

These days we are swamped with pop science books (mostly by physicists—perhaps because they lost their big toys like the Supercollider and want them back?) that purport to answer religious questions about the beginning and the end and the reason for everything. Mary Midgley is a good antidote for that. But these people aren't doing science (gathering data, running experiments, testing hypotheses) when they write these books; they are expressing their beliefs.

PCT is as fundamental in the lives of some people as religion is. It makes emotional as well as intellectual sense for some people in that it seems to explain human nature in a satisfying way, be a source and rationale for a system of ethics, and lots of other high-level stuff. As such, it is not a religion, although it shares those functions with religions. It isn't a science either, at that level, but it generates science, and it may be the path to learning more about ourselves than a lot of people care to imagine (because people resist knowledge that they fear will enable somebody to control them).

In his book, Descartes' Error, Damasio talks about people with brain damage at the highest level, who seem to have lost, through accident or disease, the ability to have feelings about beliefs. One patient could talk about ethics, for example, knowing right from wrong, but it was no longer important to him—there was no value attached. Importance, value, believing—these are words we use to talk about the highest level, and they all carry an implication of the deep physical involvement we call emotion. Systems concepts matter.

But that doesn't make them all religions.

I want to add that I know that here I am indulging in HPCT theories that are a long, long way from experimental proof or disproof. I think, however, that they are consistent with the general model.

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Control Theory: A New Direction for Psychology

A reply to Todd Nelson

Mary A. Powers

This unpublished paper from 1994 was discovered following Mary's passing in October 2004.
Mary was a tireless supporter and advocate of Perceptual Control Theory.

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Books

Over the last dozen years or so, beginning with Carver & Scheier (1) a number of psychologists have adopted the control theory model of William T. Powers (2)(3)(4) as a taking-off point from which to address the topics of self-regulation and goal pursuit. The recent article by Todd Nelson (5) is the latest example. These well-intentioned efforts to bring control theory into mainstream psychology have unfortunately come at a price: the distortion of some of the key concepts of control theory, and the addition of elements which are inconsistent with the main theory.

I think that such authors (and their reviewers) believe that they understand control theory, and that their interpretations and embellishments are in the service of bringing an obscure but interesting behavioral model into view. Control theory from this perspective is an extension of existing thought on goals and purposes which merely requires an adjustment here and there to be compatible with the body of work that already exists.

But control theory is a model unlike any other yet seen in psychology. It is not an input-output, independent-dependent variable model, nor is it a self-regulatory model in the planned-action sense. To both environmentalists and cognitivists it says "you are both partly right, and therefore you are both wrong." This, of course, is not a welcome message to anyone who has spent a lifetime of honest work trying to cope with the elusive variability of behavior, to find order and predictability in this "softest" of the sciences.

The problem of variability has been approached by severely controlling the environment in which subjects are immersed, or by trying to eliminate it through the use of increasingly sophisticated statistics, or by speaking of distal behavioral consequences rather than the immense variety of proximal acts that achieve those consequences. Control theory takes a different path. It views variability as the essence of behavior: the phenomenon to be explained, not explained away. The heart of control theory is that organisms control, and that what they control is not behavior at all, but perception.

This shift in viewpoint resolves the problem. Organisms achieve consistent ends in a variable world. The consistent ends that are achieved are the perceived consequences of their actions in combination with any environmental disturbances; not the actions alone, or the environmental disturbances alone. Organisms do not, cannot, program a series of actions that will have a consistent result. The simplest movement is immediately affected by the infinite variety of positions from which it begins, and by the state of fatigue of the muscles depending on previous actions. These are environmental disturbances, as much as the uneven ground one walks on in the country, traffic on the highway, and so forth, on up to one's social milieu and the requests and demands—and cooperation—of other people.

The only known organization that can maintain itself in a variable world is a control system. A control system receives input—perceptions—from its environment. This input is a combined function of environmental effects plus the effects of its own actions. The input is compared to a reference state, and the difference drives the output, which is immediately and continuously perceived, along with its effect or lack of effect on the environment. The output varies to reduce the difference between input and reference states.

The reference state is not a fixed quantity: if one thinks of an organism as a hierarchical arrangement of control systems, the lower levels, such as those which actuate muscles, receive continually varying reference signals from higher levels, which receive their reference signals from higher levels yet. Each level embodies an order of complexity derived from the levels below: on the perceptual side, the lowest level is a perception only of intensity, which at the next level is perceived as a sensation of a specific kind, while at levels above that such constructs as configuration, motion, and sequence are developed, with the highest levels hypothesized as controlling perceptions of programs, principles, and systems concepts (such as personality). This suggests that the highest level, once developed, is relatively fixed, but that all the lower ones vary as required to maintain the integrity of the highest. It suggests a way of understanding human intellectual growth, as the development of levels, and relates the various forms of life to one another as a matter of number and degree of complexity of levels.

A crucial aspect of this model is that it is a generative model—a model in the physical science sense, not vague, conceptual boxes and arrows on a blackboard. The functions and signals of a control system model are actual and quantitative. Assembled correctly, they generate the phenomenon of control, and conversely, given control phenomena, the model itself can be constructed. Control systems are designed and built all the time in the engineering world, and computer simulations of the organic, living version can be simulated on small computers. These simulations (specifically a three-level model of an arm tracking a randomly moving object) show that a control system does not require elaborate calculations of actions in order to track, and tracks, in a rapid, graceful, and entirely life-like manner, an object subject to continuous random disturbances.

Again with a computer, a person can track a randomly disturbed object, and a control model of that person's characteristic mode of control derived, such that in tracking another target, disturbed in a different random way, the model matches the person's behavior to a degree unheard of in the life sciences, even though the two tracking performances take place one or more years apart (6). Unfortunately, in the behavioral sciences, correlations of .997 are thought to be indicative of triviality or tautology, and these demonstrations have not found acceptance in the literature.

While these experiments and demonstrations are focused on the lower levels of the multi-level hierarchy, the rigorous modeling they represent is intended to be applied to higher levels as well, addressing such topics as personality and the conduct of psychotherapy, the phenomena of social interaction and of organizations. But the value of the control-theoretic approach is diluted by the gratuitous use of concepts which are contradictory or irrelevant to control theory, or by the use of the control theory model as simply a metaphor.

What we find in much of the literature about control theory, then, are assertions about it which are inaccurate and fanciful. They may succeed in making control theory more like other psychological theories, but do so at the cost of making the model unworkable. And the unique feature of control models is that they work: in electronics, in computer simulations, and, given what is known about nervous and chemical systems (with relabeling of signals and functions) in living systems as well.

Drawing on Nelson's recent article, a variety of misapprehensions about control systems can be identified and confuted.

1. Self-regulation keeps an individual on track towards attaining a goal. (Self-regulation is the process of maintaining a perception, including the perception of moving toward a goal.)
2. The brain sends a signal to the appropriate muscles to take action. (This is a plan-execute model; in control theory the brain specifies perceptions, which makes it unnecessary to calculate "appropriateness".)
3. Standards for behavior can be imposed by external sources. (An external standard is a property of the perceived social environment. One can align one's own reference standard with a perceived one—or not—depending on whether or not such a standard is identical with or compatible with one's own standards or goals.)
4. The comparator function is used occasionally to determine whether one's perceptions match a reference value. When perceptions do match, the negative feedback loop is disengaged after the comparator function. (Comparison is an ongoing, continuous process, and the loop remains closed; a condition of no error, however, requires no action.)

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5. It is behavior that is regulated rather than perception. (This is the fundamental difference between control theory and other theories. From inside the organism, where we all live, however objective we try to be, what we know of our actions, the actions of others, and the world around us, are perceptual constructs. There is no extra-sensory means of knowing. Objectivity in science means fairness, lack of bias, and the ability to reproduce, communicate and agree upon those perceptions which we construe as originating externally.)
6. That such evaluation is always conscious, that homeostasis has nothing to do with self-regulation, that goals and standards can be imposed from outside, that feedback is too slow, etc., etc. (These myths conform to present concepts of how behavior works. In the multi-dimensional space of concepts, control theory is off on a new axis entirely, and cannot be appreciated unless one is willing to suspend previous beliefs and start again from scratch. Most of these myths are present in Nelson's article.)

This is not the place to get into a detailed exposition of the control model. The primary literature (2)(3)(4) is available to anyone who wishes to pursue it. The textbook by Robertson (7) is helpful and the concepts are extended by Marken (8) in a series of experiments. Computer demonstrations of the phenomenon of control and a detailed development of the model, and the three-level arm experiment have been developed by Powers. The 10th annual conference of the CSG will be held in Durango, Colorado, July 27-31, 1994, and, like previous conferences, will draw its participants from such diverse fields as experimental psychology, sociology, education, counseling, organizational development, linguistics, economics, etc. The fundamental and productive nature of the model is reflected in the broad scope of phenomena to which it can be applied.

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BYTE 1: June 1979

The Nature of Robots

PART 1: DEFINING BEHAVIOR

About the Author

William T Powers has been exploring the meaning of control theory for studies of human nature since 1953, when he was working as a health physicist at the University of Chicago. Since that time he has spent a number of years (to 1960) in medical physics, and then another 13 (to 1975) as Chief Systems Engineer for the Department of Astronomy at Northwestern University. His occupation has been designing electronic, optical, and mechanical systems for science. Powers' book, Behavior: The Control of Perception (Aldine, 1973) was quite well received. At the moment he consults in one-of-a-kind electronics.

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In This BYTE

William T. Powers has a control theory approach to the simulation of human behavior. However, before we can simulate human behavior in a robot, we must determine what behavior is. William Powers takes a look at behavioral actions as he explores **The Nature of Robots**. Page 132

A series of four articles by William T. Powers were published by BYTE magazine in June, July, August and September of 1997:

Part 1: Defining Behavior
Part 2: Simulated Control System
Part 3: A Closer Look at Human Behavior
Part 4: Looking for Controlled Variables

These articles total 54 pages and amount to a small book introducing and explaining PCT, including a computer program and diagrams that suggest how neurons are wired in a hierarchical arrangement of control systems. All are available at www.livingcontrolsystems.com.

Look under Introductions and Papers by Bill Powers.

This article appeared in BYTE magazine, volume 4, number 6, JUNE 1979.

These four articles are posted at www.livingcontrolsystems.com

Running PCT programs

Bill Powers' work ***Living Control Systems III : The Fact of Control*** is highly recommended.

This is a book that introduces PCT and provides instructions and interpretation of updated and refined demonstration programs. The programs are available for free download at http://www.billpct.org, but you do need the book to get full benefit from them. The programs are superior in many ways to the earlier programs discussed below, but the earlier programs and their documentation are still highly instructive.

Running DOS under Windows XP and earlier versions: See discussion below.

Running DOS under Windows 7, 8, 10, and especially 64-bit versions of same, download and install the DOSbox DOS emulator from http://www.dosbox.com. The site features complete instructions.

Running DOS under Mac and other operating systems: As shown at http://www.dosbox.com under Download, this Open Source group provides emulating programs for some 11 different operating systems.

Running Windows programs on a Mac, see for example http://www.macwindows.com/emulator.html for a list of available emulation programs.

Running Powers' programs using browser: Adam Matić is converting Powers' DOS and Windows programs so you can run them using your browser, with more conversions to come. See www.pct-labs.com/

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This discussion refers to programs created by Bill Powers prior to 2008. They can be downloaded from www.livingcontrolsystems.com in zipped program packages that hold the program and its documentation in separate folders: docs and program. When you unzip, ask for subfolders. The documentaton of these early programs yields additional insight for the serious student of PCT.

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A series of programs created to explain, illustrate and simulate Perceptual Control Theory have been created by Bill Powers over time.

DOS programs include demo1 and demo2, arm_one, arm_two (also known as little man one, little man two), crowd, inverted_pendulum, ecoli, square_circle, and 14_degrees_freedom.

Windows (Delphi) programs include crowd and track_analyze, multiple_control_systems, plus a recently updated Delphi version of arm_one and a Delphi version of inverted_pendulum, programmed by Bruce Abbott.

Further developments of some simulations include effects of reorganization. The DOS programs were created in the era of the IBM XT and AT computers. They are small and run fast.

To run these DOS programs under Windows XP, you can double-click on the executable file in any file manager, such as My Computer or Windows Explorer. You can select the executable file and right-click to bring up a menu where you can select "Create Shortcut." You can drag the resulting shortcut to the desktop and you can edit the text that is shown under the MSDOS icon.

Some of these DOS programs generate files, such as tables of random numbers, as part of the execution of the program. These newly generated files overwrite previous files. Therefore, it is important that the files not be write-protected. If you copied these (uncompressed) files from a CD to your hard disk, the files will be write-protected, because you cannot overwrite files on a CD. I have found that when copying or downloading a zip file to my hard disk, then expanding it to the hard disk, the files are not write-protected. That's convenient.

If you have a problem with the program refusing to run, you can display the files in a file manager and check the attributes to make sure that they are not write-protected.

When you open one of these DOS programs, they typically are displayed Full-screen, the way they ran originally on a DOS computer with 480 x 640 resolution.

On a computer running Windows, the PrntScrn key does not work when running a DOS program full screen.

If you want to capture an image of the screen, you can (in most versions of Windows) press Alt+Enter to change the display from Full-screen to a window. An active window, including an active window displaying the DOS program you are running, can be copied to the Clipboard by pressing Alt+PrntScrn. From there, the image on the Clipboard can be pasted into any number of Windows image handling programs.

Experience, Reality, and HPCT

William T. Powers,
Post to CSGnet September 1994

> [Hugh Petrie] Well, you sucked me in at least a bit. I hope the very limited time I was able to give this is of some help.

As I expected. Yes, we put some experiences in the role of evidence, and others in the role of theory. That's the distinction I wanted, but couldn't say.

I'm going to ramble through some thoughts about theory and observation, the two kinds of experiences we're been talking about. Skip to the next post if you're getting bored with this subject.

Theory, as I see it, purports to be about what we can't experience but can only imagine (neural signals, functions like input, comparison, output functions, mathematical properties of closed loops), while evidence is about what we can experience. Both theory and evidence are perceptions, but the way we use these perceptions in relation to each other puts them in different roles.

In the behavioral/social sciences, the word "theory" seems to mean something else: a theory is a proposition to the effect that if we look carefully, we will be able to experience something. A social scientist can say "I have a theory that people over 40 tend to suffer anxiety about their careers more than people under 20 do." The theory itself describes a potentially observable phenomenon. The test is conducted by using measures of anxiety and applying them to populations of the appropriate ages. If we observe that indeed the older population measures higher on the anxiety scale than the younger, we say that the theory is supported—or, as some would put it, the hypothesis can now be granted the status of a theory that is consistent with observation.

This meaning of theory leads to the popular statement that a theory is simply a concise summary of, or generalization from, observations. That definition has been offered by quite a few scientists past and present. I think it misses an essential aspect of science, the creative part that proposes unseen worlds underlying experience. Before the "unseen worlds" definition can make any sense, however, it is necessary to understand, or be willing to admit, that there is more to reality than we can experience.

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If reality is exactly what we can experience, then there are no unseen worlds and in ways obvious or subtle every theory is just a way of describing experience. Our senses and measuring instruments indicate to us the state of the real world. A properly-constructed and tested theory, therefore, cannot be false. The only way it might be false is for some error of observation or description to be made, or for the test to contain some internal error or inconsistency.

It is this view that leads some scientists to take a rather self- congratulatory view of science. A scientist is simply someone who has learned to describe and generalize correctly. If no mistakes have been made in observation, description, or method of generalization, then the theory that summarizes these results must be correct. The personality or the wishes of the scientist play no part in this process; truth is independent of the observer.

It is this view, I think, that leads to the Gibsonian approach to perception. To maintain this view, it is necessary that what we perceive of the world be a true representation of the world. So by hook or by crook, we must find a way to show that we, as observers, look ***through*** our perceptual systems at the real world. The existence and the functions of human neural perceptual systems cannot be denied. But to accept what seems to be the case at face value would mean that we perceive only an interpreted world, a partial view of the world, or a projection of the world through unknown transformations into the space of experience. This, in turn, would mean that all descriptions of the world are functions of human nature, and thus that all theories about the world are human theories, not ultimate truths. And it would mean that the phenomena we experience are related to the properties of the real world in ways that we can't directly perceive. This is exactly the conclusion that the Gibsonian approach is intended to deny.

More to the point, the implication would be that some elements of our theories are not really, in some subtle way, reducible to reports of observations, but are ***made up*** by human imagination. It would mean that the concept of "an electron," for example, amounts to an ***imagined observation***, with no justification other than that assuming its existence leads to consistent explanations of experience. If this were admitted, the result would be to make science much less secure in its claims to logically-derived knowledge about the real world.

Some scientists know this; others vehemently deny it. Richard Feynman, for example, knew it. When he was asked how he arrived at his diagrams showing particle interactions, he said "I made them up." There were physicists who considered this a flippant answer, consistent with Feynman's reputation as a joker. But Feynman was quite serious. Particle physics, he said, is a game we play. It takes a sense of humor to admit that.

This same dispute underlies the controversy over whether the Heisenberg uncertainty principle describes a true uncertainty in nature itself, or a limitation on our methods of observing nature. If you assume that reality consists exactly of what we can observe about it, then uncertainty is an aspect of reality. If you assume that there is a reality independent of, and perhaps quite different from, our observations of it, then you leave open the possibility that nature is regular but our observations of it are uncertain. This was Einstein's view. I say you "leave open the possibility" because in the latter view, there can be no question of verifying the causes of the uncertainty; all we can do is make up possible properties of the world which, if they existed, would account for our observations. There is nothing to prevent our imagining that the world itself is uncertain, but that does not prove that it is. It proves only, at best, that making that assumption leads to a consistent view of the observations, an ability to predict particular observations with some degree of accuracy.

In PCT there are observations and there are theories. When I attempted to describe levels of perception, I was trying to describe observations, how the world seems to come apart when analyzed and how these parts seem to be related to each other. There is no theory intended in these proposals. It seems to me that when I see a relationship, I also see the things that are related, which themselves are not relationships. I could not see any relationship if there were not things to be related, yet I could see any of those things (events, transitions, configurations, sensations, intensities) individually, not in relationship to anything else. The only question I have is whether anyone else in the universe experiences the world in the same way. Either they do or they don't; we're talking observation here, not theory. If these are truly universal classes of perception, then every undamaged adult human being should report the same elements of experience, and the same dependencies. Again: either they do or they don't. That is a question of observation, not theory.

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The theoretical aspect of PCT comes in when we try to explain why it is that the world of experience is organized in this way (if, in fact, my experiences are like anyone else's). That's when we start talking about input functions and signal pathways and control systems, none of which has a direct experiential counterpart. Of course in theorizing one tries to imagine hidden aspects of the system that might, one day, actually be observed. But today, at the time the theory is proposed, we do not observe them. We can only imagine them. And no matter how much verification the theory receives from future observations, there will always be a level of description at which we can only imagine the level that underlies it.

The same interplay between theory and observation is involved in experiencing control. You do not need a theory in order to hold your hand in front of your face and deliberately will the hand to assume various configurations. Nor do you need a theory to tell you that what you will is very closely followed by what you then experience your hand doing. You don't need a theory to tell you that when you grasp the knob on a door, your intention is for the door to take on an appearance other than the one you are now experiencing. These are the facts, the phenomena, that we need a theory to explain.

The theory of control offers an explanation in terms of perceptual signals, closed causal loops, and mathematical properties of such systems. These entities, while perfectly experienceable in the mind, are not the experiences to be explained. We are saying that ***if*** such an organization existed in the nervous system, ***then*** the experiences we are trying to explain would follow. The theory proposes the existence of entities in the world hidden from direct experience; perhaps not all of them hidden forever, but certainly hidden now.

The most important part of such theories is that they not only account for what we do experience, they predict experiences we have not yet had. The models of PCT are adjusted so that in simulation they behave in the same way as the particular instance of control behavior we're trying to explain. But once the model is constructed, we can vary the conditions that, hypothetically, affect it, and strictly from the properties of the model make predictions about how the real system would behave under those changed conditions. This is where the power of modeling shows up; not in its ability to fit the behaviors we observe, but in its ability to predict how behavior will change when we alter the conditions presented to the real system. We can fit a model to the hand motions involved in tracking a target moving in a triangular pattern, and then using the best-fit parameters predict very closely the hand motions that will occur when the target moves in a random pattern, and when a second random disturbance is applied directly to the cursor in parallel with the effects of hand motion.

I think that one main reason for the misunderstandings that occur in the life sciences about control theory is that this kind of modeling is essentially unknown to most practitioners. The idea of proposing a model that is more detailed than our observations, and then using this model to predict new observations under new conditions, does not appear in textbooks of psychology, sociology, psychotherapy, or related sciences. It is an idea with which engineers are familiar from their earliest days in college, but only where engineering has encroached on the life sciences does it appear in relation to the behavior of organisms. This method is almost the diametric opposite of generalization; instead of deriving general classes of observation that include actual observations, the method of modeling proposes the existence of more detailed variables and relationships below the level of observation, from which observations can be deduced. I have heard the term "hypothetico-deductive" used in situations that make me think of modeling, although I'm not sure that is what was intended.

Honestly, I'm almost finished.

Now think about what happens when a person who has never heard of the method of modeling comes up against PCT. To this person, the diagrams of PCT are simply diagrams of observations. The arrows show how one event leads to the next event. If this diagram describes any particular behavior, then it can be accepted as a theory (or not—people quite often draw different diagrams, because they "have a different theory"). But such a person does not see what we see: a diagram of a specific physical system, connected in a certain way, ***which we can't directly observe***. This person doesn't realize that what we can see is supposed to arise from the operation of the diagrammed system, not that it is supposed to be represented by the diagrammed system.

When, some day, the Center for the Study of Living Control Systems goes into operation, one of the introductory classes that must be taught there will be an introduction to modeling. It is obviously possible to teach what modeling means; all engineering students learn it, although nobody ever tells them what they are learning. They pick it up from seeing it done and learning the mechanics of doing it. They learn by osmosis the difference between describing the behavior of a system and describing the organization of a system that can produce that kind of behavior (as well as many other kinds). I think this can be taught explicitly, and that by learning it, students will not only come to grasp the meaning of PCT as it applies to human behavior, but will discover that they can probably come up with better models than their mentors managed to build.

Wordily, Bill P.

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Underpinnings of PCT; Systems Theory and PCT

Post to CSGnet on Feb. 25, 1994.

[From Bill Powers (940224.2030 MST)]
> Cliff Joslyn (940224.1400)

Regarding the underpinnings of PCT:
There was no one in cybernetics/systems theory after Ashby's book in 1953 (Design for a Brain) from whom I learned anything about control theory and its role in behavior. Wiener's book of 1948, which I read in 1952 thanks to Kirk Sattley, got me started: the concept of feedback control, and the particular relations to behavior that he laid out, clicked in my mind as the obvious successor to all the psychological models I had ever heard of, including the one in which I then believed. Ashby's book gave me an organized view of how one would start applying these principles on a grander scale—it was as much his organization as his ideas that turned me on.

But Ashby lost me when he starting treating behavior as if it came in little either-or packages—I felt he had abandoned the main trail and was going off in unproductive directions. I especially felt, later, that his drive for the utmost generality was premature and based on only a sketchy understanding of control systems.

My main mentors were the control engineers themselves, and especially the pioneers of analogue computing and simulation: Philbrick, Korn and Korn, and Soroka, who not only provided the machinery and systematized the art of analogue computing, but developed penetrating insights into the principles of negative feedback. I never met any of my mentors, in or out of cybernetics: I just read their books and manuals. Wiener and Ashby inspired me to go back to the sources of the ideas that they had adopted. When I did, I gradually came to realize that neither of them had learned very much about control systems.

You question the primacy of control theory as used in PCT:

> (B) the particular negative feedback loop architecture that PCT advocates.

Unlike many other approaches, PCT does not assume an architecture and then look for phenomena which fit it. It starts with the simple fact that organisms can produce regular and disturbance-resistant outcomes despite the fact that their motor outputs have highly variable effects on the local environment. As far as we know, this can be explained only if the organism is able to represent the outcome inside itself, compare the current state of the outcome with an internally-defined intended state, and convert the difference into an amount and direction of action that will keep the difference small. That is the basic architecture of PCT, and the only one of which I have heard that can actually explain what we observe.

>... you have shown a very interesting result of SYSTEMS THEORY: namely, that a particular real-world phenomenon requires a particular system architecture, independent of the type of components.

But isn't this a platitude? It would be more surprising if a real-world phenomenon required NO particular system architecture. The phenomenon is simply an expression of the architecture; a different architecture would result in different phenomena. It has been the case for over 300 years that when we observe a phenomenon, we try to relate it to the properties of the objects involved in it. If a general theory is to prove useful or interesting, at some point it must tell us something we didn't already know.

My beef with general systems theory is that while it purports to apply to ALL systems, so far it has had to wait for others to explain particular systems in detail before it can claim to have known the result all along.

> If BOTH (propositions mentioned) are true then you have correctly defined PCT with respect to ST, namely that it concerns systems OF ANY TYPE which demonstrate control phenomena and, equivalently, have correctly constructed negative feedback loops.

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We have shown that a negative feedback system with a specific architecture will reproduce the phenomenon we call control (as opposed to what some others call control). Neither we nor any other person knows whether some other kind of system could not equally well explain the same phenomenon. We may not now know what such a system might be, but simply to assume that no other idea will ever be discovered is unwarranted; we have simply come up with one positive instance of a type of system that will create the observed phenomenon. To claim on this basis that PCT is the ultimate general theory of control is not legitimate and I do not make that claim. Any theory depends on the factual truth of its postulates. This is the Achilles' heel of all claims about "general" theories. You can show that a general theory is consistent with its premises, but theorizing will not show whether those premises are related to the real world or whether some other set of premises would not serve just as well and will not turn up tomorrow.

In discussing how ST people could be doing PCT "without knowing it," you say

> >The idea is that (1) an ST person considers the operation of living systems; (2) (s)he considers that feedback may be important; (3) (s)he then uses feedback to describe some interesting result. Bingo.

How many of these people, in considering the operation of living systems, have considered the phenomena with which PCT is concerned? How many, in considering that feedback may be important, have correctly analyzed the way in which it is important, and the consequences that it creates? How many, in using feedback to describe some interesting result, have used it correctly, and with respect to a result that actually occurs as opposed to one that is only imagined? "Bingo" requires that you have markers on all five numbers, and I have seen no evidence of that outside PCT.

> > Also, it depends on if you take the term "living system" to STRICTLY mean a single organism or merely a system which INCLUDES an organism.

From your own writings, I glean that there is very little agreement in ST on what constitutes a "system" or how a living system differs from other sorts. If you can freely apply a basic term to vastly different situations, you may create the illusion of generality but what you actually achieve is vagueness. I don't really care what you call "a system." The term is hopelessly compromised by careless usage and lack of definition. What I care about is explaining behavior.

> >For example, is an economy a living system or not?

If we agree on an answer, what will we know that we don't know now? We can create categories at the drop of a hat, with any membership we please. Sure, if you want to include organisms and interactions among organisms in the same category, an economy is a living system. If you don't, it isn't. What difference does it make?

> >If so (I think this is cleaner), then for example any economist, whether an ST economist or not, who presumes that individuals have desires (like the desire for food) and make economic decisions based on satisfying those desires (like purchasing food) is ACTUALLY doing PCT.

No, that's too much! PCT is about what it is to have a desire, about the relationship of desires to actions and their consequences. It's about how making a decision or having a desire gets turned into just those actions which will have effects in the real world that result in an outcome that matches the decision or satisfies the desire, even if the action required differs from one instance to another. An economist who says only what you describe hasn't a clue about how any of these obvious phenomena come into being: he's simply describing the phenomena that need an explanation.

The conclusions you can draw from PCT match what anyone can observe under natural conditions. That says it is a good theory. It should surprise nobody that an economist who uses common sense will see that desires relate to what people purchase. That's commonplace, it's not an insight and it's not a theory. It's just a description of something ordinary in ordinary terms. That is where you would START if you wanted to apply PCT. You don't need PCT to conclude that people desire things and act to satisfy the desires. What you need PCT for is to explain how they can possibly do that. Can this economist of whom you speak explain how it is that when a person decides to purchase Grape-Nuts, the result is a long train of motor actions that carries the person from one store to another until the Grape-Nuts are in fact selected, carried to the checkout counter, and paid for? Of course not. The economist has no idea how a decision or a desire gets fulfilled, because the

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economist doesn't know anything about PCT. I know of only one economist who does know anything about it.

>... the study of systems of all kinds, NO MATTER HOW THEY'RE HOOKED UP, is ALSO very interesting (at least to me!), and THAT'S what ST is about.

I dispute whether ST is about systems of ALL kinds, and whether it has deduced the properties of ALL systems NO MATTER HOW THEY ARE HOOKED UP. It is about a certain range of systems that fall within the definitions of system with which ST begins. It is unlikely, furthermore, that ST will have deduced everything there is to say even about systems within that range, because essentially no time is spent exploring the properties of specific examples of systems, and looking for unexpected behaviors in natural examples of those systems (when the systems are physically realizable). Or put it this way: in general statements about systems, how come I can so often think of counterexamples?

Everyone is entitled to be interested in whatever seems interesting. Conflict arises, however, when there is competition to see whose idea anticipates whose idea. A common strategy, in and out of science, is for people to go up a level of abstraction, trying to make true statements that anticipate true statements that others might make at a lower level. You say, "It's going to rain tomorrow." I say "There is a chance of rain tomorrow," thereby seizing the opportunity to prove me wrong and you right if it doesn't rain tomorrow. And the third guy, looking for another step up, says "Of course it could snow as well," thus showing that he has a more general understanding of the situation than either of us. In this game of who is rightest, the temptation is strong to rely on more and more remote abstractions with less and less chance of being contradicted by the facts.

But in my book, it's the guy who says "It's going to rain tomorrow" who wins in the end. Even if this guy is wrong, he is going to be less wrong the next time, and finally he will be right most of the time. The guy at the top level of abstraction will see to it that he is right all of the time, but that will be only because he has covered his ass in all possible ways. There are no prizes for predicting that tomorrow there will be weather, even if that should prove to be true.

Best, Bill P.

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Teaching Dogma in Psychology

By Richard Marken

Dr. Richard Marken, Associate Professor of Psychology, joined the Augsburg College faculty in 1974.
Lecture date: May 15, 1985.

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I HAVE COME HERE to come out of the closet—I am not a straight psychologist. I have been convinced for at least five years now that the foundations of my discipline are wrong. I feel like the little boy who noticed that the emperor was not wearing any clothes. All the people who would like to be considered smart are saying that behavior is controlled by environmental events.

This is the central dogma of scientific psychology and of the social sciences in general. It is the basis on which all research is conducted in these disciplines.

Things look quite different to me. It looks to me as if behavior controls the environment—not vice versa. Behavior is the process by which we control the things that matter to us—to behave is to control.

The difference between the conventional view of behavior and my own is fundamental. From my point of view the introductory psychology texts are wrong from the preface on. There are irreconcilable differences which I will try to make clear. As you can imagine, given what I have just said. It has been terribly difficult to teach some of the standard psychology courses, notably the intro course and the research methods course. It is not a problem that can be cured by putting a little section on "my point of view" in these courses. It would be like having to teach a whole course on creationism and then having a "by the way, this is the evolutionary perspective" section. Why waste time on non-science? From my point of view, most of what is done in the social sciences is scientific posturing and verbalizing.

First, let me tell you a little about how I came to this revolutionary position. I did not set out to be in this boat; I am not a revolutionary by temperament, and I have not been brainwashed by some weird cult.

I was trained as a standard experimental psychologist. My specialty was auditory perception. I did my thesis research on an esoteric but conventional topic—auditory signal detection. I knew my stuff—I became an expert in experimental design and some of the more powerful aspects of statistical analysis.

Shortly before coming to Augsburg, in 1974, I was browsing through the library at UCSB and noticed a new book with the intriguing title: *Behavior: The Control of Perception*, by William T. Powers. I was curious, because I was a student of perception and interested in behavior. But I couldn't imagine what this book might be about. I looked through it briefly. My impression was that the author knew what he was talking about. I, however, did not. The book, it turns out, was about control theory as a model of behavior. I had no idea, at the time, that control theory would eventually turn my professional life into agony and my intellectual life into bliss.

During my second year here I discovered that Powers' book was in our library. I went back to take a look at it. I had an idea that it might help me in a talk I was preparing, at the time, on the control of behavior. This talk was to be sort of a rebuttal to one given earlier by Dr. Ferguson on the glories of behavior control. I was trained at a school that was very oriented toward cognitive psychology, bristling with the then new computer-oriented approach to behavior. I thought Skinnerian behaviorism a dinosaur that had been comfortably interred so I was surprised to find so many people here who not only admitted but were proud of their adherence to Skinnerism. I was going to present the enlightened cognitive view. I know now that the differences between cognitive, behaviorist, and other approaches to psychology are matters of form more than substance—different verbalisms for the same basic model.

I tried formulating the talk on the basis of concepts from cognitive psychology—along with some of the stuff I was learning from Powers' book. But as I read and re-read Powers, he seemed to make more sense than anything I was reading in the cognition texts. Powers spoke directly and clearly to the fundamental problems that I had only intuitions about. I realized that cognitive psychology was trying to differ from behaviorism by talking bravely about mind, but the basic approach was the same: behavior is caused by inputs into the system; the inputs just swirl around more inside the system before coming out as behavior. I eventually based the entire talk on Powers' book, which I really didn't fully understand at the time.

After the talk, my interest in challenging Skinner diminished, but my interest in control theory continued to grow. I was still a conventional psychologist. I was even trying to do some perceptual research—based on the standard model. But control theory kept bugging me. I wanted to do research based on control theory. I tried to graft control theory into some of my research projects. This really didn't work; Control theory implies such a fundamentally different orientation to behavior that attempts to apply control theory to the results of most conventional research will be fruitless—I will explain why in a moment.

This was about 1978, and I was starting to see the beauty of control theory. My faith in conventional psychology was waning, and this was very troubling. I read all I could find on control theory. I started to realize that much of what was said about control theory or feedback theory in the behavioral science literature was wrong.

In 1978, Powers came out with an excellent article in *Psychological Review*. This was a significant event, because it was the first new publication I knew of, since his book, and it described some actual experiments demonstrating some of the basic principles of control theory. The article was rough going—mathematically and conceptually. But I set up the experiments on my computer and started really to understand what was going on—and what was going on was downright amazing. The process of behaving is a truly remarkable phenomenon; I began to understand what the title of Powers' book meant: To behave is to control, and what control systems control is not their actions but the perceptual consequences of their actions.

My understanding was further expanded by a series of four articles Powers published in *Byte* magazine in 1979. The experiments I was doing (and still do) look pretty simple. They involve controlling events on a computer screen. Though simple, the experiments demonstrate the way control systems work—and the results are completely inconsistent with all current models in psychology. Control systems behave in ways that are quite counter-intuitive. The experiments are simple for the same reason that the experiments in physics labs are simple—we know what results we're going to get. The results are perfectly repeatable. They show how control works. Once you know the principles and can repeatedly demonstrate them, you have a solid foundation for going on to more complex phenomena. The experiments I do are of a type completely alien to conventional "Psychology Today" mentality, so they are sometimes dismissed as trivial. To my mind, one quality fact is worth all the statistical generalities in all the social sciences.

In 1980 I began my own little research program on control theory. I designed a number of studies that were aimed at showing how the behavior of a control system (like a person) differs from that of the kind of system that psychology currently imagines people to be. I have had little difficulty publishing these reports, and the reception of my work at meetings has been positive—probably because no one really understood what I was talking about.

By 1981 I had become a complete prodigal. I now understood control theory rather well and knew precisely why it was usually a waste of time to try to interpret existing research findings in terms of control theory. This is the usual challenge I get—how does control theory explain this or that "fact"? My first answer is that the statistical results you find in the social sciences do not, for me, constitute meaningful facts. But the real problem is that facts obtained in the context of the wrong model are simply misleading and worthless.

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Once you get to a certain point in your understanding of control theory, you realize that almost all of traditional psychology can be ignored. This is a rather sickening experience at first, and everyone I know who gets excited about control theory eventually encounters the problem. A clinician friend of mine in New Jersey, an avid control theorist, just isn't willing to cross the line and ignore what deserves to be ignored—yet. I sympathize. It's not easy to ignore everything you were once taught to take very seriously. But this is what had to be done in physics after Galileo. You just have to take off in the right direction. Physics doesn't need to spend a lot of time explaining why pre-Galilean physics is wrong. Revolutions are revolutionary—you don't gain anything by clinging to old ideas that are wrong, no matter how much you used to love them.

Current approaches to psychology and the social sciences are based on an input-output model of behavior. In every methods class you learn that the proper way to study behavior is to manipulate independent variables (environmental input, such as room temperature or reinforcement schedule) to determine their effects on dependent variables (behavioral outputs that you have carefully operationally defined so as to be measureable). This should all be done under controlled conditions, so that you can correctly infer causality—that is, if there is a change in behavior, this change can be attributed to variation of the independent variable.

In some social sciences manipulation and control is impossible, but the approach is the same: look for correlations between input and output variables, between environment and behavior. This is bread-and-butter psychology and sociology and economics and political science. It's easy to do once you get used to it.

This method of doing research will give you good results only if the objects of study are input-output devices. Whatever the verbalisms used to describe different theories, the model of research in the social sciences assumes that organisms are some type of input-output device—arguments concern only what type (computer, conditioning machine, etc.).

The social sciences have persisted in using this model in spite of the fact that it *clearly does not work*. The results of research in the social sciences are a mess by any reasonable scientific standard. They are extremely noisy. Statistics must be used to determine whether anything happened at all in most studies. The reason for all this variability in the data is usually attributed to random stimuli flying around in the environment. But after 100 years of doing this kind of research, using more and more sophisticated apparatus and control, the variability is still there and it is still large.

Nowadays the variability of data in the social sciences is attributed to the inherent variability of behavior. Besides being unscientific by blaming the failure to understand a phenomenon on the objects of study, this posture can be seen as ridiculous just by looking around. If the behavior of the architects, engineers and workers who built the buildings in this city were as variable as social scientists imagine it to be, few of these structures would still be standing.

In fact, behavior is variable only when looked at from the wrong point of view—the point of view of the input-output model. What's wrong with the model can be seen by considering the output side of the model in more detail: Just what is behavior? The textbooks say that it is anything that organisms do—but we know that's not so. Psychologists don't study the acceleration of animals as they are accelerated to earth by the force of gravity, but the animal is behaving.

The behavior we are interested in is the kind that is generated by the organism itself—not only generated by the organism itself, but consistently so. If organisms never did anything more than once, we would see chaos. Instead, we see regularity—pressing a bar, getting dressed, having a conversation, making love.

The events that we recognize as behavior are named for the uniform results produced by organism actions, not for any particular pattern of the actions themselves. Thus we see an animal pressing a bar, but fail to note that the result (the lever going down) is always produced by a different pattern of actions. In fact, the detailed actions that produce any behavior are always different and must be different if the result is to repeat. The appropriateness of this variability cannot be understood in terms of the input-output model, so it is ignored.

Students of behavior have noticed that organisms use variable acts to produce consistent results, but few have noticed that these variations are necessary. Skinner, for example, considered the different ways the rat gets the lever down to be arbitrary—one way is just as good as another. In fact, if the rat pressed in the same way each time, the lever would not go down

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on each occasion. The apparently random variability is really not random at all. But this causes a problem, because it then appears that the organism is varying its actions in just the right way to produce a consistent result. It looks like the animal is trying to get the lever down. This implies internal purposes, and there is no room for such things in an input-output model.

E.C. Tolman was on the right track. He showed that rats who could run a maze to a goal could still get to the goal when the maze was filled with water. Tolman correctly concluded that the rat had the purpose of getting to the goal and was using whatever means necessary to produce that result. But this was in the 1930s, before control theory and hence the tools to explain how purpose could be carried out. So everyone said, "response generalization" and went back to the labs with the input-output model intact (in their heads, if not in reality).

However, if one thinks about it for a moment, it is clear that Tolman's phenomenon—together with many everyday examples of the same thing—is completely inconsistent with the notion that behavior is the last step in a causal chain, as the input-output model implies. There is no way for any input-output system, however smart, to produce actions that will always have the same result in an unpredictably changing world. The straight-through causal model breaks down completely.

When we do anything we are adjusting our actions, usually without even being aware of it, to produce the intended result, regardless of the prevailing environmental circumstances. The rat pressing a bar is not just emitting this result—it is producing forces which, when combined with all other forces acting on the bar, produces the result "lever press." These "other forces," which I call disturbances, are always present when we do anything. We usually don't notice their contribution to behavior because their effects are usually precisely canceled by the actions of the organism. If I pressed a bit on the other end of the rat's lever, the lever would still go down because the rat would increase the forces it exerts in just the right way to produce the intended result. If I block a route you usually take to get to the store, you will get there by another route: the same result produced by different means. Thus, the effects of disturbances are not noticed, and behavior seems to just pop out of animals.

The process of producing consistent results in an unpredictable environment is called control. To behave is to control. The only system known that can do what organisms do every instant of the day is the negative feedback control system. A control system produces the consistent results we call behavior by producing pre-selected perceptions, not outputs. Control theory consists of the equations describing how closed loop control works. Control is not explained by muttering words like "feedback" and "error correction." I have never seen a correct treatment of control in the behavioral literature.

To the extent that behavioral scientists have dealt with it at all (and they have really tried), control theory has been twisted into what is really a disguised version of the old input-output model. This is usually done by imagining that closed loop control systems can be broken up into an alternating sequence of inputs and outputs. What you get is a sequential model where a person makes a response which produces a new input, which produces a new response. Input and output are preserved, alternating in time. In fact, such a system would not control anything. Real control systems work much more beautifully—there is no alternation in time. Input and output are joined in a continuous wheel of causation. The system is a wholly different thing from that which psychologists imagine it to be.

One reason psychologists have not learned control theory is that they think that they already know it. They don't—they just know terminology. When they get close to understanding it, they realize that it is completely different from their beliefs—so they redesign it to be consistent with their preconceptions.

Now I can try to explain why the results of behavioral research based on an input-output model is bound to be largely useless. According to control theory, when we are watching behavior we are watching a control system from the outside. This system will be controlling many different results of its actions (actually the perception of those results), some of which will correspond to very complex functions of the events that are part of the observer's perceptual experience. To control these results, which are almost certainly going to be quite abstract and, thus, hard for an outsider to notice, we will see the system doing many things in the process of protecting these results from the effects of disturbance. We might want to find the "cause" of one of these actions. So we do an experiment in which we manipulate stimuli to see if there is some effect on the action. Some effect is almost certain, although it will be only statistical. Almost anything you do is bound to disturb, in some

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way, some controlled result of actions. The behavior you are studying may be only incidentally related to the means used to protect against the disturbance you have created. Hence we get statistical relationships —usually by averaging over several subjects.

If you had a better idea of what the subject was trying to control, you could get more precise results. This is what happens in operant conditioning experiments. Of course, the experimenters would never consider reinforcement a controlled result of actions, but it is. In operant situations you create disturbances to the rat's ability to control the reinforcement rate. This leads to precise and dramatic corrective actions by the rat. For example, if you require more bar presses per reinforcer, the rat presses faster, preserving the rate of reinforcement. Of course, to the experimenter it appears that the change in reinforcement schedule is controlling the rat's bar pressing. But this is an unfortunate illusion that has prevented psychology from progressing beyond the input-output conception. This illusion of stimulus control (a well understood property of control system behavior) is just as compelling as the illusion that the sun goes around a stationary earth—just as wrong and just as difficult to dispel.

What you get by studying control systems as input-output systems is exactly what you have in the social sciences—a confusing and often inconsistent array of findings, only weakly reproducible and little more than verbal models to account for them, models with virtually no predictive or explanatory power. If you knew what the subject was controlling, you would not have to do such experiments any more. You would know how the system would respond to any disturbance. This is one goal of research based on control theory: to discover the kinds of things that can be or are controlled. Then you can ask how they are controlled, and why. The "how" question will take you to lower-order control systems (What results are controlled in order to control this result?). The "why" question will take you to higher-order control systems (What higher-order result is being controlled by controlling this result?).

Control theory is revolutionary, and the revolution is going to be tough. One reason is that most social scientists see no problem with the status quo. People will continue to do bread-and-butter social science because it's what they know how to do—they know what kinds of questions to ask and what kind of results to expert. Social scientists are experts at having an explanation for the results, no matter how they come out, so long as they are statistically significant. It is easy to turn the statistical crank. With sufficiently powerful statistical tools, you can find a significant statistical relationship between just about anything and anything else.

Psychologists see no real problem with the current dogma. They are used to getting messy results that can be dealt with only by statistics. In fact, I have now detected a positive suspicion of quality results amongst psychologists. In my experiments I get relationships between variables that are predictable to within 1 percent accuracy. The response to this level of perfection has been that the results must be trivial! It was even suggested to me that I use procedures that would reduce the quality of the results, the implication being that noisier data would mean more.

After some recovery period I realized that this attitude is to be expected from anyone trying to see the failure of the input-output model as a success. Social scientists are used to accounting for perhaps 80% (at most) of the variance in their data. They then look for other variables that will account for more variance. This is what gives them future research studies. The premise is that behavior is caused by many variables. If I account for all the variance with just one variable, it's no fun and seems trivial.

If psychologists had been around at the time that physics was getting started, we'd still be Aristotelian, or worse. There would be many studies looking for relationships between one physical variable and another—e.g., between ball color and rate of fall, or between type of surface and the amount of snow in the driveway. Some of these relationships would prove statistically significant. Then when some guy comes along and shows that there is a nearly perfect linear relationship between distance traveled and acceleration, there would be a big heave of "trivial" or "too limited"—what does this have to do with the problems we have keeping snow out of the driveway?

Few psychologists recognize that, whatever their theory, it is based on the open-loop input-output model. There is no realization that the very methods by which data are collected imply that you are dealing with an open-loop system. To most psychologists, the methods of doing research are simply the scientific method—the only alternative is superstition. There is certainly no realization that the input-output model is testable and could be shown to be false. In fact, the methods are borrowed, in caricature, from the natural sciences, where the open-loop model works very well, thank you. Progress in the natural sciences began dramatically when it was realized that the inanimate world is not purposive.

Psychologists have mistakenly applied this model of the inanimate world to the animate world, where it simply does not apply.

This was a forgivable mistake in the days before control theory, because before 1948 there was no understanding of how purposive behavior could work. Now we know, but the social sciences have their feet sunk in conceptual concrete. They simply won't give up what, to them, simply means science.

It is not, however, science, and the input-output framework is not the way to study closed-loop systems. There is a methodology for studying purposive systems; I have written a little about this. It is quite objective and experimental, and it gives results that are completely precise—and without statistics. But it is based on the rigorous laws of control, not on loose verbal, or mistaken quantitative, treatments of behavior.

I am not here seeking converts. I do not expect a social scientist to become a control theorist. Control theory requires a great deal of work; it is a lonely enterprise, and involves a painful change. But I hope that you can see why I can no longer teach the dogma.

I love psychology, and I consider it potentially the most exciting field left to explore. That is because it is basically virgin territory. All the attempts to understand behavior up to this point have been well-intentioned stabs in the dark. They have been based on the only tools available and on an allergic fear of committing metaphysics.

One might well ask. "Why should I believe you?" Well, you shouldn't. Understanding human nature is not a matter of finding the right words to use to describe a phenomenon, although one might easily get that idea by spending enough time in the social sciences. The only way to become convinced about the value of control theory is to learn it, to test it, to try to understand it. And then see if you can still buy the old approach. But learning control theory takes time, in my case at least two years—really four years before I was really comfortable with it.

I don't have a private pipeline to truth, and control theory is the beginning of a search, not the end. It won't solve all your problems. But it will, once you really begin to understand it, give you the extremely satisfying experience of finally knowing a little part of one of nature's secrets: the secret of purposive behavior. Then you can start looking at how learning, memory, consciousness, individual differences, and so on, enter the picture. But at least you will know that you are on the right track, proceeding from a solid foundation of replicable facts rather than from a trembling network of unreliable statistical generalizations.

Control theory has made me a revolutionary, not against psychology, but against the current dogma that passes for scientific psychology. If you are happy with the dogma, then go with it. If you want to understand human nature, then try control theory.

So my problem is what I, as a teacher, should do. I consider myself a highly qualified psychology professor. I want to teach psychology. But I don't want to teach the dogma, which, as I have argued, is a waste of time. So, do I leave teaching and wait for the revolution to happen? I'm sure that won't be for several decades. Thus I have a dilemma—the best thing for me to do is to teach, but I can't, because what I teach doesn't fit the dogma. Any suggestions?

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A PCTer's Lament

Or *50 ways to leave your PCT*

A post to CSGnet by Rick Marken, September 28, 1997

(Still relevant 18 years later)

During my perennial musings about the lack of public interest in the most important (and ennobling) scientific development in the last 400 years (PCT of course) I realized that the answer is really very simple:

There are far more reasons for rejecting than for accepting PCT. In fact, I could think of only one reason for accepting PCT and here it is:

1. Because the correlation between the behavior of the PCT model and the behavior of humans in a control task is .999.

Here are a few of the many reasons I could think of for not accepting PCT:

1. There are no self-help best sellers based on PCT.
2. There are no famous psychologists who support PCT.
3. There are no famous scientists of any kind who support PCT.
4. PCT has been around since the mid-50s and there have been very few references to it in the behavioral and life science literature.
5. PCT doesn't tell you the best way to live your life.
6. There are no PCT self-help tapes available in video stores.
7. There are no charismatic motivational speakers telling people they can "have it all" if they would just control their perceptions.
8. PCT has *not* been condemned by the Catholic Church nor has *Behavior: The Control of Perception* been placed on the *Index* (which was a real shot in the arm for Copernicus ☺)
9. PCT is not based on research where rats press bars to get food. Therefore, it is clearly not relevant to real life.
10. PCT is not based on natural selection so it is either a religious movement or not very important.
11. PCT can't quantitatively account for all the statistical research results that are readily handled—verbally— by current theories of behavior.
12. PCT supporters always argue against my favorite theory, which is almost the same as PCT. PCT is so *negative*.
13. PCT is never mentioned in PBS specials about the brain.
14. PCT says that there is no such thing as reinforcement.
15. Modern neurophysiology has already shown that the brain is a complex information processing device.
16. Control is bad.
17. PCT is against everything.
18. Psychologists have been studying behavior for over 100 years. They *must* know what they are doing.
19. Who is this Powers guy anyway?
20. Where does some engineer from Podunk, Illinois get off thinking he's found a fatal flaw in the life sciences.
21. There are tons of psychology books in the library written by smart, famous people and advocates of PCT say "What's in those books is all wrong. I'm afraid you'll have to start all over again". Get real!

22 PCT can't be very deep because it is not based on any "Golden Age" Greek dramas like "Oedipus" or "Electra".

23. PCT doesn't view language as anything special; it's just another set of perceptions that people control. The non-Chomskian nerve!
24. No one has gotten rich doing PCT.
25. PCT is too complex.
26. PCT is too simple.
27. PCT doesn't have anything to say about learning.
28. Parts of PCT are right but the theory doesn't capture the most important facts about human nature—the ones captured by [insert your favorite theory here].

Well, that's enough for now. I guess I'll spend the rest of the day trying to become less cynical.

Best, Rick

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On emotions and PCT: A brief overview

William T. Powers

Emotions are confusing experiences, because they seem to be both cause and effect. To be angry is to feel a surge of energy and a powerful intention to act (whether it is allowed to take place or not), but it is also an experience that seems to arise passively or be "triggered" from some external source. An old question is whether an emotion arises before the action it seems to demand, or after the action and because of it. When there is danger, do we know there is danger because we feel afraid and flee, or do we flee because of the danger we perceive, and feel afraid as a consequence?

The PCT model of emotion is informed by control theory, in which closed causal loops are the rule rather than the exception. Sequential causality is not adequate as a description of how a control process works; rather, we must consider local causes and effects as existing in various parts of the system at the same time. We can see that emotion, as a physiological state of arousal or relaxation, is produced by the brain as it adjusts the neurochemical reference signals that are sent from the hypothalamus into all the major organ systems via the pituitary. This makes emotion a result of brain activity, for example the sort that is often called "emotional thinking." On the other hand, disturbances that call control systems into action result in perceivable changes of physiological state, and those changes can be the first that one's conscious awareness knows of the presence of a disturbance. In that case it seems that the emotion is a direct response to the disturbance, as if emotion represents the arousal of some independent primitive form of intelligence that is designed to take over to save us from threats we do not consciously perceive at first. According to PCT, both of these views of emotion are quasi-correct, but both require considerable clarification.

In closed-loop terms, we must recognize that an experienced emotion is in fact a collection of inputs, perceptions that we call "feelings," and at the same time, an output-caused change in physiological state: heart rate, respiration rate, vasoconstriction, metabolism, and motor preparedness—the "general adaptation syndrome" in the case of avoidance or attack behavior. Beyond those basic views we can see also that there are reasons for emotions that are based on what we seek and what we avoid: when we wish a high level of some experience, we give "good" names to the emotions that go with achieving them; when we wish to avoid some experience, we give "bad" names to the feelings even if, considered only as sensations, they are identical to the "good" ones. Exhilaration and terror are very similar if not exactly the same in terms of sensations, though one is involved with experiences that we, or some people, enjoy, while the other goes with experiences that are almost always disliked. Most of the large collection of emotion-words that we use describe error states or goals, with the number of actually different physical sensations involved being very much smaller, or different mainly in degree.

When we think of emotions as inputs, we tend cognitively to attribute them to external causes, as if the feelings were being stimulated directly by something outside us. Neurologists, in support of this view, have come to identify certain volumes in the brain such as the "limbic system" or end-brain as the producer of emotions. They do recognize that disturbances, external stimuli, must act to produce emotions through some mediating brain function rather than directly, but they have failed to see the limbic system as just one level in a hierarchy. Knowing essentially nothing about hierarchical closed-loop control, they do not realize that the limbic system, like any subsystem at that level, has to be told by higher systems whether to seek or avoid any given amount of a perception. The output of the limbic system may operate through the hypothalamus to produce the changes we detect as feelings, but it is not the limbic system that assigns a value to the perceptual signals it receives. That is done by higher systems via reference signals. The limbic system may be the proximal cause of changes in physiological state that we associated with emotions, but it is far from the final cause.

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The final cause of an emotion is a reference signal in some high-level system which specifies a high or low intended amount of some perception. If the current state of the perception matches what the reference signal specifies, there is no emotion because there is no call for action to correct an error.

An emotion arises when there is a nonzero error signal in a high-level control system. This error signal is converted into changes in the reference signals of some set of lower-order systems, in a hierarchical cascade that, at some level in the vicinity of the midbrain, bifurcates. One branch of this cascade ends in the motor systems of the spinal cord, the systems that produce overt actions. The other branch passes through midbrain systems like the limbic system, through the hypothalamus and possibly the autonomic nervous system, through the pituitary gland and other glands, into the physiological control systems, the life-support systems of the body. That second branch adjusts the state of the physiological systems as appropriate to the kind and degree of action being produced by the first branch, the behavioral branch. This second branch is the one in which the changes we call feelings (other than the feelings of muscular activity) arise.

Under normal circumstances, behavior comes about for one of two reasons: either there is a disturbance which changes some perception and thus generates an error signal, or there is a change in the reference signal demanded by some higher control system, which change also generates an error signal. So whether the change is initiated by a change of reference signal or by a disturbance, the immediate result is an error signal, and it is the error signal that gives rise both to actions and to feelings.

When an error signal results in a change of action, the physiological changes that simultaneously take place support the change of action, either by providing the resources needed for an increase in activity, or by turning down the physiological/biochemical systems when less metabolic energy or other resources are required—when the organism relaxes and rests. Since the behavioral and physiological changes happen at the same time, they remain approximately in balance, so there is neither an excess or a deficiency in the state of preparedness.

If the requested action is prevented from happening, then the physiological state is no longer appropriate to the behavioral state. The system is flooded with energy that is not being used up because the motor systems have not come into action, or a reduced state of preparedness becomes insufficient when the level of motor activity remains high instead of declining as demanded. Either combination of states is abnormal; both combinations are experienced as unpleasant.

When we perceive the unpleasantness together with the perceptions and goals behind them, we call the whole pattern an "emotion"—specifically, an unpleasant emotion.

(A pleasant emotion may simply be a sense that the physiological state is in harmony, or is coming into harmony, with the behavioral state; rates of change may be involved. At any rate, pleasant emotions are not ordinarily a problem, so we can ignore them here. People do not seek counseling to cure them of pleasant emotions.)

Consciousness and emotion are not directly related. Since an emotion arises when there is an error signal, and error signals can arise in control systems of which one is not currently aware, feelings can appear without any apparent cause or any apparent connection with the current objects of awareness. It is perfectly possible for an emotional reaction, a change in physiological state and even an automatic change in behavior, to occur before one is conscious of anything amiss. This fact is well known and has been used as a reason for assuming that emotional reactions are truly wired in and permanently unconscious. This has lead to a picture of emotion as a holdover from primitive ancestors, or as an early-warning system built into the brain by evolution.

The PCT view of emotion is very different: emotion is simply part of the normal operation of the central nervous system and the physiological systems it uses to achieve its ends. The behavioral hierarchy has many levels with many systems at each level; awareness is in contact with only some subset of these systems, and those systems not involved with awareness simply go on working automatically according to the way they were last reorganized. A change in behavioral and physiological state can result from any error signal without regard to consciousness. Emotions, therefore, exist any time there is an error signal, which means any time we are acting, consciously or unconsciously, to reach a goal or correct an error at any level of organization.

When the degree of error is small, however, we do not use emotion-words: it seems that there is some minimum amount of error that must be exceeded to qualify a state of being as emotional. We use emotion-words when the degree of error

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is significant, important to us. When the systems involved are conscious, we can understand what the error is about; otherwise we just feel the arousal without any explanatory cognitions, and say we are worried or anxious or apprehensive without being able to identify the cause.

Normally, unidentified arousals draw our attention to them and we become aware of the perceptions in the control systems that are the source of the problem. But when the error arises because of conflict, there are two control systems involved, each part of its own context, while the conflict is expressed as a control process that is satisfying neither of the higher-order systems trying to use it. Such conflicts are ordinarily resolved by normal processes of reorganization as soon as they arise. But a person may find the conflict so painful that the whole subject is thrust aside—the person avoids getting into situations where either side of the conflict arises. Then, of course, the control systems continue as they were when last reorganized, and the conflict remains. That situation will have to be avoided from then on.

So-called emotional behavior is simply ordinary behavior. However, strong feelings are involved because the errors are considered very important, so a small error produces a large output, and large outputs call for strenuous action and a high degree of physiological preparedness to support the action. The technical term for this state is "high loop gain." In most circumstances the actions take place, the error is corrected before it can become large, and the physiological state returns to normal with no noticeable emotional state being seen. But if the actions are not allowed or if they fail to correct the error, the result is a continued state of preparation that does not return to normal, and the result is what we recognized as an emotional state.

Therefore emotional behavior and emotional thinking are simply ordinary behavior and thinking concerning subjects which are very important to the person, so that strong actions will be used as required to correct errors, and even small errors are not tolerated. There is nothing in this picture to suggest that emotional thinking or behavior are inferior to any other kind. That the behavior is ineffective is suggested by continuation of the emotions or lack of action, but to dismiss an argument because it is "emotional" is unjustifiable. In fact, it may be the unemotional argument that is defective, in that it concerns errors of no importance.

This conception of emotion suggests that we should understand it as simply a normal part of any behavior, on a continuum that varies from tiny changes in physiology involved in correcting small and unimportant errors, to large, protracted changes that entail extremes of action, feeling, and reorganization. The most intense negative emotions arise in connection with the largest errors and errors that we consider the most important to correct, and their greatest intensity and duration occur when something internal or external prevents us from acting to correct the error. Emotions do not come into us from outside, nor do they represent the action of some automatic or inherited system that exists separately from the rest of the control hierarchy. They are one aspect of the whole integrated hierarchy of control.

Bill Powers
Lafayette, Colorado
April 25, 2007

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Effective Personnel Management: An application of Perceptual Control Theory

By James Soldani

Effective Personnel Management: An application of Perceptual Control Theory (1989)
How I applied PCT to get results (2010)
These two articles complement each other.

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The observations and ideas in this chapter are based upon personal experiences I have had working within various organizations, either as a part of management, or as a consultant specializing in performance-oriented personnel management. My purpose in this chapter is to describe and illustrate several management techniques that I have derived from perceptual control theory. In contrast to stimulus-response psychology, perceptual control theory emphasizes internal goals and voluntary actions.

I have always found that organizations of quality dutifully articulate the importance of people to the success of the company. However, I have also noticed that this talk often resembles superstitious incantations, as if, for example, touting the value of team work in mere words were enough to bring it about. For instance, a company I worked with spent over one million dollars on team development training over a 4 year period. When people who attended were polled within two to three weeks of the experience, with rare exception, they responded very positively to the training. When polled four to five months later, they remembered the experience as having been fun and worthwhile, but nothing had really changed in the workplace, where it counted. They still did not meet goals on time and there were still just as many conflicts as there had been prior to training. This was a tragic waste of resources, particularly considering the fact that workers' jobs were at stake: companies need the maximum productivity out of every dollar they spend in order to compete.

Note: This article originally appeared as Chapter 24 in W.A. Hershberger (Ed.) (1989). *Volitional action: Conation and control*, Amsterdam: North-Holland. Reprinted by permission of the author.

THE PROBLEM

Fortune Magazine published an article in its Nov. 10, 1986 issue describing a group meeting of 500 senior managers at GM. The chief financial officer addressed them. He stated that during the last six years GM had spent about $40 billion dollars on the most modern plants and automated equipment in the world. To put that number in perspective, the article said, "... for $40 billion dollars GM could have bought Toyota and Nissan outright."

Instead, in that six year period GM lost about seven percent of the market share. Most disturbing was the fact that the Nuumi plant in Fremont, California, a resurrected failure reborn through a joint venture with Japan, was running more productively than the modern GM plants. At Nuumi there had been no significant investment in automation. With Japanese managers in control of building the management culture, Nuumi was outperforming every other GM plant, as near as could be determined, solely on the basis of how it was managing and leading its people. It is interesting to note that the Japanese managers hired back 85% of the same people who were the "militant union failures" under GM management.

This and other similar stories point out that American managers, while they may do wonders with innovation, market strategies, and financial analysis, do not know how to manage people. In actual practice, the management of personnel is all too often mismanagement. And it is my experience that mismanagers are to be found virtually at all levels in all organizations. Typically, these individuals are unaware both of their own shortcomings and their missed opportunities to dramatically enhance the productivity of their people. It is as if they assume that their management position automatically confirms their leadership ability or that the position confers that ability, ex officio, as it were, in much the same fashion that pregnancy is thought to prepare women for parenthood. Of course, neither assumption is warranted.

Some managers are simply ill prepared for leadership responsibilities. They understand little about what it takes to motivate employees to work for the organization's goals. And, consequently, their management "style" tends to be unproductive, or worse yet, counterproductive. This fact is firmly documented by the extensive research of Tom Peters and Robert Waterman, as presented in their best selling book, *In Search of Excellence* (1982). Peters and Waterman also identify some companies and managers who do manage personnel very effectively. They note that these more effective managers, i.e., those getting superior results, tend to use positive rather than negative reinforcement (i.e., the carrot rather than the stick) to motivate their people. But there is far more to motivation than the carrot and the stick; there are also important internal factors comprising what is sometimes called the will.

The idea of reinforcement as a motivator or conditioner of behavior is based on a Cartesian notion of stimulus-response determinism. Behavioristic theories of performance based upon this narrow notion of determinism imply that we are organisms who behave because stimuli in our environment cause us to behave. Psychologists have suggested that by studying these cause-effect relationships we can understand why people behave the way they do and even learn how to use certain stimuli to motivate or control people's behavior.

During the 18 years I served as a manager, I found that management techniques based on this principle were hit and miss. Sometimes they worked; often they did not. This puzzled and frustrated me. What was wrong? Could the experts who taught me management theory have been wrong about the proper methods for motivating and handling people? Had not stimulus-response psychologists experimentally demonstrated the "law of effect?" In the end, it seemed to me that any true theory of human motivation had to be able to explain why sometimes the law of effect works and sometimes it does not. Behavioristic psychology provided no answers.

THE SOLUTION

Eventually, I found a satisfactory answer in Perceptual Control Theory, as developed by William Powers in his book *Behavior: The Control of Perception* (1973). There are three important concepts in Powers' theory: (a) internal reference signals, in the form of goals, or wants, which specify intended perceptions, (b) internal and external feedback, comprising the individual's controlled (i.e., actual) perceptual input, and (c) a hierarchical organization of such controlled perception. Perceptual control theory opened up new perspectives for me and answered many practical questions. I have come to accept Powers' ideas, not only because they make sense, but because I have found that they work. The purpose of this chapter is to share three personal examples of instances where Powers' perceptual control theory helped me (a) explain certain "unaccountable actions" of a person in the workplace (i.e., where the carrot was not working), (b) understand and resolve an intractable personnel problem, and (c) develop a program of productive teamwork

A psychology developed around the concept of volitional actions or purposive outcomes may seem tautological to most managers in organizations. They do not perceive anything new in the idea of setting goals to direct or control the outcome of behaviors. To them, goal setting is a fundamental idea commonplace in organizational guidance and performance. So is feedback. That is why they have so many meetings and reports.

What managers fail to understand is that setting goals for organizations through senior management oratory or written directives does not guarantee that people in the organization will internalize these goals and work for them. Nor does investment in modernized equipment or computer reporting systems provide the kind of feedback that really matters. Even high pay, promotion, and other incentives will not always work. Managers who believe otherwise simply do not understand how the human system functions, how goals can affect perceptions, or how goals and perceptions interact. When this process is understood, all behavior, even the most aberrant becomes understandable, and therefore more capable of being influenced.

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When a Reward is Not a Reward

The concept underlying positive reinforcement is the idea of a reward. Psychologists and management development experts teach us that rewards are positive, pleasant stimuli that are supposed to motivate desired behaviors. However, as Powers posits on page 14 of his book, we cannot really say what is rewarding about a reward. We can guess that recognition, promotion, or money are rewards, and we can certainly find instances where these rewards and desired behaviors correlate, but we cannot define what makes them rewards.

I have seen many cases where such rewards or incentives did not motivate people, or motivated them in the opposite direction from what was desired. I remember Dan, the manager of a medium sized manufacturing facility in the Southwest. He was notified that the company had decided to close his facility within a year and transfer operations offshore.

Dan was a highly respected performer in his organization. He was offered an equivalent position in Oregon at another company facility. He turned it down. Management thought he was crazy. In the eight years Dan had been with the company he had always done what was asked of him. He had always gone where he was needed. He was a fast-tracker. Management offered him a promotion and a significant raise to take the transfer. He still turned it down. Neither praise, recognition, promotion, nor money could persuade Dan to move.

Frustrated with his decision, management began to turn a cold shoulder. Dan's job was disappearing and if he could not take what the company generously offered, perhaps it was time for him to move on. This is what he did, leaving the company by the year's end, a valuable resource lost to competition.

As foolish as it sounds, not once in the entire process did management seriously consider what Dan was trying to control or work for in this particular decision. Of course, what Dan was trying to control, reflected Dan's motivation, what Dan wanted. This want was not represented by a single unitary goal. Rather it was made up of many specific goals interrelating with each other at various levels of a perceptual hierarchy within Dan. A simple questioning of Dan would have revealed how this hierarchy was currently organized. Dan had made some significant changes in his personal goals over the years, changes which affected how he perceived himself, his company, his future, and therefore his decision.

A few years earlier Dan still held goals for building and pursuing a career. He felt he should take advantage of every opportunity and do everything management asked. Thus, Dan perceived opportunities to move as beneficial. This was a value judgment he made within his own perceptual system.

At the time of the company offer, Dan had demonstrated a high level of capability. He had proved himself and reached a pay scale that satisfied his life style and life goals. He did not want to prove himself further. The change in status of these several internal goals altered the way he perceived moving. Moving was no longer a goal connected to other goals he controlled for. Neither was more money.

What were Dan's goals? Questioning him would have shown that he was presently more concerned with the stability of his family, and the fact that his kids had found good schools and friends with whom they were involved. His kids were building lasting friendships. They were putting down roots. He wanted them to experience more stability. He wanted this for his wife and for himself as well. These statements represented new specifications (goals) for relationships between Dan, his kids, his wife and their social environment. Moving to a new site with new challenges, which once was perceived as a reward for his family and himself under one set of internal goals was now perceived as a penalty. The same stimulus produced a very different perception and response.

The point of this example is to show clearly that rewards are not in stimuli, which are merely things in the environment, but in the perception of the stimuli, which involves a particular person. How an employee chooses to perceive a "reward" and whether it satisfies his many goals will determine what choices he will make. Thus, managers trying to stimulate and positively reinforce good productive behavior with rewards will find many instances where their reinforcements will not work.

One Minute Manager, written by Ken Blanchard several years ago, advocates one minute of praise every time an employee does something right and a one minute reprimand every time an employee does something wrong. The constancy of this positive and negative reinforcement will, according to Blanchard, serve to extinguish undesirable behavior and anchor the proper behavior.

Ask yourself what effect such automatic expressions of praise would have if they came from a supervisor you perceived as selfish and manipulative.

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Would you trust the praise and feel good about it? Most people I have polled respond with answers like: "I wouldn't trust the praise." "He's being phony." "He's insincere." "I can see right through him." "His praising would have no positive effect on me at all." Consider a series of reprimands coming from a similar manager. Again, most I have polled respond unfavorably. "I would perceive reprimands from this type person as highly ineffective." "I would resent them." "I wouldn't pay much heed considering the source." "I would be very angry and upset but not because I did anything wrong." In other words, these people are not reacting to the stimulus of praisings or reprimands but to their own perception of the person who is giving them.

Understand, I am not against giving praise or recognition for a job well done, but I am against pretending that such things "cause" or "motivate" behavior. Reinforcement is just a component in a far more elaborate system.

Resolving an Intractable Problem

Sue was a very bright and ambitious young woman who became a supervisor of a five-person group responsible for supporting equipment in the field. Sue had no previous supervisory experience, but in other ways had earned the right to her new position of responsibility. However, soon after taking over, Sue experienced employee problems. Her people were not performing the way she wanted. Absenteeism was on the rise and she had almost daily arguments with her people. She heard from others that her people were complaining about her autocratic behavior. She was also feeling stress from complaints and criticism reaching her from other managers about the performance of her department.

Not being a quitter, Sue took to having weekly meetings with her people. In these meetings she fed back to them the things they had done wrong. She had learned that good managers give feedback. She shared the complaints she was getting, and told them quite clearly that she did not intend to have her career go down the tubes because of their lack of performance. She not only defined the problems in the department for them; she analyzed the causes, and told them what they needed to do to make things better. In spite of the weekly meetings, things got worse. Finally, her new manager asked if I might talk with her, since his advice was not helping much.

What many consultants would do to help in this situation would be to evaluate Sue's problem for her, tell her what she was doing wrong, and suggest alternate ways of behaving which might produce better results. Perceptual control theory helps me understand the process by which behavior is created and leads me to a different approach. I also realize from experience that telling a person what they are doing wrong rarely guarantees that they will understand or do what is needed. So, instead of telling, I ask a lot of questions.

When I talked with Sue she told me that her people were the reason she had to behave so autocratically. They were a group of undereducated underachievers that really did not care about the performance standards she had set for the department. They were careless, slow to react to problems, made too many mistakes, did not follow through, and made her look bad. They deserved the way she treated them. It was the only way she could get their attention.

Although Sue thought her heavy handed behavior was being caused by her people, this was not so. Actually, her behavior was evidence that something she was trying to control was not under control. In a sense her behavior was only a symptom, evidence of thwarted intentions, or error signals, which if found, would prove to be the real engine behind her behavior. She was trying to control the performance of her people, and trying unsuccessfully. I needed to find out what goals Sue had in mind. If I tried to deal with her behavior directly I would probably be unsuccessful in helping Sue. Trying to get her to change her behavior directly is like trying to steer a horse by pushing on its hind end.

Using simple questions, I found that Sue perceived herself as a hard-driving perfectionist. She was not used to making mistakes or being criticized for them. She had achieved a Masters Degree cum laude. Sue could not allow herself to be in a position of mediocrity or failure. I asked her whether she thought her standards were too high to be applied to others working for her. She did not think they were. She thought they could be achieved with effort.

I asked her how she might get her employees to meet her standard of performance. For this she held no hope. She responded that within this particular group of employees, which she had inherited, not one of them had a college degree. To her this showed that they were not ambitious, smart, motivated, or

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disciplined. I asked her when she held a meeting with them, how she perceived them. She said she hated to have meetings with them. She perceived her people as stupid, uncaring, and a threat to her career. She did not evaluate her own behavior, and did not see herself as being an ineffective supervisor. As she saw it, her responsibility as a supervisor was to tell her people what to do, and their responsibility was to follow her orders because she was better educated and the boss.

When I further questioned Sue about her goals, her answers were focused on her career. She wanted to shine. She wanted to earn the respect of her new boss and other managers, whose departments she supported. She wanted a superior performance review and a pay raise at the year's end. She had never had less than superior reviews in her career. She expected another promotion, perhaps to manager, within a year. I asked her if she had any goals pertaining to her people. She said she wanted only to keep them from destroying her plans and career.

Managers who want to lead a person beyond themselves, to truly help them develop, must start with a consideration of that person's goals and perceptions. Just as I was considering Sue's goals and perceptions, she would need to consider her people's goals and perceptions in order to understand and effectively supervise her people.

During the time I consulted with Sue, I talked with her people. I asked about their goals. All they wanted was to keep her off their backs. I asked if they wanted to do a good job. They responded that they did, but with Sue you either had to be perfect or nothing. One said, "It isn't worth trying." I asked if they could try to talk this out with her. They said she wouldn't listen to them. They weren't smart enough, they said, to have an opinion she would listen to. Each of them expressed it differently, but their goals were not for working hard or performing well, but for avoiding Sue's criticism and badmouthing. They did not see how working hard would change any of Sue's behavior, but they did think that if they complained enough, someone might get the message and transfer Sue. So they complained a lot amongst themselves and to others.

I also talked with the previous supervisor of this group. He said that the people were not superstars, but neither were they losers. In the past they had done a creditable job.

It was apparent that Sue's people might very well be able to perform satisfactorily, but that, for the moment, Sue's goals and her people's goals were at cross-purpose. That is, although both Sue and her people were interested in doing a good job, her people were even more interested in keeping Sue off their backs, and this they could achieve only by doing a poor job and blaming it on Sue, or so it seemed to them. The group's poor performance, in turn, threatened Sue's reputation which was under high-priority control. She was trying to defend her reputation as well as encourage performance by scolding her people and imputing blame. This only antagonized her people and, in turn, exacerbated the threat. Sue was hung up in a vicious cycle; she was being too defensive for her own good. Sue had to discover that her best defense, ironically, was less defense.

From a perceptual control theory perspective, the problem was perfectly understandable, and the solution obvious. Sue had to discover for herself that her people were actually interested in doing a good job, despite their currently poor performance, and would possibly do relatively well for her if only they found her less aversive. Sue had to stop wanting to perceive (and wanting others to perceive) her people as her adversaries; that is, as "stupid, uneducated, and lazy incompetents."

I asked Sue if perceiving her people as stupid and uncaring was helping her deal with them and bring them along. She said that was the way they were. She didn't make them that way. I asked again, if, in addition to the way she perceived them currently, she might be able to perceive them as overwhelmed with her new standards and aggressiveness in wanting higher levels of performance. "Is it possible that they might be intimidated and a bit scared of failing, or incurring further criticism from you?" This had not occurred to her. She said she might be able to perceive them that way. I asked whether, she would possibly conduct herself differently in the next meeting if she chose to perceive them as more overwhelmed and scared than stupid and unmotivated. She thought for awhile and then said yes, she would handle the meeting differently. I asked her what she would do. She described a different softer approach to presenting the problems of the week and then talked about asking them for some of their ideas so she could put them more at ease. I was helping Sue visualize new behavior based on new perceptions possible for her.

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At my suggestion, Sue tried the "softer" approach in her dealings with her people, and as she did so, her people's "latent" desire to perform well began to manifest itself. This process, once started, was self-perpetuating. When Sue discovered that she could improve her people's productivity and attitude by being less defensive, she became more tolerant both of herself and her people. Accordingly, she became a more flexible and effective supervisor. It took several meetings with her over a period of a few months before she resolved her difficulties with her people to the point where they began to meet her performance expectations. There were setbacks, and unfortunately she did lose a person, who did not have the patience or faith that positive change was taking place. A few weeks into our sessions together, Sue began to see each of her people as having significant contributions to make. When she lost one, she was devastated. She even talked of resigning. She had made some mistakes. There are always consequences from mistakes. But, Sue was learning to be a manager.

It is beyond the scope of this chapter to share with the reader the details of the several discussions I had with Sue. My intention has been to show that in managing people effectively one must start with an understanding of the process that drives them internally, and then help them resolve conflicts, competing priorities, or other difficulties within that process.

Teamwork

Much is written today about teamwork, and companies are investing unparalleled dollars in team development training in hopes of getting the kind of high performance out of their workgroups that they need. However, much of this training brings only a temporary *esprit de corps*. Rarely does it translate into lasting results. As I mentioned above, I once worked for a company which spent over one million dollars on team development training over a four year period, all to no avail. Although traditional approaches have failed to develop effective teamwork, perceptual control theory has helped me to develop teams that actually work.

A team is a group of individuals that share a common goal. This goal is the team's focal point. Many different types of goals could qualify as a focal point. It could be: better customer service, better performance to schedule, better production efficiency, better quality. It is the characteristics of the focal point that are critical. A focal point goal to be used for team development must have 3 characteristics:

(a) It must be very specific and capable of being measured.
(b) Each group member must internalize the goal; achieving the goal must become a mission for each member.
(c) The goal must be such that the team cannot achieve it without a contribution from every member who makes up the team. This interdependency ties the individuals together into a team.

Once a team has accepted a focal point goal, several things must be done. First, the goal must be talked about daily, to keep it firmly defined as a priority against other competing priorities in each person's mind. Second, the teams' performance must be reviewed regularly and this information must be shared with all the team members. This feedback has to come often enough to allow for control. Formal reports usually are not fast enough, or they are so voluminous that nobody can read them all and put the feedback in focus to create an action plan. Therefore, part of the process is a daily meeting, a short stand-up meeting, which reviews how the team did yesterday compared to yesterday's goal, and what they have to do to make today a success. Obstacles and problems that might prevent today from being a success are identified by the team members. Actions required (AR's) are assigned to specific people on the team, who then own the responsibility to resolve the action and report back the next day.

This feedback not only tells everyone on the team how they are doing, but instills responsibility and accountability between them. They learn to make commitments and to keep commitments to each other. The more of this they do, the more trust and confidence they build as a team. The frequency must be daily, at least in the beginning.

Third, effective team leaders realize that individual team members have their own strengths and weaknesses. They have their own personal struggles; they have to resolve both to fulfill the requirements of their jobs and to fulfill their responsibilities to the team. Each member of the team will need one on one time with the team leader. This time is spent helping people come to terms with their own internal problems and conflicts as they relate to the goals of the job. The same technique I used with Sue is employed.

Those on the team who are not comfortable with this focus and accountability must be taught the difference between a reason and an excuse. Excuses are facts which a person uses to absolve themselves

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of responsibility to perform. "Joe didn't do his thing so that's why I didn't get my part done." Reasons are those same facts being used to create and recreate action plans that succeed and meet goals in spite of problems or obstacles. "Joe didn't do his thing, and when I realized this, I worked two hours overtime, so that I could complete my AR (action required) for the morning meeting." This is the ultimate in responsibility to self and support of another team player. It is what we strive for in every team development situation.

An example of effective Teamwork

To illustrate the process I will describe a teamwork program that I developed in a manufacturing group which was having difficulty meeting production schedules. Literally every order in production was behind schedule. Constantly changing priorities and hot lists (very important priorities to get done immediately) prevailed as the only mode of getting things done.

The manufacturing manager and I picked a focal point goal called "performance to schedule." We established a production schedule and our focal point goal was to reach 95% of the schedule on time. This performance was to be measured on both a line item basis and a volume basis so that production could not push easy parts to get the volume and neglect small but difficult orders and still look good. It was going to take a lot of teamwork to control all the variables that impinged on this goal.

The manufacturing manager and I conducted a series of meetings with not only the members who would make up the immediate performance teams, but also with all supporting people, whom the teams might need occasionally to do things that were in support of the goal. The importance of the program was explained. The management commitment was explained. The potential benefits of working in this new way were explained: the people themselves would be empowered to remove obstacles that kept them from doing their best. Everything in the kickoff meetings was oriented to selling the participants, getting them to buy in, creating a sense of mission.

We encouraged opinion and feedback. Most did not believe the goal could be achieved because management was always changing priorities and probably would not support the program long enough for change to take place. This was an important insight into their individual perceptions. If they believed they would fail before they started, they could not be expected to seriously try to succeed.

We re-emphasized the management commitment. We held another larger meeting where the top manager addressed the group to affirm the commitment. We went back and conducted one-on-one sessions with all the players. If they felt they could not commit fully, we would let them off and replace them with someone else. This choice turned control over to them. All but one committed to the program.

To make a long story short, the program was a success. The results are reflected in the top line of Table 1 [see next page] which summarizes the average productivity of the teams relative to the focal point goal of 95% of schedule. The teams actually achieved 98%. Table 1 also summarizes the teams' performance relative to other focal point goals and their byproducts. As can be seen from an examination of the figures in the right hand column of Table 1, the value of this teamwork, expressed in dollars, was substantial.

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CONCLUDING REMARKS

William Powers' Perceptual Control Theory has redirected my understanding of people and has helped me make significant positive impacts on managerial careers and on operational performance. However, let me observe that there is no magic in this new volitional psychology. The challenge of productive personnel management is essentially the age old challenge of the human condition: finding the means to control what we want without infringing upon the rights and abilities of others to do the same. Failures to meet this challenge result in costly conflict. Success, on the other hand can yield profits that are equally substantial.

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Table 1. Effectiveness of the Teamwork Program Based Upon Perceptual Control Theory Shown as a Before Versus After Comparison

Performance to schedule: A measure of control over a manufacturing line's ability to meet its first commitment date given for delivery of an item to a customer.

Vol. % to F.G.: Percent of volume shipped relative to finished goods. Many manufacturing lines produce product to a forecast of volume sales. If they don't put finished product into F.G. inventory, both customer service and sales suffer.

Overtime: Usually expressed as a percent of the total direct labor hours worked. Overtime should average less than one percent in an ideally running line. Overtime is useful to take care of temporary overloads. When overtime becomes regular and excessive, it costs more (paid at time and a half) and it leads to fatigue, which shows itself in more mistakes and higher absenteeism.

Days of inv.: Inventory control is often measured in days of inventory carried. Typical carrying costs of inventory in a company can equal 30% a year of the average inventory balance. Thus, in addition to liquidating 2.1 million dollars into cash, ongoing sales of 600,000 dollars were also realized.

Mtl. shorts: Material shortages in production cause delays and missed schedules. Both are costly. When material inventory is high, logic would imply that shortages would be low. Usually this is fallacious because it is the control over inventory and getting the right parts to the line on time that are the issue. When a team learns how to control, both numbers come down.

Quality: Dpu means defects per unit. Note the significant improvement.

Linearity: Measures the evenness of production. Ideally, a manufacturing line puts out 1/20th of its work each work day. Linearity measures line control, but its effect shows up in higher productivity and especially higher quality.

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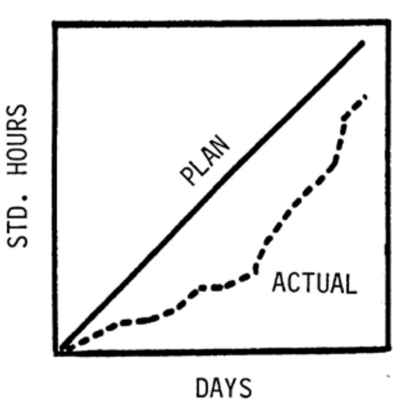
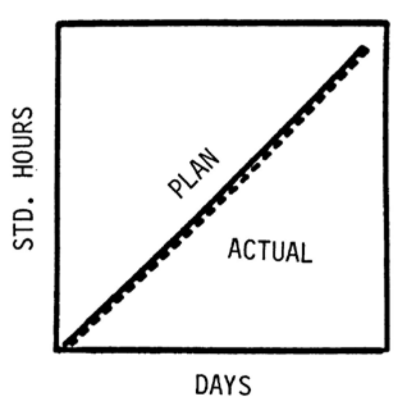
COMPARISON OF PERFORMANCE

	BEFORE PROGRAM	AFTER PROGRAM	BENEFITS
PERFORMANCE TO SCHEDULE	23%	98%	customer satisfaction
VOL. % TO F.G.	82%	101%	customer satisfaction more sales
OVERTIME	12%	3%	$17,000 / mo. saved
DAYS OF INV.	75 days	52 days	$2,100,000 reduction
MTL. SHORTS	4%	1,5%	productivity plus 21%
QUALITY	1.26 dpu	0.25 dpu	
LINEARITY	avg - 7.0 days	avg ± .1 day	





"CONFLICTS HAVE BEEN REDUCED ... CREDIBILITY AND TRUST HAVE BEEN IMPROVED SUBSTANTIALLY"

the plant manager

How I applied PCT to get results

By James Soldani

Effective Personnel Management: An application of Perceptual Control Theory (1989)
How I applied PCT to get results (2010)
These two articles complement each other.

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I had an opportunity to experiment using Perceptual Control Theory (PCT) as a senior manager at Intel for 14 months in 1980 and 1981. From time to time, people have asked me how I was able to get such superior results so quickly and for such an extended period of time. Looking back, I see that my various attempts to answer that question in writing and in conversations have been fragmentary, and have not captured the total process I was able to create during that marvelous year.

I was also a very serious student of Bill Powers' Perceptual Control Theory. The more I learned the more I was remolding my approach to parenting as well as management. It is a manager's lot to be under enormous pressure to deliver results every month, so I had little time to reflect on how I might structure organizational experiments with PCT or formally document the results. So my experiment at Intel was done on the fly amidst all the other daily pressures and distractions, yet done with very deliberate and focused intent based on PCT principles. I applied new methods and techniques with an almost obsessive focus for a period of about 14 months.

I never deliberately set out to create an organizational process, but as I led the team and moved from solving one set of problems to another, five elements of a process did emerge:

1. Intel's organizational culture facilitated the use of PCT-based methods
2. I worked with the various groups to set organizational reference conditions.
3. I worked with the various individuals involved to set individual reference conditions that supported the organizational ones.
4. I helped establish feedback mechanisms in groups and in individuals so they could control.
5. I provided personal PCT-based coaching to resolve conflicts in that control.

I will explain these elements in the following sections. This explanation assumes at least a basic familiarity with PCT, whose terms and concepts I am not going to try to explain here. The reader should also know that as I learned more about PCT I incorporated it into my own management style and experience. I have no way to separate the two in the way I speak about this experience. In other words there is no way to objectively measure how much of what was accomplished might have been done by me without PCT and how much only because of PCT. I can only attest that without PCT I would never have had the awareness, insight, or skills to deal with all these organizational dynamics as effectively as I did.

1. Intel's Culture: Risk taking, Responsibility, Results-oriented

From its inception, because of the insight and focus of Andy Grove, Intel has placed a high priority on creating an operating philosophy and culture that both demanded and enabled excellence. There were many facets to this which we need not go into here. Three elements of Intel's well documented culture were very important to my experience. These particular cultural elements were ingrained in the very fabric of the managers in the company because of Intel's extensive corporate training program.

The cultural element of **Risk Taking** provided me the freedom to take the risk of experimenting with new methods based on PCT. Had this not been so, it is highly unlikely that I would have tried to apply PCT, and much less chance to succeed with it in the time that I had. The cultural element of **Responsibility** further enabled me to succeed with new PCT-based techniques. Responsibility meant no excuses. A reason and an excuse were two presentations of the same information set. When employees used the information to analyze a problem and figure out a corrective solution to overcome a problem it was a reason. When that same information was used not to overcome a problem but rather to justify non-performance, it was deemed an excuse. In the Intel culture, excuses were never acceptable.

This was a very demanding value, and although both managers and employees understood it, only some were able to live up to it in practice day to day. PCT skills applied at both the group and individual level were critical to developing the confidence and internal strength (read super healthy operating control systems) in the people. Because this cultural principle was so well known in such a wide portion of the Intel population, I did not have to spend inordinate amounts of time trying to get people to adopt it. Rather I spent my time teaching them the skills to live up to it.

Lastly, the term **Results Oriented** meant that nothing cosmetic and superficial mattered. Only results mattered. Organizational goals or strategies were always defined in terms of results, and those results had to be achieved. Employees at all levels knew that half truths and partially achieved objectives would not be rewarded. This principle significantly reduced the politicking, game playing, superficiality, and spinsmanship in performance assessments at group, department, managerial, or individual employee levels. It also significantly reduced the blame game inside or between departments. If results were not achieved, everyone who might have contributed was in the same boat, no matter who was to blame. People at all levels were used to hearing the unvarnished truth about performance. Receiving evaluations, even criticism, while never comfortable, was expected and accepted. This enabled me to have easy access not only to my direct reports but to all the people involved. I was able to approach them with critical evaluations. But the way I provided those evaluations changed radically because of my understanding of PCT. Using the skills which I had developed, my influence over people became extraordinary.

My understanding of PCT has grown deeper during the years that have followed. As I reflect on this experience, I now realize that these cultural elements were systems concepts, a very high order of perceptual control in the PCT hierarchy. Because Intel spent so much time and money training managers and encouraging them to internalize these systems concepts as reference conditions in their own perceptual hierarchy, it made my introduction of new ways of interacting with others and teaching them new ways of interacting with each other much easier.

2. Setting group reference conditions for organizational goals

Achieving even the simplest goal often requires very complex interactions between different departments, and between groups of people within these departments. For example, senior executives might say, "Our company has a bad reputation with customers for not delivering orders on time. We need to improve this. We need an organizational goal for on-time performance." Thus they spell out the goal to their staffs of senior managers and expect that they will 'make it so'. At Intel, our manufacturing group's performance to schedule in any given month was terrible. Management wanted this improved to at least 90% on-time delivery to the customer.

When trying to implement new things, individuals and groups must be brought to focus. Focus means paying acute attention. In typical organizations, managers provide this focus by holding lots of meetings harping and criticizing and expecting their people to react because of the pressure. But paying attention to pressure isn't where the control lies. Control, in PCT terms, means establishing a strong reference condition and establishing at every level of the perceptual hierarchy all the control systems necessary to control for the satisfaction of that reference condition. It also means making that control system strong enough to withstand other conflicts or disturbances which might cause a person to abandon the control. Managers can't do this for their people. The people must do this for themselves. But the manager is crucial in motivating people to start this process. The manager is also critical to helping people acquire confidence and skill to control for the organizational goals. More on this when we get to elements 3 and 5.

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Doing this for a single person is difficult enough. Doing it for an organization of interdependent departments is a level of complexity greater.

Before I go further I need to digress briefly. I cannot explain how I implemented this step at Intel without talking about the specifics of both the manufacturing operation I managed and those I did not directly manage, but whose cooperation I needed for success. For those readers who are not already familiar with the language and elements of the manufacturing world, I want to describe this world in simplistic terms. I will oversimplify. My aim here is not to teach about manufacturing but to show how a single overall reference condition takes on so many different forms inside the perceptual hierarchies of the various people involved, and what it takes to establish uniform control of the overall process.

So we hear from on high that we must improve on-time delivery performance significantly. Here are some of the functional groups that must perform just so to ship a complex system on time. By complex system I mean one of the first semiconductor add-on memory systems for IBM mainframe computers. These systems stood 6 feet high and 5 feet wide, contained 4,000 parts or more, 75 to 100 highly sophisticated memory and logic electronic circuit board assemblies, dozens of large and small power supplies, thousands of feet of cabling and connectors, hundreds of mechanical parts, numerous dials and panels, and sold for $500k to $1 million depending on memory size and configuration.

a. The **Planning** department must make a schedule for all the independent activities it will take to assemble, test, and deliver the system on time. They must coordinate these schedules with all involved. These schedules must be realistic. They must have a reasonable chance of being achieved.
b. **Purchasing** must make sure that all 4,000 parts required to build the system are delivered on time
c. The **Stocking** department must receive all the parts, stock them until needed, and when the schedule demands, put them in required assembly kits so the elements of the system can be built on time.
d. The **Assembly** department puts all the elements of the complex system together.
e. The **Test** department must receive the system from the assembly department and put it through a full battery of tests to assure that it performs as it should and that there are no defects.
f. The **Quality** department oversees the whole process. They must inspect the system and its documentation at many points throughout the process, identify discrepancies, and assure that they are corrected before the system can ship. Failure at any inspection point may mean delay while a problem is corrected.

If you go to the manager of every one of these individual departments and ask them to accept the goal of 90% on-time delivery it is pretty easy to get them all to say yes. Why? Because, not one of them really controls that goal alone. They already know they have built-in excuses. Consider this. Of the six groups above, four are directly involved in the production process (b thru e). If each of those groups performs all their tasks at 95% on-time level the manufacturing performance overall can never be better than 95%x95%x95%x95% or 81%. This is quite far from the 90% organizational goal. Each individual group has to perform at about 97% for the whole group to achieve 90% on time. So 90% translates to 97% at the department level. No one articulated that goal. No one in the departments even believed they could achieve that degree of control in their hundreds of daily tasks. The departments didn't have the processes in place to perform at that level of perfection.

Now consider the Quality organization which stands outside the actual production process—inspecting but not building or testing anything. They would agree to the 90% on-time shipment goal, but only as lip service, not as a real reference condition to control for. Why? Because their job was to inspect and make sure every quality standard was satisfied before shipment. They knew from experience that production made numerous mistakes and they had to stop a lot of scheduled activity for corrective action, causing schedules to be missed. They weren't measured on missed schedules. They were measured on how many mistakes they caught. So they said yes because it was politically correct, but were in no way committed to control for this organizational goal of on-time shipments. Yet, they could have a big negative impact on meeting the goal, always able to blame someone else for the failure.

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So here are the problems and how PCT helped me implement solutions.

Start with the quality organization. In order to contribute to the 90% on-time shipment goal rather than just be able to detract from achieving it, they had to define things to control that on the surface seemed to have nothing at all to do with meeting schedules. When senior executives set the high level organizational goal, they probably weren't even aware of what it meant to the quality organization. And the manager of the quality department wouldn't be inclined to interpret this either. He was plenty busy dealing with his own day to day issues, and he wasn't even being measured or rewarded for on-time delivery. PCT helped me see this disconnect because now I was asking questions about what people were actually perceiving and what they were controlling for.

The Quality manager didn't perceive how he could contribute to on-time delivery without violating his charter. I went to the quality manager and had numerous discussions. I asked for his commitment to help meeting this goal. I helped him to perceive he could actually contribute to this goal and not sacrifice what he was chartered to accomplish. He could do this if he would consider moving inspectors right to the production line in process rather than at the end of the line. This change alone meant mistakes would be caught and corrected right in the process rather than at the end of the process where they would be cause for delay and retro-work on the system.

I helped him perceive that changing how his department did things not only helped the production managers meet the schedule performance goal, it helped improve quality. The production workers were getting more real time feedback about their mistakes and could correct them faster and better. By agreeing to control for on-time delivery, the Quality manager began to see how he was directly affecting the quality of the product, even though his people didn't actually touch it. Once he saw this, he was excited and motivated to look for other ways he could contribute. He was now engaged in the process of creating new control systems (at his organizational level) that would continue to contribute to the organizational goal of 90% on-time delivery.

Now let's return to the actual production organizations. They had to turn in levels of performance they never even thought possible. (Remember 97%). Well, the first step was helping them perceive that 90% meant 97%. That in itself was progress. They didn't know how they were going to do it, but at least they now knew what level of performance they had to control for. This was a beginning. I facilitated numerous individual meetings with department managers and also group meetings between them. I challenged them to think and create the solutions, which in PCT terms meant to establish the control systems in their groups that would enable them to reach the goal. There were so many changes needed, and there was no way I could define them all. But the groups, now engaged and empowered, began to define them. As they did so, more and better control was established, and they increased the amount of creative change they would take on.

3. Individuals set reference conditions for subgoals that will realize organizational goals

As a perceptive reader must realize by now, shipping a complex system on time requires control of hundreds of tasks and events across the organization. Getting the managers to define the specific goals for their departments and getting them to commit to focus and organize around achieving those goals is a major accomplishment. However, unless those goals become further interpreted and established as subgoals with attendant control systems in all the people under them, it is not enough.

Materials must get thousands of parts to the right place at the right time so the system can be built. Production must get the dozens of subsystems built and then integrated in the final system in time. Once the system reaches final integration and test it has over 4,000 parts and has been touched by dozens of people in the process. Test validates the final functional quality of the system before it is shipped to the customer. With so many parts and so much complexity there is a high probability that failures will occur. If failures occur they must be fixed, and then retested, all of which takes time, requires complex coordination and follow up, and is cause for missing the on-time shipping goal.

In other words—a lot of work requiring precise control, and this work is not done by the manager, but by the employees on the front line. Therefore, they too need to be just as committed to the goal as the manager and set up their own control systems around that goal. This may seem like common sense, and one would think it would be a natural consequence of the manager defining a new goal for the department. But it is neither easy nor obvious to people what they must do. This is because the worker's perceptual organization doesn't include anything related to this new goal. Take for example a test technician. He isn't tasked with meeting a schedule. He has a general sense that he is expected to accomplish his work in a timely fashion, but he has no specific control system set up to meet schedules reliably. What he does have are dozens of potential reasons for why meeting a schedule every day is in conflict with what he is tasked to do and what he is measured and reviewed against, namely doing a comprehensive test and assuring that there are no issues. Still, he is on the front line of discovering a

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problem which will cause a delay. What he controls for when he does discover a problem is vital. A manager cannot 'police' all the different technicians and all the tasks they are involved in all day long. We need the technician to do this himself if we are to succeed in meeting this higher level of performance.

We must involve the technician and persuade him to control for this goal. This can most effectively be done by his manager. But the technician isn't going to accept this goal just because the manager says so. We have already shown that the technician will readily perceive all the conflicts that a focus on schedule will produce for him related to his primary responsibility. The manager must be skilled if he is to help the technician resolve these conflicts so that he is willing to control for schedule as well as his primary tasks. Just as I was able to deal effectively with the Quality manager and help him perceive how he could do this successfully and not compromise his primary responsibility, so also the managers of various departments were influenced to deal with their people to accomplish the same thing. This is where the techniques for applying PCT that I developed in collaboration with my mentors Ed Ford and Bill Powers come into play.

Here is a brief outline of the basics:

1) **Find out how a person's perceptual system is currently organized** as it pertains to work. You do this by asking and listening. How do they perceive their job, the department, you as the boss, their co-workers, other departments, goals and standards of performance for the group and for themselves?

   Ask what they presently want, their goals. Ask them how they think others perceive them. These types of questions—if you listen carefully and with an understanding of PCT as the context,—will give a manager quite a bit of insight into how that person's perceptual system is organized and particularly what they might be controlling for at the time. Now let's apply this generalization to our specific case. Find out exactly how the technicians would perceive a goal to meet the schedule at a 97% level. If the manager facilitates an open and non-threatening meeting, encouraging them to engage in a thorough discussion, the manager will get an earful of all the reasons why it can't be done and in the process he will obtain a very specific map of how the technicians are organized internally related to this goal. At this step it is absolutely critical not to make any value judgments, good or bad, related to what you are hearing. Any value judgments offered at this stage will almost certainly restrict the insight you can gain. People shut down (as opposed to opening up) when you tell them what you think.
2) **Ask the person(s) to make a value judgment** about what his wants, goals, perceptions, behaviors are or would be related to the new goal. For example: Do you think it is good for our department to not be serious about delivering on time? What will be the consequences to our business if we continue to disappoint customers with late or unreliable delivery schedules? Do you care about that? Do you perceive that you could focus on more than one key driver at a time? If you cannot, do you think that is a good trait or one that should be improved? Do you think it could ever be possible for you to combine a high concern for schedule performance and a high concern for quality? Would you be open to finding a way to do both?
3) **Ask the person(s) for a commitment** to become an active participant in the process of making the changes necessary to achieve this new goal. They, not you as the manager, must make this commitment. This is an extremely crucial step. It must be articulated by them. If you think this commitment is shallow, that's OK. As long as they articulate that they are willing to try, you can work with them with a high probability of success. Make it clear that you will hold them to their word.
4) **Cooperate with the person to work out a plan** to implement necessary changes. A successful plan should be focused on the single goal, written, specific and measurable. It should be a 'do' plan, not a 'don't do' plan. It should be possible to put the first step of the plan into action right away. The plan should have two commitments. 1) What the person(s) will do. 2) What you as manager will do to support them and ensure that the plan works.

The plan should define the means and timing for routine review and evaluation. The plan should be open to revision as the need arises.

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4. Providing means for feedback

To effect control, evaluations must be frequent, timely, and relevant to the goal that is being controlled. This is clear to those who understand the structure of a control system. It is equally important and necessary at the organizational level. I used a daily startup meeting as the main vehicle for this. Many different organizations have used start up meetings to kick off a day's work. I did not innovate the idea of a daily startup meeting, but I did innovate the focus and dynamics of the meeting as well as the number of people involved—over 40 every morning at the beginning. This was a large number, representing about 25% of our total organization. Each morning, we reviewed results from yesterday and then defined only those tasks that were required to make today a success. Tasks often included set-up tasks that would make future days a success as well. I asked the group to define these tasks. I was careful not to define tasks for them. I needed evidence that these goals were adopted voluntarily by each person, not imposed by command from me. At first, this took a long time—often an hour and a half—and the meeting seemed sloppy and unfocused. The size of the meeting was criticized. Managers did not want so many of their people tied up for so long at the start of the day. I asked the managers of the various departments involved to attend so they could see for themselves what we were trying to accomplish. The managers were reluctant. They did not feel they had the time and they did not see the point. It was their people who would effect the control I was striving for, but I wanted the managers to know what I was doing, support it if they could, and at least not actively contradict what their people would be trying to accomplish.

We provided accurate and realistic evaluations. We devised charts and metrics and the responsible people presented them so the entire group could see how each part was doing. If someone failed to complete a task that was defined, I facilitated the interactions of the group to keep the evaluations constructive. Every failure had to be explained and the person responsible had to define what he would do to correct it for tomorrow.

The benefit of having all those people in the same room was that they all had common perceptions of the day's plan and clearly defined perceptions of the dependencies and commitments each player was making for the day. They began to see what establishing reliable control meant they had to do.

It would be impossible to describe all the detailed dynamics here. Suffice it to say that I managed and led the meeting, respecting the way the participants had organized their own perceptual systems around the goals, but nevertheless demanding accountability and results orientation. I applied the above defined PCT skills when appropriate to resolve any problems or conflicts that came up in the meeting. Occasionally, these issues were complex enough that they had to be dealt with in another venue. After several months the morning meeting was taking no more than 20 minutes and forty or so people had their activities for the day fully defined and integrated. Managers would pop in from time to time just to stay tuned, but they had developed full confidence that I was not undermining their department objectives. The performance improvement was remarkable. (See chart at end.)

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5. Individual coaching using PCT skills

In addition to the daily startup meeting, numerous individual meetings were required with managers and key people to help them understand and to teach them how to control. Frequent one-on-one meetings were a natural part of the Intel communications culture, so these meetings were easy to arrange. These were critical to the success we achieved. When people trust a manager, they will open up and provide insight into how they have organized their own perceptual control systems. With this insight, and using the above defined PCT applications skills I was able to coach people and influence them to resolve their own conflicts—especially when they were trying to control several objectives at once, both on and off the job. It is interesting to note that the way I dealt with people in this process taught them how they might deal with others whom they needed to influence in a similar manner to resolve conflicts and attain results. So while my intent was to help them resolve a problem, I found that I was equipping them to be more effective with their peers and subordinates everywhere they went in the organization. These skills are teachable, but they require practice to apply reliably.

In closing, I want to say a few words about human needs. In my many years of managerial experience and most assuredly in this experience described above, I have observed that most (if not all) people control to fulfill needs for love, belonging, recognition, a sense of self-control and many other highly individual and sometimes surprising, even contradictory considerations, both inside and outside the workplace.

When managers interface with people in ways that are more aligned with the way they are designed internally, with sensitivity and competence, then their effectiveness with people increases dramatically. Since managers get paid to accomplish organizational goals through the influence they have with others, it is clear to me that applying PCT significantly increases the skill set a manager can use to accomplish goals.

The results speak for themselves.

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Comparison of performance

Measure	**Before program**	**After program**	**Benefits**
Performance to schedule	23%	98%	Customer satisfaction
Overtime	12%	3%	$17,000 a month saved
Days of inventory	75	52	$2,100,000 reduction
Quality defects per unit shipped	1.25 dpu	.25 dpu	Cost savings & Customer satisfaction
Linearity	neg. 7.0 days off plan	± 1 day off plan	Productivity + 21%

A Consultant's Lament

There are times when I despair of getting management to be interested in, let alone understand, appreciate, and adopt a view of human behavior and performance based on Perceptual Control Theory (PCT) as developed and articulated by William T. Powers. Then it dawned on me that before I can get them to adopt something new they must relinquish the old. They're not interested in something new, even if it is much better, because they believe that what they have works. But it doesn't work. It's an illusion. What is it to which they cling? As succinctly as I can put it, it is "carrot-and-stick" management. I believe management believes they can control (or at least shape and direct) human behavior through the use of carrots (rewards) and sticks (punishments or the threats of it). That's a mistake. Why do they cling so fiercely to what is demonstrably non-functional and more than a little dysfunctional? A better question still is why do they want to control the behavior of others? That, too, is a mistake. I don't know that I can disabuse them of that notion. Still it's worth a try. So here is my lament in story form. Maybe it will have an effect.

Fred Nickols

About the Author

Fred Nickols is an independent writer and consultant, the managing partner of Distance Consulting LLC, a consulting firm he has headed since 2001. His career includes 20 years in the United States Navy and 40 years in the private sector. For many years he has been concerned with what the late Peter Drucker called "the shift to knowledge work," especially the different view of work and worker it calls for. Chief among those differences is a view of human beings as "living control systems," a view rooted in the late William T. Powers' Perceptual Control Theory (PCT). Fred's website www.nickols.us contains more than 200 articles, book chapters and papers. Many deal with human behavior and performance in the workplace, and with Perceptual Control Theory.

Scenario:

Imagine if you will a gathering of senior managers and executives, along with several management gurus, all there to discuss ways and means of motivating employees, managing their performance and, in general, getting the most out of them, "The best they have to offer" as one speaker put it. The last speaker, selected to represent employees in general, had been challenged by the organizers to sit in on the session, take notes and then tell the attendees what he heard and what he thought. His remarks begin below.

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You Still Don't Get It!

I've listened carefully to the presenters and the discussions. What seems clear to me is that if you strip all those ideas and recommendations of their psychological and management speak finery, they boil down to carrot-and-stick management practices. You are clearly focused on controlling employee behavior and you rely on carrots and sticks to do it. That's a big mistake and here's what I have to say on that score.

After all these years you still don't get it! Carrot and stick doesn't work. Truth is it never did. It was all an illusion. You wanted so badly to believe it worked that you deceived yourself into believing that it did. It didn't. What has been going on is what has been going on for thousands of years; namely, the folks in charge use carrots and sticks to try and get the rest of us to go along with their program, to do what they say and behave in ways they want. And so the rest of us have played along for thousands of years, making it look like were going along with the program when in fact we were gaming the system. We got what we wanted and we made it look like you were getting what you wanted. To be honest, sometimes you did. But we adopted protective coloration; we walked, talked, looked and acted like the compliant little pawns you seemed to want. Sad to say many of you still want compliant little pawns and so many of the rest of us continue to game the system, *your* system.

What you don't seem to get is that you and the rest of us are whole lot more alike than you want to admit. You have purposes; so do we. You are a "living control system;" so are we. We all have goals and we all pursue them. Our chief means of doing this is our behavior. We all behave in ways that are meant to bring what we see into alignment with what we want to see. When you start messing around with my behavior you are interfering with my means for obtaining what I want. You probably don't care about that but you should know this as well: When you interfere with my behavior you are also interfering with the chief means I have at my disposal for delivering what you want from me. You need to back off and let me do my job. I'm perfectly willing to bust my buns getting you what you want, providing you pay me a decent amount, support me in doing it, don't ask me to do something that I believe is illegal, immoral or unethical, and say "Thanks" when I deliver.

There was a time not so long ago when you were primarily interested in my overt, observable behavior. My working activities consisted of interactions between me, my tools and the materials on which I worked; I made things, I produced a product. You could see what I was doing and how I was doing it. You could even pay an industrial engineer to figure out the best way of doing it and then pay me to do what the engineer had figured out. What you wanted from me was compliance and I gave it to you. On occasion, you wanted me to do something stupid. At first I tried to explain why that was a dumb thing to do but you told me to shut up and do as I was told. I shrugged and did what you asked. I was right, you were wrong. Sorry about that but you wanted compliance and I gave it to you. In any case, because you could see what I was doing and if what I was doing was what you wanted me to do you came to believe that your carrots and sticks worked. You could see that for yourself – or so you thought.

Today, my working activities consist primarily of interactions between me and information, and between me and other people. My tools have changed; instead of hammers and saws and wrenches and lathes and drills, I now rely on language, mathematics, concepts, models and other information-processing tools (and, yes, that includes the computer). You can't see what's going on in my head and, often enough, you can't tell me what to do. It falls to me to figure out what to do and how to do it. Gone are the good old days of prefigured working activities; now, those activities have to be configured in response to the circumstances at hand and I have to do the configuring. Whether you realize it or not you are no longer paying me to comply with your wishes or dictates or commands; instead, you are (or should be) paying me to produce results of value. To do that I require no small amount of discretion regarding the what, how, when and why of my work. In a word, I require "autonomy." I also require support, cooperation, the right tools and help coping with various obstacles and barriers when they crop up. You require my understanding, commitment and skill set. I can't do it alone and you can't do it without me. We need each other.

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Yet, you cling to those cursed carrots and sticks and I find that very puzzling. Why? Because I know you know they don't work with you so why do you think they work with me? You and I are both human beings. You and I are both "living control systems." Why do you cling so tenaciously to those carrots and sticks? Is facing up to the fact that we are more alike than different too much for you? Is it perhaps that you can't relinquish the illusion of control? Or is it perhaps that you're just a mean S.O.B. who doesn't care about people? I certainly hope not but I have run into a few of those in my time. I will tell you this: We can accomplish a whole lot more working together than we can if we're at odds with one another. Think about that. Think about what we might be able to achieve if you had an army of committed, dedicated, competent, autonomous employees, all of whom were communicating, cooperating and collaborating in pursuit of goals and objectives that all of us valued. Nothing could stop us.

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If you think all of this is just an empty rant on the part of a disgruntled worker let me assure you that is not the case. I opened with "after all these years" which was my way of referring to the shift to knowledge work which knocked carrot and stick approaches into the dust bin of history. So let me tell you a little story, a "sea story" from my Navy days, one that took place way, way back in 1957, in the early days of the shift to knowledge work. It's a story about compliance and I've titled it "Aye-Aye, Sir."

AYE-AYE, SIR

The year was 1957. The ship was the *USS Gregory (DD-802)*, an old WW II Fletcher-class, 2100-ton destroyer. We were in Subic Bay in the Philippines, taking a break from our assignment of patrolling the Formosa Straits.

Tommy Lee Crabtree, a Gunner's Mate second class (GM2), was working on Mount 53, one of the ship's five, five-inch gun mounts, trying to repair an as yet unidentified malfunction. I was new on board – a Fire Control Technician (FT) with the rank of seaman (FTSN) – and I was working on Tommy Lee, trying to persuade him to invite me to join the armory coffee mess. The armory coffee mess was, in my mind, the most prestigious coffee mess on board the *Gregory* and I badly wanted an invitation to join. The invitation had to come from Tommy Lee; he was the Gunner's Mate in charge of the armory. Short-term, my hopes weren't high but I was prepared to hang in there for the long haul.

Tommy Lee and I were taking a break, hunkered down on our haunches next to the gun mount, sipping coffee and chatting in a way calculated to help him take my measure, when we spotted our division officer approaching.

Our division officer was a Lieutenant Junior Grade (LTJG) whose last name was Wilson. A bit of a martinet, he had been nicknamed "Whip," an appellation borrowed from a star of western movies of the 1940s.

"What are you two doing?" he demanded.
"Drinkin' coffee and shootin' the breeze," replied Tommy Lee.
"What are *you* doing here?" Whip asked of me.

As a Fire Control Technician, my work required close coordination with the Gunners Mates so I had a convenient and true cover story. Standing up, I said,

"I came down to find out when Tommy Lee thinks we'll be able to include the gun mount in the daily workouts and if he thinks we'll have to realign it with the rest of the gun battery."
"Well," demanded Mr. Wilson, turning to Tommy Lee who was still squatting, "when will it be fixed?"
"I dunno. I'm workin' on it. Probably sometime today."
"That's not good enough! Get off your ass and get back to work! I want that gun mount back in working order A.S.A.P.!"

Tommy Lee looked up at Mr. Wilson, studying him much the way he might contemplate a cockroach he was thinking about stepping on. Then, rising slowly to his feet, Tommy Lee grinned wickedly and asked,

"Are you *ordering* me to fix this here gun mount, Mr. Wilson?"
"You're damn right, I am," snapped Mr. Wilson.

Shifting his coffee cup to his left hand, Tommy Lee saluted smartly, and said,

"Aye-aye, Sir. What would you like me to do first?"

The reactions played across Mr. Wilson's face like moving scenery: first puzzlement, then comprehension, followed in quick order by surprise, shock, humiliation and, finally, red-faced, apoplectic anger.

"Whip" Wilson had been hoisted with his own authoritarian petard by a master of the game. Tommy Lee had done what all those who must submit to authority have been doing for thousands of years, he submitted. He went passive. He asked Mr. Wilson to tell him what to do and he would do it. The problem for Mr. Wilson was that he couldn't issue the necessary orders. Tommy Lee knew that all along. "Whip" Wilson was just now finding that out.

Furious, Mr. Wilson glared at Tommy Lee, then turned and stomped off without a word.

Tommy Lee watched him go, and then turned to me, doubtless feeling expansive as a result of besting Wilson, and said,

"Nick, you can hang your cup in the mess when you're finished."

Witness to Tommy Lee's triumph, the potential value of my testimony at future gatherings outside the armory had earned me the invitation I sought. I was in.

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So, ladies and gentlemen, let me ask you,

"Do you get it now?"

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About The Method of Levels

Tim Carey posted the following to an email group in January, 2006 in response to suggestions that MOL be used with couples and in groups.
For more, see the Postscript in Tim's book *The Method of Levels*

MOL is not what gets people better. Reorganization is what gets people better. Reorganization is a private event that occurs within the neural hierarchies of each individual. To the extent that therapy facilitates the process of reorganization, then, therapy can only ever be individual. So, MOL is not the way people get better, reorganization is the way people get better.

MOL does not make reorganization happen. Reorganization is a natural process that occurs within individual neural hierarchies from probably before a baby is born. There is still much to learn about reorganization but it certainly doesn't belong to the province of psychotherapy. Reorganization can occur on a plane or in a train (this sounds a bit like Dr Seuss ...), it can happen in a crib or in a classroom. Reorganization also happens with cats and rats and elephants and the three towed sloth.

Awareness seems to be linked in some way to reorganization. Many therapeutic approaches and even Eastern psychologies have acknowledged the importance of awareness in achieving certain states of mind. All of these approaches seem to have tapped into something useful but, because their theories are useless, there's been a haphazard and serendipitous approach with regard to what to do about awareness.

MOL doesn't make awareness move. The fluidity of awareness is a natural phenomenon that is not well understood but undoubtedly exists. Awareness floats around while you're driving a car, while you're on the beach, when you spot a clever bumper sticker, and while you're engaged in conversation. In fact, it's probably harder to make awareness stay still for a minute or two than it is to get it moving. Awareness moves up and down and side to side and back and forth and round and round.

Awareness, like reorganization, is a private event that occurs within individual neural hierarchies. As an outsider we can never be sure of what's happening with the awareness of another person but we have hypothesized that, when a person disrupts their own stream of dialogue, with a pause, or a grin, or a shake of the head, that disruption might indicate that the awareness we can't know about might have just moved around. Some of this moving we've supposed has been a move to a higher level system that is, in fact, setting the references for the lower level system/s of which the person was previously aware.

MOL does not make disruptions to dialogue occur. Disruptions to dialogue occur in the course of normal everyday living. They occur at dinner parties, down at the pub, and after a game of croquet. If you ever watch politicians or athletes being interviewed on television you can often notice disruptions to their dialogue. Sometimes, even in an email, you can spot a sentence that seems to be a comment about the words that came before. Is any of this making sense? Those sentences might signal that the typist had a shift of awareness.

So, MOL is not what gets people better, it does not make reorganization happen, it does not create the fluidity of awareness. So what is MOL? ***MOL is a way of helping people get themselves better.***

MOL is not the only way of helping people get themselves better. People have been getting themselves better through various courses of psychotherapy before MOL ever came on the scene. People don't just get better in psychotherapy. Sometimes, people discover what they need to get better, by searching on the internet, or going for a jog, or doing a course, or chatting with a friend.

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MOL is the minimalists way of helping people get better. What you, Bill, proposed, and what I have developed is a structured and systematic approach that, based on the principles of PCT, does the least amount possible to helping people get themselves better. It is a method that attempts to do the only thing necessary and nothing that is unnecessary in helping people get themselves better.

The least amount possible is not nothing at all. Something different from what is currently happening needs to occur if the person's situation is to change. It is also not sitting in front of a person and passively listening to them discussing their experiences. These things are actually doing something, not doing nothing. They are providing a time for the person to remain in the place where their awareness currently is. Curiously though, even in these situations, some people manage to get themselves better.

So the least amount possible turns out to be, talking with someone about that which they want to discuss, and then, when a disruption to their stream of dialogue occurs, asking them about that to investigate if their awareness just shifted to a higher level. Then do it all again from where their awareness is now at.

MOL has been developed as a method to use with individuals who voluntarily access psychotherapeutic services. Obviously, there are more problems to address than those involving the individual psychological distress of internal conflict. Clearly, people getting themselves better is not the only problem we have to tackle. How should learning best be facilitated in classrooms? How should workers best be managed? How can group cohesion best be promoted by a group member who is an equal player? How can group satisfaction be enhanced by someone who is facilitating the group? How can people who don't think they need help be helped? How can we more appropriately assess someone's physical and psychological functioning? How can we address physical diseases more accurately?

All of these are important issues and areas that require serious thought from a PCT perspective. Some of that serious thought, in some of these areas, is well underway and that is something I completely endorse. MOL, however, is not the way to address these problems. MOL is not a panacea for all the different kinds of problems that can occur as the living of autonomous, biological control systems unfolds. These problems all need solutions but attempting to use MOL in these situations is not the solution that's needed. Using MOL in these contexts is an inappropriate use of the method that will only serve to impede the progress of the development of both MOL and the other approaches that are sorely needed.

The term *MOL* is not synonymous with *talking to someone.* The approach was developed for a specific purpose and someone using the approach should adopt particular purposes while they are engaging in MOL. A person is not using MOL whenever they ask someone else about their goals. Nor are they using MOL whenever they notice a disruption in someone's dialogue and wonder if the person has just gone up a level. These things are components of MOL to be sure but they are no more MOL than carrying a tennis ball around in your bag means you're having a game of tennis.

MOL needs further focussed attention and development. Continued expansion and sophistication of the research being conducted is a priority.

Other approaches also warrant serious and, in some cases, urgent consideration. This is unlikely to happen, however, when methods become blurred and the techniques of one are used to achieve the purposes of another. Maybe some techniques, wrapped up in a different package, will be able to achieve different purposes and maybe they won't. We'll never know the answer to this if we undertake to apply MOL in areas in which it is not designed to be used. Based on the precision and sophistication of PCT, managers need ways to manage, parents need ways to parent, group facilitators need ways to group facilitate, teachers need ways to teach, folk need ways to get along. What we don't need is people trying to make MOL do things it was not designed to do. What we need are more applications for specific contexts not the expanded application of a specific approach.

It will be a great day when we have the same (or even similar) number of applications and programs and packages based on PCT principles that we currently have based on stimulus-response/cause-effect principles.

Warm regards, *Tim*

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From Reorganization to Evolution and Back

By William T. Powers

The development of Perceptual Control Theory began in the early 1950s when many workers were investigating similar behavioral models based on control theory. The thread that is now called PCT drew on control engineering, cybernetics, and engineering psychology, as well as applications of control theory in physiology. As PCT was taking shape, questions of learning and development arose and were addressed in the form of "reorganization theory" patterned after W. Ross Ashby's concept of superstability (Ref). As models were developed, this learning theory lagged behind the performance aspects of PCT which were aimed primarily at the analysis of ongoing well-organized kinds of behavior.

The most important underlying principle of reorganization theory, described in the initial article published in 1960 (ref), was that deviations of important variables in a organism from specific states called "reference levels" activated a system that produced random variations in the parameters of control. This was simply the old idea of "trial and error" reified, brought up to date, and described in terms suitable for modeling. The concept is irrefutable. Given that deviations of critical variables from their reference levels set the changes going and maintain them, it follows that if the changes correct the deviations, reorganization will stop and whatever organization is then in effect will persist. That organization of behavior will be superceded only if some change in internal or external factors causes deviations to occur again and random changes start again. This establishes a mode of learning quite distinct from the idea of reinforcement, which proposes that favorable events cause behavior to persist. Reorganization theory says that unfavorable events cause behavior to change.

The only hitch is hidden behind that word "if." This process is guaranteed to work only IF a series of random changes of organization will result in correcting the deviations of critical variables from their required states before the organism dies. Initially, it was very difficult to imagine how such a random process could be anywhere near efficient enough to work. Because of that difficulty, references to "reorganization" during the next 20 years simply had to assume that somehow it would work, and efforts to model this process and thus demonstrate its features and flaws never got started. Clearly, if the trial-and-error concept could somehow be made to work, we would have a very powerful theory of change applicable to many aspects of living systems, so the decision was to remain optimistic. The result was very much like what has happened to the theory of natural selection in evolutionary theory. Natural selection was a sort of general explanation which would rescue any part of the theory that was having difficulties, rather like previous theories in which all difficulties were resolved by reference to God's Will. Reorganization theory offered a strong temptation to use it the same way.

At about the same time that reorganization theory was formulated, others trying to model evolution invented what is called the "genetic algorithm". In this theory the random changes of organization were brought about by the equivalent of random sexual recombination of genomes. Aside from the mechanism of random change, it was the same idea behind reorganization theory. Unfortunately, it does not solve the basic problem of inefficiency, either. To make models using this algorithm work, it was necessary for programmers to permit simulated organisms to survive and reproduce if they only changed *toward* the new organizations necessary to counteract selection pressures. They didn't actually have to succeed. This meant that the programmer included abilities in the model that the real organism was not thought to have: knowledge of a goal-state and the ability to detect how far from that state the organism was. Somehow the organism was allowed to survive if the distance to the goal-state decreased; how it could know that and what set the goal were unexplained.

It was not until 1980 that the breakthrough occurred which made the basic concept of reorganization theory described in 1960 into a practical idea. The breakthrough came in the form of a book on bacterial chemotaxis (Koshland, 1980). In this book an interesting principle is exemplified by the method of gradient-climbing used by E. coli.

Note: This essay was inspired by posts on CSGnet August 17-22, 2009, Subject: Memory and August 24, Subject: Reorganization and Evolution.

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E. coli reorganization

The bacterium E. coli progresses up (down) gradients of attractants (repellents) by generating a series of random variations in its direction of swimming. These random variations, referred to as "tumbles", produce new directions of swimming that are demonstrably unrelated to the gradients, yet the result is reliable travel in the right direction. The mechanism behind tumbling seems to be nothing more than briefly reversing the direction of spin of some but not all of E. coli's flagellae.

E. coli's gradient-climbing ability is not a result of some subtle bias in the random tumbles. Instead, the mechanism depends on sensing the concentration of an attractant or repellent in the medium through which E. coli is swimming and changing the timing of tumbles according to whether the sensed concentration is increasing or decreasing. All the biochemistry involved in this odd control process is known. If the concentration of an attractant is decreasing, the next tumble occurs right away; if the concentration is increasing, the next tumble is postponed. For repellents, the relationships are reversed. The result is that the bacterium spends much more time swimming up the gradient of attractant than down it. In simulations of this process, the mean velocity of travel up the gradient is lower than it would be if the bacterium could simply turn and swim the right way, but not by a great amount.

Abstracting the principles involved in E. coli locomotion leads to an algorithm for optimizing processes which have effects that can be measured in terms of gradients. The "swimming" of E. coli turns into a continuing steady change in the parameters of the process, and the "tumbles" turn into reorganizations that randomly alter the rates of change of the parameters. If there are N parameters, the direction of swimming is the vector sum of N velocities along the axes of N-dimensional hyperspace. This can be visualized as repeatedly adding a small speed vector to the parameter vector, so a point representing the current parameter values moves through this space in the same way E. coli swims through the medium in which it lives. The parameters change continually at different rates. After a tumble, which is like a mutation, the parameters go on changing continually, but now at different rates relative to each other. That changes the direction of motion through the parameter hyperspace. The operant phrase is "different rates relative to each other"—the hyperspace part is just a useful metaphor.

So far we have a process that continually changes the parameters of a system, and which can be switched from one direction of change (in hyperspace) to another by randomly altering the rate of change of each parameter. The remaining part of the model determines the conditions under which a random reorganization will happen. In Perceptual Control Theory, a fictitious "reorganizing system" is proposed which alters the learned systems in the brain so as to control, indirectly, certain critical variables on which life depends.

The phenomena produced by the theoretical reorganizing system bear strong resemblances to at least one geneticist's description of genetic drift, allowing for some differences of interpretation:

http://lifesci.rutgers.edu/~heylab/sconcept/sexdrift-select.html#drift

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Jody Hey, Evolutionary Genetics
Professor, Department of Genetics
— Rutgers University

> From a genetic perspective, natural selection can be defined as variation in reproductive success caused by genotypic variation (Lewontin, 1970), and it is often cast as a directed force of evolutionary change in contrast to the random force of genetic drift. However at the level of DNA where there is linkage, natural selection on functional DNA sequence variation contributes to the genetic drift that occurs among linked sequences. **In a genetic species of asexual organisms, a mutation that changes a DNA sequence and causes natural selection, also causes a new pattern of genetic drift among organisms that carry that mutation.** In effect, a new genetic species is created by the mutation; although one of the species will probably be replaced by the other. For the DNAs of organisms with recombination, the acceleration of genetic drift by natural selection depends on the degree of linkage, the number of sites of functional variation, and the strength of natural selection on the functional variation (Hill and Robertson, 1966; Felsenstein, 1974).

There are some difficulties with this view, in that "degree of reproductive success" implies a gradient of successes, whereas reproduction either happens or does not happen. There can be degrees of success in a population, but characteristics are passed through individuals. Individuals either reproduce or do not;

whether they succeed or fail, they have no (or little) effect on another individual's characteristics or degree of success. Nevertheless, this view can be modified to use a much more efficient method of selection. Clearly, the analog of E. coli's "swimming" has been observed in the genetic drift of organisms, and the phenomenon of reorganization as current visualized has been seen: *"... a mutation that changes a DNA sequence and causes natural selection, also causes a new pattern of genetic drift among organisms that carry that mutation."* The "mutation" is, of course, a tumble, and the "new pattern of genetic drift" is a new direction of change in hyperspace.

We now have a vastly more efficient form of random change which makes the creation of successful new organizations much more likely than it was under the old idea of random jumps from one organization to any other within the possible range. The increase of efficiency over random jumps in only two dimensions is 50 to 70 times in one model, and increases rapidly as the number of variables increases. This will greatly help the genetic algorithm model (in cases where this algorithm is not already used without being named), and has made the PCT concept of reorganization practical.

Purely local reorganization

In more recent years, in connection with psychotherapy, a principle was proposed in an attempt to solve the problem of reorganizing what didn't need to be reorganized. "Reorganization follows awareness" said that while deviations of critical variables from genetically-specified reference conditions caused reorganization to start, awareness could then direct the process to various places in the hierarchy. If awareness tended to seek out problem areas, we then had at least one way to keep reorganization focused where it was needed. But this introduced another bit of magic: awareness and its mobility. While those phenomena clearly exist, they are wild cards in any explanatory theory since we can't explain *them*. We do not want any more wild cards in our explanatory theories that we absolutely have to have. Even when we have no alternative, they never stop nagging at the theoretician's conscience.

In the 2000s, a serious attempt was made to model rather complex reorganizations as part of a book on the computer models associated with PCT (Powers 2008) [*Living Control Systems III: The Fact of Control*]. Although there are still unsolved problems, the attempt to model the reorganization of output processes, given arbitrary sets of controlled variables, was quite successful as far as it went. The E. coli algorithm clearly works well. Richard Kennaway was the first to see and point out (in an appendix to the referenced book) in mathematically respectable terms that this model enabled a control system to optimize itself with no knowledge about the properties of its environment. There are probably some properties of the environment that have to exist to make this sort of reorganization work, and we do not yet know what they might be, but in these models those requirements are clearly met.

This leads us to the most recent reorganization of the theory of reorganization.

Keeping in mind that bathwater may contain babies, we can now try to summarize all the considerations that have gone into developing the theory of reorganization, in the form of an updated model. We got rid of the embarrassing inefficiency of the random-jump mutation model by adopting the E. coli model. Now we can get rid of the problem of action at a distance, meaning the problem that discrepancies in one control system can drive reorganizing effects that work on other control systems even at different levels of organization. In one successful model in the cited 2008 book, a collection of 14 control systems reorganizes so as to modify all the output effects that could cause conflict between the control systems that are learning independent control of the joint-angles of an arm. The model begins with all 14 control systems affecting all 14 joint angles. The weightings in the output effects of the model are then altered by E. coli reorganization, until at the end most of the cross-connections have disappeared, and each system can control its own joint angle without causing any interference with the other control systems. This is reminiscent of the "pruning" process that reduces the large oversupply of neural connections in the neonate to a much smaller number by the time motor control has been established.

These control systems are all at the same level of organization. The simulation allows for either "global" or "local" control. In the "local" mode each control system reorganizes the fourteen weights in its own output function on the basis of whether its own control error is increasing or decreasing (averaged over a time long in comparison with the behavioral response times). That is sufficient for independent optimized control to appear in all the control systems.

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But "global" reinforcement also works: the directions of change of all 196 weights are "tumbled" when a reorganization occurs: 14 output weights in each of 14 control systems. The signal for reorganization is based on the sum of all 14 error signals, in quadrature (square root of sum of squares). Local reorganization works just a little faster.

Now we can recognize a set of control systems proposed by Bernard and Cannon as the "homeostatic" systems. The outputs of these systems are biochemical; the reference signals are either genetically determined or in many cases are varied by neural signals reaching the pituitary from the hypothalamus. In the first crude model of reorganization, discrepancies between the controlled variable and the reference setting produced the usual actions that maintain homeostasis. If the errors became large or persisted too long, reorganization would commence—everywhere in the hierarchy of control. Let us now change that and say that reorganization will occur only in the system where the large protracted discrepancy appears, or possibly in the same level of organization where the errors appear.

If reorganization succeeds in a homeostatic system, the controlled physiological variable will once again be under control, remaining constant if the reference signal remains constant or changing as the reference signal changes. The higher systems that depend on the operation of the homeostatic system will experience no disturbances and their behavior will continue unchanged.

If, however, the homeostatic system cannot adapt far enough to regain control, the variable it is controlling will start to depart from the reference level it is receiving, or that is part of its innate design. That will constitute a disturbance of control systems higher in the hierarchy. For example, if blood glucose concentration is not maintained at the proper level by metabolizing fat or releasing glucose from storage, and if no reorganization of the system restores control of glucose concentration (perhaps because the organism has not been eating anything for a while), an error will be sensed by higher systems that is recognized as a sensation of hunger. Normally that would result in learned behaviors that find and ingest food. So that level of control could work well enough to limit the glucose concentration error at the lower level and also eliminate the hunger signal at the higher level.

If insufficient food is found, the food-seeking systems will begin to reorganize. They will continue to reorganize until the organism starves to death, or a new organization for getting food succeeds and restores the food intake to the level needed to maintain glucose concentration at the homeostatic level, and allow eating enough to eliminate hunger.

We can begin to see that local reorganization can eliminate control problems starting with the lowest levels, even biochemical levels, and extending as required to the higher levels of control. There is no need to direct reorganization to happen where it is needed: it always happens where it is needed. The connection between homeostatic control systems at a low level to reorganization of behavioral systems at higher levels is still there. It is just not direct now; it takes place in stages, level by level.

In fact, we may be near an answer to questions about where new levels of control come from. Reorganization can work from a number of starting points, including a starting configuration in which all the output weightings are zero, and all the input weightings are zero, too. All that is required is for a supply of uncommitted neurons of the right type to exist (a product of evolution), and for the raw capacity to reorganize to be present. The highest existing level of control will reorganize and behave so as to control its own variables as external disturbances change, and grow. When that control reaches its limit, the reorganizing capacity of the pools of uncommitted neurons will come into play and start adjusting the parameters of control, forming new control systems that control perceptions of the world in new ways. Of course the right types of neurons for supporting perception of the new type of variables must exist, and the right types of neurons for constructing the output functions that will be needed. What is possible to acquire by way of higher levels of control is set by the whole past history of evolutionary changes.

We have lost, temporarily, the role that awareness played in directing the locus of reorganization. We know that directing awareness does affect the places where reorganization is to happen. But what we have to determine now is just what that directing accomplishes. Then the model of reorganization will add its next small increment of credibility.

Bill Powers
24 August 2009

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Reorganization—an evolving concept in PCT

Notes by Dag Forssell May 2013

On page 3, Bill wrote:

> "This leads us to the most recent reorganization of the theory of reorganization."

PCT is not a finished product. It points in a new direction and lays a foundation for a future science of psychology based on solid scientific principles.

As Bill points out, the concept of reorganization has been part of PCT from the outset, as presented in his 1960 paper by Powers, Clark and McFarland: *A general feedback theory of human behavior*, but there are differences between noting the necessary existence of reorganization as such, attempts to illustrate a conceptual understanding of it, attempts to show that a process of reorganization can work to stabilize a large number of interconnected control systems and ultimately, finding out how it actually works at various levels of biological and mental functioning.

Clearly, Bill's concept of reorganization has been and continues to be a work in progress. It may be of interest to students of PCT to examine the original illustration in Bill's major work of 1973 (below), the update when it was republished in 2005 (page 6), and the updates to this same illustration Bill requested in emails to CSGnet in 2009 (page 7).

Bill's thoughts developed yet again following my belated (March 2013) implementation of his 2009 request. Such a progression of thinking, speculation, testing and understanding seems to me normal and natural when one works to develop illustrations in order to communicate a concept with others. The idea of reorganization driven by local error that Bill expresses in his essay may require a very different illustration. This may best be left for future PCTers to sort out.

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The concept of reorganization as illustrated in *Behavior: The Control of Perception* (1973)

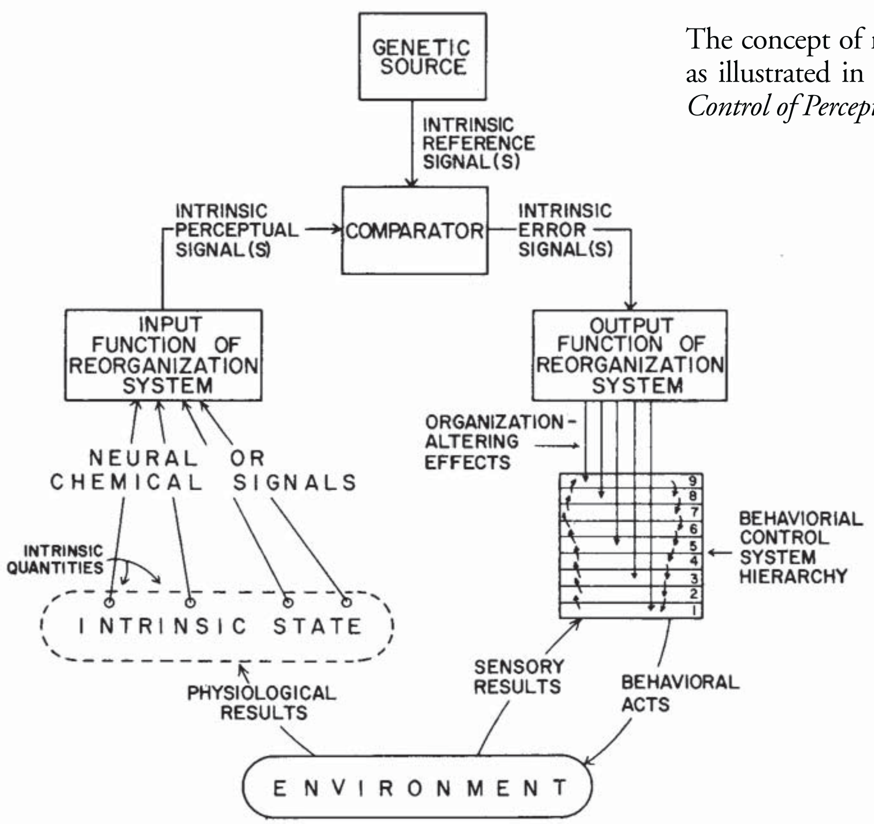

FIGURE 14.1. *Relationship of the reorganizing system to the behavioral hierarchy and physical environment. The control loop for the reorganizing system is closed via physiological results of behavior, not through sensory effects.*

The concept of reorganization as illustrated in *Behavior: The Control of Perception* (2005) p. 191 Redrawn by Dag Forssell per Powers' instructions.

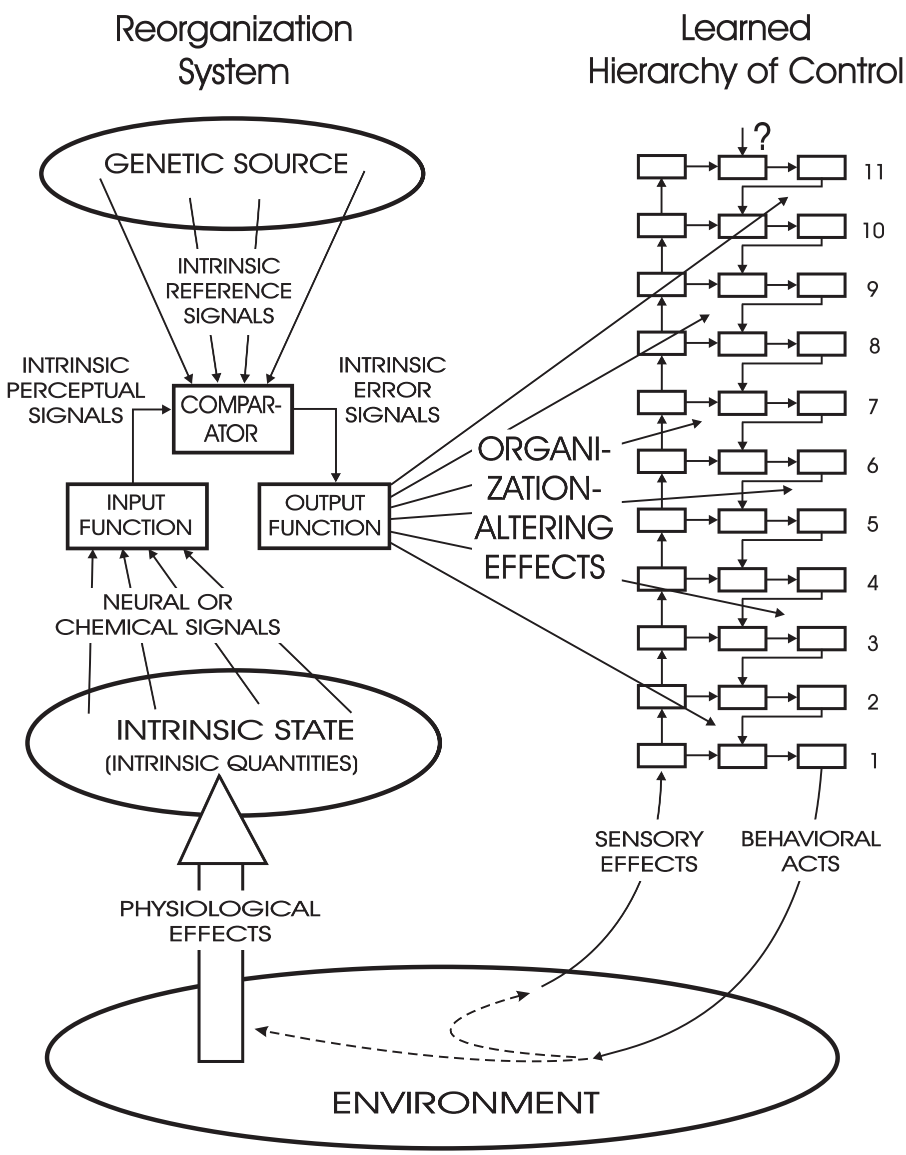

Figure 14.1. Relationship of the reorganizing system to the behavioral hierarchy and physical environment. The control loop for the reorganizing system is closed via physiological results of behavior, not through sensory effects. —Powers, 2003

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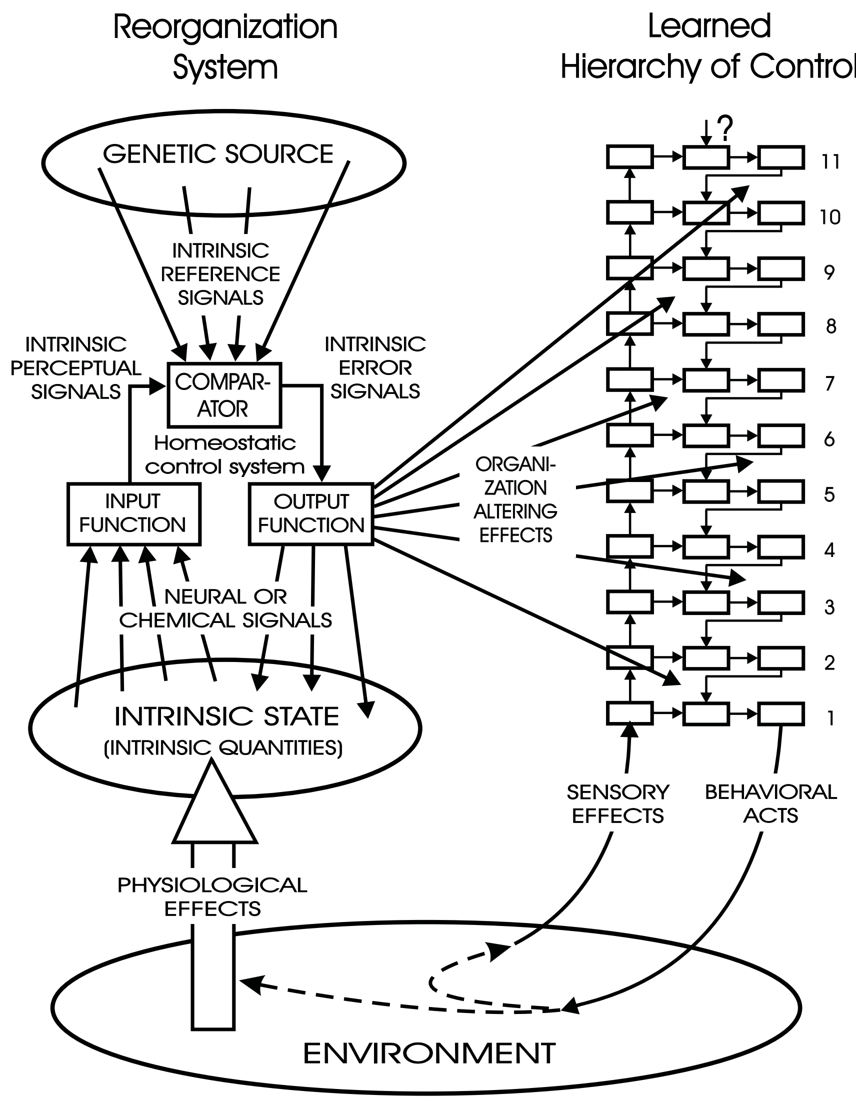

As requested by Bill in a post to CSGnet on August 20, 2009, this is an update of Figure 14.1 in *Behavior: The Control of Perception* (2005) page 191.

Added:

1) Down arrows from Output function to Intrinsic state.

2) Labeling the Homeostatic control system.

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In a private email March 27, 2013, Bill made this comment about the diagram shown above:

The new diagram suggests something to me, coming from the two different effects of the homeostatic output functions. This suggests perhaps that there should be two different output functions associated with a homeostatic system, one having to do with performance and the other with learning.

However, one factor makes me hesitate. As modeled, reorganization is driven by error, but the reference condition is irrelevant. It doesn't matter to the reorganizing system as currently conceived what condition the homeostatic system is trying to bring about. All that matters is that there is error, and reorganization will continue until the error is gone. As far as I can see, that's all that's required. If the specific reference condition doesn't figure into reorganization, then the perceptual signal and reference signal don't figure in, either. Only the error signal is monitored by the reorganizing system.

If that's the case, then we can ask whether the reorganizer thing is just a separate system that has the goal of reducing error signals, without regard to what they mean. It doesn't have to be an inherent part of a homeostatic system.

How would it know that a signal is an error signal? I don't know. But error signals as we model the system now do have a special relation to control systems: they are the outputs of comparators, and comparators are simple subtractors. much the same in any control system. Is that enough to make them recognizeable? Again, I don't know. But let's leave that question open until some sort of data comes our way to help us decide.

The Neglected Phenomenon of Negative Feedback Control

William T. Powers

INTRODUCTION

In a commentary in *Nature*, Rodney Brooks[1] proposed that something is missing from our models of living and behaving systems. I would like to suggest that it is not something undiscovered that is missing, but something old that has been passed over without sufficient examination. What is missing from most "modern" conceptions of behavioral mechanisms may be a sufficient understanding of a remarkable phenomenon called negative feedback control, reduced to a formal theory over half a century ago.

Systems organized to carry out negative feedback control behave in a way that a great many scientists do not believe is possible. Given a specification for some state of affairs, they can continue to produce or reproduce the specified outcome even though the actions needed to do so vary from one moment to another. The actions of such systems are of the type that has been termed *purposive*, in that they appear designed to achieve some specific predetermined end. They are also of the type that has been termed *adaptive*, for such systems are able (within limits) to vary their actions in just the way needed to continue to produce a particular outcome despite changes in circumstances.

In contrast, what most life scientists seem to believe in can be termed a *causal* system. A causal system mediates, stands between, causes and effects. The effects created by a causal system are those dictated by its physical structure and external forces or other influences acting on that physical structure. If circumstances change, the effects necessarily change, either because the behavior-causing external forces and influences change or because the structure of the system is changed by other forces and influences. What we see a causal system doing corresponds to what is being done to it; its "actions" are more properly called "responses," for no action of a causal system takes place without an adequate prior external cause or stimulus.

Before the 20th century was half done, engineers had discovered (and rediscovered) the phenomenon of negative feedback control and had founded a new formal discipline, control engineering. But this new concept clashed with what most scientists concerned with living systems already believed. From the very start there was a concerted attempt to assimilate the new concepts of control into the old ideas of causation.

The result has often been a strange blending of purpose and causation – for example, the frequently-used idea of an organism learning how to respond the most effectively to stimuli or "cues" from the environment. The idea of responding to cues or stimuli belongs in the causal model, but to "respond the most effectively" requires the organism to perceive the effects of its own actions and modify the actions so as to achieve some desired degree of effectiveness —a concept that is more appropriate to a negative feedback control system.

Another effect of this blending has been to conceal the problem of purpose by hiding it behind a screen of causal complexity. Brooks (op cit), for example, describes a "behavior-based" approach. "... this new mode of thought," he says, "involves the connection of perception to action with little in the way of intervening representational systems. ... this approach relies on the correct short, fast connections being present between sensory and motor modules." But "correct" implies "correct for achieving a specified outcome," which is a concept that derives from the properties of negative feedback, not simple input-output causation.

Probably the most elaborate blend has come to be called (somewhat hubristically) "modern control theory." As an approach to engineering control problems it has its merits, but as a model of organisms it only reinforces the old causal model. The basic idea is that the behaving organism picks (somehow)

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an outcome of behavior that is desired, and then, computing backward through the environment and the acutators with which a control system affects its environment, deduces the quantitative commands that must be issued to create that particular outcome. Once the inverse calculations have been done and the correct commands have been formulated, the system behaves causally, since the commands are converted into actions just as in any cause-effect device. The problem of purpose is put aside by assuming that there is some desirable outcome of behavior, without spelling out what desires or intends it or, for that matter what a desire or an intention is.

These attempts to assimilate control systems into a causal model of organisms have effectively usurped the role of a pure control-system approach, delaying the introduction of negative feedback control concepts into the mainstream of science. At present, the delay amounts to fifty or sixty years, depending on whether one starts counting just before or just after World War Two. There is a backlog of unassimilated evidence from all branches of the life sciences, all the way down to cell biology, that negative feedback control is a basic principle of life processes. Let us review briefly some known systems among the many that have been and eventually will be discovered.

BIOCHEMISTRY-LEVEL CONTROL

The requirements for making a biochemical negative feedback control system are not complicated. Consider Figure 1, from *The dynamic analysis of enzyme systems* by Hayashi and Sakamoto[2]. The diagram shows a biochemical system in which an enzyme catalyzes the rate of one stage of the main reaction from substrate A through X1 to X4, and in which effects of the last product in the chain are connected back to the enzyme, so that the final stage of the reaction affects a prior stage.

The labels X1 through X4 stand for concentrations of biochemicals, with the arrows indicating reactions that break down one substance to produce another, as in metabolism (not all reaction products are shown; reverse reactions also occur). The Y1 through Y3 labels represent signaling molecules that serve primarily to carry information, being present only in minute amounts. The enzyme in the middle is shown in two states, active (e_a) and inactive (e_i). When most of the "allosteric" (alternate forms) enzyme molecules are in the active state, they increase the rate at which X3 is used to form X4. When the enzyme molecules are mostly inactive, the rate of the net reaction is slowed almost to zero. Since X4 is being used up all the time through the path k_4, the steady-state concentration of X4 is raised and lowered by the activation or inactivation of the enzyme molecules.

The concentration of the signaling molecule Y1 is affected by the concentration of X4. If (the concentration of) X4 increases, (the concentration of) Y1 increases, and the population of enzyme molecules moves more toward the inactive state. But that would decrease the rate of the reaction from X3 to X4 and *lower* (the concentration of) X4, the negative of the change we started with. We can drop the expressions in parentheses if we just remember that, for example, "X4" used to indicate

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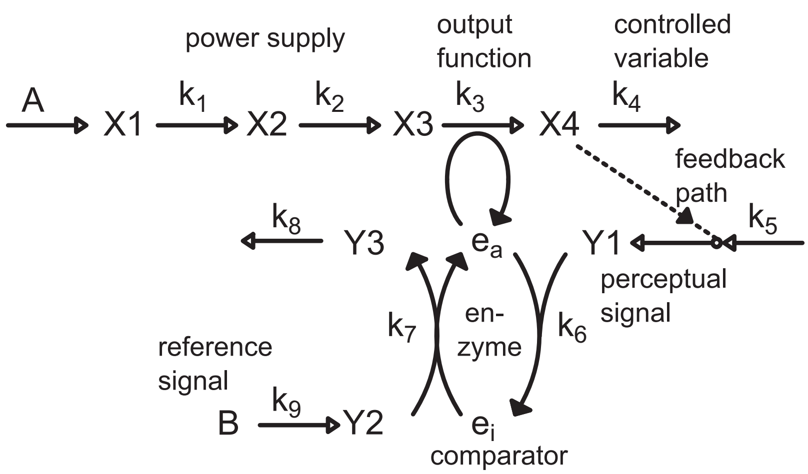

Fig. 1. Biochemical system with annotations suggesting functions in a standard negative feedback control system. X4 is the controlled variable. Redrawn from Hayashi and Sakamoto.[2]

a quantity always means "the concentration of X4". So if X4 increases, the immediate result is for X4 to *decrease* because of feedback effects. This is what is meant by negative feedback.

The state of the enzyme molecules is also affected by another signaling molecule, Y2. An increase in Y2 causes the enzyme population to move toward the active state, increasing the concentration of X4. When X4 increases, however, Y1 increases and progressively inactivates the enzyme. So we have Y2 increasing the enzyme activation, Y2 decreasing it, and X4 being increased by an increase in Y2 and decreased by an increase in Y1, which here is the same as X4.

This may illustrate why the operation of negative feedback control systems has not always been intuitively obvious to a person tracing out the individual relationships in the whole system one at a time. What, in fact, will this circular conglomerate of causes and effects *do* when set free to act by itself? For example, what will happen if we set Y2 to some starting concentration, wait a while, then set it to a different concentration?

The originator of a biochemical simulation program[3] kindly constructed a simulation for the author in which Y2 above was set to one steady level for a period of time, and then halfway through the run was switched to a different steady level. The time scale was such that after each change, the system was allowed to come to a steady state. The result was Figure 2, in which the concentration of X4 is plotted against time.

This result could hardly be deduced from a simple causal analysis. In this simulation, Y2 begins at some high concentration and at the start of the run is switched to a value of 0.15 millimoles (mM). The scaling in the simulation is such that Y1 has the same concentration as X4, although signal-molecule concentrations would normally be only a small fraction of the concentrations of primary metabolic substances. We can see that the concentration of X4 (and Y1) first drops, then rises, then quickly settles down at a value close to 0.15 mM. The numerical record of the simulation shows that the final value is *exactly* 0.15 mM, to better than one part in a thousand.

Then, at a simulated time 20 seconds later, Y2 is switched suddenly to a concentration of 0.3 mM. After a few rapid oscillations, the concentration of X4 comes to (exactly) 0.3 mM. So, ignoring the rapid oscillations (they can be eliminated), what can we say that this biochemical system *does*?

Note that when Y2 is set to 0.15 mM, X4 is rapidly brought to a concentration of 0.15 mM, and when Y2 is set to 0.3 mM, X4 is brought quickly to that new concentration. It is reasonable to assume that there is some range over which varying the concentration of Y2, not too rapidly, will make X4 vary in precisely the same way (a control engineer might recognize this as a servomechanism). As a bonus, this system also protects X4 from disturbances of various kinds. Altering the concentration of X1 over a wide range has no significant steady-state effect on X4, even though X4 is one of the products of X1. And changing k_4, which represents a drain on X4, also has almost no steady-state effect on X4 over a significant range of k_4. Thus a negative feedback control system can be used to set a molecular concentration involved in a main metabolic path to a specific value and keep it there in a varying environment. Clearly, to recognize these basic phenomena of negative feedback control is to open the door to some very new interpretations of what we observe.

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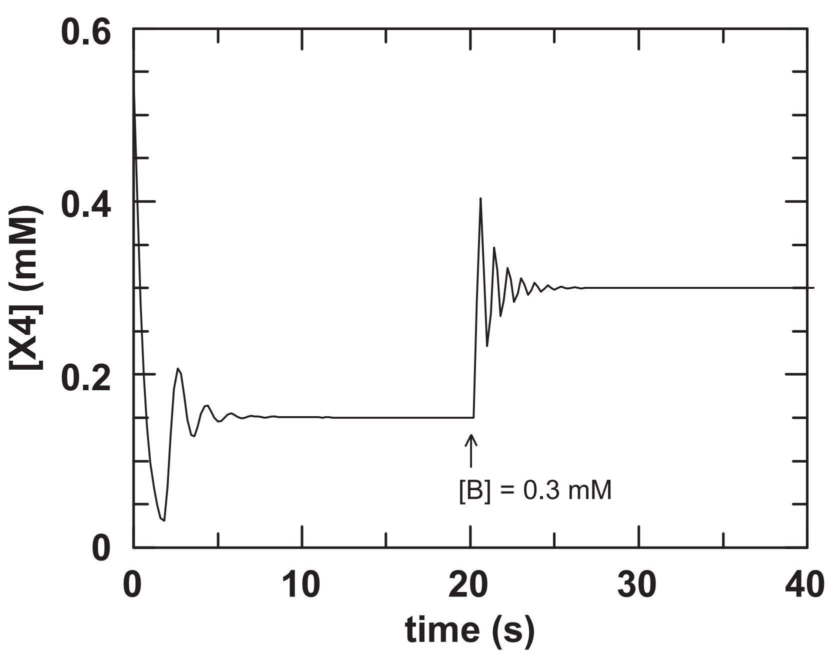

Fig. 2. Simulation of system in Fig. 1.

ORGAN-LEVEL CONTROL SYSTEMS

Walter B. Cannon, early in the 20th Century, invented the term "homeostasis," a term that has been known widely for almost three quarters of a century. Not so well known is the term "rheostasis," introduced by Nicholas Mrosovsky[4]. Both homeostasis and rheostasis are evidence of biochemical control systems, but now at the level of organ systems rather than detailed biochemical reaction dynamics.

One well-known homeostatic system regulates the concentration of thyroxin circulating in the bloodstream. Thyroxin comes from the thyroid gland, which is stimulated to produce it by thyroid-stimulating hormone or TSH. The higher the concentration of TSH in the bloodstream, the greater the rate at which the thyroid gland secretes thyroxin into the bloodstream.

TSH is secreted by the pituitary gland. There are two major influences on the production rate: stimulation by messenger molecules (TRH, or TSH-Releasing Hormone) produced by neural signals reaching the neural part of the pituitary, and suppression by circulating thyroxin molecules reaching the pituitary through the bloodstream (negative feedback). The homeostatic aspect of this system comes from the negative feedback loop: if something such as injecting thyroid extract tends to raise the level of circulating thyroxin, the increasing thyroxin reduces the production of TSH by the pituitary, lowering the TSH concentration and reducing the output of the thyroid gland. A decrease in thyroxin concentration has the opposite effect: more TSH and more thyroid output. The overall effect is to stabilize the level of thyroxin in the bloodstream: hence the "stasis" in "homeostasis."

Essentially every organ system in the body works this way, with various parts of the pituitary gland participating in those comprising the endocrine system. A product of an organ feeds back ultimately to inhibit its own production, with the result that its concentration is stabilized, or as physiologists say "defended," against various kinds of disturbances.

Mrosovsky's book contains a long list of homeostatic systems, but its main point is something else: the set point or defended level or reference level of the stabilized variable is, under many conditions, *itself variable*. The idea of homeostasis applies only over the short term; on a longer time scale, we find that the reference state is quite often, and maybe always, adjustable. Rheostasis, as in rheostat.

Mrosovsky discusses many examples of rheostatic systems, including the thyroxin control system. When an organism is put on a reduced diet, eventually the level of circulating thyroxin hormones drops by as much as 50% (Mrosovsky op cit, p. 88). The TSH level still varies within the normal range. Thyroxin concentration continues to be controlled at this lower level, resisting disturbances tending either to increase or decrease it. So evidently the reference level in the pituitary (set by the concentration of TRH) has been reduced, which means, presumably, that the neural signals determining it have been set to lower values by centers in the hypothalamus where those signals arise.

What would cause the reference level of a homeostatic system to vary? Mrosovsky offers a hint: some higher-order process which uses the whole homeostatic system as its effector. Since the homeostatic control loop is already controlling a variable of interest, a higher system that needs to manipulate the same variable would first have to disable the homeostatic controller if it were to act directly on that variable. Rodney Brooks' "subsumption" architecture[5] works this way. But the higher system can easily alter the variable simply by altering the reference signal that tells the homeostatic system the level at which to hold its controlled variable. We can see the beginnings of a *hierarchical control* architecture, in which one system acts by varying the reference signals of several lower systems. And of course they, in turn, can act the same way to use still lower-level systems such as the allosteric-enzyme biochemical control system we saw above. It is also possible for higher systems to monitor the *quality of control* achieved by lower systems, and to act by varying their parameters as well as their reference signals: adaptive control.

There are phenomena like these throughout the body's organ systems. But we move on now to still higher levels, quite possibly skipping some levels, in what is beginning to make sense as a very extensive hierarchy of control systems.

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SPINAL-LEVEL CONTROL SYSTEMS

John Dewey, over 100 years ago, recognized that there is something peculiar about the so-called "spinal reflexes." He realized that the stimuli which seem to elicit them act on sensory nerves which also, almost instantly and indeed while the stimuli are still acting on them, are affected by the motor responses they are producing. To Dewey, it was obvious that the simple concept of stimuli causing reflexive responses was too simple. Instead, he said[6], we have to think of the reflex arc as a complete circle (or as control engineers later would come to say, a feedback loop).

Consider the lowliest of all spinal reflexes, the Golgi tendon reflex[7]. Any force generated by muscle fibers due to signals from the spinal motor neurons excites Golgi tendon organs, which generate sensory signals. Those signals return to the spinal cord where, uniformly, they *inhibit* the same spinal motor neurons that are generating the signals that are causing the muscle to generate a force. When a steady muscle tension is being maintained, there is a continuing feedback signal and a continuing inhibition of the motor neurones. Of course something must also be exciting the motor neurons, to produce any tension to create the negative feedback signals.

Clearly, we have the same situation we have seen at the organ and the biochemical levels. The exciting signals correspond to Y2 in the biochemical control system. The inhibitory feedback signals correspond to Y1, and the muscle tension corresponds to the concentration of X4. The spinal motor neuron, affected both by the excitatory input and by the negative feedback signal, corresponds to the enzyme which is affected positively by Y2 and negatively by Y1, and in turn affects the controlled variable X4. Again, once we know what to look for we find obvious negative feedback control, the same architecture we have seen now at two lower levels.

At the spinal level there are also muscle-length and length-rate-of-change control systems, together making up the stretch control system (commonly called the stretch reflex). These systems act by altering the net excitatory signal entering the tendon-force control system, in a quasi-hierarchical manner. They are most useful when a limb is free to move, whereas the tendon system that appears hierarchically below them can regulate applied force when the limb is constrained and the muscle length control systems are ineffective (isometric operation).

BEHAVIOR-LEVEL CONTROL SYSTEMS

When centers higher in the brain issue commands to the muscles, those commands appear either as alpha-efferent reference signals that set reference levels for applied force, or gamma-efferent reference signals that set reference levels for muscle length or rate of change of length. No command from the brain is simply relayed to the muscles via the spinal motor neurons: the control loops are always there, strongly affecting the net signal going to the muscles. But the brain does not have to disable the spinal control systems when it needs to produce actions. Instead, it *uses* them by adjusting their reference signals. It tells the control systems not how much to contract the muscles, but what tension or what muscle length to sense. This means that any higher systems stand in hierarchical relation to the spinal control systems, using whole spinal control systems as effectors. This is quite clearly rheostasis at the level of spinal reflexes.

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This is the fourth level of negative feedback control we have examined: biochemical control, organ-level control, spinal-reflex-level control, and now what we can call behavior-level control. We have reached the higher reflexes, such as the iris reflex, the balance reflex, and others. But what we see goes much farther than that: we see control loops in which the variables being controlled are located outside the nervous system and muscles, or even in the environment. The controlled variables are now sensed in ways that involve, or can involve, complex perceptual interpretations and even consciousness. The means of controlling them consists of the entire musculature and all the motor control systems that operate the body, and what is controlled is now known to the organism simply as the world of experience. We have entered the realm where behavior is a process by which the organism uses its motor systems to control the states of perceived variables of all kinds.[8, 9, 10.]

CONCLUSIONS

Negative feedback control is not a new principle, but as far as the sciences of life are concerned it is an underutilized principle, mentioned by many but fully understood by few. Many people have suspected the existence of some such architecture, but the mainstream has never been willing to give up the causal model, at least not to an extent sufficient to encourage a major commitment of resources to the study of living hierarchically organized negative feedback control systems. Perhaps in this new millennium we will see a return to this basic concept, and finally an understanding of what it can mean to the sciences of life. I suggest that this is the concept that Brooks said was missing.

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Papers

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Once Around the Loop

An interpretation of basic PCT

By Dag Forssell

Elements of the control loop have been labeled slightly different by different people at different times and for different purposes, whether for a very plain explanation or for more mathematical treatment of the physical functions. Here, I will take you by the hand for a descriptive trip around the loop and do my best to put it all together. Embellishments over and above basic Perceptual Control Theory, especially the discussion of the input function, reflect my understanding—the way I think about it as I watch myself and other people acting and interacting.

Please refer to Figure One on page 3.

One thing that sets control in living things apart from other conceptions of control is the internal reference signal, so I'll start with that right at the top.

The ***reference signal (r),*** a neural signal, specifies the state to which the ***perceptual signal (p),*** another neural signal, must be brought. The reference can be thought of as a want, or a goal, or an aim, or a wish, or a desire, or any word that conveys the state of something to be experienced (the words used are not as important as understanding the function of the signals and components). It is like an example of the perceptual signal as it would be if control were successful, but it is set from inside the person as a whole, not by sensory inputs. High-level reference signals involve memory, as when you recall a certain position, move or experience and in essence think: "I would like to feel like that again." As we develop very high level mental concepts such as love, honesty and science, we specify that we want to experience that too. Some low-level reference signals, however, have nothing to do with our mental development and memory, but seem specified by our genetic makeup. We have built-in, intrinsic references for body temperature, CO_2 in lungs and much more.

The reference signal enters the ***comparison function (c)***, as does the perceptual signal. By engineering convention, the reference signal is assigned a plus-sign and the perceptual signal a minus-sign.

The output from the comparison is an ***error signal (e).*** This signal is the difference between the reference signal, what you want to experience, and the perceptual signal, what you experience right now. Since human beings are living control systems, it should not be surprising that we have many terms that reflect this, just as we have many terms that reflect the reference signal. Terms that come to mind are dissatisfaction, unhappiness, unease, something is wrong, hunger, thirst, fatigue… As an interesting aside, note that the reference signal comes from higher-level systems. We don't necessarily perceive it consciously, since awareness does not include all levels of control at any given time. A simple, elementary control system never perceives its reference signal, but since humans have a great many control systems operating at the same time, another part of us may have an idea. What we perceive is a signal that represents what we experience. It seems consistent with experience that we don't necessarily know what we want, but we have a sense that what we experience is wrong. We likely have a stronger sense of the error signal than we do of the reference signal. You may not like a certain dress, but you don't know quite why. You know something is wrong with this one, but you can't say what it is you do want. So you keep trying on different ones until you find one that does not feel wrong. More obvious examples are the error signal called hunger, which indicates a low level of blood sugar. But you have no idea what blood sugar level your system wants. Same for thirst, which indicates too little water in your blood.

The error signal enters an ***output function (o)*** that processes this error signal into output signals that are sent as reference signals to lower control systems if the loop is somewhere in the hierarchy, or to actuators at the interface with the environment of the nervous system. If you think of this diagram as representing a simple physical control system such as the cruise control in your car or the heating system in your home, the output function can be very simple indeed. But here, it represents an extensive neural network in the form of a hierarchy of control systems.

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Actuators* can be glands or muscle fibers where energy is used to greatly amplify the signal, converting it into physical effects such as the release of hormones or the contraction of muscle fibers.

Whatever kind of action we talk about, it is often labeled ***output quantity (qo)***. This is something physical. It may be located deep inside your body (but outside the nervous system) such as releasing adrenaline, stomach acid or sweating, or it may be muscle fiber contractions that combine into actions such as movement of heart, lungs, limbs, jaw or tongue as we move about and talk.

Action/output quantity affects the environment in many ways. Some of these are effects we want, others not and many we don't pay any attention to at all.

What we label action/output quantity is what is commonly referred to as behavior. As you can see, PCT provides an explanation for what behavior is, how it works, and what it accomplishes. More on behavior at the end of this trip around the loop.

Unintended effects include muscle fatigue, heat generation and more. For instance, when you wave your arm, you not only control its position and speed, but create air movement, noise and flapping clothes, and your arm may knock something off a table.

Let us skip ahead to consider the ***controlled variable (cv)***, also called input quantity (qi). Generally speaking, the controlled variable is what the reference signal is all about. The reference signal defines how we want to experience something in our environment. Something that can vary and that we can affect or control: what kind and how much.

As noted, action/output quantity has some physical influence on the unintended effects, but we are more interested in the influence on that which we care about—the controlled variable. Whether you put your shoulder to a door to open it, or put on a sweater to feel warm, or eat to reduce hunger pangs, or step on the brake to stop your car, or ask someone to pass the salt (yes other people are often part of our environment and we use them as we attempt to control), the effect of your action on the controlled variable is described by the ***feedback function (f)***. This term is a fancy name engineers use to cover all the physical effects of the action on the controlled variable. Think of it simply as the effect of your action on the controlled variable, the thing you want a certain way. The effect may be immediate and effective as when you grab a glass and bring it to your lips to drink, or it may be totally ineffective as when you thrust your shoulder against a sturdy, locked door, or it may be indirect as when you compliment an official hoping for favorable treatment. For sure, not all attempts to control are successful.

You may not be the only thing affecting the controlled variable. Our world is full of ***disturbances (d)*** that influence the controlled variable separately and independently. While you may be controlling all the leg movements required to walk across the deck of a ship and keep your balance, the deck may be heaving and wind gusting. These disturbances affect your balance at the same time, so you have to adjust your action to compensate. When driving from A to B, you steer the car to stay in its lane. Disturbances that independently affect the steering of your car include wind, slopes and ruts in the road, so you have to compensate—not to mention major disturbances such as other cars and people that get in the way so you have to compensate by changing your path or speed. The way all these disturbances affect the controlled variable is represented by the disturbance function, which is equivalent to but different from the feedback function.

The arrows in the environment merely indicate the direction of the effects of the physical influences for the purposes of control.

As you can see, the controlled variable is subject to influences from you as well as from other people and things in the environment. The current state of the controlled variable is sensed by ***sensors*** at the interface between the environment of the nervous system and the nervous system itself. Sensors include nerve cells on the retina in your eyes, in your ears, nose, mouth, skin, tendons in all your limbs, and sensors deep within your body sensing carbon dioxide in your lungs, temperature in your body, adrenalin levels, heart contractions and much more.

Signals from all these sensors are processed by the ***input function (i)***. In a very simple control system such as your home heating system, the sensor and input function together consist of a thermometer that measures temperature, the controlled variable. But here the input function, when representing the entire hierarchy, should again be thought of as a neural network that receives the various signals and constructs interpretations of them using both the current input and signals retrieved from memory. The latter is obviously required when we communicate using

**Actuate:* To put into motion or action; activate.
Actuator: Converts a signal or current into action or physical effect.

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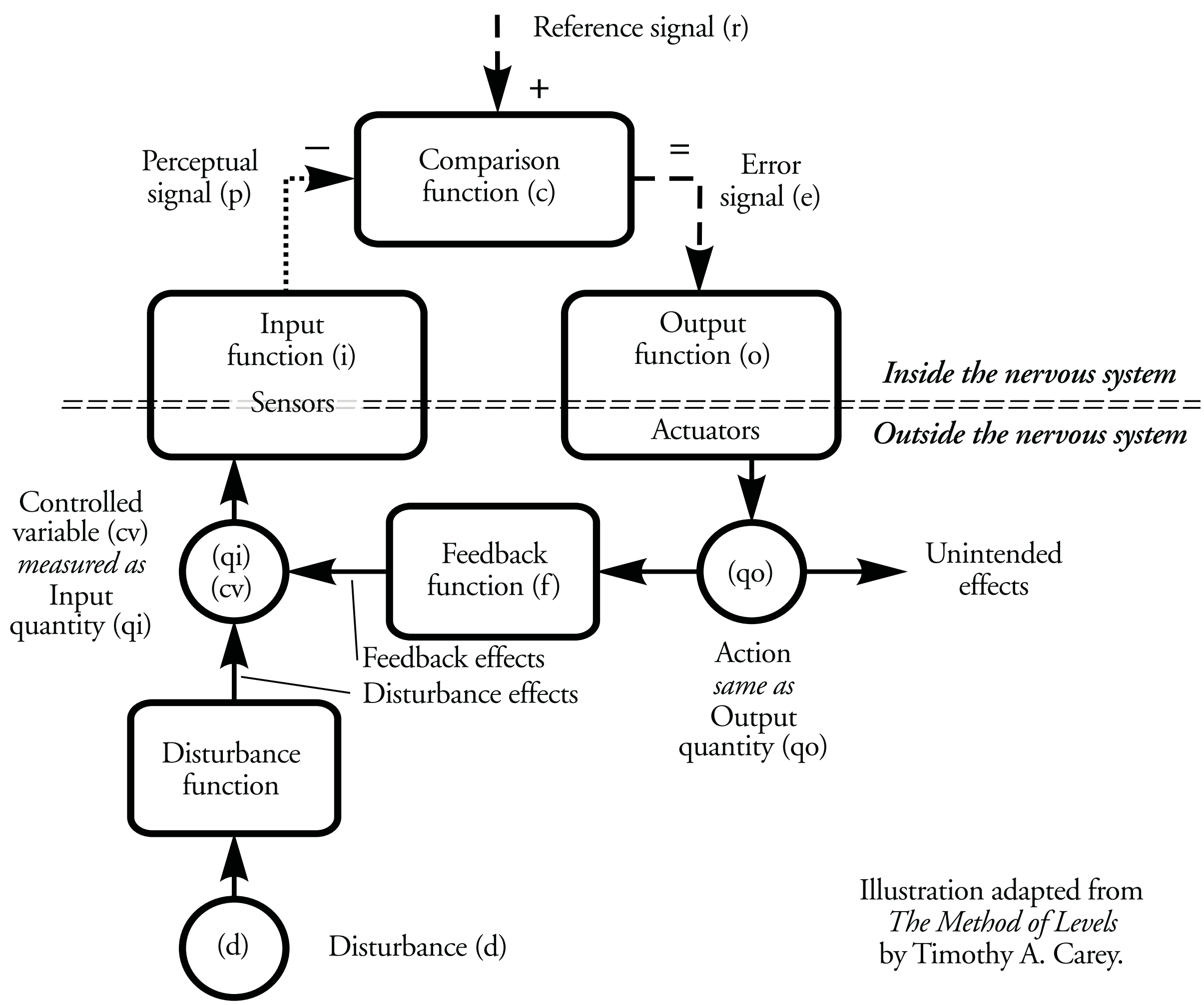

Figure One A closed causal loop: A basic control system acting on the environment.

Note: This illustration can be seen as a single elementary control system, consisting of a few neurons and muscle fibers acting at the interface with the environment, or as a summary of an entire hierarchy, thousands of control systems at many levels, acting in complex ways on the environment.

Arrows in the nervous system indicate neural signals carrying information from one function (neural network) to another. Arrows in the environment indicate physical links that give the output of one function a physical influence on a physical variable. The circles show where physical variables are, or where they could be measured. Functions in the environment usually indicate physical laws that determine how physical variables at the output of the function depend on physical variables at its input.

language. Sound vibrations are sensed by neurons in our ear at the interface with the world outside the nervous system. As these signals are processed up the hierarchy of the neural network, their meaning has to come from prior experiences stored in memory. The fact that memory must be involved begins to explain how we can create high-level perceptions from sensory input such as sound and light any number of ways depending on what memories are evoked. We can replay songs and events from memory, can anticipate what a speaker will say next as we listen, and can visualize wet sand between our toes, a beach, waves, and a sailboat on the horizon while closing our eyes wherever we are. Seems to me that a major part of the perceptions you create when you hear and see someone communicate may come from your memories of prior interactions, while only a small part of your overall impression may come from current sensory input. This provides for sometimes rather

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subjective interpretations of the world around us and explains how two persons can hear or see "the same thing," yet construct completely different meanings. We are very capable of "hearing" and "seeing" that which we want or expect to hear and see, as it relates to past experience and convictions. Progressing up the hierarchy of perceptual levels proposed in PCT, signals from sensors combined with signals retrieved from memory are ultimately displayed in our brains in living color and three-dimensional sound as well as non-visual, non-verbal impressions, thoughts, principles, and systems understandings. This is what we experience. This is what gets compared to the reference signal.

While a description like this can give the impression that the loop operates step-by-step, all signals and functions operate simultaneously, continuously in a seamless flow where everything influences everything else all the time.

That's once around the loop the way I understand it.

Now that we have a rather comprehensive idea of how elements interact in a fully functional control system such as a living organism, I will comment on action, which is commonly spoken of as behavior. Action or behavior is what is visible to an outside observer. What's inside is invisible. Therefore, attention gets paid to action/behavior and the rest of the system ends up being largely misunderstood in our society today. Parents, educators, spouses, politicians, police—all strive to change the behavior of others (and end up creating lots of conflict in the process). The idea that behavior is controlled by the individual and can be modified by others is widely accepted. But do people control their behavior? Are people even aware of their action/behavior in such a way that it is reasonable to say that they can and do control their behavior?

As you can see from this trip around a control loop, action follows from the comparison of the reference signal (the current want), with the current perceptual signal (the sense of what is right now). Automatically!

The input function of the controlling system perceives nothing but the controlled variable. It does not perceive its own action. Just the same, the thermostat in your home heating system perceives air temperature but knows nothing about the furnace and its behavior. The heating system controls its perception of temperature. It most certainly does not control its behavior. Neither do you.

We are most aware of what we perceive or experience. We can also be aware of what we want or intend through thinking and imagination (PCT deals with these, too, but not this paper). We are much less aware of what we actually do. While the low-level systems controlling movement of our limbs perceive their inputs, not their action outputs, we can be aware of our action/behavior by in effect watching ourselves act because we have massively parallel input functions and perceptual pathways. But to be somewhat aware of what we do, we must make a deliberate effort to pay attention. Normally we don't. When you left your house on vacation, you may remember that you intended to turn off the stove, but not whether you actually did. You can't usually remember many details from your last drive or walk to the office, because your system in action automatically brought you where you wanted to be. You did not have to pay attention to your actions to get there.

Action/Behavior is the (automatic) means by which we act on our world in order to experience it the way we want it. Thus we control what we perceive.

Behavior is the control of perception.

One obvious consequence of this understanding of what behavior is, how it works, and what it accomplishes, is a change of focus from action/behavior (which is of little interest), to understanding and wants (a complex system of reference signals) because the latter drive the system, depending also on current circumstances. Changing from trying to modify behavior to asking questions, exploring a person's wants and the personal reasons for them, makes a huge difference to personal relationships, personal effectiveness, and conflict resolution.

For more on the effect of focusing on what people want, I recommend Jim Soldani's paper on *Effective Personnel Management.*

Dag Forssell October 2005

Appreciation is due Tim Carey, who inspired me as I worked on Figure One for *The Method of Levels*, and Bill Powers, who reviewed this explanation.

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The Experimental Method is Crippling Psychology

By Dag Forssell

When I was new to Perceptual Control Theory, PCT, I had a discussion with a psychologist (a dear friend) about the scientific nature of psychology. "Of course it is a science—that's why we have the scientific method," my friend said.

However, the scientific method, and the experimental method that goes with it, borrowed from physical and engineering sciences, has been used the same way it is used in these sciences—as if people and animals are inanimate objects. You do something to the object and see what happens. This approach is appropriate in physics and engineering, where objects and processes are inanimate. But people and animals are not inanimate. The difference requires a significant change to the experimental method. [1]

The failure to recognize that living organisms control what they experience, not merely respond to stimuli in the environment, and the failure to understand how control works, has been keeping scientific psychology trapped in erroneous concepts and methods.

Seems to me there are two basic reasons for the use of erroneous methods in scientific psychology:

1) The current experimental method is intuitively obvious. As you look at other people and animals, what you see is what goes on in their environment and how they respond to it. From this, you draw conclusions about how they function.

2) When in 1927 H.S. Black described how control works, this intuitive approach had already become an established scientific and experimental method in psychology, where changes in the environment are the Independent Variable, IV, and action/behavior the Dependent Variable, DV. A high correlation between these two in an experiment is taken to mean that there is a relationship and you have learned something about the organism.

If you pay attention when new scientific findings are reported on the evening news, you will notice that something in the environment of people or animals (in experiments, that is the Independent Variable, IV), is contrasted, compared or correlated with actions/behaviors by the organisms, usually averaged over a group of individuals, each of whom may behave quite differently (that is the Dependent Variable, DV). Both variables—as we shall see when we examine a control system on the following page—are located in the environment of the organism and this approach cannot possibly shed light on the internal workings of any organism. [2]

On Nov 20, 2012, Bill Powers wrote in an email:

> There is one clear message that we have to send to the life sciences concerned with behavior, which in one way or another means all of them. It is that all the behavioral sciences have been pursuing an illusion during their whole history, the behavioral illusion. They have been misled by the actions that organisms use for generating effects that are of importance to them into thinking that those actions are the effects of importance.

In the Editor's preface to *Dialogue Concerning the Two Chief Approaches to a Science of Life,* I claimed among other things:

> The Scientific Method has been employed for the study of living organisms without regard to the fact that they control their environment, not the other way around. As a result, psychologists have studied *the wrong thing, the wrong way*.

To follow the illustration and reasoning on the next page, it is essential that you recognize that people are indeed control systems.

For a compelling demonstration, review *The Rubber Band Experiment*, featured in several books on PCT and in the script and video by the same name.

1 For the methodology required, see Marken, Richard S. *You say you had a revolution: Methodological foundations of closed-loop psychology*. Review of General Psychology. Vol 13(2), June 2009, 137-145.

2 For a review of what kinds of information current research methods do and do not provide, see Runkel, Philip J. (1990, 2007). *Casting Nets and Testing Specimens.* Hayward CA: Living Control Systems Publishing

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Illustration from *Once Around the Loop.*
For a discussion of each signal/function, please see the paper.

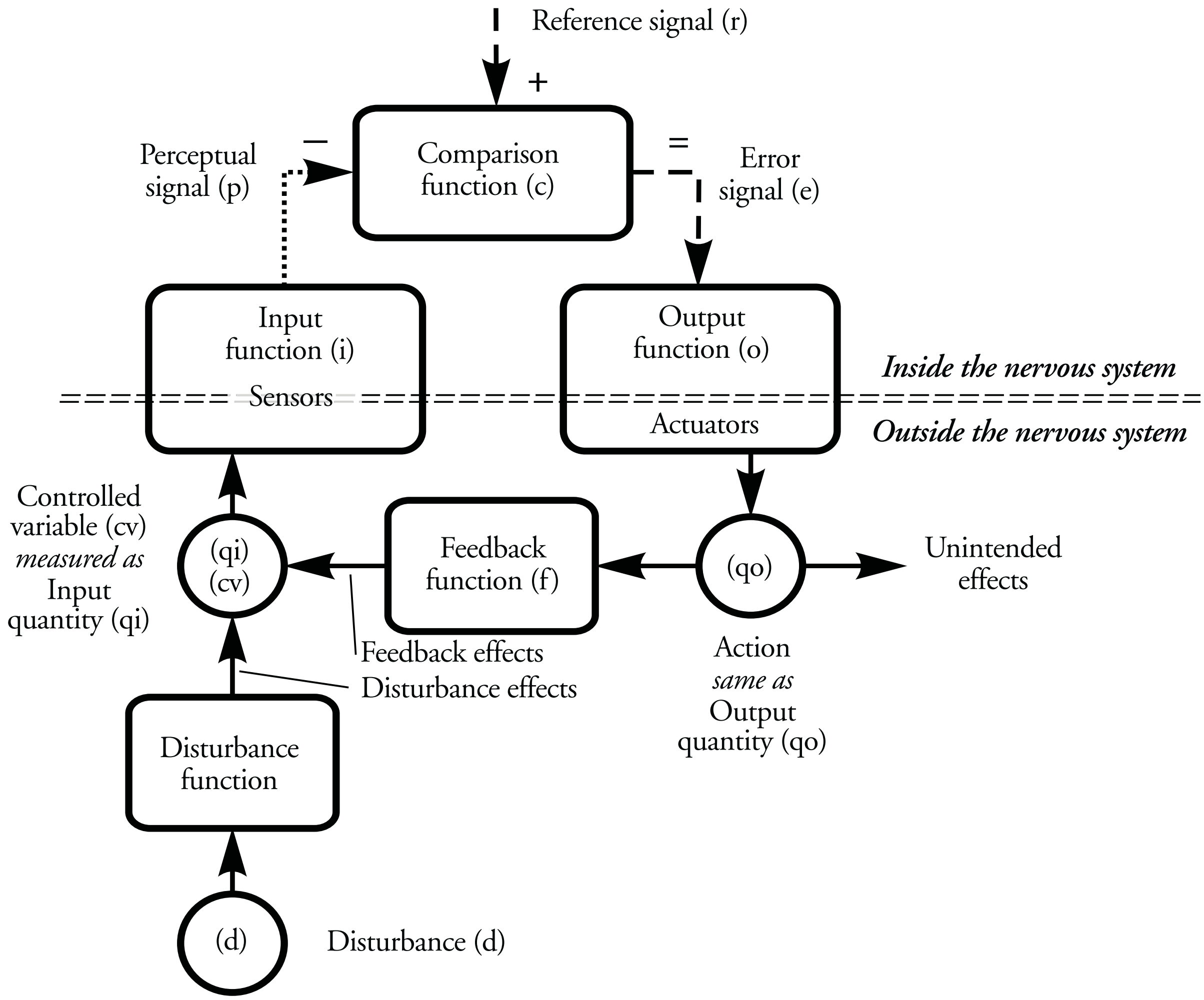

Figure One A closed causal loop: A basic control system acting on the environment.

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With reference to *Once Around the Loop*, there are 11 signals/functions at play in this summary illustration of a living control system.

1	Reference signal	(want, intent, will)
2	Perceptual signal	(interpretation of 8)
3	Comparison function	(subtract 2 from 1)
4	Error signal	(the difference, 2 – 1)
5	Output function	(neural processing)
6	Action output	(by muscles, physiology)
7	Feedback function	(action effect on 8)
8	Controlled variable	(the thing that matters)
9	Disturbance	(environment acting on 8)
10	Disturbance function	(action effect on 8)
11	Input function	(neural processing)

Psychologists have been studying the two that happen to be visible (and least interesting), 9 Disturbance, and 6 Action output, and determining a correlation between the two.

Of significance to any living organism are the Reference signal (what you want) and the Perceptual signal (what you experience). Action is automatic; what it has to be under the circumstances.

For more than a century, scientific psychologists have used a mistaken experimental method, studying the wrong things the wrong way, learning essentially nothing about how people and organisms function.

Dag Forssell, May 2013.

Three "Dangerous" Words

By W. Thomas Bourbon

This very personal essay was composed for consideration as a foreword for a book with the apt working title *Starting Over—Psychology for the 21st century* which became *Making Sense of Behavior—The Meaning of Control*

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"Behavior controls perception." Three simple words that summarize the subject of this little book. They don't look very dangerous, do they? But they are. What could possibly be dangerous about that little phrase? Many things, if you really understand it. Let me tell you about some of the "dangers" that I have seen during the 24 years since I first read the phrase. Remember that I am describing things I saw during a quarter of a century—everything did not happen all at once.

For one thing, many people don't perceive the words the way they are written, or spoken. Instead, they believe the phrase says "perception controls behavior." How could that be? How could people, including widely-respected behavioral scientists, influential editors of scientific journals, and respected educators all believe the phrase says something that means the opposite of what it really says? Ah, that's the danger! The phrase says that the relationship between behavior and perception is *exactly the opposite* of what most scientists believe it to be. Nearly everyone in behavioral science believes *perceptions cause behavior*, whether directly, or as a step in between stimuli from the environment as the cause, and behavior as the effect. When those scientists see or hear the phrase "behavior controls perception," they experience a feeling of *error*, between the way they *think things are*, and the way the phrase *says they are*; immediately, they say something to correct the error they perceive in the statement, so that they can hear themselves saying what they believe *should* be said. Those scientists behave to make their perceptions be the way they want them to be. They behave to control their perceptions.

This book is about those three simple words, and about what they imply for all of the sciences of behavior and for all of the practical applications that grow out of those sciences. When he first wrote those words, back in the 1950s, Bill Powers created an entirely new theory of behavior—an entirely new science of life itself. Bill's theory is called Perceptual Control Theory (PCT), and it is different from every other kind of theory I know in behavioral science, social science, or the life sciences. "Behavior controls perception." I can tell you, for certain, that if enough people ever understand that simple phrase, the world will be a different place—a better place. In this little book, Bill Powers gives you some clues about why that will be so, and he invites you to join in the excitement, and the challenge, of behaving to make it happen. I can tell you another thing for certain: the challenge in teaching people about PCT is great, and that brings me back to the "dangers." You need to know something about them, in case you decide to join in the PCT project. Let me describe just a little of what has happened to me, and to people I know, during the 24 years after I first read and understood Bill's little phrase. Let me tell you about some of the dangers, while we follow my path from the university to medical schools. Remember that nothing I describe here even came close to discouraging me, or any of others who are most closely associated with PCT. It is a unique and powerful theory. I simply want to tell you a few of the ways that some people misunderstand it, and the ways that others are threatened by it.

My first encounter with PCT came in 1973, when I read a journal article by Bill (William T. Powers, 1973, Feedback: Beyond Behaviorism, *Science, 179*, 351-356) [Reprinted in *Living Control Systems* (1989) p. 61-78.] I knew, immediately, that Powers had created a new theory that explained a festering mess in my own mind, he had found one clear principle that explained many seemingly unrelated facts in the behavioral and life sciences. The principle? You know it by now: behavior controls perception. That same day, I ordered Bill's book, *Behavior:*

The Control of Perception. The danger? I read it, and knew my life would never be the same. For one thing, I knew in a flash that my career as a traditional research psychologist was over. I could never go back to accepting all of the "theories" and research methods that I had learned were "true," and that I was teaching to innocent university students. It took many years for me to absorb some of the big implications of PCT and the process is not complete.

Immediately after I read Bill's book, the danger began to spread from me, to my students. I changed what I taught in all of my psychology courses, for undergraduates, and graduate students alike. For the sake of my students, who had to survive in traditional psychology, I still taught the "essentials," but I put them in the context of PCT—the comprehensive theory that explains how behavior controls perception. Over the next nineteen years, in practically every class, the time came for "The Declaration and The Question." A peer-selected class member raised a hand and declared (often with an appearance resembling fear and trembling), "What you are teaching us is different from what we learn in all of our other psychology courses." An accurate declaration, to which my reply was always "Yes, it is!" Then came the question, with unmistakable fear and trembling, "What are we supposed to do?" And my reply was always, "Each one of you will decide what to do."

My students accurately identified the danger of what they learned in my courses: behavior controls perception. Most of them did whatever was necessary to finish my class, and then they vanished back into the world of traditional psychology. However, during most semesters, at least a few students decided that PCT was a better scientific basis for psychology than the traditional ideas taught to them by my colleagues. Those students began to share in the rejection, and sometimes ridicule, that some of my colleagues had directed at me. Some of those students gave up trying to learn more about PCT, but others persisted. I shall always admire my imaginative and daring students who found ways to use ideas from PCT in clinical activities that were always closely monitored and regulated by members of the clinical faculty, some of whom were strongly opposed to anything having to do with PCT. Along with me, several students experienced the frequent rejection of research articles we submitted to scientific journals. Often, the editors and reviewers said bluntly that our papers were about a subject they were not familiar with, and they did not want to read anything about it. Bill Powers, Rick Marken, and anyone else who has tried to publish about PCT research, have all encountered similar rejections. So much for the myth that scientists are an objective and inquisitive lot! In spite of the obstacles in their paths, several of my students maintained their interest in PCT and they use it today, in their clinical practices and their research.

From time to time, one of my faculty colleagues would examine PCT, even if only a little bit. One day, a bright new faculty member, with a shiny new Ph.D. in experimental and theoretical psychology from a major university, came to my lab to learn a little about PCT. One of my thesis students had asked the fellow to serve on his thesis committee. I ran a few simple PCT demonstrations. One product of those demonstrations is a set of statistics that describe what happened during the session. Some of those statistics reveal, unambiguously, the inadequacy of traditional methods in experimental psychology. After one demonstration, my young colleague sat quietly for a while, staring at the computer screen. Then he turned slowly, looked at me, and said, "You know, of course, what this implies about the past three hundred years of research on behavior." Perhaps he expected me to realize the folly of my PCT ways and retract the point of the demonstration. Instead, I paused, then said, "Of course." He sat a while, quietly. He was a bright and energetic fellow, with a brand new doctoral degree. To earn that degree, he had to demonstrate that he knew all of the traditional theories and methods in psychology. Here he was, at the beginning of his professional career, staring directly in the face of something he knew refuted what he had just learned. I ran a few more demonstrations, with their inescapable evidence that most of the traditional statistical analyses in psychology are worthless. Once again, my colleague looked up slowly and said, "You know what this means about the things we teach in statistics and research methods." (In our department, he taught those courses. Back then, all psychology majors took them.) I replied, "Yes." My young "colleague" understood, perfectly, what he had seen, and the danger in it was as clear to him as it could possibly be: he had witnessed compelling evidence that traditional behavioral science was indefensible. How did he handle the danger? He became one of the faculty members who was the most critical of my students when they expressed an interest in PCT.

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Nineteen years after I first read the phrase, "behavior controls perception," I decided I would never convert my faculty colleagues, or the community of research psychologists, to an understanding of PCT. I left the university for a new career of research in medical schools. Perhaps there I would find people who were more interested in understanding this exciting little phrase. How could there be any danger in a move to a place where there are "real scientists," rather than just a crowd of traditional psychologists? Three years later, I left the medical schools. My interest in PCT, and my work related to the theory, did not fit there, any more than they had in the university.

Most of the scientists were intent on discovering something in the environment, or in the brain, especially in the brain, which controls behavior. Their reputations, and their funding, were firmly rooted in one or the other of those two ideas about where to look for what causes behavior. Even a passing glance at the idea that behavior controls perception could prove dangerous, in the extreme, to a respectable scientist's professional well being! Four or five brave souls did look, briefly, at our simple demonstrations of control, and at the precision with which the model from PCT explains how behavior controls perception. Each of them described the demonstrations and the model with terms like, "interesting," or "intriguing," and then they went their traditional (safe) ways.

On the clinical side, I made a modest proposal, and a couple of clinical neuropsychologists agreed that we should test it. I suggested that some of the performance tasks and research methods used in PCT yield behavioral data and modeling coefficients that might help assess the functional status of various clinical patients. (Most of the patients had a history of stroke, or of injury to the head or spine.) I survived long enough at the medical school to make a start on testing that proposal. It looked like we might be able to identify effective levels of control in some patients who were classified as, "nonfunctioning," after conventional diagnostic procedures in neurology, and clinical neuropsychology. (In those clinical areas, practically all of the diagnostic procedures grow out of research and theorizing about environment, or brain, as the locus of whatever it is that allegedly controls behavior.) It looked like we could also identify a range of ability to control, in patents who were all lumped into single categories of functioning, or non-functioning, by conventional diagnostic procedures.

I vividly recall several patients who expressed thanks, and appreciation, that someone finally tested them in a way that allowed them to show what they can do, rather than in ways that always show how they fail.

Some of the clinicians described our early results with terms like, "fascinating," and "interesting, but… You knew it was coming! …there was no way to use results like those. The numbers did not fit into existing diagnostic protocols or categories, and… Purely incidentally, of course! …there was no way to bill an insurance provider for procedures like those. Now *that* is real danger! And so it goes.

The simple idea described in this little book is unique in behavioral and life science, therefore it is viewed as a threat by many people in those fields. That's too bad. They are missing out on a chance to participate in the creation of a new science of life, an experience I would not miss for the world!

Well, there you have a quick tour of some of the dangers I have seen for people who understand the simple phrase of Bill's that I first read in 1973. Bill Powers, and his wife Mary, have lived with those dangers since the 1950s. Many others have lived with them over the past few decades. Most of us have "survived," although a few former colleagues have dropped by the wayside, professionally and intellectually. For all of us who remain, and for the many others who have joined us, we would not miss a minute of the adventure. When it comes to developing the science and the applications that grow from the idea that "behavior controls perception," nothing I have described is really a danger, after all. At the worst, they are annoyances and nuisances. If "dangers" like the ones I described don't frighten you, and if you want to become part of the revolution that PCT *will* bring to the behavioral and life sciences, and to all of human kind, then I urge you to read this little book. There is no better place for you to begin your adventure!

Tom Bourbon
Houston, Texas
July, 1997
Revised January, 2008

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People as Living Things: The Story

By Dag Forssell 2005

ABOUT PSYCHOLOGY AS A SCIENCE

Psychologists have long expressed concern about the lack of basic principles and scientific rigor in their field. William James, considered by many to be the first great American psychologist, said in 1892 that psychology is not a science, but only a hope of a science. Robyn M. Dawes expressed concerns in *House of Cards: Psychology and Psychotherapy Built on Myth* (1994).

Why is this? Since Francis Bacon, the bedrock of science has been the experimental method. Theories that fail when you attempt to disprove them are rejected. In *People as Living Things*, Philip J. Runkel surveys a welter of descriptive concepts that coexist in the diverse field of psychology (see especially Models and Theories, pages 97-101). None have ever been put to a definitive test; few have been rejected, they merely go out of fashion, like phrenology. Very few psychologists ask "how does that work," and if they do, it is never successfully answered in terms of physical processes. Instead, "explanations" consist of metaphorical word pictures and flow charts. People who are familiar with the physical sciences and engineering recognize that psychology lacks basic principles that can be tested in ways that are essential to the scientific method. Lacking these, psychological research is limited to gross statistical "results" that are often little better than a coin toss.

Thomas S. Kuhn's landmark work *The Structure of Scientific Revolutions* (1962, 1970) showed how science progresses by a kind of "punctuated equilibrium." With numerous examples of revolutions in the physical sciences, he showed how revolutions typically are resisted by people engrossed in and committed to the current scientific paradigm, or ways of working in the field. As Mary Powers said in a brief essay, *Mary on PCT**, "It is very hard to believe that one's training and life work, and that of one's mentors, and their mentors, must be fundamentally revised." One well known example of a scientific revolution is the replacement of Ptolemy's earth-centered cosmology by the sun-centered astronomy of Copernicus and Galileo. Kuhn has no examples from the field of psychology, because there have been none—so far. The new paradigm that will change all this is called Perceptual Control Theory.

ABOUT PERCEPTUAL CONTROL THEORY

Developed by William T. (Bill) Powers starting in 1953, Perceptual Control Theory (PCT) proposes that our nervous system is made up of a very large number of control systems in a hierarchical arrangement, each a simple circuit of neurons which quickly and efficiently can perform the way we do. PCT provides an intuitively satisfying explanation of how purposeful behavior works and what it accomplishes. This is a testable explanation, rooted in the physical sciences, that allows for the complexity of our experience. PCT explains behavior from the inside perspective of the controlling organism rather than from the outside perspective of an observer. Control turns out to be the defining quality of life, the key physical function that distinguishes animate living things from inanimate objects.

When you study PCT, you learn what control is and how it works. You understand how control gives rise to conflict or cooperation, depending on what individuals want and how they interpret their experience. When you understand PCT, dealing with people no longer has to be complex and confusing, a matter of luck, a gift, or something best left to specialists.

Powers's major technical, detailed and lucid work outlining PCT, *Behavior: The Control of Perception* (1973, reissued as paperback in 2005), as well as other books and anthologies of selected papers by Powers, are featured at www.livingcontrolsystems.com.

With the advent of personal computers, Powers began creating tutorial programs, demonstrations and simulations that anyone can run. These and much more are available at www.livingcontrolsystems.com. As people study PCT in depth and grasp the generative concepts, PCT is destined to revolutionize today's descriptive, non-functional concepts of psychology as thoroughly as the generative conception of a solar system revolutionized the descriptive, non-functional earth-centered astronomy four centuries ago.

* Files mentioned here are available at www.livingcontrolsystems.com.

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ABOUT PHILIP J. RUNKEL

In 1985, the year before he retired as Professor Emeritus of Psychology and Education at the University of Oregon, Phil Runkel wrote Bill Powers a six-page letter asking questions about an article by Powers published in Psychological Review in 1978, seven years earlier: *Quantitative analysis of purposive systems*.

Powers replied with a nine-page letter dated only six days later.

As Runkel studied PCT, he found it necessary to jettison crucial assumptions that underlie traditional theory and method. It is possible that Runkel relinquished those assumptions more easily because of some earlier experiences with the way things work in the physical sense; for example, he worked some years as an engineering draftsman, and he was granted a patent in switchboard circuitry.

By 1989, Runkel published *Casting Nets and Testing Specimens—Two Grand Methods of Psychology*, in part as a way of trying his understanding of PCT on for size. This book is an excellent exposé of proper and improper use of statistics in psychology, and includes an introduction to PCT.

Runkel continued his project of writing a book on life in organizations (spelled out in that first letter to Powers) accumulating materials and planning how to introduce and explain PCT to a wider audience. In *People as Living Things*, he introduces PCT and relates it to the broad panorama of contemporary literature and thinking in psychology and related applications.

Here is a comment from Dr. Frans X. Plooij, Director, International Research-institute on Infant Studies (IRIS), The Netherlands: "I started reading your book to see whatever you have to say about systems. Then I really got fascinated by your book and read it from start to finish. Very impressive! And a feast of recognition where you say that integrating PCT into your thinking does not come overnight but takes years. Your knowledge of the psychological literature is enormous and the way you linked PCT thinking with that literature (or discussed it against the background of that literature) was very instructive to me."

ABOUT THE BOOK TITLE

Control of input by means of output is the defining characteristic that distinguishes living things from inanimate objects. Runkel discusses this crucial difference on pages 13-18, with a summary on page 122.

The essence of the scientific method is to apply a force, stimulus or disturbance to an object and observe the result or reaction. A high correlation between cause and effect is taken to indicate a causal relationship. Where linear causation applies, such as with inanimate objects, this method is appropriate.

Linear cause and effect is appropriate for describing inanimate things like billiard balls. It is an enormous mistake to presume that linear cause and effect can explain the behavior of living things. If a force (a stimulus or disturbance) is applied to a variable that a living organism perceives and is controlling, the organism produces countervailing forces to maintain that variable in states that it prefers. It does this by processes of circular causation with amplification. The usual simple conceptions of cause and effect are not sufficient. A high correlation is found between the disturbance and the action by which the organism resists it, but this tells you nothing about the inner working of the organism. The important fact is that the correlation between the disturbance and the state of the disturbed variable approaches zero, depending on how well the organism is controlling that variable.

A lack of understanding of the fundamental property that distinguishes living things from inanimate objects has trapped psychologists in inappropriate applications of the scientific method blindly modeled on the methods of the physical sciences, which presume linear cause and effect.

The point of the book title is that PCT—*the psychology of perceptual control*—enables us to study and understand people on the basis of a scientific explanation that recognizes that we are alive and purposeful—that we are living control systems, not inanimate objects pushed about by linear cause and effect.

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ABOUT THE SUPPORTIVE MATERIALS

(Posted at www.livingcontrolsystems.com)

Perceptual Control Theory is a technical explanation of how we can walk, talk, and chew gum, all at the same time, and on the rolling deck of a ship at that. To understand the theory, it is essential that you develop a correct understanding of how control works. In the world today, very few people have such an understanding—after all, control was not clearly described until 1927 (by an engineer at Bell Laboratories).

The tutorial programs DEMO1 and DEMO2, plus Track Analyze will help you understand control in detail. Other demonstrations and simulations build on the basic insight you will develop by studying these tutorials.

As you study PCT, you will naturally ask yourself how PCT explains this and that phenomena discussed in psychology. PCT explains some phenomena very well indeed, while some others prove to be illusions. Things may appear one way, but the way we talk about our observations suggests an explanation that may be wrong and misleading. People observed long ago that the planets periodically move in reverse. Aristotle incorporated epicycles in his astronomy to account for that "fact" and these ideas survived well into the 1600s. The planets never reverse direction—it just looks that way from the earth. When you understand the explanation of the solar system, you understand why the idea of epicycles was mistaken. The same thing is true of many contemporary behavioral "facts" in relation to the explanation PCT offers.

As you run the tutorials and simulations so you understand control well, and as you experience various situations, you are bound to reconsider what is going on—and the explanations inherent in our language and culture—based on your new understanding.

It is very difficult to determine the scientific validity of PCT by just reading about it. Look at the technical details to see just exactly how things work—run the simulations yourself. Mary Powers put it succinctly in a communication to CSG net in 2003: "At the blah-blah-blah level, Hierarchical PCT is no better than any other theory." The tutorials and simulations are there to take you way beyond the blah-blah-blah level.

ABOUT THE PUBLISHER

I read *Behavior: The Control of Perception* in 1988. I found a truly scientific approach to explaining human nature. It is remarkably simple, lucid and compelling. Perhaps it was easy for me as a mechanical engineer, but I know others who have found it just as lucid and compelling, people without a technical background, but willing to work their way through the detailed explanations. I joined the Control Systems Group (CSG), a loose association of people interested in PCT in 1989. My involvement with *People as Living Things* started in 2000 when Phil Runkel tugged at my shirt sleeve during a break at the CSG conference and said he wanted me to review his forthcoming manuscript for technical accuracy.

Once the MS was finished Phil wrote: "I have a file of my paper-mail correspondence with Wm Powers that started in 1985. I have no more use for it. Do you want it?" Of course I did! I scanned the thick pile of letters and sent a CD to Bill. He wrote: "Dag, I have received the CD-ROM and have spent several hours reminiscing through that old correspondence with Phil. It seems as if it happened in a different world, but only yesterday. Phil truly brought out ideas I had only halfway considered, and made me think carefully where I had been careless. I have come to think of him as Brother Phil."

I now have Runkel's side of the correspondence, and Powers's side too. I am determined to share the letters. Phil's and Bill's focused, respectful correspondence covers the waterfront of PCT-related issues and makes a wonderful PCT tutorial.

Dag Forssell, April 2005

Update 2009: Note the updated tutorial programs that are part of *Living Control Systems III*, published by Benchmark Publications in 2008.

Update 2010: The correspondence between Runkel and Powers is now available as *Dialogue Concerning the Two Chief Approaches to a Science of Life.* Powers and Runkel (2011). Living Control Systems Publishing, Hayward, CA.

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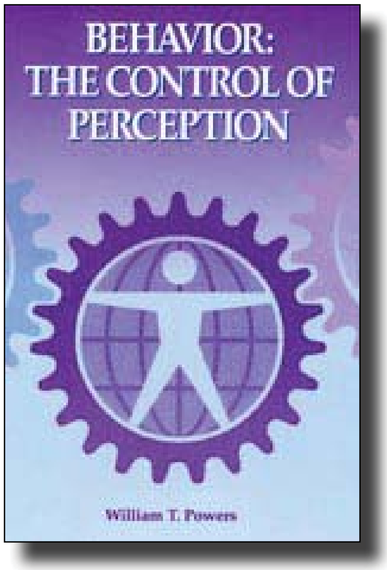
Behavior: The Control of Perception



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By William T. Powers

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Premises

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One man, John Von Neumann, was largely responsible for the two major classes of modern automatic computers, analog computers and digital computers. His first "differential analyzer" was a mechanical contraption that solved simultaneous differential equations with pulleys, cables, levers, and balls rolling on disks. His first "stored program digital computer" was by today's standards also crude. Nevertheless, both inventions have profoundly affected modern engineering and science—and modern theorists.

The Digital-Computer Premise

An unfortunate coincidence caused almost every theorist following Von Neumann to select the *digital* computer as the basic model of nervous-system activity. The coincidence was the fact that nerves behave in an all-or-none fashion: They generate an impulse or they do not, depending on whether the stimulation is above or below a threshold level. The comparison with the binary on-off elements of a digital computer was obvious, and was immediately taken up as the basis for a huge amount of theoretical effort.

McCulloch's (1972) nerve-net analysis was based on this concept; so was Wiener's "stationary time series" analysis in *Cybernetics* (1948). Many others have continued in this tradition, and the mathematical theorems have multiplied and prospered. The main difficulty with such analyses is that they quite regularly require assumptions about the nervous system that are contrary to known fact.

In a typical analysis, activity in a nerve network is described in terms of *time states.* A given nerve cell which receives impulses from several fibers coming from other nerve cells has a *threshold of firing:* If an impulse arrives at the cell in each incoming fiber, there will be a summing (over some short interval) of excitatory effects; the threshold will be exceeded; and the cell will be triggered to produce an impulse. If too few incoming impulses arrive together, the nerve cell receiving them will *not* fire.

A time state refers to a whole set of nerve cells which are receiving multiple impulses at a given moment. Some of the cells will fire and some will not, creating a pattern of *on* cells and *off* cells which is called the state of the neural network at that moment of time (Arbib 1964).

Given the initial time state of *on* and *off* cells, one can then proceed to the next time state, when the impulses generated by the cell firings have reached a new set of cells. Once again, some of these cells will receive enough multiple impulses from different incoming fibers to fire them, and some will not. Thus one can proceed time state by time state to describe the activity of the network of nerves.

The assumption contrary to fact is simply that these time states are synchronized. In real nervous systems, summation effects do occur in each nerve cell that is stimulated by incoming impulses, but the summing occurs at random times owing to variations of conduction speed in various paths. The cells that change state at a given moment may be anywhere within the whole network. Thus there is a basic difference between nerve networks and the computing flip-flops in a digital computer: There is no clock in the nervous system to cause changes of state to occur in neat sequence. Electrical rhythms in the brain that have been observed are far too slow to do the necessary clocking; they are results, not causes, just as the interference caused in radio reception by an operating computer is a result, not a cause, of the program that is running.

Comparison of nerve activity to digital computing elements is not only factually suspect; it is of no practical help in experimental work. The *only* correlations that have been found between nervous-system activity and behavior have been discovered through measurement of

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what I have come to term *neural currents:* the rate at which impulses pass a given point, averaged over just enough time to *erase* the discrete nature of nerve impulses. For these reasons I am not going to accept the digital-computer premise for a theory of nerve activity.

The Analog-Computer Premise

In effect, I am choosing to use Von Neumann's other invention as a conceptual model for nervous system operation: the analog computer. More basically, the choice is for a *continuous* representation over a *discrete* representation, although the concept of quantitative analogs is also of great usefulness. The meaning of this can be illustrated by a comparison of nerve impulses with the discrete charges that carry electric current.

We know now that electric current is not a flow of continuous substance, but the drift of tiny individually charged particles (electrons) through the atomic matrix of a conductor. That was not the initial picture, however, nor is it the concept that is used in modern electronic and electrical engineering (except at levels of current so low that effects of individual charges can be seen). For purely practical reasons, engineers treat electric current as a smoothly variable continuous quantity and ignore what they know to be too detailed a representation of reality for their purposes.

The level of detail one accepts as basic must be consistent with the level of detail in the phenomena to be described in these basic terms. One can always, for other purposes, analyze further. If we wish to describe the activity of the nervous system that correlates with the phenomena of direct experience, and constitutes the inner component of such behaviors as walking, talking, and execution of action patterns in general, then it would be inappropriate to begin with an individual neural impulse. No one neural impulse has any discernible relationship to observations (objective or subjective) of *behavior.* Even if we knew where all neural impulses were at any given instant, the listing of their locations would convey only meaningless detail, like a halftone photograph viewed under a microscope. If we want understanding of relationships, we must keep the level of detail consistent and comprehensible, inside and outside the organism.

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Neural Currents

As the basic measure of nervous-system activity, therefore, I choose to use *neural current,* defined as *the number of impulses passing through a cross section of all parallel redundant fibers in a given bundle per unit time.* The appropriateness of this measure depends on the maximum neural current normally expected to occur in a given bundle of fibers. If the maximum in a bundle of 50 fibers is 200 impulses per second in each fiber, the maximum neural current will be 10,000 impulses per second, and statistical variations will not be important at any level of neural current in proportion to the whole normal range of operation (they will be roughly 1 percent of the maximum, or less).

The use of neural current is appropriate, for example, in considering the stimulation of a whole muscle, especially in terms of the forces thereby developed on the tendons and thus on the bones. The impulses going to the muscle arrive via hundreds of individual pathways, each terminating on one tiny contractile fiber, but the net force developed depends on all these parallel events, not on any one of them. The individual random twitches are averaged out.

The only quantity inside the nervous system that correlates with the net force exerted by, say, the biceps muscle is the neural current obtained by counting all the impulses reaching that muscle per unit time. That is essentially the same as counting the impulses passing a cross section of all the parallel motor-nerve fibers running from the spinal cord to the biceps muscle. I am doing nothing more here than formalizing a measure that is commonly used in neurology and physiology, even if not instrumented with just this definition in mind.

The single-impulse model of neural activity treats the convergence of separate trains of impulses on a single nerve cell by instant-to-instant evaluation of the summation of excitatory effects. The neural-current model handles the same situation in terms of continuous average summation effects. Unlike the time-state analysis, the neural-current analysis handles this summation effect easily whether several small (low repetition rate) signals are converging, or one large (high repetition rate) signal is present. Binary computing elements do not distinguish the rate at which input events occur (in normal operation), and so a digital-computer model cannot handle the common situation

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in which one high-frequency current can cause a nerve cell to fire, while two low-frequency currents cannot. Neural impulses may either increase the tendency of a nerve cell to fire (excitatory effects) or may decrease that tendency (inhibitory effects).

The difference seems to reside in the type of nerve cell in which the impulse originates: *Renshaw cells* are apparently specialized to emit an inhibitory substance at the end of the outgoing impulse-conducting fiber (Wooldridge 1963). Therefore in the summation of neural currents, some currents contribute positively to the net excitation of the receiving nerve cell, while others contribute negatively.

Some connections seem to involve such low thresholds that only a few impulses arriving at once—even just one—can fire the following nerve cell. In a case where two impulses are required, and at relatively low neural currents, the chance of two independently originated impulses arriving nearly enough at the same instant is the *product* of the probabilities of arrival of an impulse in each incoming path per unit time. Thus the neural current generated by the receiving cell is proportional not to the sum of incoming neural currents, but to their product.

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Neural Analog Computers

The nervous system, no matter what kind of computer to which we liken it, does not operate according to the forms we find convenient to express mathematically. At best, mathematical descriptions can only provide a form that is reasonably close to reality. The "summation" of neural currents is only roughly linear—2 + 2 may equal about 4, but 4 + 4 may equal a little less than 7; 7 + 7 may equal 8, and ½ + ½ may equal 0. This nonlinearity means that everything we would like to call "summation" also contains a little of what we would see as "multiplication," and vice versa.

Nevertheless, many other nonlinear systems have been successfully understood on the basis of linear approximations, and if we do not demand great precision, such approximations can be suggestive of interesting arrangements in the nervous system. At least this degree of approximation (if not more) is required to make the digital approach plausible, so the neural-current analysis rests on no shakier premises than the digital analysis.

In the next few pages, the basic elements of a model of neural function will be developed, not as a complete treatment of the continuous-variable approach, but as a sort of existence theorem to justify the general shift from discrete to continuous representation of behavioral variables. (Some reference will be made later in the book to specific computing functions to be described here.)

We begin by laying some conceptual foundations for later discussions, with a simple model of neural conduction. Trains of neural impulses are generated either by a sensory receptor or a nerve cell excited by other neural impulses. These are neural currents which propagate rapidly enough that they may be considered to exist simultaneously over the whole length of a nerve fiber. The impulses travel in the direction from the cell body to synaptic knobs terminating the fiber just a few microns away from the next cell body in the chain. They do not "jump the gap" to the next cell; rather, they act to speed up or slow down the spontaneous repetitive firings of the next cell body. That is a correct picture when the rates of firing are near the middle of the normal range of operation. With *no* input impulses arriving, a cell body will seldom fire spontaneously.

A *large* input neural current results in repetitive release of many tiny quanta of excitatory or inhibitory substance per unit time, having a large effect on the rate at which the following cell body recovers from each firing and fires again, and hence having a large effect on the neural current generated by that receiving cell body. Thus input neural currents have quantitative effects on output neural currents, although there is no one-to-one correspondence required between incoming and outgoing impulses.

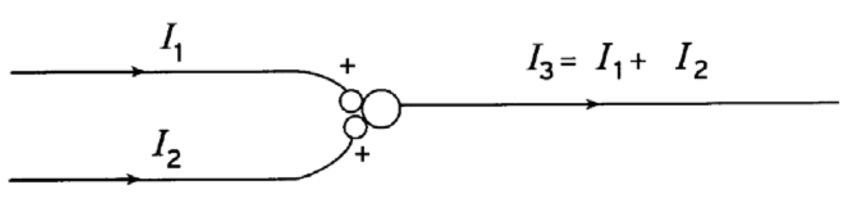

Figure 3.1. Adder

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In the following discussion we will consider a basic array of analog computing functions based on this linear-approximation approach.

Addition of positive neural currents is diagrammed in Figure 3.1. *Open* circles indicate *excitation.* If I is used (as in electricity) to designate current, then $I_3 = I_1 + I_2$. The plus signs emphasize the *excitatory* effects.

Subtraction of neural currents can be indicated by using a blacked-out circle and a minus sign (or either alone) to indicate *inhibition* (see Figure 3.2). This is the general case of algebraic summation: $I_3 = I_i + (-I_2)$ or $I_3 = I_1 - I_2$. If the negative current is equal to or greater than the positive current, the output current I_3 is *zero.* This is the first main difference between neural and electrical currents. All currents are in units of impulses per second, or frequency of firing. A frequency of firing, in impulses per second, cannot go negative—the nervous system cannot "owe" impulses, and we can count only the number that occurs in a unit of time, which must be zero or greater.

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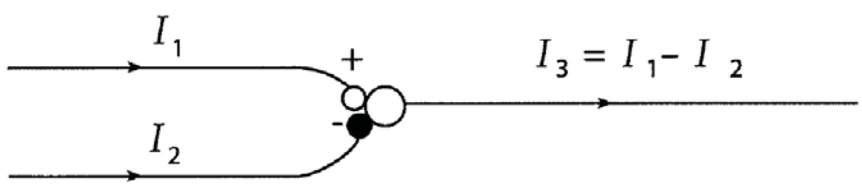

Figure 3.2. Subtractor

The second main difference is in the meaning of positive and negative signs. In electricity all current carriers have the same effects, and sign indicates direction of current flow. In neural current analysis all currents resulting from firing of a neuron flow in one direction only (away from the cell body) and sign indicates *only* excitatory or inhibitory effect.

The third important difference can be seen when a neural current reaches a branch in a nerve fiber. To see what happens we must return to the single-impulse level of analysis. A nerve impulse is an electrochemical breakdown phenomenon. A drastic but highly localized change in the walls of the nerve-fiber tube permits the flow of ions in and out of the fiber, and this sudden flow triggers a similar event in the adjacent section that has not just undergone this change. Thus a wave

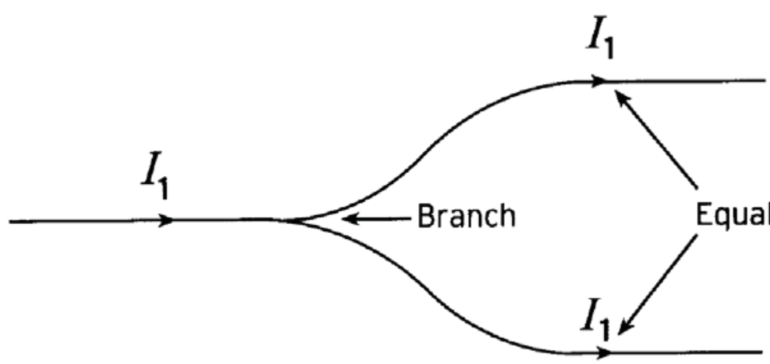

Figure 3.3. Nonconservation of neural current

of chemical activity progresses along the fiber away from the point of origination.

When the disturbance reaches a branch where one fiber splits into two, the breakdown is triggered in *both* arms of the Y, and an impulse travels down *both* branches just as strong as ever. Thus at a divergent branch, each impulse splits into two impulses. The energy that keeps the disturbance going is not derived from the event that originally triggered the impulse, but is continually supplied to the fiber, along its whole length, from the surrounding fluids. *No conservation law is needed.*

This means when a fiber splits, the current is not weakened at all, but is duplicated. This is shown diagrammatically in Figure 3.3. From this nonconservation law can be derived the concept of the weighting of currents. In the simplest case we have an *amplifier* (see Figure 3.4).

The k-way branch duplicates the original current k times; these k copies are then summed at a neural junction, and the current leaving

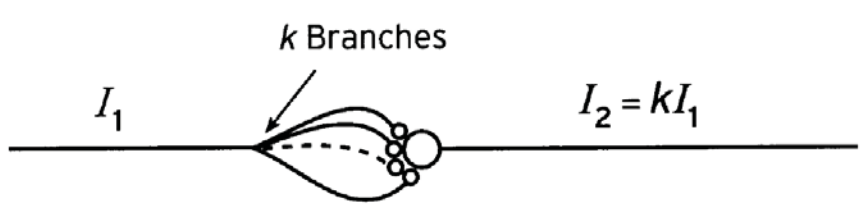

Figure 3.4. Amplifier

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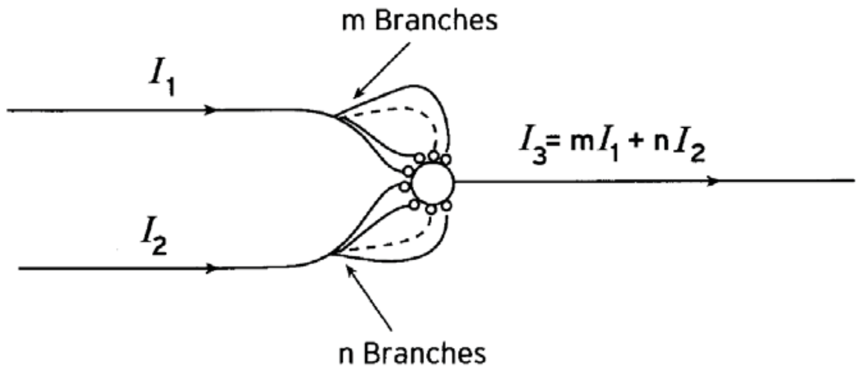

Figure 3.5. Weighted summation

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the following cell is *k* times the magnitude of the incoming current (roughly). Even though the duplicated impulses arrive at the junction at nearly the same time, they can initiate many impulses if the net excitatory effect greatly exceeds the firing threshold. The neural current is thus amplified by a factor of *k*.

Several different neural currents may reach a receiving cell body after each has split into several branches, a very common arrangement throughout the nervous system (see Figure 3.5). In this case the effect of each input current on the output current I_3 depends on the number of branches that form. The relative contribution, or *weight*, of each input current thus depends on the number of branches: $I_3 = \mathrm{m}I_1 + nI_2$. This is a *weighted summation*, which can include negative contributions, a computing function that can have considerable significance. (Note that overall proportionality factors are being left out for simplicity.)

As mentioned, if simultaneous arrival of impulses in two (or more) paths is required to initiate *one* output impulse, especially when recovery time is *very fast* after a firing, the output frequency varies as the *product* of the input frequencies (see Figure 3.6). If one input is inhibitory, we obtain approximate *division* of the excitatory current by the inhibitory current. So far we have all the computing functions required to develop any relationship among neural currents that can be expressed in *algebraic* terms not involving time as a variable.

For time functions we require time integrations and time differentiators. With the addition of these, we will have all the computing

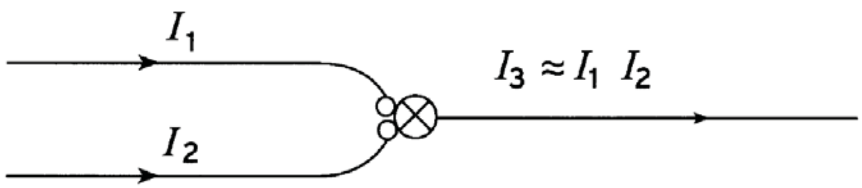

Figure 3.6. Multiplier

functions required to create dynamic relationships over time—in fact, any known continuous analytic function.

The identity of the proposed *time integrator* may be something of a surprise. It has long been assigned an entirely different role. Time integration is accomplished by so-called "reverberating circuits"; that is, closed chains of neural connections.

Imagine a single impulse entering from the left in Figure 3.7, and a receiving cell body with a threshold of less than one impulse—it will fire for *each* incoming impulse in any input path. The second cell is similar. Recalling that impulses *duplicate* at branches in a fiber, it is clear that after the initial impulse from the left, cell 1 and cell 2 will fire alternately, forever, as if a single impulse were racing around and around the closed loop.

Every time cell 2 fires, a duplicate impulse will travel off to the right, and the neural output current I_4 will be equal to the rate at which cell 2

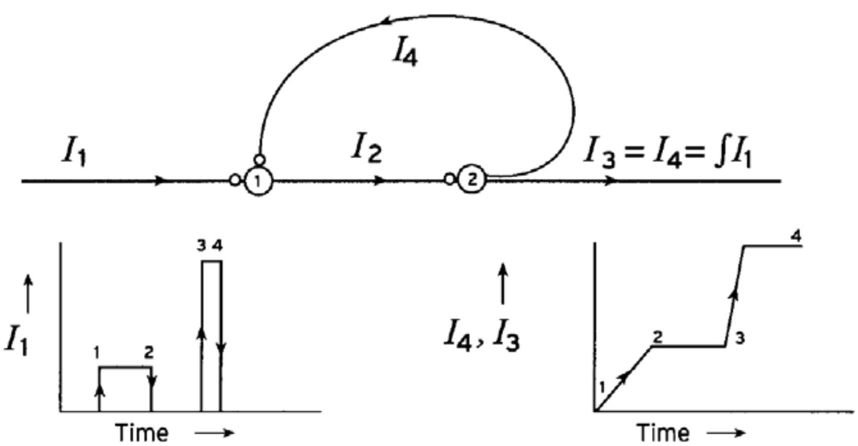

Figure 3.7. Time-integrator

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fires. If the transit time around the loop is $^1/_{10}$ second, the neural current I_4 will have a magnitude of 10 impulses per second.

Assuming that the output current is 10, let a second impulse arrive from the left. Immediately the output jumps to 20, since now *two* impulses make the round trip in every $^1/_{10}$ second. If a succession of five more impulses enter from the left, the output current will increase by 50 more, to 70 impulses per second.

The *rate* at which impulses leave this circuit on the right is equal to 10 times the *total number* of impulses that have entered from the left, regardless of how long they took to arrive. Of course the closed circuit must be long enough to allow the necessary number of impulses to be circulating at once.

This means I_3 is proportional to the time integral of I_1, or to the time integral of the net excitatory signal if several sources contribute inputs of both signs. As with other analog integrators, neural integrators are probably not perfect—an impulse will *not* circulate forever, but has some finite lifetime in the loop. Also, if a circulating impulse arrives back at cell 1 just as a new input impulse arrives, only one impulse can survive. The cell can generate only one impulse at a time. As the number of circulating impulses approaches the capacity of the loop, the input cell will more and more often be firing just as a new input impulse arrives, and accumulation must eventually level off due to such "coincidence losses." The metabolic energy supply that actually drives the impulses can be exhausted, which also limits the lifetime of an impulse.

This integrator will respond to negative (inhibitory) inputs as well as excitatory ones, since a train of inhibitory input impulses will eventually destroy all circulating impulse.

Time differentiation can be accomplished in two quite different ways. One involves *habituation*, a fatigue-like drop in rate of firing of a nerve cell after abrupt appearance of a steady input signal. Many sensory endings, especially the annulospiral sensors in the muscles, respond in this way. When a steady stimulus is applied, the sensory nerve at first generates a large neural current which immediately declines to a much smaller value. If the stimulation is then lessened slightly, the neural current will drop sharply, then rise again somewhat (see Figure 3.8). This kind of response can be represented as a combination of first derivative response and proportional response, though in some cases the

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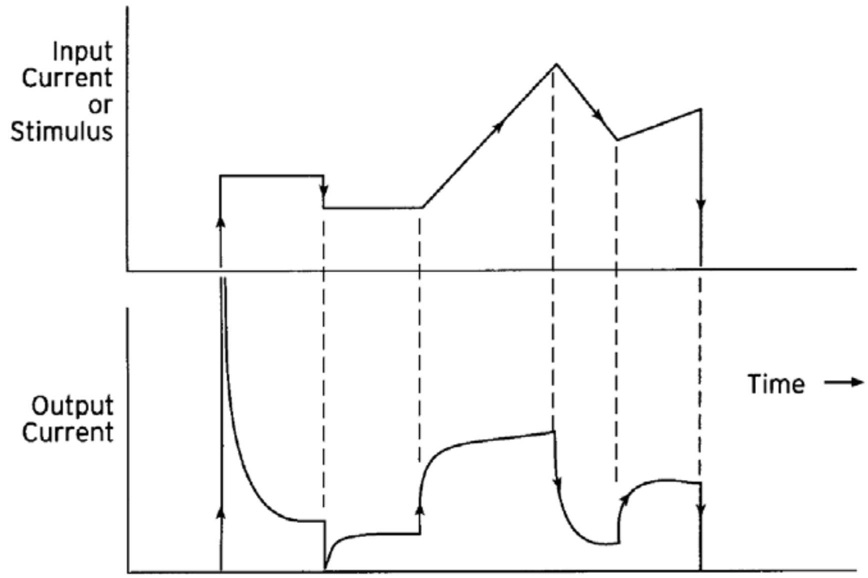

Figure 3.8 Differentiator: Input-output relationships

proportional part is all but missing.

A second way of achieving time differentiation is to connect a neural integrator in a negative feedback loop (see Figure 3.9). The integrator's output inhibits an input amplifier, but the amount of inhibition starts at zero and increases at a rate depending on the output current I_2, so that the output current shows the same response to changes that the habituating sensory ending shows. As drawn in Figure 3.9, of course, this differentiator could be used only once and would not respond properly to a *decrease* in input current. The added design required to make a complete differentiator is left as an exercise for the reader, being fairly obvious.

These components—algebraic summer, amplifier, integrator, and differentiator—together with the multiplying function mentioned earlier are the standard set of building blocks for analog computing. All of these arrangements can be found in the nervous system, but of course the input-output relationships will not be linear as in the idealized model. Nevertheless, these kinds of computing blocks can be interconnected in an endless variety of ways to create any imaginable relationship between an input current and one or more output currents.

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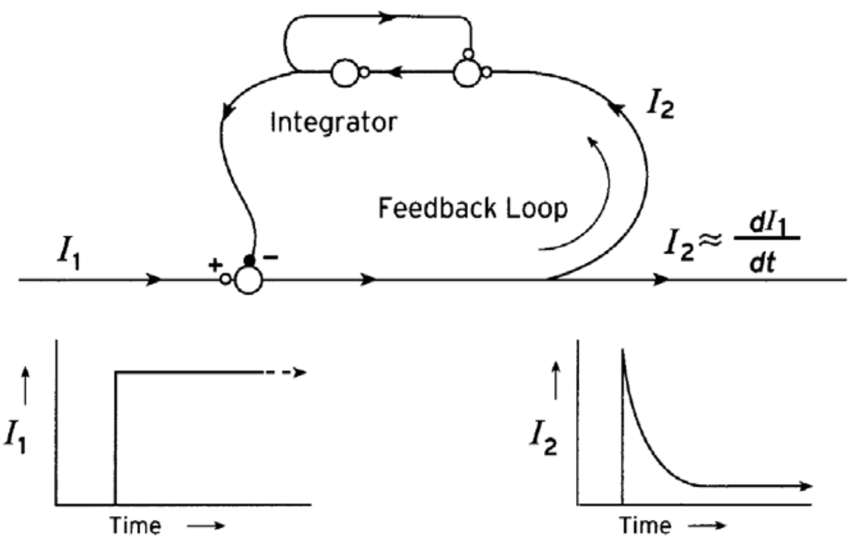

Figure 3.9. Differentiator: Using integrator in feedback loop

There is one last class of computing functions that has to be considered—logical functions. Despite the fact that neural current is a continuous variable, circuits can be constructed that behave like digital on-off devices in exactly the way in which electronic circuits operating with continuous electric currents are in fact built. Some parts of the brain may use logical functions of this type, especially those parts involved in the perception and control of logical propositions.

The simplest logical element that can be built with neurons is the *storage* unit, or flip-flop. If a single cell's output pulses are returned to that cell in enough copies, a large enough input current will start that cell firing, after which it will continue to fire spontaneously at a high speed until a large enough *inhibitory* input current arrives. Thus it can be triggered *on,* after which it will generate a continuous neural current until it is triggered *off.* It can produce no output other than zero or maximum. This is one of the few examples of *positive feedback* in this book (see Figure 3.10).

Given the definition of *one* and *zero* as maximum and zero neural current respectively, and identifying inhibition as the not operator, it is possible to go on from here to design logic circuits functionally identical

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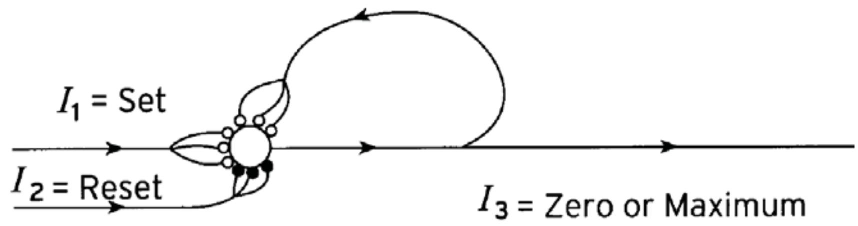

Figure 3.10. Set-reset flip-flop

to those used in digital computers. Since neural currents instead of single impulses are used to represent one and zero, there is no clocking problem to contend with: The logic can be asynchronous. Those who are not already familiar with logic circuitry can find unlimited detail in the literature (for example, Richards 1971). This is a point of interest only, however, since I will not use logic circuits in the model proposed in this book, or for that matter try to set up *any* specific computing designs. A proper investigation of the nervous system will tell us the proper design details by direct measurement of output-input relationships in terms of neural current.

A Premise Concerning Perception

The foregoing discussion of computing functions has been in preparation for a discussion of how we will be dealing with the activities of the nervous system in this book's model. The most important activity to be dealt with is *perception,* which we know consciously as *what is* and *what happens* around us, to us, and inside of us. I am not going to subdivide perception in the way the dictionary suggests, separating sensations and concepts from perception. When I refer to perception, I mean in general the entire set of events, following stimulation, that occurs in the *input* part of the brain, all the way from sensory receptors to the highest centers in the cerebral cortex.

More specifically, *perception is* to be distinguished from *conscious perception.* A perception is occurring if the neural current corresponding to that perception has a magnitude greater than zero. The perception is *conscious* if there is reason to believe that awareness is involved also. Thus we can speak of perception as a brain phenomenon, and

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leave the subject of consciousness for later discussion. Clearly there are often sensory responses going on in nerves with no consciousness of the presence of these signals; for example, consider the pressure sensation from the seat you are in (as of 10 seconds ago). Presence of perceptual neural currents is a necessary prerequisite of conscious perception, but is not sufficient to assure consciousness of that perception. Thus many perceptions may be involved in behavior even though the subject is not always paying attention to them.

A "perception" means a neural current in a single fiber or bundle of redundant fibers which has a magnitude that is related to the magnitudes of some set of primary sensory-nerve stimulations. I suspect, although I cannot prove, that every distinct object of awareness *is* one such neural current. The neurologist Jerzy Konorski (1967) has arrived at essentially the same conclusion for different, and perhaps better, reasons than mine.

A neural current that is a perception I will call a *perceptual signal.* The first perceptual signals to arise in the nervous system are produced by the sensory endings themselves as a direct result of a physical phenomenon just outside the nervous system. A light intensity, a chemical concentration, an influx or outflow of heat, or a mechanical deformation can cause these *first-order* perceptions to arise. If you are aware of these perceptual signals directly, you perceive only *intensity,* for that is all that these single signals can represent—they carry no added information to identify the kind of intensity.

Perceptual signals are continuous functions of something outside the nervous system. Some receptors emphasize rates of change. All of them habituate to some extent so that the zero of the perceptual scale may wander. Nevertheless, an acceptably accurate general statement is that the state of the perceptual signals of first order reflects the state of the immediate environment impinging on the sensory receptors on a continuing basis. It is simply not true that perceptions arise mainly from brief stimuli or changes in stimulation. Look around: *That* is perception. It is always there.

Suppose now that a set of first-order perceptual signals enters a neural computer, a collection of analog computing devices like those we have just discussed. The outputs of these devices will be neural currents that represent weighted sums, differences, or other functions

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of the incoming neural currents. Any one of the output currents is a specific function of the many input currents. As those input currents vary in magnitude, so will the output current vary, in accordance with the relationships defined by the intervening computing devices. If an intervening device performed simple summation of two first-order currents, the output or *second-order* current would remain constant if one first-order current increased while the other decreased by the same amount.

In that example, a second-order current depends on physical events impinging on sensory endings, but not in the same way as the first-order currents depend on the same external phenomena. The second-order current varies according to the sum of two physically distinct effects, and not either one alone. It can remain constant while both of the first-order signals on which it depends change, and hence while both physical effects change. This means a second-order neural current corresponds in magnitude not to any single local physical effect, but to the magnitude of some more general variable—temperature, for example, or pressure—rather than local flow of heat or local mechanical deformation.

It is also true that a second-order perception may correspond to nothing of physical significance. One can see how second-order perceptions might correspond to some physically meaningful attribute of the outer world such as temperature, but that significance depends entirely on the kind of computing functions involved. There is nothing to prevent the nervous system from performing computations leading to second-order perceptual signals that have no external significance. A taste sensation such as the distinctive taste of lemonade results from combining sweet and acid sensory responses, but there is nothing contained in the glass that corresponds to the sum of these sensory responses. The sugar concentration and the acid concentration do not physically add to each other. They are simply in the same general location. Yet the total lemonade taste is just as unitary a perception as is the image of the glass.

We are led by this kind of reasoning to a peculiar concept of perception. The brain may be full of many perceptual signals, but the relationships between those signals and the external reality on which they depend seems utterly arbitrary. At least we have no assurance that any

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given perception has significance outside of a human brain. It could be that none of them have, not even the first-order perceptions. We may strongly suspect that there is a real universe out there, beginning a millimeter outside of our nervous systems, but *our perceptions are not that universe.* They *depend on it,* but the form of that dependence is determined in the brain, by the neural computers which create perceptual signals layer by layer through transformations of one set of neural currents into another.

What might we learn about that external reality by learning more about ourselves? What assumptions have we made about reality that are really no more than limitations of our brains?

A Premise About Brain Organization

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The neural currents (which I will refer to regularly as *signals* from now on) corresponding to perceptions are related to one another by the computing functions that cause one signal to be a function of others.

These computing networks can be called *perceptual functions* and can be represented in a block diagram by a box receiving several signals and emitting one signal. If an actual neural network emits multiple output signals as in Figure 3.11, we will simply consider it to be a collection of functions, one for each output signal, as in Figure 3.12.

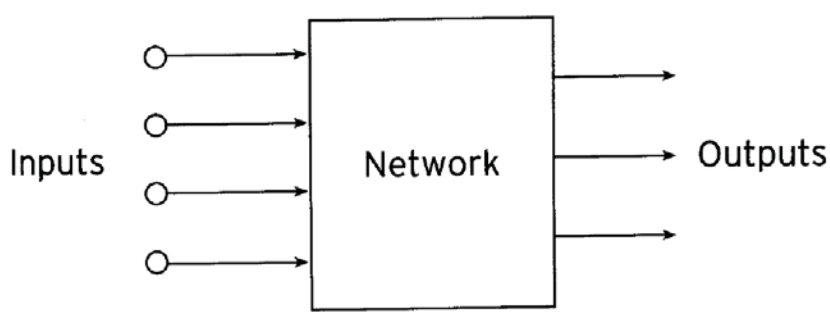

Figure 3.11. Likely organization of neural network

Karl Pribram has recently suggested the possibility that the brain is like a hologram which is a light-interference pattern on film from *any part* of which can be reconstructed the image recorded on the film. A functional block diagram of the brain's organization, however, can remain valid even if it were later to be discovered that each function is a distributed property of the brain and each perception is a pattern of neural currents pervading the brain. Some features of the brain suggest separation of function and localization of perceptions; that is, if the brain is like a hologram, perhaps it is more like a collection of localized holograms. Perhaps, also, the brain is *not* like a hologram.

In the model described here, which is the brain model that is part of the theory to be developed in this book, the basic elements of organization are *neural signals* and *neural functions,* where *functions* is to be taken in the sense of the form of a many-to-one relationship between signals.

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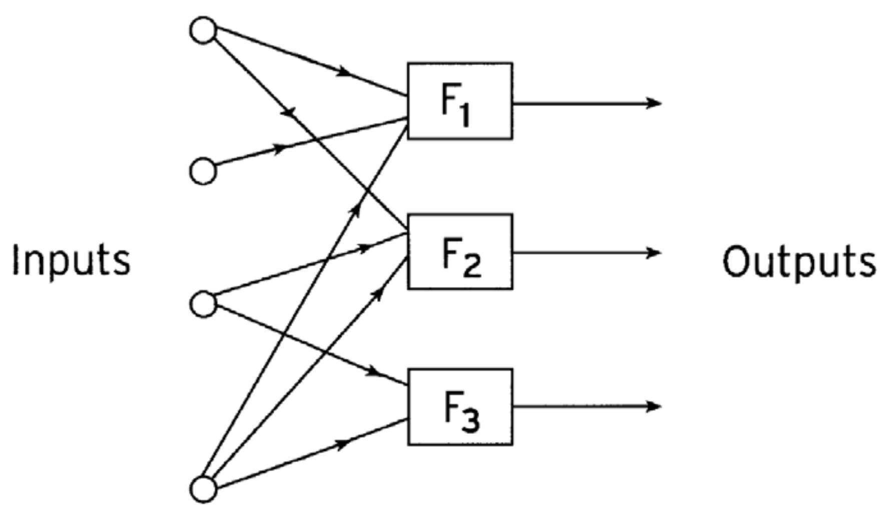

Figure 3.12. Functional representation of neural network (one function per output)

Summary

In the remainder of this book we will adhere to the basic premises given in this chapter, even though no formal use may be made of some of them. We will assume that neither single neurons nor single impulses are significant elements of behavior, taking instead computing functions (neural networks) as the least element of organization, and continuously variable neural currents (in units of impulses per second) as the carriers of information to and from computing functions. The principal purpose of laying out these premises in some detail, even more detail than is really essential, has been to show that there *is* a defensible alternative to the strict digital-computer model of the brain that has been so popular for several decades.

The analog or continuous-variable model provides a way to describe perceptions as the outcome of a process whereby an external state of affairs is continually represented inside the brain as one or more continuous neural signals. These signals—perceptual signals—*are* reality as far as the brain experiences reality, yet are functionally dependent on something else, a supposed external reality, which is not the same thing as experienced reality.

It is convenient to think of the brain as a collection of localized functions, and of neural signals as occurring in definite pathways linking functions together. The model, however, will not be invalidated if these elements prove some day to be distributed over large volumes of the brain. The organizational properties of this model do not depend on its geometrical properties.

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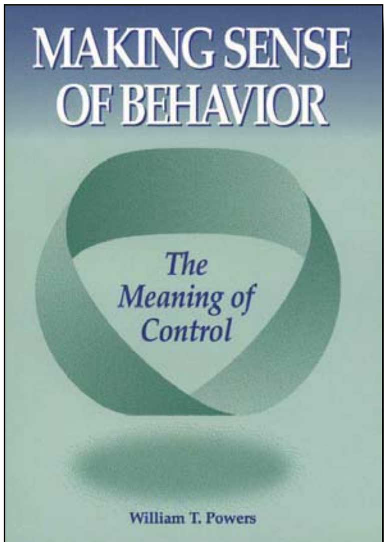
LEADING QUESTIONS: CHAPTER 3

1. How many brief, abrupt stimuli have you experienced in the last ten minutes? Were you aware during that time of any continuous stimuli?
2. How many brief, abrupt responses have you made in the last ten minutes? Have any of your actions been smoothly varying or continuous?
3. When you steer a car around a curve, do you make a steering movement, wait to see the result, make another movement, wait to see the result, and so forth? Or does it seem that the steering motions and their results vary smoothly and continuously during the same time interval?
4. Does a continuous-variable model rule out perception of brief, abrupt events? execution of brief, abrupt responses? instantaneous responses?

Making Sense of Behavior:
The Meaning of Control



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By William T. Powers

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Chapter 2

Perceptual Control

In which we see that behavior is the process by which we act on the world to control perceptions that matter to us

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Perceptual Control

Perception plays a central role in controlling. This is why the theory behind this book is called Perceptual Control Theory, or PCT. The emphasis in PCT is not only to understand control from an outside observer's point of view, as in engineering control theory, but to grasp how control appears to the controller—that is, to you and me, who occupy our own copies of this marvelous mechanism and participate in running it. Taking this point of view gives us a new slant on perception. But first, let's look at the most usual concept of perception, one that has caused many difficulties.

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The External View of Perception

When we look at another person, we can see that person's body movements and the effects of those movements on the person and the environment. But we can't see the other person's perceptions. From neurology we know that there are sensory receptors in the person's eyes, skin, ears, joints, muscles, viscera, and mucous membranes, and that each tiny sensory ending generates nerve signals when the environment stimulates it. These nerve signals converge into the lower parts of the brain, where they give rise to more neural signals in a series of steps going upward through the brain to the highest levels. Logically, we know that all of human experience must be carried by these signals, these perceptual signals, including the experiences that are occurring right now as we read these words. So from this external point of view, it seems there is a physical body and a physical environment, with the other person's perceptions of those things existing invisibly inside the other person's brain.

This point of view is useful for constructing models of behavior and of the brain's functions. We use such models, as far as we can construct them with today's knowledge, in PCT, as many others use them in constructing and testing other theories about the brain and behavior. When using these models we treat the nerve-signals in the brain as representing things outside the brain; intensities, shapes, movements, events, relationships, and much more. Psychology itself began with "psychophysics," an attempt to find relationships between physical measures of the outside world and the subjective experiences we have of that world (which we would now identify with the neural processes in the brain that represent the outside world).

When we try to transfer this picture of perception to ourselves, however, we are led straight into an intellectual error. Since you probably have at least one of your hands readily available, we can use it to illustrate the problem.

Look at your hand. There it is, with fingers and skin and wrinkles. You can wiggle the fingers, turn the hand palm up and palm down, make a fist. As you do these things, you are, of course perceiving that they are happening. So you can see your hand and what it is doing—but where is the *perception* of your hand? If you take the externalized neurological point of view, you will say that the perception of the hand must be somewhere inside you, behind your eyes and nose, under your hair, and above your neck: in your head.

Unfortunately, it's hard to see those perceptions because you can't see inside your head any more than you can see inside

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someone else's head. You know, intellectually, that those nerve-signals must be there because you can't be the only person in the world who has no brain. Seeing how perception works in other people—and there is lots of neurological evidence to show that perception does depend on nerve signals in all human beings—you have to admit that it probably works the same way in you. But for you, or me, or anyone else, that knowledge is strictly theoretical. We have no direct way to check it out.

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I hope I have succeeded in diverting your attention away from your hand for a moment, and that you've been enticed into trying to imagine those ghostly perceptions inside your own head. If you've been doing that, your hand, the real hand you were looking at before, may have receded into the background. You're not trying to understand the hand, but your own inner perception of it, in that place inside your head where you have to feel your way as through a darkened room. A lot of people have felt their way through that darkened room in search of perception.

The Internal View of Perception

If you will attend once again to that hand, you may notice that we have been ignoring a problem. If you can't see your perceptions, but you *can* see your hand, how do you know there is a hand there? I mean literally *how?* When you looked into your own head, where all those neural signals are supposed to be, you didn't see any signals *or* any hand. But when you look at the hand, there it is. You must have some way of knowing about the hand directly, that doesn't depend on neural signals! If you agree that this is true, you will be in good company; even some scientists believe that we can have knowledge of things outside us without having to rely on neural signals. This, of course, is a great mystery because when we study other people, they seem to depend entirely on the presence of neural signals to perceive things outside them. If a person's optic nerve ceases to function for any reason, that person becomes blind. That person can't hold up a hand and see its skin, fingernails, and wrinkles without using neural signals. But apparently, we can. That is extremely odd.

It is so odd, in fact, that we have to conclude that it's wrong. *What's* wrong? The idea that we can know about anything outside us without the aid of neural signals. Therefore, let's just accept that even our own perception works the way it seems to work when neurologists poke around inside people's brains: no neural signals, no perceptions. That leaves us only one explanation of how you know that hand is out there.

The hand you're looking at has to be made of neural signals. There's no other explanation that works. What you're experiencing is not the object outside of you, but a set of neural signals representing something outside of you. You don't need to look inside your head to find perceptions: *When you look at your hand, you're already looking at them.* You're directly experiencing the signals in your brain that represent the world outside you. There is no second way to know about the skin, the wrinkles, the fingernails, the palm, and so on. There is only one way, through neural signals, and you're looking right at them.

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From inside yourself, the only place you can be, you have a unique view of your own perceptions that *nobody else in the world can have*. The way these signals appear to human awareness is not as a set of neural signals, blips travelling around in the brain. They appear simply as the way the world looks to you. When a neurosurgeon sticks a probe into your informed-consented brain, he sees only a voltage or a series of blips on an oscilloscope or strip chart; that is how perceptual signals look to an electronic device. But to you, the aware entity in your brain, the very same brain activities look like a hand, an arm supporting the hand, a glass being held by the hand, a room, a world, a universe.

Vision provides a great many perceptions, but let's not forget all the others: touch, smell, hearing, and many more. When that image of your hand moves close enough to an image of another object, you suddenly feel a touch: that's a neural signal, too. When you make the hand squeeze into a fist, you experience the pressure on the skin, the efforts in the muscles of the forearm, the coolness or warmth of your fingertips against your palm. More neural signals. When the hand grasps a glass of water, you feel the contact, the shape, the temperature of the glass. When you lift the glass, you can see the motion, and also feel the changing angles of your joints at shoulder, elbow, and wrist. When you drink the water, you can feel the rim of the glass against your lips, the flow of water over your tongue, the efforts of swallowing and the sensations of water exiting from the world of neural sensations into (you presume) your stomach. You can hear the clink as you set the glass back onto the table. All these experiences are your awareness of neural signals.

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When others watch you take a drink of water, they think they're seeing what you're doing. But they see the backs of your fingers curled around the glass, which you don't see; they see the glass tilt away from them toward your mouth, but you see only its rim tilting toward you. They experience nothing of the smoothness, hardness, weight, or temperature of the glass, or how the rim tastes. They see your throat working, but experience nothing of the water in your mouth or the swallowing efforts or the sensations of liquid going down the tube. Most of the experiences you are having are invisible to them; most of what they see happening is invisible to you.

Whenever anyone watches another person behaving, most of what that other person is experiencing goes unobserved. *What little is observed is observed from the wrong point of view.* We come closest to understanding what another person is doing when we try to imagine doing the same things ourselves; when we try to put ourselves inside the other's skin, seeing through the other's eyes, feeling and hearing and tasting with the other's senses. Then we can bring our own experiences to the understanding, and realize that more is going on than the outside observer can possibly see.

Perception, for any one person, is simply the world of experience. This world appears to be partly in a place we call "outside," and partly in a place we call "inside"—that is, inside our own bodies, although still outside the place from which we observe. And, to get to the point, when we *control* something, what we control, necessarily, is one or more of the perceptions

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that make up this world of experience. Our only view of the real world is our view of the neural signals that represent it, inside our own brains. When we act to make a perception change toward a more desirable state—when we make the perception of the glass change from "on the table" to "near the mouth"—we have no direct knowledge of what we are doing to the reality that is the origin of our neural signals; we know only the final result, how the result looks, feels, smells, sounds, tastes, and so forth.

This is why we say in PCT that behavior is the process by which we control our own perceptions. This doesn't mean that we change a perception of an orange into a perception of a bird; it means only that we act on the world to change where the orange is, whether it is in one piece or in slices, whether it is round or squashed, and so on. It means that we produce actions that alter the world of perception, and that we do so specifically to make the state of that world conform to the reference conditions we ourselves have chosen (to the extent we can change the perceptions by our actions).

Since the world we experience is the world of perception, it usually makes little difference whether we say we're controlling perceptions or controlling the state of the real world. It does, however, make a difference when we try to explain behavior in terms of some physical model of a behaving system. When we do that, we have to stand with one foot in each viewpoint; we construct an objective model as if our own perceptions were exactly the world as it exists, including physics, chemistry,

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physiology, and neurology. In doing so we explain how it is that another person can be controlling as we observe controlling to occur, using a brain organized as we think it's organized. At the same time, knowing that all experience is experience of neural signals, we are explaining how *we* can control things, and why controlling seems to us the way it seems, and how we can be making up models and theories about controlling.

Half of the jokes in the world are about one person assuming that everyone else sees the world the same way. The husband hangs his new moosehead over the fireplace in the living room and says to his aghast wife, "There, doesn't that look *great?*" The other half of the jokes are about people who are unable to see what everyone else (supposedly) can see—that the wife looking at the moosehead is trying to remember the phone number of her lawyer.

The two problems go together: the problem of reaching agreement with each other about reality, and the problem that all perception is fundamentally private. If our perceptions were not private, we would never disagree with each other about the world and its meanings. If they were not, somehow, similar, we wouldn't be able to tell jokes or communicate about anything. It is, of course, possible that our perceptions are both private and similar. We are all constructed more or less alike, so even if each of us independently develops a system of perceptions of our own, the chances are that what we end up with will not be too radically different from other systems of perception at least in terms of simple matters like light and dark, sweet and salty. But

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even if we can count on some similarities between perceiving people, we will always remain uncertain about the relationship between human perception in general and the real nature of the world outside us.

I won't pretend that these puzzles about perception and point of view are completely solved by the propositions put forth here. All of this is just my best try at bringing consistency into the study of both publicly observable behavior and private experience. Using the external point of view, we can make objective models that, on a computer, will reproduce some simple forms of human behavior with great precision. Using the internal point of view, we can understand many aspects of behavior by seeing control as control of perception rather than of an objective world. We can make sense not only of other people's behavior, but of our own, using the same concept of perceptual control.

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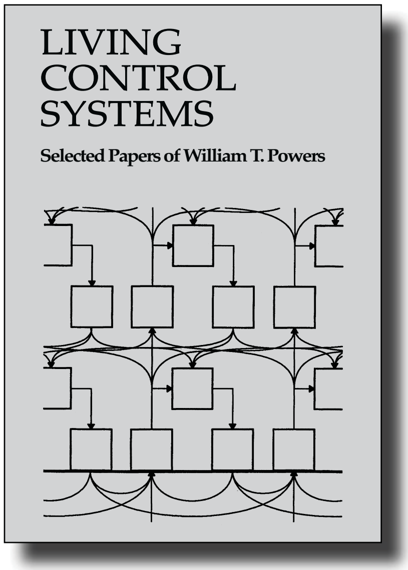
Living Control Systems

Selected Papers of William T. Powers



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By William T. Powers

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[1976]

The Cybernetic Revolution in Psychology

The picture of a cybernetic model of an organism which I will present in this essay represents what has condensed out of an amorphous cloud which has floated over the United States, Italy, Russia, and England, continuously changing shape but always seeming to gather itself into a more and more definite form. While much is still indefinite, the fundamental principles of a new concept of human and animal nature are now clear. They have nothing to do with automation, man-machine relationships, the study of vast social systems, or the creation of a cybernetically planned political system; some cyberneticists will be as disappointed by that as some psychologists will be relieved. Instead, these principles seem to point in the direction of individual autonomy and freedom, and a level of individual responsibility some might find daunting. I will not pursue such conclusions, however. The main aim here is to present, as dearly as possible, a set of ideas which are likely to cause some of the most fundamental assumptions of behavioral science to be discarded.

Background

Cybernetics began when Norbert Wiener[1] and his associates saw the parallels between the organization of automatic control systems and certain neuromuscular organizations in living systems. This occurred in the middle of a technological explosion and a war, so perhaps it was inevitable that the accent lay on the technology rather than the living systems[2]. Wiener himself became very concerned with the impact of automation on society, and spent the rest of his life trying to warn us of the consequences of mishandling that technology.[3] Other cyberneticists followed other trails,[4] but most of them seemed bent on reducing human behavior to a technological model of one sort or another. Many of those trails, I believe, were false. The search for general theorems concerning the properties of social and man-machine systems, the efforts put into applications of information theory and digital computer models,[5] and the attempts to find sequential-state neural models that would reproduce behavior[6] were all, I believe, off the main track onto which Wiener, knowingly or unknowingly, set us. Some admirable talent went into these efforts, but despite them cybernetics has not yet lived up to its original promise of providing a dramatic new understanding of human nature.

There are several reasons for that temporary failure. In my opinion, the primary reason was that the leaders of the cybernetic movement either were or tended to become involved in a search for the most general possible mathematical theorems, general enough so that any conceivable human action or interaction could be treated as a special case. As a result, the pursuit of complexity postponed the understanding of *simple* relationships[7]. Not many who led that movement had ever designed and built a control system, or cursed and sweated to make it work properly, or experienced any extended personal interactions with a working control system; the interactions tended far more to be between cyberneticist and block diagram.

There is a world of education in the simple experience of pushing on a control system and feeling its firm and instantaneous resistance to the push; it literally feels alive. It feels the way a human organism feels when you push on it. It pushes back. The explanation for this behavior is not that human organisms are really nothing but soft technological machines, but that servomechanisms were modelled after human behavior in the first place. The engineers who were designing devices to take over tasks formerly requiring a human operator

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would have been insulted to be told they were psychologists, but as they studied what a person had to do in order to carry out a control task, and boiled those requirements down to the basic working components of a control system, they were modelling human organization just as certainly as if they had intended to do so.

The concepts behind control theory, developed during the 1930s, could not have been discovered by the psychology of the 1930s, because scientific psychology was then convinced that no physical system could have the properties a control system has. The phenomena to be seen in control behavior involve subjective perception, goal-selection, and intentions; psychology had been engaged for some thirty years in reaching a consensus that such notions were metaphysical and had no place in science. Thus, American and other psychologists were busy explaining away the very properties of life which control engineers, living in a different universe, were discovering to be essential in any control organization. That is why control theory had to enter through the back door, out of electronics, through Wiener, and thenceforth via a few mavericks who could call themselves less psychologist than engineer. That is why I am writing here about the earliest and simplest of the cybernetic notions, the notion that organisms act as control systems. It is time this idea got into psychology without being so distorted as to preserve basic assumptions which are really totally incompatible with it.

In order to say anything about the cybernetic analysis of human behavior, it is necessary to have a model of what a human being *is*. I say that human beings are self-reorganizing hierarchies of negative feedback control systems. Now that we have seen how little a string of words can mean, I hope it is obvious that before getting to the subject I have to begin by talking about what a control system is. Before I can talk about what it is I have to define what it does.

What a Control System Does

A control system controls some physical variable, or some function of a set of physical variables, *outside itself*. That state-

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ment leads another step into detail: what does "control" mean in the context of interest here?

The central concept that has to be defined is *controlled quantity* or *controlled variable.* I prefer "quantity" to remind us that control is always quantitative. What is there about a quantity that distinguishes it from other quantities and makes it become a controlled quantity?

The distinction can only be made in terms of a behaving system that senses and affects that quantity. The sensing part comes from control theory, which shows that no system can control anything except what it can sense; we do not need that part of control theory however, to identify controlled quan-tities in a clear way that has experimental significance.

Let us talk about controlled quantities, actions, and disturbances. An action is something a behaving system—an organism—does to its surroundings, in a way that depends entirely on the organism's activities and is not subject to direct external interference. A disturbance is a physical quantity in the environment that can be caused to take on any value, without regard to the action. A controlled quantity then belongs to the class of all quantities that are *jointly* affected by the action and by the disturbance.

Generally when the effects of an action and of disturbances converge on some physical quantity in the environment, that physical quantity will be caused to change in some way, but there will be no regular kind of change, save accidentally, since action and disturbance have no common cause. A controlled quantity, however, is an exception. We say that a jointly affected quantity is a controlled quantity if and only if for every magnitude and direction of effect a disturbance has on it, an action has an equal and opposite effect, with the result that the controlled quantity does not change.

This formal definition can be translated into laboratory methods for discovering human control systems and then evaluating their properties; I will get into that later. But it can be put much more simply. A quantity is controlled if, when one attempts to alter its state by pushing on it or otherwise performing acts that should physically influence it, something else pushes back and keeps it from changing. If one is satisfied that the quantity would have changed as a result of the push

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if only the pushing-back had not occurred, a control system has been discovered even if one does not yet know where it is. Any behaving system that can create this result consistently (when trivial explanations are ruled out) is a control system; that is what we mean by a control system, and why we have built so many of them. Control systems are capable of stabilizing aspects of their surroundings against disturbances of any kind, predictable or unpredictable, familiar or novel.

Control phenomena are difficult to explain in terms of any traditional cause-effect model. Suppose one controlled quantity proved to be the amount of food delivered into a food-tray and ingested daily by a rat. This would mean that any change in the environment of the rat tending to alter the amount of food delivered and ingested would be countered by an alteration in the actions of the rat which kept the amount of food delivered and ingested, per day, from changing. If we believe, as most scientific psychologists have believed, that behavior is caused by stimuli impinging on the sense-organs of animals, we must somehow find a stimulus which not only affects the sense-organs to create very precisely defined and quantitatively determined changes in actions, but continues to do so despite continuous alterations in the rat's position, and produces just the change of behavior at all times that will cancel the effects of the disturbance. If the disturbance changes, the stimuli have to change and affect behavior in just the way that will leave the joint consequence of action and disturbance, the daily food intake, undisturbed.

It would be easy to explain this strange matching of behavior to disturbance, and the stranger constancy of the consequence, if we were allowed to say that the rat wants to eat a certain amount every day, and simply does whatever it has to do in order to get that amount of food. That's the simple-minded, common-sense explanation, but it was specifically rejected by scientific psychology. In scientific psychology, there is no way to translate terms like "want" or "in order to" into terms of the deterministic cause-effect model that has always been accepted.

As a result scientific psychologists have had to find *other* explanations, or else, like B.F. Skinner, give up finding explanations altogether and claim just to record the facts.[8] Those

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other explanations have become extremely involved creating a cancerous growth of jargon as a result and little agreement among factions. It is very difficult to handle control phemomena without using the common-sense model, for the simple reason that the common-sense model has been the right one all along, and the others based on simple determinism are wrong. It takes a great many words to make a wrong model seem to be the right one.

A somewhat more precise way to state the common-sense model is to say that organisms control what they sense relative to internally specified reference levels. Controlled quantities and their relationship to actions and disturbances are the externally observable parts of a control process, the rest of it happening inside the system doing the controlling. We can thank those non-psychologists, the control engineers of the 1930s, for having discovered the kind of internal organization a system must have in order to create these external appearances.

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How a Control System Works

It is astonishing how little difference there is between a control-system model of an organism and the old stimulus-response model. Only two relatively minor modifications have to be made, for a stimulus-response organism to become a control system.

First, the concept of a stimulus has to be broadened to include something more than instantaneous events. Most sensory stimuli, after all, are continuous variables that always have *some* magnitude, and while sensory nerves show some hypersensitivity to rate of change, they are far from insensitive to steady values of stimulation.[9] So we must think of stimuli as continuous variables, not just pokes and jabs. Of course responses, too, have to be generalized to include continuous outputs.

The other change seems even more innocuous. Instead of assuming that a behavioral output goes to zero only when the stimulus input goes to zero, we will treat that as a special case of a more general input-output relationship: the output action is a function of the input stimulus, but goes to zero when that stimulus is at some particular value we can call the *reference level.* In many cases this has no more effect than re-defining the zero-point of the physical scale of measurement of the stimulus. The old model says in effect that an organism will do nothing if it is not stimulated to act. The control model says that the organism will do nothing if the stimulus input matches some particular reference level of input. That may hardly seem worth writing a paper about, much less calling it the basis for a revolution, but we shall see.

Cybernetics has nothing on psychology when it comes to recognizing feedback phenomena. John Dewey, in 1896, was preaching (to deaf ears, unfortunately) that the reflex arc could not be divided into causes and effects because it was a closed loop.[10] Many other psychologists, especially Thorndike in the early days,[11] recognized that behavior has effects on the organism itself—on what it is sensing and on its physiological state. In fact these ideas led to several stimulus-reduction or drive-reduction theories, which logically concluded that behavior tended to reduce stimulation, and hence that organisms always tended toward the state of total lack of stimulation.

That quite logical conclusion didn't hold up, because organisms do not always seek zero stimulation. A lizard moving from the shade into the sun refutes stimulus-reduction theory. But that theory is really a control-system theory; its only fault is that it assumes reference levels always to be set to zero.

When we recognize that a reference level can have any value, zero being only one example, we can immediately generalize from stimulus-reduction theory to stimulus *control* theory; i.e., to control-system theory itself. Organisms tend to bring stimulation not to zero but to specific reference levels. How they do this, once the basic requirement is understood, is not hard to see.

The reference level represents some kind of bias in the perceptual process. Let us start with that bias set to zero, and see how action and disturbance would relate to a controlled quantity that was also a stimulus input to the organism. If we start with the stimulus input at zero, there will be no action. Now we introduce a very small constant disturbance acting on the controlled quantity to raise the level of stimulus input slight-

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ly above zero. This small input causes some amount of output, the exact amount depending on the sensitivity of the organism to small steady stimuli. The continuous output, the action, affects the controlled quantity and hence the stimulus, and the feedback loop is dosed.

If the effect is to *further increase* the stimulus, the feedback is positive, and if the organism is at all sensitive this will lead instantly to a runaway condition; the small increase of stimulus due to the action *aids* the effect of the disturbance, making the net stimulus larger and leading to a still greater effect of action on the stimulus. Only if the organism has a very low sensitivity to stimuli will this system not run violently to its limit of output. There are few examples of positive feedback in behavior.

If the feedback is negative, the output will be designed to affect the stimulus in the direction that makes it *smaller.* If the organism is highly sensitive to small steady stimuli, only a very small amount of stimulus will be needed to produce enough action to cancel most of the effect of the disturbance. As the disturbance is made larger and larger, the stimulus grows and grows, but since it therefore produces more and more action opposing the disturbance, it does not grow very much. If the organism were highly sensitive to stimuli (and a few other design details were properly taken care of), this system would effectively cancel the influence of any disturbance on the stimulus input; that input would be actively held at zero. The action would continuously and precisely balance out the effects of the disturbance. In real control systems this condition of exact balance is very closely approximated, and all but the poorest control systems can be treated for most purposes as if they were ideal.

Now let us change the bias on the perceptual apparatus, which is to say we will set the reference level at a non-zero value. A non-zero level of input will *look* to the system like zero input.

We begin as before with the stimulus input at the reference level: that now means there is some finite level of stimulation, but the output is zero because the bias just cancels that amount of stimulation. Introducing a steady disturbance that tends to *increase* the stimulation, we find exactly the same situation as

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before except that the effective stimulus is now not the actual stimulus magnitude, but the excess over the reference level. A steady disturbance tending to increase the amount of stimulus above the reference level will, as before (for negative feedback), result in a steady degree of action that cancels most of the effect of the disturbance; the stimulus rises slightly above the reference level, but the more sensitive the organism is to what we will now call error, the less will be the change in the stimulus needed to bring about a properly opposing output.

Previously we could consider only one sign of disturbance and of output action, since there could be neither less than zero stimulation nor less than zero output. Now that the reference level is moved away from zero, we can have disturbances tending to *decrease* the stimulation. A suitably constructed system would then produce the opposite sign of output, as the stimulus fell *below* the reference level (because of a disturbance or spontaneously) and the opposite sign of error was created. As before, if the system were sensitive enough, only a very small fall would generate all the output needed to cancel most of the effect of the disturbance.

Now we have a model in which a stimulus input is actively held at a particular reference level, different from zero, despite disturbances that tend *either to increase or to decrease it. We* have, in fact, a complete control system that will behave exactly in the way needed to satisfy the definition of external controlled quantities. The stimulus, or whatever physical measure we use to define it, will prove to be a continuously controlled quantity.

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Reference Levels and Intentions

The reference level of the stimulus input is determined by the bias that exists in the perceptual processes inside the organism. It is *not* determined by the stimulus but by the organism. A given amount of the controlled quantity might lead to behavior that tends to increase the controlled quantity, or to decrease it, or to do nothing to it; which will happen depends entirely on the amount of perceptual bias, the setting of the reference level.

The reference level in a given control situation is a property of the organism, not of the environment; it is the organism's perceptions that are biased, not the physical variables outside it. That bias determines whether a given stimulus input will be treated as *not enough, too much,* or *just right.* Therefore this perceptual bias or reference level specifies the amount of stimulus input which the behavior of the organism will create and maintain despite all normal disturbances.

A strong, fast and highly error-sensitive control system does not "correct errors" or "seek goals." Being designed to work properly in an environment where some maximum amount of disturbance is possible, and where disturbances are expected to vary in magnitude no faster than some maximum speed, a good control system never permits the controlled quantity to stray significantly from its reference level. Its actions always provide whatever forces are needed to maintain the controlled quantity at the reference level, and whatever further increases or decreases of forces are needed to oppose the effects of disturbances. The only time we see a good control system correcting an error or seeking a goal is just after it has been turned on, or just after the termination of some disturbance larger and faster than it can cope with.

An accurate way to describe an organism acting as a good control system is to say that it *carries out intentions.* This common-sense term, intention, reflects an intuitive understanding of reference levels, although a confused understanding of what they pertain to. Whatever is being controlled, there is an intended state relative to which that control takes place. We have seen that this state is determined by a perceptual bias that defines the "just-right" state; hence what is intended is not an action or an objective external consequence of actions, as common usage suggests, but the state of a perception.

Perception and Control

In the course of simply living our lives, we human beings do not constantly refer to philosophical reflections about the nature of reality: there is a world of appearances and we learn

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to deal with it. When we speak of an intention, such as the intention to go to Kansas City, we imagine some future state of the external world, some objective state of affairs with a little picture of ourselves in it. In imagination we can take any point of view we like, and call it past, present, or future.

When it comes time to carry out that intention, however, we must always work in terms of present-time perceptions, and even if we continue to project those perceptions into a real objective world, all we can actually control are the perceptions: we will or we will not perceive ourselves to be in the place we perceive as Kansas City. If there are errors—if we get the uneasy feeling that this looks *like* St. Louis—we can only base our actions on the difference between what we are perceiving and what we *intend* to *be* perceiving. It makes no difference whether our perceptions are exact copies of reality or transformations of a reality with utterly different dimensions; it is always the perception, not the reality, we must control, here and now.

All control, artificial or natural, is organized around a representation of the external state of affairs. If that representation is created in a consistent and quantitatively stable way, controlling the representation to keep it in a particular state will, presumably, entail actions that bring the external state of affairs to some corresponding state. As it were, we reach around behind our perceptions and manipulate whatever it is that is causing them until the perceptions look just right, in precisely the way one reaches behind an alarm dock and adjusts the alarm pointer until he sees it in the right position. If physics has taught us anything in the past three hundred years, it ought to be that we do not experience the actual effects of our actions in the physical world; we experience only their perceptual consequences, those capable of being represented in human nervous systems. Most of what goes on out there connecting action to perception is not experienced at all. When we reach around behind the alarm dock we *feel* the knob and the turning efforts, and we *see* the pointer move, but most of us have no accurate knowledge of how the feeling causes the seeing, inside the dock's case.

The object of behavior, therefore, is always the control of perceptions relative to reference levels.

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Variable Reference Levels

Good control systems never allow perceptions to stray far from their reference levels: if that is the case, how can there ever be *dynamic* controlled perceptions? There are really two answers to this question; we will postpone the answer having to do with types of perceptions.

One important way in which controlled perceptions can be caused to change is for the reference level to change. The bias-point of the perceptual system determines the level of the perception that is just right—that calls for no *action—and* thereby defines the state toward which all actions will force the perception via effects in the external world. If that bias changes, what was formerly the "just-right" condition of the perception will become "too little" or "too much," depending on whether the bias increased or decreased. If the perception is now "too little," the negative error will result in actions that increase the level of the perception; if "too much," the positive error will drive actions that decrease the level of the perception. In a good control system only a small error is required to produce a large change in output, and it doesn't matter what caused the error—an external disturbance or an internal change in reference level. The perception will be kept at the reference level, and now we see that this means the perception will *track* a *changing* reference level.

We can begin to see how a hierarchical control model is constructed. If we associate one subsystem with each kind of controlled quantity, we can see that anything capable of varying the perceptual bias of a subsystem will vary the reference level for the controlled quantity of that subsystem. The subsystem will cause the controlled quantity to track the varying reference level, so in effect whatever can vary the perceptual bias can alter the state of the controlled quantity, the control subsystem providing the action and taking care of disturbances all by itself. The command that alters the perceptual bias does not tell the subsystem what actions to perform; rather, it tells the subsystem how much of its perception it is to create. The action will correlate with the command only in a constant environment. When varying disturbances are present, the major part of the action will be directed so as to oppose the errors

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which the disturbances would otherwise cause, and there may well be no discernible correlation between command and action. The command, in effect, specifies a perception, not an action.

Higher centers in the brain do not command lower systems to create certain behavior patterns, but certain patterns of perception.

Types of Controlled Quantities

In order for an aspect of the environment to become a controlled quantity, it is necessary for a control system to exist which can sense the current state of that quantity and by taking action affect that state. The causes of changes in the controlled quantity, extraneous disturbances, do not have to be sensed directly; only their effects have to be sensed, and those effects are already taken care of by the fact that the control system operates on the basis of error, and acts directly on the controlled quantity to oppose error.

The phrase "aspect of the environment" does not, as one might at first suppose, refer to some objective property of the external world; it refers to perceptual processes. In any given environment, there is an infinity of different quantities that might be controlled. What they are depends, of course, on the raw material from which perceptions are constructed, stimulation from outside, but it depends even more crucially on how a given perceptual system combines the lowest-level sensory signals into higher-order variables.

There is no need to think of all controlled quantities as simple physical variables: force, angle, position. Human beings are equipped to perceive not only such elementary variables, but highly complex functions of such variables.[12] For instance, one can perceive not only the position of a passing automobile, but the rate of change of position, which we name speed. One can perceive, at every moment, the speed of a pendulum of a dock, but perceivable at the same time are higher-order variables that are functions of speed and position: the amplitude and period of the swing. One can perceive events or finite sequences such as a tennis serve, a backhand volley, or a lob,

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but these become variables in a higher-level function perceived as a *relationship* among independent sets of such elements: two persons controlling such finite sequences in *relationship* are playing tennis.

The most interesting human relationships are those in which each person, in controlling his own perceptions, disturbs the perceptions being controlled by others.

The general pattern of hierarchical control is this: in order to control perception of one level, one must control at least some of the lower-level perceptions of which the higher is a function. The lower-level perceptions which are not under control by lower-order systems are disturbances; as the uncontrolled perceptions vary, the controlled ones must be adjusted so that the net result at the next higher level matches the reference level.

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Clearly, a constant state of a perception at many of these higher levels entails a constantly varying state of lower-level perceptions; a driver's constant impression of the speed of his automobile entails a constantly-changing configuration of the visual field. A person cranking a bucket out of a well perceives and controls a constant cranking speed or angular velocity, maintained by continuous variations of arm position. This illustrates the other way in which control of a perception relative to a fixed reference level can lead to dynamic conditions.

The object here is not to develop any specific hierarchical model; that is too much to cover in a short essay. It is primarily to introduce the kinds of relationships that exist between levels of control, and even more to the point simply to broaden the concept of what a controlled quantity can be. Anything that a person can sense and affect, regardless of its nature or its objective existence, can become a controlled quantity for that person.

The Meaning of Empirical Correlations

The phenomena of control in human behavior are organized around a highly subjective set of perceptions. In order to understand what a person is doing, it is necessary to understand what that individual is perceiving. Simply watching a person's actions is insufficient; all that will do is show, indirectly, the presence of disturbances. It will not reveal why certain environmental events are accompanied by certain actions. To understand why there is a relationship between events and actions, it is necessary to find the controlled quantity being affected both by the independent event and by the action, and to understand how control systems work.

Under the old paradigm, it is impossible to discover controlled quantities. The traditional approach to an analysis of behavior is to select some set of environmental variables that could determine a given behavior, and to vary them while looking for correlations with changes in the behavior. When a high correlation is found, it is assumed that the stimulus or situational variable is acting on the organism to make it produce a corresponding change in behavior. The organism is thought of as *mediating* between cause and effect; between the manipulated variable and the resultant change in behavior. If changes in behavior are observed to be a regular function of the manipulated variable, it is assumed that the form of that function describes the organism's transfer function, the overall process in the organism between its input and its output.[13] What is normally called a stimulus or a "track input" is what we are calling here a disturbance.

Control theory shows that such a transfer function is an illusion, in any case where a controlled quantity exists. When a controlled quantity is being stabilized against disturbances, the observable relationship between a disturbance (stimulus) and the system's action is dictated completely by the physical connections, external to the behaving system, from disturbance to controlled quantity and from action to controlled quantity. Whatever effect the disturbance tends to have via its physical link to the controlled quantity, if the controlled quantity remains undisturbed, the action must be precisely the one which, acting through the physical link from action to controlled quantity, continuously cancels the effects of the disturbance. The more nearly ideal the control system, the more exactly will the relationship of action to disturbance be predictable strictly from an examination of these physical relationships in the environment. The transfer function that is observed describes external physical relationships, and very little

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about the organism.

If the controlled quantity is not of an obvious nature, and few of the interesting ones are, the link from either action or disturbance to that controlled quantity may be subtle and indirect. Thus not every way of measuring action or disturbance will be appropriate.

If I am controlling the position of a car on the road, forces caused by the muscle tensions I use to turn the steering wheel may not often *be* exactly tangential to the wheel; a direct measure of muscle tension as a measure of my behavior, therefore, will include force components that are unrelated to the control task, and which will introduce noise into the observed relationship. Furthermore, the car's position is not affected directly by muscle tension, but by the effects of those tensions transformed by intervening mechanical linkages and by laws of mechanics involving at least two time integrals. A direct measure of muscle forces might show some significant correlation with a direct measure of the car's position, but it would not be a very high correlation.

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For the same reason, the effect of a crosswind on the same variable will be indirect and complex, involving laws of aerodynamics and again laws of mechanics.

The tensions in my arm muscles will show some reasonably high correlation with wind velocity, and it may seem that in my soundproof car with the windows rolled up I am still able to sense and respond to wind velocity, but neither the correlation nor the apparent response to the stimulus is real. If one were to calculate the effect of muscle tension on car position using the correct physical principles, and also compute the effect of wind velocity on car position using the correct physical principles, it would be seen that the relationship between the properly transformed measures would be *exact:* the effects, integrated, would be equal and opposite. It would not be merely a statistical correlation, but a continuous and precise quantitative relationship. And it would be obvious that this exact relationship reveals almost nothing about the behaving organism.

The presence of a control system creates an apparent cause-effect relationship between disturbances and actions. This relationship is what scientists have been studying since the beginning of the life sciences. It tells us very little about the organization of the behaving system, except the bare fact that it is acting as a control system. That is, of course, an important fact to know, but it does not need to be proven ten thousand times.

Discovering Controlled Quantities

The behavioral scientist is not in the same position as a servomechanism engineer who works with a known system controlling known variables. The behavioral scientist sees only the multitudinous actions of an organism and variations of immense multiplicity in its environment. He does not know in advance which effects of motor behavior are parts of control actions and which are merely side-effects; he does not know which extraneous events are significant and which can be ignored. If he is studying a human being, any aspect of the environment that the experimenter might notice could prove to be a quantity under control by the behaving system. It is not very likely, if the experimenter simply attends to aspects of the environment or of the other person's behavior that are interesting to himself, that he will happen across variables that are actually of any behavioral significance. Some sort of systematic procedure is required.

As a start toward discovering controlled quantities, one can look for regular relationships between disturbances and actions. In this regard, previous empirical searches for behavioral laws will not have been entirely wasted, although they will almost certainly have stopped short of revealing the final object of such a search. When a regularity linking extraneous events and behavioral actions is found, this is a hint that there may be a controlled quantity being jointly affected by both. That quantity, if controlled, will be hidden precisely because it does *not* alter in response to changes in the disturbance or in the action. In order to find the controlled quantity, one must understand the physical situation well enough to detect variables that do not change when they ought to change.

Most physical quantities or aspects of the environment that are jointly affected by an action and a disturbance will show

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variations which reflect the resultant of both effects. Since most such jointly affected variables will *not* be controlled quantities, their variations *will* show significant correlations both with disturbance and with action. Examination of the details will reveal that the variations are simply those due to variations in two independent causes, both of which can affect the quantity but which are uncorrelated with each other.

A controlled quantity will be identified when a variable is found that is affected equally and oppositely by action and disturbance. The action itself does not have to be "equal and opposite" to the disturbance itself, nor will it generally have any effect on the disturbance. It is the *effect of each one on the controlled quantity* that must be equal and opposite to the *effect* of the other. If the measuring instrument were affected by the disturbance and the action in exactly the way the controlled quantity is affected, the equal-and-opposite relationship would be obvious, but most convenient measuring instruments will not be affected that way. A device for measuring muscle tension in a driver's alms will be calibrated in dynes or pounds, not in units of change in car position. A device for measuring wind velocity will be calibrated in units of dynamic pressure, not in feet of displacement relative to the center of the road. Before one can evaluate either action or disturbance, therefore, it is necessary to apply the correct transformations to the direct measurements, and one cannot know what transformations to apply until the controlled quantity has been identified.

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The Test for the Controlled Quantity

Therefore, controlled quantities cannot be found by deduction, but only by induction. One must make an intelligent guess as to the nature of a controlled quantity, and then test that guess.

The test for the controlled quantity is carried out as follows. Given a definition of a controlled quantity to serve as the hypothesis, one searches for physical links from action to the controlled quantity and from disturbance to controlled quantity. Those links are analyzed in terms of physical laws, and the effects of action and disturbance are separately calculated in units of effect on the controlled quantity. The predicted sum of those effects must be zero (or zero change), and the measure of the controlled quantity must correspond to that prediction, if the hypothesis is to be accepted.

The experimenter does not generally have the ability to predetermine the organism's action, but he is free to select and vary disturbances at will. Thus one way to apply the test is to select disturbances which, through known physical relationships, are capable of altering the state of the proposed controlled quantity when acting alone. If the *observed* variation in the quantity is only a small fraction of the calculated change, that quantity is likely to be under control. To complete the proof that an organism is in control, one must then show that the reason for failure of the controlled quantity to change is that the action of the organism, working through known physical links, is continuously cancelling the effects of the disturbance that were calculated. Further support of the hypothesis requires showing that the controlled quantity *must* be sensed by the organism in order to be controlled.

More conventionally, the hypothesis is *disproven* if applying a disturbance to the proposed controlled quantity succeeds in disturbing it as if only the disturbance were acting. There is a gray area that calls for judgements; if the effect of the disturbance is less than predicted, but not dramatically less, the chances are that the defined quantity is related to a controlled quantity but not identical to it. One must then select some criterion for "good enough" proof—proof that will permit one to proceed on the assumption that the quantity is a controlled quantity. One might decide, for example, that if the observed effect of a disturbance is more than 10 per cent of the predicted effect, the quantity is not controlled. The criterion level will depend on how well one expects the organism to be able to control variables of that kind, even when they are defined perfectly correctly. Most human control systems can cancel 90 per cent of those disturbances lying within their range of control; not a few can cancel 95 per cent or even 99 per cent. Controlled quantities discovered by this method are normally clear-cut; there is little need to consider "statistical significance," although occasionally that is appropriate.

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The Test for the Controlled Quantity is a direct nonverbal experimental procedure that teaches the experimenter to perceive the environment in essentially the same terms in which the behaving system is perceiving it. Neither the experimenter nor the control system needs to know the actual physical situation underlying the controlled quantity: in other words, epistemological questions are bypassed by the Test. I believe the Test to be the first scientific method by which an experimenter can come to know the subjective world of his subject without involving the medium of symbolic communication. It will work with anything that behaves.

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Cybernetics and Behavioral Science

The cybernetic model of a behaving organism is fundamentally different from the model which has been assumed for over three hundred years, in all branches of biology, physiology, neurology, psychology, and the social sciences. Even those schools of thought which profess to abhor mechanistic explanations revert to the old cause-effect model when it comes to testing hypotheses in the framework of scientific method: they still manipulate condition A and look for correlated changes in behavior B. To many psychologists, this is simply scientific method itself; whatever hypothesis one may make concerning inner processes, one must finally put those hypotheses to the test in a cause-effect setting.

The cybernetic model is based on a new principle of organization in which closed-loop relationships exist. Before control theory was fully developed, no person on earth understood how such systems could exist, or why their mode of operation could not be described in the simple cause-effect terms that apply to inanimate systems. Without control theory to point out the possibility of controlled quantities, no scientific interpretation other than a simple deterministic cause-effect one was possible, for the appearance is that disturbances are stimuli that act on organisms to make them behave.

In the light of control theory we can now understand some of the most baffling phenomena that have been noticed, particularly the peculiar *rationality* of behavior. Under the old deterministic picture, it was impossible to explain why stimuli should so kindly combine their effects to produce just the behavior that was good for an organism; a great deal of qualitative arm-waving has taken place in the attempt to give the impression of an explanation, but such explanations have had little explanatory power and no predictive power at all. If a rat pressed a food-delivering bar often enough to keep its own body weight constant, that result was normally treated as a piece of good luck for the rat.

When B.F. Skinner concluded that behavior is controlled by its consequences, he came the closest of any psychologist to discovering control theory in its original context, that of behavior. But this statement taken literally is an affront to determinism, and belongs with certain other concepts such as "retroactive inhibition" that are phrased as a challenge to know-it-all physicists. Consequences are, as far as anyone knows, caused by their antecedents, not the other way around. Behavior in a Skinner box is not caused by the food it delivers to the animal; quite the contrary, the rate of food delivery is determined by the behavior, via the properties of the apparatus. No behavior, no food. There is no need to state the obvious situation any other way.

The statement that behavior is caused by its consequences can be converted easily into a correct statement of how a control system works if we add just one phrase at the end: "... relative to the consequence the animal wants." The organism always acts to keep the consequences of its behavior, as they affect the organism, matching the reference-consequence determined inside the organism, not in its environment. As in the case of early notions of drive reduction or stimulus reduction, Skinner's formulation missed the key concept by omitting the concept of the reference level.

It was not possible for Skinner or any earlier approximators of control theory to follow through to the correct conclusion, because the proper train of thought was cut short by an assumption so strong as to be impervious to reason: the assumption that physical determinism required all behavior to be caused from outside the organism.

Control theory shows that assumption to be false; the principal determinants of behavior lie inside the organism, and ultimately trace back to the inherited requirements of survival,

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not to any present-time external events. The environment provides the setting in which the organism must achieve its fundamental requirements; the environment determines the links from action back to perception and from action back to physiological effects on the organism. But none of those reflected effects of action would imply the necessity for any particular behavior if it were not for the fact that inside the organism there are specified quantitative reference levels for those reflected effects. The organism requires that certain effects occur to a certain degree; it learns what to do to the external world in order to assure that they do occur (or that effects which must not occur do not occur).

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A Cybernetic Model of Evolution

We cannot yet be sure which reference levels are acquired and which are inherited; essentially no work has been done on this question in the framework of control theory. But there must be some set of inherited reference levels, specifying conditions which must be sensed as holding true inside the organism, the specification remaining unaffected by the events of a single lifetime. These fundamental reference levels, not the nature of the external environment or particular events in that external environment, ultimately determine which consequences an individual organism will learn to create for itself. The actions which the organism performs will, of course, come to be those which, in the current environment, will in fact oppose disturbances while maintaining the required consequences at their required reference levels. This is the cybernetic picture of "adaptation." The organism adapts to the environment by altering what it does, but not by altering what it accomplishes by what it does, not in terms of the fundamental reference levels. To say that the organism adapts to its environment is to say that it alters what does not matter to it in order to maintain control of what does matter to it.

This concept of adaptation is even clearer in terms of a hierarchical model.[14] In such a model, lower-order reference levels become the means by which higher-order systems act; the higher systems freely adjust the lower-order reference levels, to create the lower-order elements of perception which will result in the specified higher-order perception. This creates a hierarchy of adaptations. A given subsystem can learn new actions when a change in the environment renders the old actions ineffective for control, but it cannot change the consequences it wants those actions to produce; only a higher-level system can change the reference level. The highest-level system must be the one that says, thou shalt breathe, thou shalt perceive harmony, thou shalt not experience hurt and illness. In whatever specific nonverbal terms the message is cast, the effect of all the inherited reference levels is to say, thou shalt live. That is the only reference level that will propagate through the ages.

All sorts of proposals have been made to explain the processes of mutation that create variations of parts of the genetic message. Control theory provides a rationale for suggestions that these changes are directed, not simply induced by cosmic rays or background radiation. Once the fundamental principles of control are understood, it is not hard to apply them even in situations far from the subject of present-time behavior. For example, it is not hard, in principle, to see how there could exist a kind of master control system at the chromosome level of organization, one which is a part of the microstructure of every cell. Control systems do not have to be made of vacuum tubes or transistors or even neurones; there are great biochemical control systems in every organism, and evidence of control systems even on so tiny a scale as to control the permeability of individual cell membranes. There is nothing farfetched about imagining a control system which acts by setting into motion slow processes of change at the level of DNA, in response to errors of the most fundamental kind conceivable —and for that reason, a kind scarcely conceivable. If the rate of variation depends on the amount of error, it does not matter whether the variation be systematically appropriate to the error; at least some of the changes will be appropriate, and those that are not will not propagate.

It is thus possible to see evolution itself as a control process, the same control process in every living thing. Donald T. Campbell has called the kind of process proposed here as "blind variation and selective retention,"[15] recognizing that

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the organizing principle is to be found on the input side, not the output side. What results from a process of blind variation depends on what is retained, and what is retained is determined by criteria for retention which, when met, result in termination of the process of blind variation. The most widely accepted concept of evolutionary processes makes the retention criterion simply a binary variable: survival or extinction. It would be far easier to explain speciation and variations within species if room were made for specific stored criteria that did not require extinction to see if they had been met. Control theory, by providing the concept of a reference level, provides a place where genetically-transmissible criteria can actively specify what consequences of blind variation shall be retained (i.e., shall terminate the variations); all we have to imagine is that the error between actual and specified states of certain fundamental quantities drives the variations. This model expects that the variation rate will be low for some organisms in certain epochs, and high during others. The organism ideally adapted to its niche experiences no error of the kind proposed (if not defined) here, and its rate of blind variation of the genetic message is at the lower limit. An organism evolving rapidly is suffering extreme error; it is varying the details of its genetic blueprint relatively rapidly. This model explains all that the simpler model of evolution explains, and more besides.

This model no doubt raises shades of Lamarck, the transmission of inherited characteristics. But by accepting the idea of *blind* variation, it avoids that trap. Furthermore, the time-scale on which this master control system works has to be taken into account. It is an example, perhaps, of a "sampled control system," one which works only at intervals, in this case perhaps just for a brief period in each generation, prior to sexual maturity, but long enough after birth for the consequences of current organization to have their effects at the cellular level. Since the magnitudes of the variables in the control system are stored in the DNA, and change only slightly with each active period, we would have to look at hundreds or thousands of generations in rapid succession to see the dynamics of control —to see how the rate of variation corresponds to error, and how error corresponds to changes in the external situation. In

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effect that is what paleobiology is already doing, but without this model as an organizing concept. I think it would be a fascinating project to see whether the basic reference levels of life itself could be discovered by such studies. "Survival" is too crude (and too verbal) a reference level to explain all adaptations.

One need not extend control theory to speculations about evolution in order to apply it to behavior, but I think that doing so creates a rather grand and coherent picture of life that is satisfying to one's sense of order. We can see the principle of the control system as possibly extending from the very beginnings of life to its most detailed expressions in present time behavior. Indeed, we can begin to see the principle of control as possibly providing the principle that makes all organisms one. *Life* adapts by altering what does not matter to it in order to maintain control of what does matter to it. What does *not matter to* it, in the long run, evidently includes being plant or animal, being of small or large size, being of one species or another species, or behaving in one way rather than another. What does matter? Something, I imagine, rather basic.

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The Cybernetic Revolution

The analysis of behavior in all fields of the life sciences has rested on the concept of a simple linear cause-effect chain with the organism in the middle. Control theory shows both why behavior presents that appearance and why that appearance is an illusion. The conceptual change demanded by control theory is thus fundamental; control theory applies not at the frontiers of behavioral research, but at the foundations.

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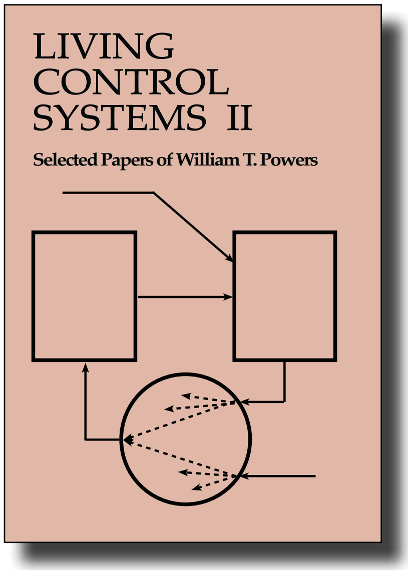
Living Control Systems II

Selected Papers of William T. Powers



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By William T. Powers

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Foreword

In 1979, Bill Powers wrote a prophecy: "A scientific revolution is just around the corner, and anyone with a personal computer can participate in it.... [T]he particular subject matter is human nature and in a broader scope, the nature of all living systems. Some ancient and thoroughly accepted principles are going to be overturned, and the whole direction of scientific investigation of life processes will change." (William T. Powers, "The Nature of Robots: Part 1: Defining Behavior," *BYTE* 4(6), June, p. 132) Powers foresaw the overthrow of the idea that either stimuli from the environment, or commands from the mind or brain, are sole causes of behavior. In its place, he offered the concept that people (and in their own ways all other organisms) intend that they will experience certain perceptions and behave to cause the perceptions they intend. The social, behavioral, and life sciences had simply missed the fact that living things control many features of their environments. Powers acknowledged that fact, and he realized that to an organism the environment exists only as perceptions, hence his insight that organisms act to control their own perceptions. His formal statement of the new concept was control theory, and he said amateurs, working with personal computers on their tables at home, would be major players in the revolution. Thirteen years later, the revolution is not accomplished, but it is underway.

Powers' perceptual control theory is new, but he is not the first to describe many of the key ideas in the theory. Over 2200 years ago, Aristotle wrote about intention—"that for the sake of which," the desire or wish that causes actions that result in a particular end. Aristotle used many examples in which a person acts to produce an intended object, such as a bed, statue, tray, or house. The person's intention to create the object is the "final cause" of the actions that produce the object. Aristotle wrote that, depending on the condition of the world and the intention of the person, the same actions sometimes produce different ends, and different actions sometimes produce the same end. All of that sounds like good control theory, so why are those ideas considered revolutionary today?

For many centuries, Aristotle's ideas disappeared from Europe and were preserved by scholars in the Arab world. They returned, in altered form, to a Europe dominated by Christian theology. Theologians changed "final cause," which to Aristotle often meant only a person's intention to manufacture a bed out of wood, into God's original plan for the linear unfolding of history, from creation, to Calvary, to Apocalypse, to the end of time. Aristotle's original idea was unrecognizable.

Most early European scientists worked within Christian theology, embracing its notion of linear time and its implication of linear cause and effect. Many of these scientists mistakenly assumed that the original concept, that a final cause is a goal, implied that the future influences the present—a clear violation of the assumed linear flow of cause and effect. Eventually, potentates of The Church and potentates of Science came to a falling out over dogma. Those who established the canon for Science had yet another mistaken reason to reject final cause: they said it represented an appeal to the supernatural, in the form of God as agent. The idea that there is purpose or intention in the behavior of any living thing was pronounced "unscientific." Most aspiring behavioral and biological scientists still affirm that credo.

When William James wrote one hundred years ago, the ideas of purpose and intention were popular again. James said purposive behavior is the distinguishing feature of intelligence—of life. He said that in a variable world an organism's behavior necessarily varies to produce unvarying intended results. James wrote that people do not intend their specific actions; they intend to experience perceived consequences of their actions, then they vary their actions any way necessary

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to produce those perceptions. For a while, it looked as though the idea of intention might take hold, but once more the idea was purged from the sciences of behavior and life. Orthodox scientists asserted that intention implies final cause, which necessarily implies an appeal to supernatural forces and to a temporal reversal of causality. Purposive behavior was banished, on the one hand by behaviorists, environmentalists, and reflexologists who claimed that events in the environment determine behavior, and on the other by those who claimed that instincts acting as internal stimuli cause behavior. People on either extreme believed their positions were dramatically different, but they all portrayed behavior as the end result of a linear chain of cause and effect.

Powers writes at a time when purpose and intention remain unacceptable to most scientists. Behaviorists still believe environmental "stimuli" have the "power" to control behavior; and most cognitive scientists and neuroscientists say the mind-brain issues "commands" that cause muscles to produce appropriate behavior. Cognitive-neuroscientists frequently claim behaviorism is dead and a cognitive revolution has swept the behavioral and life sciences; in return, behaviorists pronounce themselves very much alive, and some portray cognitive theorists as "creation scientists," bent on keeping alive the concept of soul-as-mind. Once again, each camp believes its views differ markedly from those of the other, but both embrace the wearisome model of linear cause and effect—a model that was necessary a few hundred years ago to establish the physical sciences, but a model that mistakenly rejects what Powers recognizes as the defining properties of life. Neither wing of the cause-effect orthodoxy recognizes the abundant evidence that organisms control many parts of their world. But revolutions have a way of changing the minds of the orthodox.

Powers turned the millennia-old idea that living systems act to produce intended perceptions into a formal theory of behavior: perceptual control theory. Perceptual control theory identifies behavior as the necessarily variable means by which organisms control their perceptions of the world. Working first on a build-it-yourself computer (the one he used when he wrote his prophecy), then on a first-generation IBM personal

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computer, Powers created elegant demonstrations in which the simple-idea-turned-formal-model generates remarkably accurate quantitative simulations and predictions of behavior and its consequences. He identified a first principle for behavioral, social, and life sciences and showed the way to a new foundation of theory and method.

For several years, only a few people followed Powers' lead, and even fewer gathered the data and performed the modeling that could establish control theory as an alternative to traditional science. But interest in the theory grew—a tribute to the dogged efforts of William and Mary Powers, over three decades, to maintain the visibility of the theory. During most of that time, Powers published only one book and a few papers. More recently, information about control theory burst into wider circulation through two functions of personal computers that no one predicted in 1979: desktop publishing and electronic-mail networks. Those applications freed perceptual control theory from the heavy hands of editors and reviewers who routinely rejected manuscripts on the theory. They were true defenders of cause-effect orthodoxy, rejecting control theory as uninteresting and unnecessary, or as merely another way to describe things that were already understood. The new media let many people see control theory, then judge it on its own merits. The once-small circle of people aware of the theory grew into a network spanning the world, including people from many disciplines, specialties, and professions. And the demand for Powers' writings grows.

In the Foreword to the first volume of Living Control Systems, Richard Marken wrote about the difficulty he experienced several years ago when he tried to locate published material by Powers. Volume I was a collection of Powers' published work But Powers has written far more than he has published. When he writes, Bill does not revise his drafts. If he encounters a block or is dissatisfied, he starts over. He has cast aside several beginnings of books and many drafts of chapters and papers that he never submitted, or that were rejected by editors and reviewers. Most of us would be happy if any of our publications equalled the quality of the work Bill put away in drawers and boxes and, more recently, on disks.

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Over the years, only a few people have had a chance to read parts of Bill Powers' unpublished work. The opportunity to rummage about, looking for those gems, was at least part of "that for the sake of which" some of us travelled to his "laboratory" in the back room of his home in Northbrook, Illinois. When Mary and Bill decided to move to Colorado, Edward Ford, a counselor in Arizona, suggested that the mandatory gathering of possessions into boxes provided an excellent chance to select part of Bill's unpublished work for an edited volume. Greg Williams, a frequent visitor to Northbrook, journeyed there from Kentucky for the last time to gather the pages and disks and take them away so he could select the pieces in this volume.

This volume contains a small sample of the previously unpublished material from the years when Bill and Mary Powers were in Northbrook. If you want to rummage through the next accumulation, you must travel to the new site of The Laboratory of William T. Powers. That is the locus of many of today's clearest insights into purposive behavior. Over the millennia, that locus has moved from Aristotle's Lyceum, to James' Harvard, to Northbrook, and now to a house atop a ridge near Durango, with a view of the San Juan Mountains, located only a few miles away, across a broad valley—a view that, years ago in Illinois, Mary and Bill Powers said they intended to see out their back door. Stated intention, actions, and perceived consequences that match the intention. It looks like control to me!

W. Thomas Bourbon
Nacogdoches, Texas
February 1992

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[1988]

A Manifesto for Control Theorists

I. Control theory was first offered as a model of behavior because artificial control systems seemed to act in some ways like organisms

A. In the form of regulating devices they could maintain variables like temperature, pressure, chemical concentration and composition, flow, position, sound level, and almost anything else measurable in stable predetermined conditions, despite unpredictable disturbances.

B. In aircraft, autopilots could keep airplanes flying level and on course at constant altitude, despite changes in weight distribution, wind direction, engine efficiency, turbulence, and air density, automatically—meaning without outside direction of the details of their actions.

C. In homing devices they showed characteristics of goal-directed or purposive behavior, directing themselves toward distant moving or even evasive targets.

D. In general, they showed the properties that William James called characteristic of life: the persistent and repeated reaching of constant ends by variable means. Control systems behaved in ways that the traditional life sciences had proclaimed impossible for any entity in a world governed by physical laws. Yet they behaved like organisms.

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II. Investigation of human physiology and function has shown that the parallels extend to details of structure and action.

A. Structures playing the part of sensors, comparators, and effectors in living systems are connected in the same functional arrangement as in an artificial control system.

B. Feedback loops are found in all parts of living systems from biochemical level to the brain. The feedback is always negative, and the set-points are always adjustable.

C. The methods used to analyze artificial control systems, when applied to human action, reveal characteristics that are highly reproducible and stable in a given person.

D. When control-system models are used for quantitative prediction of simple motor behaviors, they do so with an accuracy that is unprecedented in the behavioral sciences.

E. The same methods can be used to measure the properties of human control systems when the consequences of motor actions are as complete as we know how to devise. The same accuracy of prediction is found.

III. The control-system model brings a new concept of mechanism into the sciences of life.

A. All traditional models represent behavior as a function of antecedent events. When these models are expressed mathematically, they amount to curve-fitting, finding a mathematical form that will express the law of dependence. Thus, a single equation is used to characterize behavior.

B. Among traditional approaches, only that of operant conditioning takes into account two connections between external events and behavior; the "reinforcing" effect of an external event, which modifies the behavior through action on the organism, and the "schedule of reinforcement," which makes the reinforcing effect a consequence of the manner of behavior. Other fields have considered closed-loop relationships (the

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law of effect, response chaining, stimulus-stimulus or response-response laws, or "interactionism"), but not in the systematic way of the radical behaviorists who follow B. F. Skinner.

C. The control-system provides the analysis that the Skinnerians did not discover, by introducing the simultaneous solution of equations representing both relationships between behavior and external events. One equation describes the organism's response to inputs, and the other describes the simultaneous dependence of those inputs on the response. Only when both relationships are specified (even if one is conjectural) can the variables be predicted and the model tested.

D. Under control theory, both stimulus and response become dependent variables: neither "causes" the other. Both behave in ways determined by the entire organism-environment system of relationships.

E. The critical independent variable is now found inside the organism in the form of a variable reference signal. This signal determines the equilibrium point of the whole system, its goal or purpose. This kind of system controls its own inputs by varying its outputs. It is not controlled by the external world. Nevertheless, its operation is completely consistent with all known laws of physics and chemistry. It is a kind of mechanism unknown to those who formulated and still support the ideas of traditional behavioral science.

IV. The control-system model represents a complete revision of the traditional concept of the mechanisms of behavior, and of life processes in general.

A. By showing in quantitative detail how purposive or goal-directed systems work, control theory makes obsolete all previous schemes that were devised to substitute a cause-effect process for purposive processes.

B. By providing a quantitative analysis of the relationship

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among stimuli, actions, and independent disturbances, control theory shows that apparent stimulus-response relationships result from actions that stabilize controlled variables against those disturbances. The apparent stimuli are not stimuli, but disturbances of controlled variables.

C. Relationships between actions and external events that seem only statistically detectable under the old paradigm become highly systematic and predictable under control theory.

D. Control theory shows that the methodology called "scientific method" presupposes its own conclusions, and discards all data relating to controlled variables. The causal relationships found in this way are almost illusory.

V. Control theory represents a new beginning for the sciences of life. It is not an extension of traditional ideas, nor was it built on the base of older theories about behavior. It is a total replacement of those older theories by a radically new concept. There can be no bridge from the old to the new: the new approach diverges from the old at its roots. The entire path of the life sciences from the time of Decartes to the present is an evolutionary track that must now end in extinction.

A. If they wish to be maximally effective, control theorists must not try to find suggestions of compatible ideas in older thinking. That generous impulse has the effect of slowing and obscuring the changes that must occur, and always encourages attempts to merge the new back into the old in order to justify the old. The result is always incompatible with control theory.

B. The motive for finding precursors of control theory in older ideas is to preserve the continuity of science, but the preservation occurs at the wrong level and in the end is a disservice to science. This implies that control theorists must break completely with older explanations of behavior: none of them contain the principles of control, and all of them, in the attempt to make sense of control processes without using control theory, propose explanations that are incompatible with control theory. Let others claim to have foreseen this

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outcome if they wish. Let future analysts trace the evolution of control theory out of the grand course of science: they will not find it roots in the life sciences. For control theorists of today, none of that matters; there must be a new start.

C. Control theorists, if they are control theorists, must begin to pose and answer questions that relate to this new understanding of human and animal organization. The traditional categories of behavior are of no use. Under control theory there are no boundaries between disciplines: a control theorist is not a psychologist, a sociologist, a biologist, a cyberneticist, or any other such specialist. All areas of the life sciences come under control theory. The control theorist studies living systems in all their aspects. Out of this kind of study will come new disciplines that have no names today.

D. If it is agreed that control theory is a revolutionary idea, then let control theorists be revolutionaries. This does not mean being dogmatic or doctrinaire: it means speaking the truth as it appears to be but being ready to modify it for any good reason. The foundations of control theory are solid; anyone can recreate the basic ideas from fundamental principles at any time. To be a revolutionary means not compromising with ideas that are know to be wrong, and insisting that any challenge to control theory be a carefully formulated as control theory is.

E. Above all, being a revolutionary means undergoing those internal revolutions of thought that utterly change one's approach to the understanding of living systems; resolving the inner conflicts with other ideas that live on in every control theorists; re-examining every idea one brings to this revolution, with the conviction that no idea, however familiar or treasured, is worth preserving if it is wrong.

VI. *Today, Kenosha: Tomorrow, Racine!*

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[1990]

Standing at the Crossroads

I'd like to try today to give you the sense that psychology is standing at a crossroads—and not only psychology, but all the sciences of life. We are about to experience the advent of something for which many people have searched, an organizing scheme that pulls together all the disparate schools of thought, specializations, movements, and evanescent fads that make up various fragmented branches of the life sciences.

The organizing scheme is called "Control Theory." This theory explains a phenomenon, as theories are supposed to do. The phenomenon in question is called control. Everyone has heard this word, and most people have occasion to use it from time to time, but in science it has become part of the metalanguage rather than designating a subject of study. A scientist does a control experiment, or demonstrates how manipulation of stimuli and rewards can control an animal's movements, or advocates a proper diet to control cholesterol level or competes for control of a department. This word is used as part of a background of ordinary language, but it has not been part of the technical language of the life sciences.

The reason is quite simple: nobody in or out of science understood the process of control until about the beginning of World War 2. By understanding the process, I mean being able to define it, characterize it, measure its parameters, predict how it will proceed, and recognize it in a real system. This doesn't mean that control was impossible to accomplish before World War 2: after all, most people accomplish digestion with-

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out understanding any biochemistry. But control is as natural a process as digestion, and like digestion can be understood in a scientific way only by studying it and learning how it works.

World War 2 started only about 50 years ago. Perhaps you can see why this fact implies some problems with studying control as a natural process. If control is a natural process, it was occurring in 1840, 1740, 1640, and so on back to the primordial ooze. In 1940, the sciences of life were already something like 300 years old (and their prehistory was far older than that). If nobody understood control until 1940, it's clear that these sciences went through a major part of their development without taking it into account. The next question is obvious: how did they explain the phenomena that arise from processes of control?

Many of the puzzles and controversies that occupied early researchers could have been resolved if scientists had realized that they were dealing with control processes. Purpose could have been studied scientifically instead of merely theologically. We can see now that all these early researchers, not recognizing a control process when they saw one, were drastically misled by some side-effects of control. The principal side-effect that deceived them resulted from the way control systems act in the presence of disturbances of the variables they control. When a disturbance occurs, a control system acts automatically to oppose the incipient change in the controlled variable. But if this opposition is not recognized (it's not always obvious), the observer will inevitably be led to see the cause of the disturbance as a stimulus and the action opposing its effects as a response to the stimulus. Furthermore, this opposition results in stabilizing some aspect of the environment or organism-environment relationship. That stabilization conceals the role of the stabilized variable in behavior; the better the control, the lower will be the correlation between the controlled variable and the actions that stabilize it. The variable under control is the one that is actually being sensed, but the logic of control makes it seem that the disturbance is the sensory stimulus.

Donald T. Campbell has proposed a "fish-scale" metaphor of scientific progress. Each worker constructs just one small scale that overlaps those already laid down by others. Even-

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tually the whole fish will be covered completely. But what if the fish is a red herring? Then all these patient workers will devote their lives to covering the wrong fish. The converse of the fish-scale metaphor is that a person who is concentrating on fitting one little scale to others already laid down is bound to have a very localized view of the problem. Seeking to extend the accomplishments of others, a single worker can make what seems to be progress—but it is unlikely that a single worker will discover that something is wrong with the whole design. The result can easily be the diligent application of fish-scales to a giraffe.

I submit that something like this has happened in the life sciences. A fundamental misconception of the nature of behavior, natural but nevertheless horrendous, has pointed the life sciences down the wrong trail. Nearly all life scientists, particularly those who try to achieve objectivity and uniform methodology, have interpreted behavior as if it were caused by events outside an organism acting on a mechanism that merely responds. This hypothesis has become so ingrained that it is considered to be a basic philosophical principle of science. To explain behavior, one varies independent variables and records the ensuing actions; to analyze the data, one assumes a causal link from independent to dependent variable and calculates a correlation or computes a transfer function. This leads in turn to models of behaving systems in which inputs are transformed by hypothetical processes into motor outputs; those models lead to explorations of inner processes (as in neurology and biochemistry) predicated on the assumption that one is looking for links in an input-output chain. One assumption leads to the next until a whole structure has been built up, one that governs our thinking at every level of analysis from the genetic to the cognitive.

Control theory, by showing us an alternative way of understanding this entire structure, therefore threatens the integrity of practically every bit of knowledge about behavior that has ever been set down on paper.

This is, of course, a message of the type that leads to a high mortality among messengers. That is why you are listening to a person with no reputation to lose and no fame to protect, instead of a Nobel Prize winner. In an utterly predictable way,

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scientists have for the last 50 years gone to great lengths to avoid learning control theory or else to assimilate it into the existing picture of behavior. Failing that, they have simply declared it irrelevant to their own fields, with the result that the authoritative literature of behavioral control theory is almost completely insulated from the mainstream. It appears in publications like proceedings of the Institute of Electrical Engineers division on Man, Machines, and Cybernetics, or in human factors and manual control publications, or in Xeroxed papers passed from hand to hand. There is a scattered literature on control theory in the life sciences, but nothing on this subject gets past the referees into a standard journal without first having its teeth pulled.

Despite all the defenses, the concepts of control theory are spreading. When our descendants look back on the latter half of the 20th Century, they will probably be amazed at the speed with which control theory became accepted: 50 years in the course of a science is nothing. We control theorists have nothing to complain about. Our greatest successes have come not through pounding at locked doors, but through continuing to explore the meaning of this new approach and learning how to apply it in many different disciplines. If we do our job correctly, acceptance will take care of itself. That job is not something one can toss off overnight, nor can it be done by just a handful of people. We are coming to a time of rigorous re-evaluation of all that is known or presumed to be known about the nature of organisms. The more people that are involved in this enormous project, the sooner it will be accomplished. That is why we are all so glad to welcome our guests at this session: after the party, you will be invited to help do the dishes.

There has been progress in understanding how organisms work, the wrong model notwithstanding. Biochemical reactions are not going to change because of control theory. Muscles and nerves will continue to operate as they are known to operate. Even at more abstract levels of analysis, many phenomena will continue to be accepted as valid observations; for example, phenomena of perception, of memory, of cognition. If competently observed, these phenomena will still be part of the legacy of earlier workers. When we pull the stopper on the

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old theories, we must keep a strainer over the drain and let only the bath water out.

Part of the task of reconstructing the sciences of life consists of separating valid observations of components from invalid conjectures about how they work together. Consider biochemistry as an example. Biochemistry is an odd mixture of solid research and wild leaps of undisciplined imagination. The research reveals chemical processes taking place in the microstructure of the body. The wild leaps propose that the chemical reactions somehow directly produce the behavioral effects with which they are associated. It's as though a specialist in solid-state physics were to propose that electrons flowing through wires and transistors are responsible for the music that comes out of a radio. While it's true that a shortage of electrons will make the music faint, and that without the electrons you wouldn't get any music, the physicist would be laughed out of town for suggesting that electrons cause music, or that you could fix a weak radio just by putting some more electrons into it. You can't understand the role of the electrons without grasping the principles of organization that make the radio different from a radio kit.

In the same way, if shortages or excesses of chemicals like enzymes and neurotransmitters are found to be associated with functional and behavioral disorders, all we then know is that these substances play some role in the operation of the whole system that creates organized behavior. If there's a shortage of some chemical substance, then some other system has reduced its production of that substance, and some other system still has decreased its effect on the driving system, and so on in chains and causal loops. Nothing in a system as complex as the human body happens in isolation. If biochemistry is to have anything to say about the organism at any higher level, biochemists are going to have to study whole systems, not isolated reactions. We need a functional theory to supplement the microscopic laws of chemistry.

There are workers in biochemistry who are investigating feedback control processes. One significant process involves an allosteric enzyme that is converted into an active form by the effect of one substance, and into an inactive form by the effect of another. When these two substances have the same concen-

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tration, the transition from active to inactive is balanced; the slightest imbalance of the substances causes a highly amplified offset toward the active or the inactive form. In one example, the active form catalyzes a main reaction, and the product of that reaction in turn enhances the substance that converts the enzyme to the inactive form—a closed-loop relationship. The feedback is negative, because the active form of enzyme promotes effects that lead to a strong shift toward the inactive form. This little system very actively and accurately forces the concentration of the product of the main reaction to match the concentration of another substance, the one that biases the enzyme toward the active form. This allows one chemical system to control the effects that another one is having on the chemical environment.

A person without some training in recognizing control processes might easily miss the fact that one chemical concentration is accurately controlling the product of a different reaction not directly related to the controlling substance. The effect of this control system is to create a relationship among concentrations that is imposed by organization, not simply by chemical laws. This is the kind of observation that a reductionist is likely to overlook; reductionism generally means failing to see the forest for the trees. Even the workers who described this control system mislabeled what it is doing—they concluded that this system controls the outflow of the product, when in fact it controls the concentration and makes it dependent on a different and chemically-unrelated substance.

To shift through several gears, consider the lines of research that began with Rosenblatt's perceptron. This device was conceived as a behavioral system that could be trained to react to patterns contained in its input information. First this idea was shown, by something of a hatchet job, to be impractical, and then it was shown to be practical again if several levels of training could occur within it (I haven't seen any apologies to Frank Rosenblatt, who died without vindication). In all its incarnations, however, the perceptron has been thought of as a system that learns to "respond correctly" to a stimulus pattern.

From the standpoint of control theory, however, organisms do not respond to stimuli but control input variables. So does

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that invalidate all that has been learned about perceptrons? Not at all. Conntrol-theoretic models desperately need something like a perceptron to explain how abstract variables can be perceived. In a control model, however, the perceptron is only one component: it provides a signal that represents an aspect of some external state of affairs. It's easy to show that behavior can't be explained simply by converting such a signal into an output action. But behavior can be based on the difference between the perceptron's output signal and a reference signal that specifies the state of the perception that is to be brought about. The control-system model shows where the functions that are modeled as perceptrons belong in a model of the whole system.

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Shifting gears again: some theorists are trying to model motor behavior in terms of "motor programs" and "coordinative structures." In these models, command signals are presumed to be computed such that when applied to elastic muscles they produce the movements of a real limb. These models contain some impressive mathematics, taking into account the linkages of the limb and the dynamics of movement of the limb masses. But control theory says that behavior is not produced by computing output; it is produced by comparing inputs with desired inputs, and using the difference to drive output. No complicated "motor program" computer is needed. Does this mean that the mathematical analysis by the motor program people is spurious and ought to be discarded?

Again, not at all. At some point in elaborating the control model, we must show how the driving signals actuate muscles to cause the movements we actually see. This entails solving all the physical equations for muscle and limb dynamics, just as the motor programmers have done. If they did their arithmetic right, it will still be right when we substitute the control-system model for the central-computer model. Both models have to produce the same driving signals. The only thing that will change is that control theory will show how the required driving signals arise naturally from perception and comparison against reference signals, instead of being computed blindly from scratch.

Finally, shifting to overdrive, what do we do about Artificial Intelligence? We take advantage of whatever it really has to offer, modifying it only where we know it fails to explain enough. One place where it fails to explain enough is in the way it deals with action. Basically, it doesn't deal with action. It starts its analysis with perception of abstract variables in the form of symbols, constructs models that imitate human symbol-handling processes as well as possible, and finishes by generating more strings of symbols that describe actions to be taken. It says nothing useful about how a description of an action, in symbols, gets turned into just those muscle tensions that will in fact produce an action that fits the description. When devices are built that are run by symbol-processing computers, the critical transformations that make action out of symbols are simply put into the device by its builders. Many of those critical parts turn out to be servomechanisms—control systems.

The assimilation of control theory into the life sciences will require a lot of this kind of reanalysis. Some old ideas will have to go, some will stay. This job is best done by people who are already competent in existing fields. Of course these also have to be people who can see that there is room for improvement along lines other than the standard ones.

In the current membership of the Control Systems Group we have representatives of at least a dozen disciplines of the life sciences, and a few persons representing some unlikely occupations such as piano teaching and law. When these people meet, there is little difficulty in communicating because all of them have a basic understanding of control theory. But communication isn't the only factor that makes these meetings valuable. The most important lesson comes from seeing how control theory applies in someone else's field.

The biggest problem with introducing control theory to scientists in conventional disciplines is that each scientist tends to think only of the scientific problems that are defined in that one field. The problem in question may involve behavior, but behavior is generally taken on faith to work the way some other specialist says it works. In fact most scientists tend to dismiss details involving other fields, assuming (often quite wrongly) that somebody else understands them well enough. We therefore find some very detailed biochemistry or neurology or personality-testing, all done competently, being used to

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explain behavioral phenomena that are very poorly analyzed and in many cases don't actually occur. The sociobiologist concludes that behavior patterns are inherited, not knowing that only the consequences of motor outputs, not the outputs themselves, repeat. What does a geneticist really know about the actions through which a bird catches a bug? You can inherit the control systems that are capable of catching bugs, but you can't inherit acts that happen to take you where a particular bug is going next. The combination of narrow expertise in one field and naive conceptions in every other field leads to facile explanations that are right only at one point.

Specialists must see the need for a model of behavior that applies in all disciplines, even those in which the specialist is not competent. Once the Artificial Intelligence researcher understands exactly why organized behavior cannot be produced by computing outputs, he or she will modify the AI model so it will work correctly with more detailed systems actually capable of organized behavior. Important effects of learning how control theory applies in other fields will occur at the boundaries between disciplines—exactly where we need to work if we are ever to have a unified science of life. At Control Systems Group meetings, specialists from many fields hear other specialists talking about the way control theory has made them rethink the problems in a different field. Because of the common understanding, this inevitably reveals one's own hasty assumptions, and encourages still more rethinking.

One last remark about the CSG. The CSG does not represent any one scientific discipline. It has no agenda of its own beyond encouraging the application of control theory within existing disciplines—no agenda, that is, except perhaps lowering the barriers between disciplines. The psychologists in the group are still psychologists, the sociologists are still sociologists, the therapists are still therapists, the engineers still engineers. This is not a political movement nor an alternative to established science. It is simply a vehicle for promoting interaction among people interested in using or learning more about control theory in any specialty whatsoever. When all the branches of the life sciences have assimilated and begun using control theory, the CSG, its work accomplished, will have no

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further reason to exist.

In this presentation I have talked around control theory, alluding to some of its conclusions without attempting to justify or explain them. Learning control theory can't be done by listening to a half-hour's talk. I hope that some of you will find the promise of a unifying principle for the life sciences appealing enough to go further into this subject.

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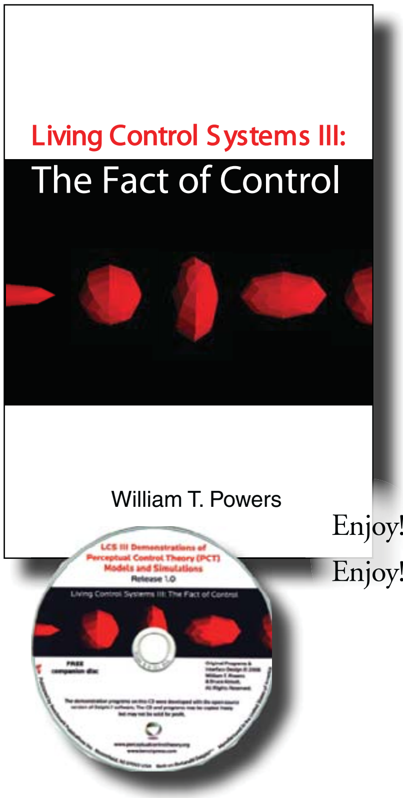
Living Control Systems III

The Fact of Control



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By William T. Powers

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Foreword

This work began in the second sub-basement of the Argonne Cancer Research Hospital at the University of Chicago in 1952, when I was all of 26 years old. That was the year I gave up my interest in dianetics and went back to physics, the same year my friend Kirk Sattley showed me a small book called *Cybernetics: Control and communication in the animal and the machine*, and unwisely let me borrow it. Kirk died in 2002, but I still have his book. In my new job as a very junior health physicist, I had time to do some experiments with human control systems. One of them was an attempt to use external positive feedback to measure the amount of internal negative feedback in the galvanic skin response to loud sounds. There is no need to inform me that this experiment was rather confused in its premises. So was I. But I did begin to study engineering texts on control theory, and the work started that led, over many years, to this book and four others before it.

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Now, with this book, I seem to have done about as much as I can to preserve my version of this thread of thinking and pass it on to those who will make the best use of it. It still seems to me, as it seemed an hour after putting down Norbert Wiener's book 55 years ago, that negative feedback control is the ingredient that has been missing from the life sciences for as long as they have existed, and is the concept that will finally put those sciences on a par with physics and chemistry. I can't begin to guess why it has taken so long, why so many people have explored the phenomena of negative feedback control in living systems without seeing that they were looking at a revolution straining to happen, and why so many more have simply refused to learn anything about it. But that's their problem.

In this book I have only one goal: to establish in the mind of the reader the literal reality of negative feedback control as the basic organizing principle of human behavior. Human beings do not plan actions and then carry them out; they do not respond to stimuli according to the way they have been reinforced. They control. They never produce any behavior except for the purpose of making what they are experiencing become more like what they intend or want to experience, and then keeping it that way even in a changing world. If they plan, they plan perceptions, not actions. If they respond to stimuli, they do so in order to prevent those stimuli from affecting variables they have under control. The root, the core, of the behavior of living systems is negative feedback control, at every level of organization from RNA and DNA to a spinal reflex to a mental concept of physics. Negative feedback control is the basic principle of life.

By the time you finish this book you may be more willing than you are right now to join me out on that limb, which you may find is sturdier than it looks from here.

The theme of this book is embodied in thirteen computer demonstrations. Each demonstration shows you something about how living control systems, or negative feedback control systems in general, work. In a number of cases, those control systems are inside of you and you can observe them working. In all cases, the phenomena are perfectly clear and reproducible by anyone; the demonstrations always work, the experiments always produce the predicted results. These are just a few of several important contrasts between the approach we will take here and the usual kinds of behavioral experiments found in the life sciences.

This is my last chance to persuade my peers on this planet that prior to the 1930s we human beings had an entirely wrong idea, only partly supplanted at the time of this writing, of who we are, how we are constructed, and why we do what we do. I hope to do this persuading by showing each person who reads this book a mirror in which certain commonplace phenomena of human behavior can be seen from a new angle. The computer age has provided a tool that allows me to create a small universe which each of you can experience and act upon directly, as if for a time you can ride with me inside my brain, doing what I do, seeing the same results I see, checking my observations against your own, and —if all goes well —reaching the same conclusions I have reached. This is basically a

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technical book, in the respect that it focuses on computer models and simulations that require some expertise to understand completely. But it is also meant as a teaching book, for anyone who is willing to wade through a few deep places and take a few assertions on trust. I will try to say everything in plain enough language to be understood by anyone, expert or not. The programs can be run and (I hope) enjoyed by anyone who can click a mouse. My colleague in Indiana, Bruce Abbott of Indiana University-Purdue University Fort Wayne, has consented to rewrite all my old demonstrations and experimental programs in a modern computer language and a consistent style, and to contribute a few of his own ideas. My colleague, Richard Kennaway, East Anglia University, UK, has agreed to provide an appendix in which my amateurish approach to mathematics is given some respectability by being done right.

I will do only a little persuading or arguing here. The main goal is simply to make sure as best I can that the points of these experiments and demonstrations are made clear. If you understand them, you will know what I know and you may even agree with my conclusions. I hope you will find things here that surprise and delight and illuminate, as discovering them and working them out did for me over the last half century. To me, this theory is beautiful, not because it is mine but because it is true. That is why I present to you here *the fact of control*, so you can see and feel it for yourself, have that joyful shock of discovery, and understand it.

William T. Powers

Lafayette, Colorado, USA

November, 2008

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Chapter 1: Concepts of Control

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This book is about control theory and its uses as a way of explaining how human behavior, and perhaps the behavior of all organisms, works. Before getting into the computer demonstrations, we'll spend one chapter on some generalizations that may be helpful, and some claims with which I hope you will eventually agree.

> *I'll make a deal with you. You can skip Chapter 1 if you will agree that before you raise objections about something said in later chapters, you will go back and read it. It's a bit heavy on mathematical concepts and not strictly necessary for understanding what comes next, but I believe the mental exercise will be at least a little helpful. If you disagree, just skip to Chapter 2 and get started with the demonstrations.*

Whatever method of control one proposes, the basic concept of control is the same. To control something is to act to bring it to a specified condition, and then maintain it close to that condition even if unpredictable external forces and changes in environmental properties tend to alter it. Human behavior, as later chapters will suggest through numerous examples, is control behavior. All of it.

Anyone encountering for the first time the brand of control theory used here, PCT (perceptual control theory), might be a little confused if some other kind of control theory has happened to get its pitch in first. PCT is actually based on classical negative feedback control theory, formalized during the 1930s and made into an engineering discipline during World War II, in the 1940s. Classical control theory was the basis of engineering psychology and cybernetics, and is still the primary theory used by most control engineers in designing artificial control systems.

Another kind of control theory has existed for at least as long as classical control theory. We can call it the "analyze-compute-act" model. It has been known under many names: *compensatory responses* in the psychology of the 1930s; modern control theory (MCT) in present time. It's quite possible to invent a way of controlling things that depends only on straightforward (but not simple) logic and physics, if you don't happen to know about classical control theory. That's how I think the other approaches to control got started. They are what you end up with if you reinvent control theory without the classical principles behind PCT.

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It will be easiest to understand the differences between these approaches to control if we look at the MCT version first. I'm going to do this in some detail because I want you to appreciate just what is involved in the analyze-compute-act way of controlling. Knowing the differences is important because analyze-compute-act is the version of control theory you will most likely encounter if you read the literature of psychology, neurology, or medicine. That version is a rather formidable obstacle to the acceptance of PCT, so it's worthwhile to take a little time to look for chinks in the stone wall.

MCT: ANALYZE-COMPUTE-ACT CONTROL

The basic idea behind the analyze-compute-act approach is simple and logical; it's based on the way an engineer would analyze a task and build a device to accomplish it. In order to bring about and control some physical effect or result, the engineer would first analyze the situation to see what actions, what forces or other influences, can be used to generate the intended result. For each of those actions, some preceding process would be needed to generate it, with the design not being complete until all required actions can be produced. An input of some kind would then trigger the start of the actions, which would be carried out in a precalculated way. If the analysis was correct and all the effects of the actions were predicted properly and physically generated with the required precision, the desired result would inevitably happen.[1]

That plan sounds perfectly reasonable until you start to apply it to a specific problem. Then you find that the deeper you get into the design the more little difficulties show up, until it becomes plain that designing the system so it can acquire, all by itself, all the data and knowledge it will need, providing the system with the facilities for doing all of the computations fast enough and accurately enough, and building the mechanical and electronic devices that can generate the necessary actions exactly as they must be carried out for the calculated result actually to happen—accomplishing all of that, you would have to conclude, is all but impossible.

That's easy to say as a generalization, so I thought it would be a bit more convincing if I walked the reader through just a sketch of what a design of a simple control system might look like when we explore one or two layers beneath the "simple and logical" summary of the design procedure. If plodding through mathematics doesn't seem very entertaining, just let it roll past and get the flavor of all the little problems that arise in trying to build a system that, all by itself, can analyze the environment, compute how to achieve a prescribed result, and then act on that environment in exactly the calculated way. I'm setting up a straw man here so you will be encouraged to knock it down, but I will play fair and not exaggerate the problems.

Suppose we are designing a control system for controlling the speed of a car on a highway. The MCT approach begins by having the control system itself analyze the physical situation— "the plant," as it is called. This is the *analyze* part of analyze-compute-act. The

1 Sometimes the analysis takes the form of a model of the external world, placed inside the control system.

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speed of a car is the result of all the forces that act on it over time, according to Isaac Newton. To change the speed of a car along the road, it is necessary to apply a force to it, using the car's engine, a tow-truck, or gravity if the car is on a downslope. The force will generate an acceleration equal to force divided by the mass of the car. The acceleration will cause the velocity of the car to increase at a rate proportional to the force (the distance of the car from the initial position along the road will increase at a rate proportional to the changing velocity). To compute the velocity V of the car at any time T after the force is applied, the control system can use the equation, $V = V_0 + (F/M)(T - T_0)$. V_0 or "V-sub-zero" as the initial velocity. T_0 is the time at which it first applied the force F to the mass M.

The correct equation is not quite as simple as this. As the car speeds up, air resistance and internal friction in the engine, transmission, axles, and tires produce an increasing force opposed to the engine force, so the net effective force is actually decreasing as the car speeds up. Frictional resistance increases approximately as the square of the velocity, so the control system really has to write

$$V = Vo + [(F - K_A V^2)/M](T - T_0)$$

where K_A is a calibration coefficient.

Unfortunately this is still not exact because now the net force applied to the mass is changing with time, so the control system has to abandon algebra and integrate the nonlinear differential equation, which is

$$dV/dt = (F - K_A V^2)/M,$$

which has a rather complex solution we won't bother with here.[2]

If the road turns uphill, another resistive force will arise which changes as the slope of the road changes. This force will be -MG[Sin(s)] where s is the upslope angle, G is the (negative, downward) acceleration due to gravity, and M is the mass of the car.

2 Partly because it would take me a day or two to figure out how to solve it.

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The angle s is a function of the position of the car along the road, because the slope begins at some position on the road, increases for a few hundred feet until the maximum slope is reached, then decreases again as the top of the hill is approached. The control system has to compute the position of the car along the road as a function of time so it can calculate the number to use for s. This gives a term involving the sine of the slope angle which changes with position. The position of the car is the time-integral of the velocity, and the velocity-changes depend on the position of the car, so the result is a really complex equation with no simple route to a solution. The difficulty is multiplied by the way the slope changes as the car moves along the road; the road does not necessarily follow any simple upward curve. It's necessary to fit some idealized curve to the actual road shape, picking a curve that leads to an equation the control system can—perhaps—solve without causing too much error because of not using the actual shape of the hill.

That's probably enough to give the picture. Simply to compute what the velocity will be at a given time after the car starts moving is far from a trivial task. And now the control system has to make what seems to be a very complex decision. It has to pick what is known as a "trajectory" for the car. It has to decide how it wants the speed to change as the car goes from zero speed to the desired speed. Should the car accelerate rapidly at first, and then gather speed more slowly? Should there be any periods of constant speed before reaching the final speed? Should the car take a long time to reach the final speed, or get there as fast as possible? Whatever trajectory it chooses, achieving it will result not from simply applying a force to the car using the engine, but from *varying* the force, changing it in just the way that will result in the chosen speed-up pattern. The formula for the desired pattern of speed changes has to be substituted for V in the last equation above. Then the system has to try to solve that modified differential equation for the pattern of forces that will result in the desired trajectory. That is the *compute* part of analyze-compute-act. And the control system still has to figure out the *act* part.

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Our very intelligent control system has solved the equations stemming from Newton's laws and the laws of aerodynamics, and deduced the pattern of forces that must be applied to achieve the intended behavior of the car. Now it has to figure out how to generate those forces. It must now analyze the car's engine and transmission, the properties of its tires, the quality of the gasoline in the tank, the settings of the engine control computer. From that it can deduce how hard it must press the accelerator down against its spring (having a known spring constant). And then it must produce that pattern of pressures with sufficient accuracy that the entire trajectory is brought into being without unacceptable errors. I will mention without further tedious details that in order to do this, the brain—er, the control system—must know about the properties of its output amplifiers and the current state of the muscles and their attachments to the accelerator. It must also predict the weather, to know whether there will be a headwind or tailwind, and use aerodynamic formulas again to compute the effect of the wind on the speed, if any.

The most important thing to realize is that all the data-taking, all the underlying knowledge about physics, and all the computations have to be done not by a team of physicists or engineers in some laboratory, but by the control system, the driver in the car. These computations are part of the proposed model: the hypothesis about how a brain goes about driving a car.

Certain proponents of the analyze-compute-act model appear to believe that because they can do computations like these slowly on paper, or somewhat less slowly by programming a computer, the brain can do them easily, instantly, and unconsciously. (If you agree with that, you may as well put this book down right now. It's not going to impress you. There is no magic in this book).

Those who are boggling at the idea that accelerating a car to a desired speed while driving up a hill requires this sort of machinery to be acting in the brain will be relieved to know that there is a far simpler way to do the same thing by negative feedback control, the kind used in PCT.

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PERCEIVE-COMPARE-ACT CONTROL

Negative feedback control also requires producing forces and other influences as required to generate a desired result. But it accomplishes this end in a way very different from the MCT method. Instead of precalculating what it needs to do and then doing it, the control system starts acting immediately, continuously adjusting its actions on the basis of their ongoing consequences. Negative feedback control as used in PCT can be summed up very quickly. It involves continuously *perceiving* the current state of whatever is to be controlled, continuously *comparing* that perception with the intended state, and continuously *acting* to reduce the difference between perceived and intended states, keeping the difference as close to zero as possible. The feedback part of negative feedback says that effects of the output (action) caused by the difference feed back to the input to change the perceptions and affect the difference. The negative part comes from the fact that the action decreases the difference instead of increasing it. Causation runs around a circle or loop. Such systems work without doing any analysis of the outside world, without "inverse kinematic and dynamic" calculations (the MCT model described earlier), and without even knowing what is causing perturbations of the thing being controlled. Here's how it works when you drive a car.

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First, you select the speed at which you want the car to be going—a reading on the speedometer, say 60 miles per hour. This provides a reference condition against which you can compare the perceived speed.

Then you look at the speed currently indicated. If that speed is far less than 60 miles per hour, you increase the pressure of your foot on the accelerator pedal, perhaps flooring it if the difference is large. The car speeds up, and you keep watching intermittently until the speedometer needle begins to approach the 60 mark. As it gets within a few miles per hour of the desired speed reading, you begin to reduce your foot pressure, so the speed increases more slowly. Eventually your foot pressure comes to some steady level and the needle is stopped at the 60 mark. At that time, your car may be going 58.27 miles per hour according to your GPS device, but you are controlling what the speedometer tells you.

You are going at 60 perceived miles per hour.[3]

That is exactly how the cruise control in a car does the same thing, except that it uses a direct linkage instead of a foot, and a sensor connected to the car's drive shaft instead of a visual image of the speedometer.

When the car comes to a hill, the speedometer reading begins to drop, because the pressure on the accelerator pedal is not enough to sustain the same speed. You will probably press down just enough harder than before to keep the speed from dropping below 59 or 58 mph. If you're really fussy, you will end up pressing the pedal hard enough to keep the speedometer nailed at 60.0, as close as you can read it.[4]

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When a tailwind springs up, the car will begin to go faster. You will reduce your foot pressure just enough to keep the car from going more than one or two miles per hour faster. You don't need to know whether a tailwind or a downslope caused the increase in speed; you need only to know that the speed is greater than the speed you want to perceive. If you're insistent about precision, you stop changing the foot pressure at 60.0 miles per hour. If a tire begins to go soft, creating a drag, and you're trying to calibrate your speedometer by timing the car as it passes mile markers, you won't quit changing your foot pressure until the speedometer says 60.0. A passenger in the rear seat opens a window, increasing the drag on the car. Speed: 60.0. Your tire reinflation system pumps the low tire back up to specs: 60.0. The roadbed gets rough: 60.0 (unless you decide to slow down).

The cruise control, a negative feedback control system, can do all these things, too, even though it can't sense upslopes, tailwinds, soft tires, open windows, or rough roadbeds.

3 If you were focusing on the speed indicated by the GPS device instead of the speedometer reading, the GPS would end up showing 60.0 miles per hour, and the speedometer would indicate 61.78 miles per hour. You are still going at 60 perceived miles per hour.

4 You will then be acting as an integrating control system.

This kind of controller can even be made to produce a trajectory of speeds. All that has to be done is for the driver to select a series of different reference speeds. The coast and accelerate controls of the cruise control let the driver change the reference speed. As each new reference speed is chosen, the controller will, all by itself, change the perceived speed upward or downward to match it. No equations have to be solved. Even a continuously-changing speed can be produced. If the reference speed changes too fast, the perceived speed will lag behind it, but that would happen with any kind of controller. A car can't change its speed instantly even if equations seem to say it can.

A negative feedback controller, or perceive-compare-act controller, or PCT controller doesn't have to know what is causing the speed to change. It doesn't need to know because its output action is applied directly to the perceived speed, and (within the limits of operation) can be varied enough to cancel the effects of any other influences, even novel ones, that tend to change the speed. Since this kind of system directly monitors the state of the controlled variable, and acts directly on that variable, it can skip all the complex computations required by the analyze-compute-act type of system. All you need to know is that pressing harder makes you speed up, and relaxing the pressure makes you slow down—as you perceive the speed.

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If made from the same components and variables, a perceive-compare-act controller is far simpler than an analyze-compute-act controller, and as you will see in Chapter 3, a negative feedback controller is also faster than the MCT controller. The PCT controller can work even when unpredicted disturbances happen. It can work just as accurately as the MCT controller when the latter is constructed with real as opposed to imaginary components—and often more accurately, because MCT controllers can't compensate for unexpected changes in their own output actuators or in the plant. Most of what has been said in the literature of the life sciences about limitations of negative feedback control is simply false. In fact, the limitations do apply to the other kinds of control. How can you resist a disturbance of a kind that has never happened before? An MCT controller can't do that. A PCT controller can, because it senses and acts on the consequences of the disturbance, not on its causes.

For all I know, the MCT concept is a giant leap forward in control theory—for building artificial control systems. I'm convinced it is the wrong model to apply to living control systems. And I'm not too convinced it is a very elegant way to control anything. Thousands, I admit, may think otherwise. But history tells us there's always a chance that thousands can be wrong.

SIMULATION AND MODELING

In chapters to come you will be seeing many simulations of control processes. Some of these are interactive and show how your own control systems work. Others are general models showing how specific control systems might be organized, and how they would then work. These are all computational models in which behavior comes out as a sequence of numbers rather than real objects doing things (this would be true whatever approach to control theory is used). In some models the numbers are converted to pictures, like pictures of a moving arm. The pictures are there just to show where the numbers come from; the control systems being modeled, however, understand only the numbers, as neural networks in the brain understand only trains of neural impulses.

Note: The calculations done in this kind of model describe physical processes that the modeled system is carrying out. It is not proposed, however, that the modeled system carries them out by doing these calculations. It does them according to physical and chemical processes that work without mathematical calculations. We may model those processes mathematically, but the system we are analyzing just does them.

It may be helpful to have some idea of how such computational models work. A simple example can be seen in a mathematical model of a faucet from which water is flowing into a bucket.

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To construct this model you have to represent some properties of the real system with equations that show how the physical variables are related to each other. A variable is just what it sounds like: something that can vary. Consider the rate at which the water flows. Say the flow rate is a variable with values ranging between zero (faucet closed) and some maximum number (faucet all the way open). In conformity to programming customs, you can represent the flow rate by a multicharacter symbol rather than a single letter as is normally done in algebra. You can, in fact, use the symbol *FlowRate*, which rather effectively reminds you of the meaning of this symbol. Using a single letter such as f would be much less memorable. How many words do you know that start with f? How many do you know (now) that start with FlowRate?

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If you use multicharacter symbols, the convention of the implied multiplication sign between two symbols does not apply. "ABE" in algebra means A times B times E. The asterisk (*) is used to indicate multiplication in programming languages, so A times B times E looks like this: A*B*E, and ABE is just a U. S. President's name.

Now, define a second variable, called *HandleAngle*, measured in degrees. With a little experimentation using the real faucet and calibrated containers, you might find a handy relationship between flow rate and the faucet's handle angle:
FlowRate = 0.01 * HandleAngle. With the handle (the round kind) cranked open by two full turns, or 720 degrees, this equation would tell you that the flow rate is 7.2 liters per minute.

Suppose now that the bucket capacity is BucketCapacity = 10 (liters). If you turn the faucet handle to an angle of 360 degrees, how long will it take the bucket to fill?

The length of time, in minutes, needed to fill the bucket is BucketCapacity divided by FlowRate. FlowRate is 0.01*HandleAngle. Therefore you can calculate as follows (units of measurement indicated in parentheses).

```
HandleAngle = 360 (degrees)
BucketCapacity = 10 (liters)
FlowRate = 0.01*HandleAngle = 3.6 (liters/minute)
TimeToFill = BucketCapacity/FlowRate = 10/3.6 = 2.8 (minutes)
```

You don't even need a formal definition of TimeToFill. Using well-chosen multicharacter symbols makes these computations readable and suggests the correct definitions. I point out once again that the bucket and faucet do not do any of these computations. The computations are a systematic and quantitative description of the physical processes.

So far this is the approach taken in physics, of setting up a system of equations and then solving them mathematically to find the values of variables you're interested in. There's another way to solve these equations, however, which is to simulate the filling of the bucket by "acting out" the equations. This is much closer to the way the physical entities actually operate. Set HandleAngle to 360, and set WaterCollected = 0 and Time = 0. Then let water flow into the bucket for 0.1 minute. At the end of 0.1 minute, at a flow rate of FlowRate liters per minute, 0.1*FlowRate liters of water, or 0.36 liters, will be in the bucket. If you do this calculation over and over, keeping track of the elapsed time and stopping the calculation when there are 10 liters or more of water in the bucket, you can read the time and see how long it took. Here is a computer program to do all that (caution: the meaning of the equal sign is different now; to be discussed soon).

```
HandleAngle = 360 (degrees)
FlowRate = 0.01*HandleAngle
BucketCapacity = 10 (liters)
WaterCollected = 0 (liters)
Time = 0 (minutes)
repeat                                          (Start of program loop)
    Time = Time + 0.1
    WaterCollected = WaterCollected + FlowRate*0.1
until WaterCollected  >=  BucketCapacity        (End of program loop)
```


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```
print Time
end
```

(The symbol >= means "greater than or equal to.")

The first time through this program loop (between repeat and until) the amount of water collected is 0.36 liters and the elapsed time is 0.1 minutes. The second time 0.72 liters of water have been collected and the time is 0.2 minutes. The 28th time around the loop, 28*0.36 or 10.08 liters have been collected (exiting the loop because that's more than 10 liters), and the time is 2.8 minutes. The printer will be stirred to print a sheet of paper with "2.8" on it, and the program will end. You could get more precision, of course, by making the time steps smaller than 0.1 minute. and carrying out the arithmetic to more decimal places.

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Notice the peculiar programming statement, Time = Time + 0.1. If you interpret that as algebra, it is simply a false statement. No variable is equal to itself plus 0.1. In a programming language, however, the equal sign used that way doesn't mean equality: it means replacement. The value of the variable on the left is replaced by the value of the whole computation on the right. So Time = Time + 0.1 means that you take the previous value of Time, add 0.1 to it, and store the result back where the variable Time is kept in computer memory, *replacing* the previous value. Because this meaning is so very different from equality, programming languages use two different symbols. Pascal uses := to mean replacement, and = to mean actual equality. The C language uses = to mean replacement, and == (two equal signs) to mean equality. Almost every computer language has a way to make this distinction.

Since I'm mainly a Pascal programmer, I'll use := to mean replacement. So imagine adding that colon in all the preceding program steps and text where there is an equal sign by itself.

It would be easy to "solve" this equation to see how much water would be in the bucket after a given amount of elapsed time. All you have to do is pick some specific ending time ("EndTime"), change the until statement to read

```
until Time >= EndTime
```

and then print out the value of WaterCollected instead of Time. Simulations are much easier to use than analytical mathematics if you have a computer to run them.

You have now seen the difference between a mathematical simulation and an analytical solution of the system equations. To solve the set of equations analytically, you apply the rules of mathematics to obtain one of the variables as a function of all the others. Then, plugging in the values of the other variables, you can calculate the value of the unknown variable just by evaluating a single expression once. This is the approach behind the analyze-compute-act model. On the basis of an analysis of the physical situation, you compute the action needed to achieve some end-result, and then you carry out the action.

A mathematical simulation acts out, step by step, each relationship defined in the mathematical description of the system. You have to give some variables an initial value because each time around the loop that is part of every simulation, the next values of the variables are computed from the previous values together with whatever changes take place during the time represented by one iteration of the loop. The final result is obtained little by little just as the actual behavior being modeled changes through time from a starting condition to an ending, or continuing, condition.

The simulation looks much less efficient than the method of just solving the equations. It is—but it will be finished long before you have found a way to solve the equations if they are complex or you can't solve them at all. The simulation can run faster than real time, so you can see the effect of changing variables or constants as you change them, without having to pause to solve equations. You don't need to make any approximations to the observed relationships to make the simulation work, as you usually must do to find analytical solutions. Analytical solutions can get very lengthy and messy, and sometimes they simply don't exist. Then the simulation method is by far the quickest way, sometimes the only way, to get a right answer. And it has one more great advantage: it gives you an immediate picture of how the whole system behaves through time, because a simulation imitates the behavior of all the variables in the system at the same time.

This is how a simulation works, and I have a strong hunch that it is also how the brain generates behavior.

It's easy to experiment with simulations. Just for fun, let's say that there is a hole in the bottom of the bucket with an area of HoleArea square millimeters, and that the leak rate out of this hole is 1.0*WaterCollected*HoleArea (liters per minute). The higher the water level in the bucket, the faster it leaks out, and the larger the area of the hole, the faster the water leaks out. You can then change the statement FlowRate := 0.01*HandleAngle to read

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```
FlowRate := 0.01*HandleAngle - WaterCollected*HoleArea.
```

You can change «FlowRate» to «NetFlowRate» if you like (it would have to be changed everywhere it appears). To plug the hole, just set HoleArea := 0.

Using a hole area of 0.4 square millimeters and a handle angle of 360 degrees, see what amount of water is in the bucket after an infinite time (you won't have to go on that long). You will notice a problem common to all models if you make the leakage rate less than the inflow rate by a large enough amount. Suppose the bucket can hold 10 liters. You can't get more than 10 liters into a 10 liter bucket, but the program thinks it can because we didn't tell it it can't. Modelers just have to think of graceful ways around such problems: for example,

```
if WaterCollected > 10 then WaterCollected := 10.
```

Finally, suppose the bucket is shaped like that bear-shaped container that honey is sold in. About the only way to represent the height of the waterline would be to experiment with the bucket and make a table of heights as a function of WaterCollected. It's really the height of the waterline that determines the water pressure where the hole is, and thus the leak rate. We've left the analytic method behind.

Now you know how all the simulations in this book work. They start with mathematical statements that describe how various parts of a control system work and how they affect other parts (as the flow from the faucet affects the amount of water collected in the bucket from moment to moment). Initial conditions are set by giving starting values to as many variables as necessary. Then the equations, interpreted as replacement statements (colon-equal), are evaluated one after another to compute the next values of all the variables. This process is repeated over and over, the system "behaving" until some condition is reached or until you stop it. In most of the simulations to follow, the time represented by one iteration of the program loop is 1/60 second. Modern home computers can do millions of computations in that length of time.

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You don't actually have to know any of this about simulations to appreciate the chapters to follow. Most people, however, like to have a little meat on the bare bones of an idea, perhaps, as my old colleague the late Robert Kenley Clark liked to quote from Gilbert and Sullivan, "to lend an air of verisimilitude to an otherwise bald and unconvincing narrative." If you didn't find the bucket example interesting, you have my permission to forget it, if you can.

SOME PHILOSOPHY OF SCIENCE

As a final preparation for the simulations and experiments that follow, we need to look at some basic assumptions of science as they relate to the behavior of living systems. One of the principles adopted by biology and other life sciences has been that organisms are made of matter and therefore obey all the laws that govern the behavior of matter. While this is true, it is also untrue. It's not true that they obey ONLY the laws that govern the behavior of matter. It's true that a lump of solid matter will, because of gravity, fall to the ground when released, accelerating just as Newton said it would (but for air resistance). It's also true, however, that if the matter is shaped into a fuselage and wings, it will fly when you drop it. Laws that apply to lumps of material do not necessarily apply when the material is organized in ways other than lumps. If you analyze an airplane chemically or physically, it will prove to be made of materials that can't, in their raw form, fly. Yet they can be organized to fly.

Therefore we can conclude that the way material objects behave can't be predicted from their physical or chemical properties alone. There is something of nonmaterial nature called organization[5] that endows material objects with properties they would not otherwise have. Or to say that better in another way, the way that collections of materials behave depends as much on how they are organized as on what the materials are. Boats have been built from hollow logs, reeds, bamboo, canvas, iron, and concrete (but not unfrozen liquids or gases). You would never find "floats" on a list of the physical and chemical properties of these materials. Whether the material floats or flies depends on how you organize the materials, and in which liquids you try to make the materials float, or how dense the medium is in which you want them to fly. Penguins fly wonderfully, but only under water. Even a boat built of hollow reeds will eventually sink in water if you don't waterproof it, as Tor Heyerdahl discovered. Balsa-wood airplanes can easily be made to fly, though the airplane kit dumped out of its box will simply fall to the ground (same materials, wrong organization for flying).

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The principle that organisms obey the laws of matter has therefore been more misleading than helpful. It has led to thinking that the same causal laws apply to living systems as to nonliving ones. While that is true at a certain level of observation—you can cause a mouse to fly by throwing it into the air—it is not true at any higher level. You can't cause a mouse to jump into the air *by itself* if it doesn't want to.

Under the traditional principle of lawful behavior of matter, wanting seems meaningless. In certain cases, that's the truth. It's not true that

5 Organization is expressed in terms of relationships among objects or parts of objects. Relationship is a nonmaterial aspect of things. The aspect referred to by between or above is not made of matter or energy.

a hot-air balloon rises because it wants to approach Heaven or that a cannonball falls because it wants to contact the Earth (as engineers used to think 500 years ago or so). Not all organizations of matter want things to happen or to exist. But other organizations do. Living systems do because control systems do, and living systems are made of matter organized as control systems.

So there you are: you are exploring, in this book, the properties of an organization of matter known as a negative feedback control system. Negative feedback control systems have, or can be given, intentions, desires, wishes, and preferences. They can act by material means on the material world to cause perceptions to appear and change until they match what is intended, desired, and so on. This does not require prediction (although prediction is sometimes useful for certain kinds of control). It does not require the future to affect the present (although a reference condition does specify a future condition that does not yet exist, just as a blueprint specifies the shape of a house that has not yet been built). It does not involve probabilities to any significant degree (given the blueprint, the house will almost certainly come into being almost exactly as specified, even if the owner runs out of money for a while or the builder finds he has run out of nails, and even if the architect scratches something out or adds something to the blueprint). The power and precision of control is evident everywhere around us; in any center of civilization almost the only things you can see or touch (unless you're outside and look straight up) are exactly what someone intended that they should be, including their shape, color, and function, not to mention the flavor and price of some of them. The world is packed so full of the consequences of human control behavior that they are invisible, utterly taken for granted, including not only the building in which the human-designed cages full of rats are studied, but the pencil and paper that the experimenter uses —exactly as he intends—to record the results of the experiments, and the journal in which the results are published.

Control, like digestion, is something everyone does, but hardly anyone understands. Let us see now if something can be done about that.

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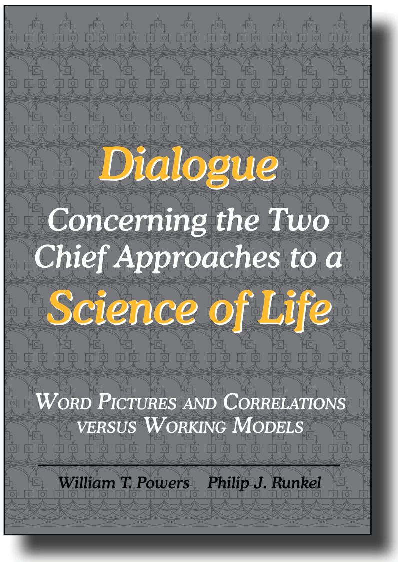
Dialogue
Concerning the Two Chief Approaches to a
Science of Life:
Word Pictures and Correlations versus Working Models



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Books

William T. Powers and Philip J. Runkel
Edited by Dag Forssell

Editor's preface

About these letters

These letters represent much more than 500 pages of correspondence between two lucid gentlemen—the creator of PCT, William T. (Bill) Powers, and Philip J. (Phil) Runkel. The significance lies in the subject matter, Perceptual Control Theory (PCT).

The letters are part of a larger whole. This preface and Part II are intended to provide context.

About the book title

Galileo Galilei is known for *Dialogue Concerning the Two Chief World Systems*, which challenged the old and introduced a new approach to astronomy. For his heresy, church leaders sentenced him to house arrest for life, where he wrote *Dialogues Concerning Two New Sciences*, a discussion of math, physics, and scientific method. For this, Galileo is considered the father of modern physical science. Runkel makes it clear in his letter of October 13, 1999 that he thinks of Bill Powers as the father of a modern science of psychology.

The title of this volume is similar to Galileo's book titles because, just the same, these letters become a dialogue that challenges the old and introduces a new approach—this time in psychology and life science.

You can read these letters as

—questions, answers, and comments on the life sciences in general and psychology in particular
—an account of the gut-wrenching upheaval Phil experienced as his understanding of PCT grew
—an account of what is wrong with methods in psychology
—a prequel to Phil's books *Casting Nets and Testing Specimens* as well as *People as Living Things*
—a tutorial in Perceptual Control Theory (PCT)
—a glimpse into the minds of two intellectual giants
—a partial history of Perceptual Control Theory

This preface and Part II provide

—a brief introduction to PCT (p. 509)
—notes regarding PCT and scientific revolutions
—a guide to resources for your study of PCT

What you will realize

Once you have studied this volume and some of the other PCT resources, especially the tutorial programs, it will be clear to you that psychologists have not provided an understanding of individuals. You will realize that other disciplines which deal with the makeup of individuals and their interactions, such as management, sociology, education, economics, and neurology, suffer due to this lack of understanding.

Specifically, you will realize that:

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—Recognizing and understanding control lays a foundation for psychology to become a science with the accuracy and reliability we expect in the physical and engineering sciences.

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—Failure to recognize, study, and understand control correctly is crippling the life sciences.

—The Scientific Method has been employed for the study of living organisms without regard to the fact that they control their environment, not the other way around. As a result, psychologists have studied the wrong thing, the wrong way.

—A scientific revolution in psychology is underway, just as upsetting, historic, and productive as the revolution in astronomy 400 years ago.

—The idea of an upsetting scientific revolution in psychology will appear inconceivable, absurd, insulting, and outrageous to people who "know" that progress in science is a matter of an indefinite accumulation of facts.

—To become a true science, psychology will have to start over. Related life sciences will also benefit from a recognition and understanding of control.

—Anyone who chooses to study PCT will understand psychology as well as, or better than, existing experts do, because as Will Rogers said:

> *It isn't what we don't know that gives us trouble, its what we know that ain't so.*

Revolutions happen to sciences

The invention of PCT causes a scientific revolution, yet scientific revolutions are little known or understood. In his book *The Structure of Scientific Revolutions*, Thomas S. Kuhn makes it clear that scientific revolutions are infrequent and, once they have occurred, are rendered invisible. Textbooks are rewritten, obscuring the fact that earlier concepts were not compatible with the new.

While my education was technical, in fields where numerous revolutions have occurred, I was unaware of the idea of scientific revolutions until I read Kuhn. I too took for granted that science was a matter of steadily accumulating facts, building indefinitely on prior research. Not so. There have been numerous upheavals in the physical sciences. The Copernican revolution in astronomy is well known. Chemistry started over when oxygen was discovered in the 1780s. Just over a hundred years ago, light was still propagating through aether, which filled the universe.

If you are not aware of our history of scientific revolutions, it must seem inconceivable that there can be such a thing as psychology starting over. Among other things, this means reconsidering a huge body of research—not necessarily all observations, but certainly conclusions and explanations. In his major work *People as Living Things*, Runkel provides an overview of psychology, reconsidered in light of PCT.

I find that much of what I want to say here I have already written, so why reinvent the wheel? My colleagues in PCT have also written about various aspects of this revolution. That is why I have added Part II, a collection of papers and notes that deal with science and revolutions in general, and psychology in particular. Additional notes regarding revolutions follow below.

About psychology and the life sciences

In the realm of science, psychology is perhaps the most important discipline. Much of our health and satisfaction depends on our ability to live well and get along with others.

It makes good sense that, along with management, psychology is the most popular major in our universities. Several other related disciplines take cues from psychology: sociology, education, economics, neurology, anthropology, psychiatry, management and organizational behavior, political science, social work, counseling …

In one sense, every person alive is a psychologist. People studying management want to acquire good people skills so they can be successful. Couples want to understand each other so they can maintain a good relationship. Parents want to know how to teach their children well so they become capable adults. Teachers want to know how to inspire their students. Politicians want to know how to negotiate agreements and lead well. Counselors want to know how to help others resolve conflict.

You would think that the science of psychology will show us how to live well and be effective, but problems persist at all levels of society; within and between individuals, within and between organizations, within and between nations. The popularity of newspaper cartoons such as *Dilbert*, which portrays bad management and morale in the workplace, is but one symptom of the problems people face in their daily lives.

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Several psychologists have pointed out that psychology is not scientific. But until now, nobody has been able to offer an alternative. All have been effectively ignored by the large number of people in this discipline.

I have long been aware that William James is quoted as saying: "This is no science, it is only the hope of a science". I just looked up the context of that quote by purchasing a recent republication. James' statement is much more powerful and aligned with the message of this volume than I expected. I want to share it with you. First some context from the back cover:

> In 1890, after 12 grueling years of writing, thought, and research, the great American psychologist and philosopher William James (1842-1910) finally published his two-volume

Note:
Most documents mentioned in this preface can be found at "the website" meaning either www.PCTresources.com or www.livingcontrolsystems.com. Each has a Google search bar to help you locate the file or document. www.PCTresources.com is my site focused on archives, while www.livingcontrolsystems.com is my publishing site, featuring a wealth of introductory documents, tutorial programs, videos, and numerous PCT-related books. Both sites will change with time, so I do not want to specify at which site any one resource can be found. Files relating to this work, such as enclosures and "About Phil Runkel", show on this volume's web page.

> *Principles of Psychology*—which, in the exhaustion of the moment, James himself characterized as "a loathsome, distended, tumefied, bloated, dropsical mass, testifying . . . that there is no such thing as a science of psychology." More neutral observers immediately recognized James' monumental work as innovative, definitive, and brilliant. Unfortunately, at 1400 pages, it was much too weighty to serve as a text, as James had intended it to be. So in the next two years, he condensed, reworked, and rewrote it as *Psychology: The Briefer Course*. (In academic circles, Principles came to be known simply as "James"—and The Briefer Course as "Jimmy.")
>
> . . . An enormous amount of what James wrote in the fledgling days of psychology is still true, relevant, and thought-provoking today. Students, psychologists, and general readers will welcome this new edition of one of the great—and most readable—classics of psychology.

Here is the last page of the book:

> **Conclusion.**—When, then, we talk of 'psychology as a natural science,' we must not assume that that means a sort of psychology that stands at last on solid ground. It means just the reverse; it means a psychology particularly fragile, and into which the waters of metaphysical criticism leak at every joint, a psychology all of whose elementary assumptions and data must be reconsidered in wider connections and translated into other terms. It is, in short, a phrase of diffidence, and not of arrogance; and it is indeed strange to hear people talk triumphantly of 'the New Psychology,' and write 'Histories of Psychology,' when into the real elements and forces which the word covers not the first glimpse of clear insight exists. A string of raw facts; a little gossip and wrangle about opinions; a little classification and generalization on the mere descriptive level; a strong prejudice that we have states of mind, and that our brain conditions them: but not a single law in the sense in which physics shows us laws, not a single proposition from which any consequence can causally be deduced. We don't even know the terms between which the elementary laws would obtain if we had them. This is no science, it is only the hope of a science. The matter of a science is with us. Something definite happens when to a certain brain-state a certain 'sciousness' corresponds. A genuine glimpse into what it is would be the scientific achievement, before which all past achievements would pale. But at present psychology is in the condition of physics before Galileo and the laws of motion, of chemistry before Lavoisier and the notion that mass is preserved in all reactions. The Galileo and the Lavoisier of psychology will be famous men indeed when they come, as come they some day surely will, or past successes are no index to the future. When they do come, however, the necessities of the case will make them 'metaphysical.' Meanwhile the best way in which we can facilitate their advent is to understand how great is the darkness in which we grope, and never to forget that the natural-science assumptions with which we started are provisional and revisable things.

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The situation has not changed in the last 120 years. Psychology remains an art, not a science. Robyn Dawes, with his book with the telling title *House of Cards; Psychology and Psychotherapy Built on Myth,* is one of many who have sounded the alarm.

Here is the Library Journal review by Mary Ann Hughes and P.L. Neill, posted at Amazon.com:

> Dawes (social and decision sciences, Carnegie Mellon Univ.) presents a strong argument, based on empirical research, that psychotherapy is largely a shill game. He argues that while studies have shown that empathetic therapy is often helpful to people in emotional distress, there is no evidence that licensed psychologists or psychiatrists are any better at performing therapy than minimally trained laypeople. Nor are psychologists or psychiatrists any better at predicting future behavior than the average person—a disturbing conclusion when one contemplates the influence such "experts" have on the U.S. judicial system. While other books have criticized the psychologizing of our society, none has been so sweeping or so convincingly argued. This book raises such important societal issues that all academic and public libraries have a duty to make a permanent place for it on their shelves.

To me, this says in plain English that any wise person is on par with educated psychologists or psychiatrists regarding effective therapy. That includes a caring and thoughtful parent or manager, wise village elder, zen master, rabbi, and caring friend. Psychology as taught in our universities is not helping.

Tim Carey, author of *The Method of Levels: How to do Psychotherapy Without Getting in the Way,* provides additional detail. You can access his observations easily. See *A Look At Where We Are*, listed on page 507.

Runkel, whom you will get to know in this volume, said in the foreword to his major work *People as Living Things*:

> I will disagree in serious ways with most of the widely accepted psychological theories you encounter in popular literature, in textbooks (of whatever discipline), and in the halls of academe. I will agree with the other theories at some points, but the underlying assumptions of the theory here (Perceptual Control Theory) are not those you will find either printed or implied on many of the pages printed about psychology. In that sense, this book is disputatious. I do not, by the way, claim that those other authors and lecturers are immoral or mentally deficient. I claim only that they are wrong.

About Perceptual Control Theory, PCT

Developed by William T. (Bill) Powers, Perceptual Control Theory (PCT) is a quantifiable, testable model of how living systems work. In time, PCT will help us understand living organisms with the accuracy and reliability we expect in the physical sciences.

Understanding PCT starts with understanding control systems. We use all kinds of mechanical control systems regularly, such as thermostats and cruise controls. We set a desired temperature, and if there is a difference between that setting and the temperature sensed by the thermostat, it turns on the heater or the air conditioner. We set the speed we want to drive, and if the car notices that we slow down, it automatically steps on the accelerator.

Bill Powers explains:

> Control is a process of acting on the world we perceive to make it the way we want it to be, and to keep it that way. Examples of control: standing upright; walking; steering a car; scrambling eggs; scratching an itch; knitting socks; singing a tune. Extruding a pseudopod to absorb a nanospeck of food (all organisms control, not only human beings).
>
> The smallest organisms control by biochemical means, bigger ones by means of a nervous system. Whole organisms control; the larger ones have brains that control; most have organs that control; if they are composed of many cells, their cells control; the DNA which directs their forms and functions controls; even some molecules, certain enzymes, control by acting on the DNA to repair it when it's damaged. Control is the most basic principle of life and can be seen at every level of organization once you know what to look for.
>
> …The problem is not that the life sciences got everything wrong; it's just that they got the most important things wrong: what behavior is, how behavior works, and what behavior accomplishes.

Papers

Books

Full disclosure:
I refer frequently to Kuhn. His opinion of PCT appeared on the book jacket when Bill's major work, *Behavior: The Control of Perception* was published. (In discussions, this title is often abbreviated B:CP).

THOMAS S. KUHN, Professor of the History of Science, Princeton University; author of *The Structure of Scientific Revolutions.*

> "Powers' manuscript, *Behavior: The Control of Perception,* is among the most exciting I have read in some time. The problems are of vast importance, and not only to psychologists; the achieved synthesis is thoroughly original; and the presentation is often convincing and almost invariably suggestive. I shall be watching with interest what happens to research in the directions to which Powers points."

How is PCT different

Once you understand PCT, you gain a perspective on contemporary psychologies.

Bill Powers portrayed stimulus-response thinking as well as cognitive psychology from a control theory perspective at a Control Systems Group conference. The following is based on his discussion.

Let us start with a control diagram. It is not my intention here to explain PCT, only to identify the variables and functions considered in a control diagram, and how they interact. A convenient summary is featured in *Once Around the Loop*, a paper posted at the website and included in the *Book of Readings*.

(By *Book of Readings*, I mean *Perceptual Control Theory; Science & Applications—a Book of Readings*, credited to Powers and updated from time to time.)

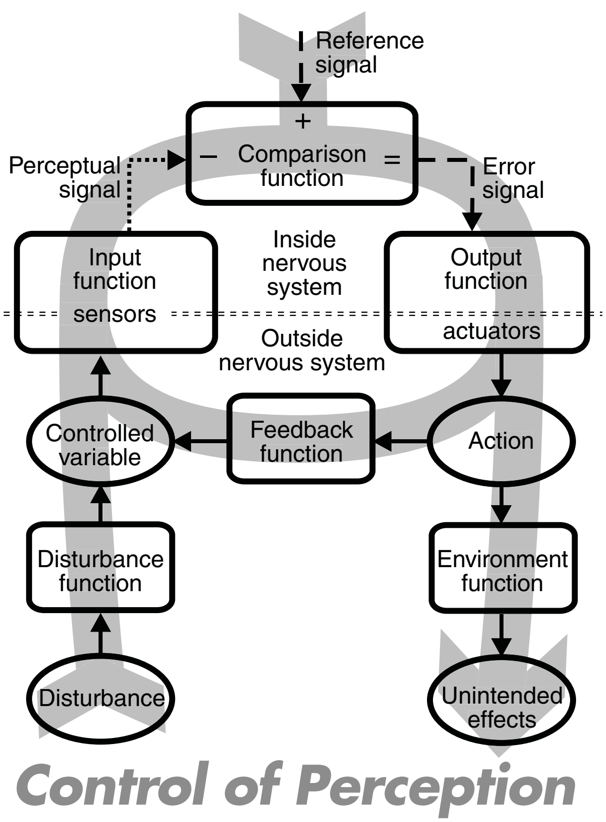

Fig. 1 Perceptual Control Theory, PCT
Closed–loop Psychology
The basic summary control diagram.
The grey overlay highlights the closed-loop flow.

Please review Figure 1: Disturbance is something going on in the environment that affects whatever the organism cares about, the Controlled variable, as represented to the brain by the Perceptual signal.

What the organism wants in regard to the Controlled variable is represented by the Reference Signal. Comparing the two results in the Error signal (a difference signal, not a value judgement) which affects actuators, whether muscles or physiology, so that the Perceptual signal representing the Controlled variable is brought to (or kept) close to the Reference signal.

And no, we do not say it is this simple. This diagram represents an entire hierarchy of control systems—by the millions—at work throughout your nervous system at all times, controlling a multitude of variables inside and outside your body, all simultaneously.

For a conceptual sketch of the proposed hierarchy, see *Perceptual Control—Details and Comments* in the *Book of Readings*. (That and similar illustrations, including the pattern on the cover of this book, draw on Mary Powers' sketch on page 405.)

Papers

Books

Behaviorism

The idea of stimulus-response seems intuitively obvious. For example, if you stand on the deck of a ship during a storm, the heaving deck makes you do things (but only if you want to stay upright ☺).

René Descartes formalized the concept of stimulus and response in the mid-1600s. Behaviorists have worked hard to build a science based on this, and while some psychologists will claim that behaviorism is out of fashion, it is very much with us and Experimental Analysis of Behavior (EAB) is alive and well.

Applications permeate our culture. Surely you have heard of gold stars, incentive programs, and one minute management.

Figure 2 shows the control diagram overlaid with an interpretation of what researchers invested in stimulus-response thinking are looking at: Disturbances in the environment and Action by the organism.

As you can see, psychologists studying a stimulus (Independent Variable) and the response to that stimulus (Dependent Variable), creating statistics galore (and mistakenly presuming that correlation implies causation and that statistics tells us about individuals–see Kennaway (1998)), are studying only that which is visible in the environment, thus looking at a very small subset of the whole. It is not possible to build a science based on such a limited understanding of what is going on.

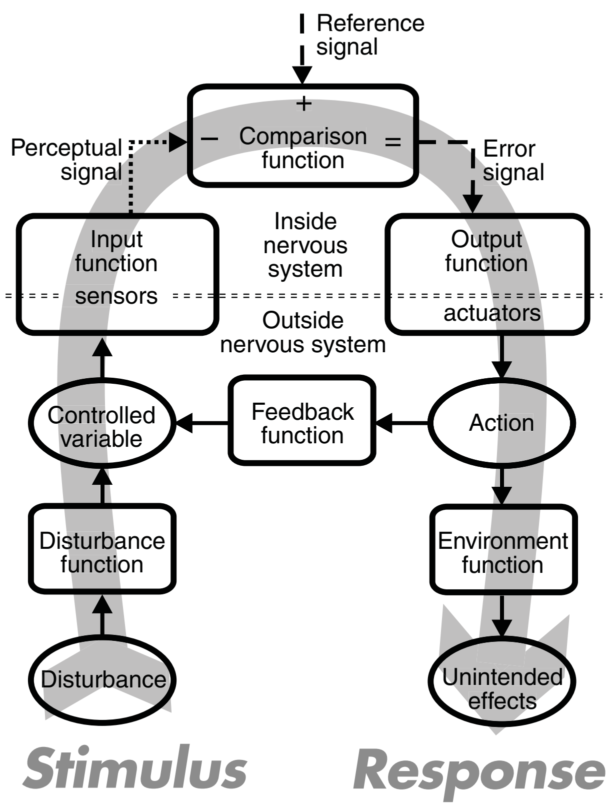

Fig. 2 Behaviorism:
Stimulus–Organism-Response
Illustrated in terms of a basic control diagram

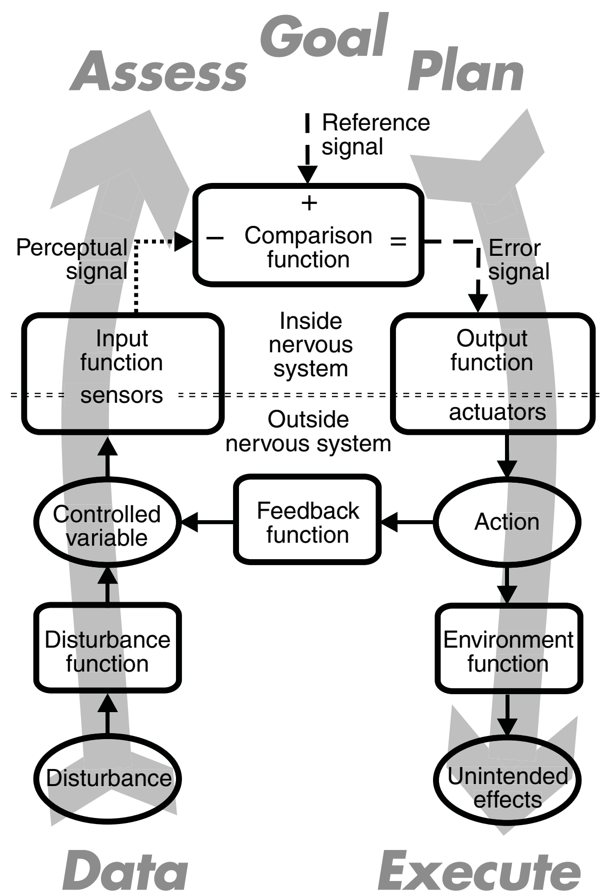

Fig. 3 Cognitive Psychology
Data-Assess-Goal-Plan–Execute
Illustrated in terms of a basic control diagram

Papers

Books

Cognitive psychology

It also seems intuitively obvious that your mind issues commands to your muscles.

For example, if your ship is at rest, the environment does not make you walk across the deck to the other side. You just decide to walk. So now we study how the mind can evaluate the environment and plan action, then issue commands to our muscles. Engineers have demonstrated (using a laborious approach called Inverse Kinematics) that it is very possible to precompute commands to muscles and motors so limbs move just so—provided you have a powerful computer and provided that there are no disturbances at all. Muscles must not tire, and the environment must not change. This is the case for robots in repeatable circumstances and for animated 3-D figures in computers, but never for living organisms in the real world.

Figure 3 shows the control diagram overlaid with an interpretation of what researchers in the discipline of cognitive psychology are focusing on.

The intuitively obvious idea that the brain processes information, plans action, and issues commands to our muscles lies at the heart of cognitive psychology, and psychologists are working hard to sort out the complexities of our minds on this basis.

Not so intuitively obvious is the fact that neither the concept of behaviorism nor that of cognitive psychology is sufficient to explain how you can make your way across that heaving deck during the storm, or how a swallow can fly right into the small opening of her nest, without fail, on a windy day.

Discussion

While many psychologists recognize purpose and feedback in general, a detailed, correct understanding of negative feedback control is missing. Without a detailed understanding it is not possible to create a science of psychology.

This situation in psychology today is not very different from the situation in astronomy 400 years ago. At the time, astronomy was well developed with extensive observations and elaborate explanations based on the intuitively obvious idea that the earth is the center of the universe and everything revolves around the earth.

As anyone who spends night after night observing the heavens can see, from time to time Mars and the other planets change course relative to the stars, moving forward, then back, then forward again. A prominent feature of earth-centered astronomy was the explanation that Mars and the other planets not only move in circles around the earth, but at the same time in little circles, epicycles, around a point on the big circle as it progresses around the earth.

Once people reviewed the evidence and understood the mechanism of the solar system, the explanations that went with the earth-centered astronomy crumbled. Mars and the planets never move backwards. It just looks that way. The phenomenon turned out to be an illusion.

Just the same, once you understand the mechanism of control and review the evidence, the explanations that go with stimulus-response and/or plan-execute psychologies crumble.

As illustrated in Figures 2 and 3, Perceptual Control Theory shows that the intuitively appealing explanations in terms of stimulus-response and plan-execute are incomplete at best. The phenomenon of stimulus-response is an illusion. Organisms do not respond to stimuli, they oppose disturbances to their controlled variables. Organisms do not plan actions, they simply change reference signals and the hierarchy of control systems acts as necessary to bring perceptual signals in line with reference signals. PCT is a larger, complete, more all-encompassing explanation than either behaviorism or cognitive psychology. Therefore, PCT cannot be integrated into these limited approaches any more than it was possible to integrate the idea of the solar system into the then existing earth-centered astronomy.

In Figure 1, you can see that Perceptual Control Theory considers disturbances in the environment, a rapidly varying reference signal (think speech, what you want to hear from your mouth varies rapidly and you can control the sound quite well), tiring muscles, changes in how your limbs affect the environment and the controlled variable. Because of the nature of negative feedback control, organisms can deal with rapidly varying reference signals, disturbances, functions and variables.

Clearly, attempting to correlate any two variables is not enough. While cognitive psychologists are fond of talking about a cognitive revolution in psychology, the mistaken application of the scientific method has not changed[1]. Research is still based on correlating an Independent Variable with a Dependent Variable. Neither behaviorists nor cognitive psychologists realize that it has been a profound mistake to focus on Action/Behavior. What is of interest to the organism is the state of its Controlled variable. Conducting research informed by PCT you would look for a very low correlation between any Disturbance and the Controlled variable rather than a high correlation between Disturbance and Action[2]. This is the point of the demonstration Bourbon relates in his paper *Three Dangerous Words*. (See Part II, page 530, right column)

For more on psychological theorizing, see Runkel's *People as Living Things*, Part III Science.

Papers

Books

About scientific revolutions

The movie Avatar provides a nice, very personal introduction to scientific revolutions.

A Na'vi girl called Neytiri has just saved our hero Jake from snarling beasts. The Na'vi are natives living on the moon Pandora, resisting the human intruders (Sky people) who are mining their incredibly valuable mineral Unobtanium without regard for the natives or their environment.

As they walk along, Jake asks Neytiri why she saved him. She answers that he has a strong heart and no fear, but that he is *ignorant,* like a child. So he suggests that she should teach him. She answers that Sky people cannot learn, they do not *see*, and that nobody can teach them to *see*.

---

1 For a discussion, see Marken (2009)

2 See Marken (1992, 2002)

Jake is brought to the village gathering and the matriarch Mo'at examines him. She asks why he came; he answers that he came to learn. Mo'at says that the Na'vi people have tried to teach other Sky People, but that it is hard to fill a cup which is already full.

Jake responds that his cup is empty; he is no scientist. Mo'at assigns Neytiri the responsibility of teaching Jake the Na'vi ways, and they will see if his insanity can be cured. How Jake and Neytiri come to appreciate each other, and then to love, illustrates what Ed Ford calls *Quality time* in his book *Freedom From Stress*—an introduction to PCT based on his experience as a counselor.

Scientific revolutions are personal

In the clash between cultures that the movie depicts, what matters are personal understandings. That is why it is significant that Jake's cup is empty. Unlike his colleagues, Jake does *not* have a Ph.D. and has *not* spent three years or more studying the human occupiers' documentation of the Na'vi culture, language, and environment. Thus he does not have an investment in a particular understanding and it is much easier for him to come to see the Na'vi world through Na'vi eyes and appreciate its beauty.

All scientific revolutions are personal. As Clark McPhail, a sociologist and student of PCT, makes very clear in *The Myth of the Madding Crowd,* there is no such thing as a group mind. All individuals are thinking and acting separately.

Thus this revolution in psychology is an issue for each individual who undertakes to study PCT. Bill Powers is the first to point out that none of the people who have looked into PCT so far were taught PCT at an early age. Everyone has a cup that is full already, making the transition that much more difficult.[3] Bill considers himself to be a student of PCT, not a guru, both as a matter of attitude and because much remains to be figured out and researched. It follows that everyone else in the PCT sphere is a student too. This is one reason Bill is tolerant and supportive of anyone who makes an effort to learn PCT.

Given that everyone who is exposed to the concept and explanation that PCT offers has already created a personal web of understandings based on personal experiences and interpretations from an early age, supplemented with teachings at whatever level in school, nobody has a cup that is empty. But there are degrees of fullness and there are variations in how a person thinks, as a result of what the person has experienced and what conclusions the person drew from those experiences.

I hope that telling my story, my journey to PCT and experience to date, will provide useful context —an overview of progress to date, where and how anyone can learn more.

Dag's story

My wife Christine and I grew up, met and married in Sweden. We traveled to the U.S. together in 1967 to see the world before we would settle down in Sweden. We never returned.

I got jobs as an engineer and engineering manager with marketing responsibilities. Christine, while she had worked as a physical education teacher during our first years together in Sweden, worked at home to raise our two daughters.

In 1975, Christine got involved in direct sales of nutritional products—in line with her interest in good health—and I accompanied her to events featuring motivational speakers. I was intrigued. I listened to the speaker spin a story of how she would tell the customer this, and the customer would think that, and then she said the other, complete with detailed explanations of what went on in the customer's mind, the customer's spouse's mind, and their circumstances. Of course the customer would buy the product package. One can get motivated by this kind of imagining, but the euphoria is fleeting. The problem is that while you buy into the story the speaker relates, this scenario is not likely to happen in the real world. Nevertheless, I enjoyed numerous tape recordings of well known motivational speakers, such as Earl Nightingale. I was open to suggestions from various directions and found some of the advice useful.

In my search for insight into what makes people tick, I continued reading books on topics such as listening and character education, one recommending the other. I found *Reality Therapy* by William Glasser, liked it, and read most of his writings. I found his book *Stations of the Mind* fascinating. Here, Glasser explained and illustrated PCT in order to provide theoretical support for *Reality Therapy.* A foreword by Powers discussed the origins of PCT.

Papers

Books

3 For some ideas on how we all fill our cups, see *Are All Sciences Created Equal*, starting on page 535 in this volume.

Discovering PCT

Curious about the foreword to *Stations of the Mind,* I overcame the high price, purchased and read Powers' *Behavior: The Control of Perception (B:CP)*. I found an elegant, very physical explanation of how our nervous systems can work. To me, the text is clear and well illustrated. I found it easy to visualize interactions between neurons as shown in chapter 3, Premises (featured in the *Book of Readings*). I saw that there are significant differences between Powers' original and Glasser's embellished, very personal interpretation (currently called Choice Theory). But I am glad that through Glasser I found the real thing.

In early 1989 I asked a member of Glasser's faculty about Powers. I was directed to Ed Ford and visited him in Phoenix. Ed supplied me with his book *Freedom From Stress* and told me about Powers' Control Systems Group (CSG) and its forthcoming conference at the Indiana University of Pennsylvania.

Getting involved—conferences, archives, email, teaching, books and recommendations

Traveling to the conference, I met Gary Cziko while waiting for the bus at the Pittsburgh airport. He told me right away that his focus was evolution, and he has since written two excellent books on evolution and PCT—*Without Miracles: Universal Selection Theory and the Second Darwinian Revolution* and *The Things We Do: Using the Lessons of Bernard and Darwin to Understand the What, How, and Why of Our Behavior*. See also *The Origins of Purpose: The First Metasystem Transitions* among Bill's introductions at the website.

Arriving at the conference, I met Bill Powers and many others who have become good friends.

One was Tom Bourbon, who was teaching psychology and PCT at the University of Texas at Austin.

Another was Greg Williams. He and his wife Pat, both MIT engineers, saw the historic significance of Powers' work a few years before I came into the picture. Greg edited the newsletter *Continuing the Conversation* (CC) from 1985 through 1991. CC started out as a forum for conversations about Gregory Bateson, but shifted to cybernetics and PCT in 1986 once Greg discovered PCT. From 1986 through 1989, CC served as the official newsletter of the American Society of Cybernetics (ASC) and is now archived at the website as well as at ASC's website. You will find CC discussed in letters on pages 280 and 345 in this volume. Greg recorded CSG meetings starting in 1987. He also edited *Closed Loop* from 1991 through 1994. At the outset this newsletter featured threads from the mailing list Control Systems Group Network (CSGnet), later complete articles. Closed Loop is archived at the website. The last issue of Closed Loop features a 54-page catalog of CSG archive materials held by Greg and Pat at their home in Kentucky. The extensive list includes items such as all 15 Masters theses by Tom Bourbon's students. While serving as archivist for the Control Systems Group (CSG), Greg made selections from Bill's unpublished papers, edited and typeset Bill's anthologies (1989) and (1992) and the college textbook by Robertson (1990).

I have become a second archivist for CSG. Greg and I will work with educational institutions to make CSG archives available to students and researchers and to ensure that they are duplicated so they will not be lost to history if any one location suffers a catastrophic loss. **Papers**

One 1989 presentation that has stuck in my mind and that any reader can replicate was Wayne Hershberger's illustration of saccades. Wayne held up a red LED, **Books** such as was common on digital clocks. These LEDs actually blink at 60 Hertz because of the AC current. Wayne darkened the room and asked us to look at the red light, then shift our gaze suddenly far to the left. It was easy to see blinks an equal distance to the right, before the light was again stationary in Wayne's hand. If you sit still and move your eyes around, the image of the room in front of you does not shift, or shifts very little, even though obviously the image falls on a different place on your retina. It made sense to me to think that the control hierarchy postulated by PCT would shift the retina's coordinate system as it shifts the directions of the eyeballs, and that the neural coordinate system would shift faster than the physical eyeballs. Thus the blink off to the right. (With a solid light you see a streak instead of discrete dots). At the time, Wayne was editing the anthology *Volitional Action, Conation and Control*, which features 25 chapters. Half relate to PCT.

Jim Soldani, formerly Director of Systems Manufacturing at an Intel plant in Phoenix, contributed the chapter *Effective Personnel Management: An Application of Control Theory*. Jim reported spectacular results from applying his understanding of PCT. For more, see Jim's recent paper *How I applied PCT to get results*. In the fall of 1990 Jim came to the Phoenix airport to spend 45 minutes with me. He shared with me that he had spent six years following his success at Intel developing a consulting business teaching PCT to industry. Despite pockets of considerable success, he found it a hard sell and had to give up.

Purposeful Leadership

I was at a crossroads at the time. I had met Mike Bosworth who was teaching a sales training program called *Solution Selling* and served as a student group coach a few times. I explained to Mike that the basics of his approach might have been based on the way PCT would suggest that you focus on how the customer wants to solve his problem, not on what the salesman wants to sell. Mike encouraged me to teach PCT to sales managers. He explained that a persistent problem is that a star salesperson gets promoted to sales manager and falls flat on his face. While solution selling was a good program for teaching salespeople how to sell, a good program teaching sales managers how to manage would be invaluable.

In spite of Jim Soldani's warnings, I undertook in early 1991 to teach PCT to captains of industry and registered the trademark *Purposeful Leadership*. I put a program together and mailed thousands of letters to executives. Most of these no doubt ended up in wastebaskets, but one technology company allowed me in 1992 to present my program on three consecutive Wednesdays. About 15 people in marketing and 15 engineers signed up. By the third Wednesday, most of the marketing people had dropped out, leaving the engineers. The Human Resources manager told me afterwards I was not as entertaining as she expected but the feedback I received from the engineers was positive. Two of the engineering managers wrote me a year and a half later to report on how they were using what I had taught them and their results.

Much later I assembled articles and an outline of my program along with the feedback in *Management and Leadership: Insight for Effective Practice*.

In the early 1990s, the Deming Management Philosophy was new and Total Quality Management (TQM), was emerging as a management tool. I saw a connection, so I attended Deming's seminar and wrote Dr. Deming, who graciously responded:

> Dear Mr. Forssell, 15 June 1991
>
> I thank you for your letter of 8 June 1991. Yes, Profound Knowledge is not what people are looking for. They seek procedures and formulas. It is a hard broad jump. I agree, psychology is the weak link.
>
> Sincerely yours,
> *W. Edwards Deming*

With the experience of my seminar under my belt, I presented a two-hour introduction to PCT to Deming Users Groups in early 1993. See the video *PCT supports TQM* at the website.

Dr. Deming's note supports the conclusion I drew from my experiences that many people do not expect understanding from seminars; people expect entertainment and prescriptions.

My efforts to develop a teaching and consulting practice failed to generate income, so by 1994 I had to give it up. I found a new profession translating technical texts between English and Swedish.

Staying involved

Gary Cziko sponsored an email discussion group, Control Systems Group Network (CSGnet) in September, 1990. CSGnet became a forum for lively, wide-ranging discussions about PCT, with Bill Powers patiently teaching all comers. Bill is still going strong 20 years later.

Papers

Books

Because I was focusing on PCT full time, I immediately began saving all the CSGnet correspondence and have continued to do so. This archive is available at the website. The earliest record consists of Word files, but as of March 1992, mailboxes created by the Eudora e-mail program are available as well. Eudora, now in the public domain, features excellent Boolean search capability, which means that you can search the many megabytes for comments on any topic.

In 1993-1994 I also undertook to assemble about 100 threads from CSGnet. Needless to say, these too are posted at the website. Threads discussing stories, belief and knowledge are particularly relevant to this discussion of scientific revolutions[4].

I had purchased a video camera and editing tape deck for the purpose of teaching PCT, so I brought it to the 1993 CSG conference and have taped most conferences since. More than 300 hours of camera tapes have now been digitized and I will be happy to provide this material to institutions and serious students.

CSG conferences are very informal indeed. That is the way Bill wants it. Participants organize a schedule of presentations on the first evening of a three-day conference and anyone is welcome to present most anything, even where the relation to PCT is tenuous at best.

As I find time to edit video and create flash files, I will post a selection of presentations at the website.

4 See especially the threads called Gullibility.pdf,

Presentations in 1993 that have stayed with me include Bill Powers presentation *The dispute over control theory*, which inspired my illustrations in this preface, and sociologist Clark McPhail telling how researchers in the past never studied crowds, but voiced opinions anyway, and these now dominate textbooks. Clark had recently published his book on crowds. A few sentences from the Foreword tell the story:

> A most peculiar thing has happened. A few scholars of crowd behavior actually have begun to observe and describe systematically the empirical features of crowds. Disconcertingly, this represents a radical development in the annals of crowd analysis. Clark McPhail is the intellectual leader without peer in chronicling and categorizing temporary gatherings before trying to explain them. As a result, his accounts of their variable features have virtually no counterpart.

Kent McClelland gave his first of several presentations on *Conflictive cooperation*, later published as *The Collective Control of Perceptions: Constructing Order from Conflict*. Kent's work is very suggestive about how large groups of people, even while bickering among themselves, control for a set of outcomes with great collective force. This helps explain resistance to new ideas by groups of scientists, as well as the glacial pace of political process involving large groups.

In his presentation, Clark McPhail mentioned that sociologists are interested in purpose. Clark is one of the many contributors to the recent book *Purpose, Meaning, and Action*, which Kent co-edited.

Other 1993 presentations I remember were Tom Bourbon on *Person-Model Interactions: Interference, Control of Another, Countercontrol & Conflict* and his student Michelle Duggins-Schwartz on the topic *When is helping helping?*

In 1994, I presented my interpretation of how *Memory* might be continuously active in the hierarchy and an attempt to sort out *Explanations*, which became *Are All Sciences Created Equal?* on page 535 in this volume.

Ed Ford and collaborators provided an overview of their development in inner city schools in Phoenix of their *Responsible Thinking Program* (RTP); a program designed to resolve discipline problems in schools in a way that is supportive of both students and staff.

In 1995 a group of five PCTers presented at the American Educational Research Association (AERA), conference in San Francisco. The demonstration / workshop was led by Hugh Petrie who at the time was Dean, Graduate School of Education, State University of New York at Buffalo. Once I met Hugh, I ordered his book *The Dilemma of Enquiry and Learning* which spells out how he found that PCT resolves Meno's classic quandary. For more on Hugh and his involvement with PCT, see his Intellectual Autobiography at the website.

In 1997, Wolfgang Zocher, an engineer, presented *Simulating eye movement*, a simulation he had carried out using an analog computer. He later demonstrated his computer when he hosted a CSG conference in his home town of Burgdorf, Germany. Bill Powers presented *Artificial Cerebellum* and *Little Man*, fruits of his increasingly realistic modeling efforts. Tom Bourbon presented *Interactive control, a survey of where PCT has been tested in social interactions*.

Also in 1997, Bill Powers presented prints of the original draft for what became *Making Sense of Behavior*. Many people have expressed appreciation for this slim volume for its simple, basic, easy-to-understand introduction to PCT—featuring neither equations nor graphics.

Papers

Books

1998 saw two conferences. The first, at Schloss Kröchlendorff north of Berlin, Germany, featured a fascinating presentation by Bill of his new program *Inverted Pendulum*. We have all balanced a broom in our hand, moving the hand around to keep the broom upright. Well, as we walk about we are our own brooms, so this demo is all about us. Bill explained that he achieved the splendid performance of his model using just five nested control systems.

Frans Plooij presented *PCT and infant research, an 11 year overview*. I consider the work of Hetty van de Rijt and her husband Frans Plooij, now available in English as *The Wonder Weeks*, to provide some of the most compelling, tangible evidence available that Powers' suggestions for a hierarchical arrangement of control systems is much more than hypothetical. When you read their book, you are reading about the mental development of infants in stages of progressively more complex perceptual capability. At the same time you are reading about how your own brain is working right now, a hierarchical layer cake of control systems, with each successive class of perceptions building on those that were developed before it. www.thewonderweeks.com features information about their research as well as supportive research by other behavioral biologists.

In Vancouver, BC, that same year, one of the new developments was Rick Marken's report on how baseball players catch balls by keeping certain perceptual variables under control.

1999 featured a separate two-day pre-conference on *The Method of Levels*, anchored by Bill Powers and Tim Carey. During the regular conference that followed, Tim Carey gave presentations on *Bullying* and *Counter-control*.

At the 2000 conference in Boston, Bill Powers introduced his recent simulation program *14 degrees of freedom* featuring an entire arm, and Hugh Gibbons, professor at the Franklin Pierce Law Center, presented a theory of rights. Hugh is the author of *The Death of Jeffrey Stapleton: Exploring the Way Lawyers Think*, in which he uses PCT to explain the structure of law.

Significant to me, this was also the conference where Phil Runkel tugged at my shirtsleeve during a break and asked me to review his manuscript (which I published in 2003) for technical accuracy. I began development of livingcontrolsystems.com in 2004 to support Phil's work. It has grown into a PCT reference site.

At the 2001 conference in Burgdorf, Germany, Richard Kennaway presented his six-legged bug named Archie, with full physical dynamics, using control systems to operate the legs and a pair of odor-sensing antennae to detect food locations. Archie can walk over uneven terrain, all without using any inverse kinematic or dynamic calculations, any analysis of the terrain, or any plans of action. Richard also presented his work on an *Avatar* that translates simple code into sign language for TV programs, moving smoothly from one sign to another in a very natural way.

During the 2003 conference in Los Angeles, we celebrated the 30th anniversary of the publication of B:CP. A delegation from South China Normal University attended. Tributes to Powers were offered. Lloyd Klinedinst unveiled the web-based Festschrift he had organized as a tribute to Powers' genius.

Bart Madden, an independent researcher, found PCT in early 2005. Bart is focused on market-based solutions to public policy issues. He recently published *Wealth Creation; A Systems Mindset for Building and Investing in Businesses for the Long Term*. The first chapter, *A Systems Mindset*, features a discussion of the importance of considering the purposes of managers as well as employees, shareholders, and customers. Bart correctly introduces the basics of PCT and adapts his insight to his presentation.

A most significant recent development is Powers' *Living control systems III: The Fact of Control.* Runkel read B:CP. I did. Many others have. But it is not all that easy to grasp PCT from the written presentation by Powers, however lucid, or from any other written description. Words get in the way. Our understandings of words are necessarily influenced by our personal experiences, so the meanings of words can never be exactly the same for any two people.

Understanding control and PCT has now become much, much easier. The 13 Windows programs that this book explains in its nine chapters are control systems. By changing parameters of these control systems, you can experience the nature of control directly, in diverse ways. These personal experiences will enable you to understand the intended meaning of the words about control that you will read in this book and in the other works that we have cited.

Shelley Roy's book *A People Primer: The Nature of Living Systems* is a welcome addition to the PCT literature. This book is an easy read, yet portrays PCT correctly as Shelley discusses common problems.

In 2009, Bill Powers wrote an outline for a TV program designed to introduce PCT. The program did not come to pass, but Bill's paper explaining *PCT in 11 Steps*, followed by *Reorganization and MOL*, an overview of how control systems may come into being, change, cause internal conflict, and ways to resolve internal conflict, is an excellent introduction to and summary of PCT.

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Final comment

As I have studied PCT, participated on CSGnet, and attended conferences, I have come to understand what turns out to be a frequent problem for PCT—people read about it, figure they understand it because the terminology sounds familiar, and proceed to publish their own distorted versions that cannot work. In his recent intellectual autobiography, posted at the website, Hugh Petrie writes in a note:

> Those familiar with the educational literature will recognize that William Glasser has written extensively in education utilizing a concept he calls "control theory." Although there are superficial resemblances to Powers' perceptual control theory, Glasser completely fails to appreciate that what is controlled are perceptions, not actions or behaviors. This renders Glasser's version of control theory no more insightful than most cognitivist theories in psychology.

I have come to understand that we all make new information fit what we already think we know. If our cups are already full, and depending on how we think, this means that the new may be interpreted and distorted so it will fit, like forcing a square peg into a round hole, even if the result is turning PCT upside down and backwards. PCT itself explains how this works.

Kuhn points out that new ideas are typically resisted by people already steeped in a science, that the new ideas often come from outsiders, and that younger scientists, whose cups are not as full, are the ones who weigh the merits of the new compared to the old and make the choice to go with the new. This is why scientific revolutions tend to take a long time to play out. They require a generation change.

You will find examples and discussions of this phenomenon in this volume and at the website under *Controversy, Comparisons and Acceptance*.

Glasser's mistake is common. The holy grail of psychology has long been the prediction and control of behavior. The idea that we control our behavior permeates our culture. Many control engineers think so too—control systems control their output, right? Wrong! It is not the movement of a motor or the position of the machine that is controlled. It is the reading from (the perceptual signal from) the sensor that reports on the position of the machine that is controlled. This becomes very clear if the sensor is poorly calibrated. Simple control systems have no knowledge of their output/actions, the only thing they "know" is what they sense, their input.

As humans, we can pay attention to and remember our actions, but for the most part we do not. We pay attention to outcomes and whether they match what we intend. People do not control their action/behavior. People control for what they want to experience, outcomes, their sensory input.

It follows that most people alive today, including control engineers, talk about control and presume they understand it, but have never realized that their understanding is deeply flawed. Our cups are full—full of mistaken interpretations—and as a result almost everybody is profoundly ignorant about how and why we all behave as we do.

There is much more available than I have touched on here, at my web sites and at those of other PCTers. More will develop as the world catches on to PCT.

As you can see, this volume, while extensive, is only the proverbial tip of the iceberg of information that is available to you. Enjoy! I hope you find this introduction and the references useful for your studies.

Dag Forssell
Hayward, California

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Papers

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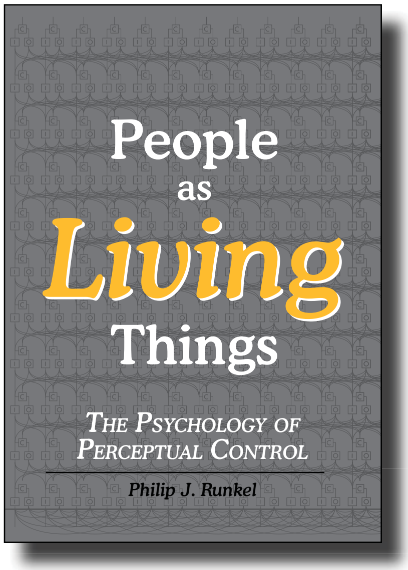
Continued...

People as Living Things:
The Psychology of Perceptual Control



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By Philip J. Runkel

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Part III

Science

In Chapters 6 through 9, I exhibited some ways that researchers have tested, through actual observations, some assertions made by PCT. I said, too, that you can carry out more precise demonstrations on your own computer by running tutorials, demonstrations and simulations found at the publisher's website

http://www.livingcontrolsystems.com.

As I went along, I made some remarks about research method and scientific assumptions. Those are important matters for this book, because PCT makes some assumptions about science and research that are very different from those common in traditional academic psychology, and I want to be explicit about them. That is the purpose of the chapters in Part III.

Traditional psychologists test their understanding of human behavior by predicting acts. Examples read something like this: More people among those who answer "yes" to certain questionnaire items will also prefer certain kinds of recreation than among those who answer "no." Or this correlational form: People who score high on a test of Phebephobia will also score high on a test of Pontiphilia, and those low on the one, low on the other. It is no surprise to anyone that only *some* of the people observed turn out to conform to the predictions. Traditional psychologists feel vindicated when the portion who do conform is larger than one would expect from pure chance. That is the reason I refer to that sort of research as nose-counting. In my 1990 book I gave it a more formal label: the Method of Relative Frequencies.

Adherents of PCT do not try to predict particular acts such as scoring high on something. Neither do they count noses. PCTers insist that the correctness of an assertion derived from PCT must be found justified in *every* individual tested. The demonstrations and experiments described in Chapters 6 through 9, for example, were published even though they were performed with few participants, because the authors (and other PCTers) are ready to discard the theory or revise it radically if *one* person shows up reliably behaving contrary to the PCT prediction.

PCT is tested by modeling (in the manner I described in Chapter 8 under the heading "Models and Theories") and by using The Test for the Controlled Quantity that I described at the end of Chapter 7 under "The Test." The Test is used to examine every sort of question about PCT. It is used to investigate how nerves work together (physiological psychology), how people can see transitions (sensory psychology), how two or more people can interfere with one another's purposes (social psychology and sociology), and so on.

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PCT does not claim that all animals have the same number of layers of control (humans probably have the most), and it does not claim that the nervous system of an octopus has the same gross morphology as that of a human, but it does claim that the negative-feedback control loop (Figure 4–1) reigns supreme. Furthermore, the claims of PCT about behavior are pertinent to all sciences (and to all lore, too) that deal with living creatures, because all those sciences make assumptions about the functioning of individuals—ethology, sociology, political science, economics, medicine, and all the rest. It is with that attitude that the chapters in Part III are written.

Chapters 10, 11, and 14 through 17 discuss some assumptions and procedures in regard to which PCT differs from conventional psychological science. Chapters 12 and 13 are reprints of two articles that I think reveal with special clarity the view of science embedded in PCT. I print them here unedited, despite their technicalities, because I want you to see these scientific reports in their pristine beauty.

REVIEW

Here is a nutshell review of what has gone before. If you forget everything else you have read so far, please remember the following as you read the chapters in Part III.

Action springs from the circular causation between internal standards and environmental disturbances to controlled variables.

The relation between nonliving things and the environment is very different from the relation between living things and the environment. Living things initiate action, and they expend much greater energy than the energy received by the sense organs.

The distinctive characteristics of living things are (1)they act with purpose, to control perception, (2) they operate through negative feedback loops, and (3) causation in the loop is circular and simultaneous.

Chapter 10

Don't fool yourself

How do you know what you know?

I have asked that question (or words to that effect) of a good many persons. Asking it about some piece of presumed knowledge a person has offered me, I have got various answers:

I just *know*, that's all!

(Somebody) told me so (or I heard it on the radio).

I read it (someplace).

I saw it in a movie (or on the TV).

Well, it stands to reason.

I saw it myself (or it happened to me once).

I read a report of a study (or experiment).

I did a study (or an experiment) on it.

I don't claim that those examples have sharp boundaries among them; I mean merely to say that the answers ranged from a vague faith (even if heartfelt) in a verbal statement to a careful personal inspection of palpable events. There are many ways to come to know something.

KNOWING SOMETHING

And what is it to "know" something? Everybody (I think) is aware of the distinction between knowing something and knowing *about* something—more precisely, the distinction between having the direct experience of something and having ideas about it or being able to say things about it. Someone might ask, "Do you know the Fiji Islands?" and you might reply, "Well, I've read about them, but I've never been there." With that reply, you are implying that while you have memories of what you have read *about* Fiji, there are experiences *of* which one can acquire memories only by having been there. Or someone might ask, "Do you know how to ride a bicycle?" and you might reply, "Well, I've seen a good number of people riding bicycles, so I have a pretty good idea how to go about it." But no matter how confident you may be of your knowledge, you might not succeed in wobbling down the street on your first try or your second or even your third. Do you know the fragrance of the frangipani flower? Well, you can be told about it, read about it, or smell it yourself.

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The kind of knowing to which I give the most attention in this book is the kind that enables you to control a perception of some variable that is affected by the "thing" the knowledge is about—and to control that perception by acting on the world outside your own neural net. If you know the location of the Fiji Islands, you can control your perception of your distance from them. The "thing" your knowledge is about is your distance from Fiji. A couple of perceivable variables (among many possible) that would be perceivable aspects of that distance are (a) the distance you read or calculate from an atlas and (b) an announcement by a flight attendant of the name of the next airport you will be landing at and your translation of that information in your mind into approximate miles yet to go to Fiji. If you know the fragrance of frangipani, you can buy some of that kind, instead of lilac, if what you smell in the bottle matches your olfactory memory.

How can you know where Fiji is? If you have not been there, you can go by what someone tells you or by what you read in a book or see on a map. Those words or maps constitute instructions for getting there. Suppose you live in Chicago. The words or maps tell you, in effect, that one way you can get to Fiji is to buy a ticket that will take you first to San Francisco, then Hawaii, and then Fiji. But how do you know that the words or maps can be trusted?

On current city maps, I have found streets that do not exist and blanks where streets that do exist should have been drawn. In the end, the only way you can be sure that you can get to Fiji by going through San Francisco and Hawaii is by trying it yourself. That kind of knowledge (seeing it yourself) is what is customarily called "scientific." Also "empirical."

Science goes further than speculating about where Fiji might be or what it might be like or how you might get there. Science is about getting there. Science offers criteria for knowing when you have arrived at Fiji. It also offers guides for telling other people how to get there. To abide by those criteria, it is not sufficient to answer, "I just *know*, that's all!" And though it may be interesting for many purposes, it is not scientifically sufficient to say, "My travel agent told me how."

Sometimes people complain about the scientist's insistence on wanting to see for himself or herself. "Nobody can always see for himself," they say. "Most of the time, you have to take somebody's word for it." That's true. You can't get your daily work done if you are always off to Fiji or Bulgaria or the moon, checking on whether they actually are where people say they are. But if I want knowledge that *can* be verified, then I want instructions on how to verify it. If someone tells me that the moon revolves around the earth, I want the person to tell me how I might check up on that myself, even if I do not intend to do so. If the person cannot tell me how to check for myself, then I must take her assertion as merely one more speculation among others. If someone tells me that the earth is four billion years old, more or less, I want the person to tell me about the procedures through which I can reach such a figure for myself. And if someone tells me the earth is about four thousand years old, I want to know that person's procedures, too. What the person tells me will be maximally useful if the information is in the form of the functions and organization in a model.

Insisting on verifiable assertions is the first necessity in the procedure we call science, but of course carrying out a verification can be very complex. A lot of this book is about the complexities. My point here is simply that science deals with the external, verifiable world, and therefore a scientific inquiry must begin with an empirically verifiable assertion. Still, scientific procedures are often difficult and subtle, and scientists sometimes honestly think themselves to be on the road to Fiji when they are actually heading elsewhere. Once in a long while, too, a scientist fabricates data. That is sad and dangerous—though I think the proportion of scientists who do that is very much smaller than the fraction of manufacturers who pollute the water supply, and usually, I think, the perfidious scientists do less harm to public health and welfare.

The scientist's point is that if there is no way to compare an assertion about the external world directly with that external world, then there is no way to resolve competing claims. You can appoint a referee, but that only postpones the difficulty. You can have someone tell you the Revealed Truth, but that too only postpones the difficulty; you may find yourself having to admit, after people have thrust contrary evidence upon you for some 350 years, that you should not have insisted that the sun revolves around the earth.

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TAKING A VOTE

You can take a vote. You may burst out laughing at that suggestion, but it has been made seriously many times. Petr Beckmann (1971) tells us that in 1897, a bill was introduced in the state legislature of Indiana entitled, "A Bill Introducing a New Mathematical Truth." The bill declared the value of pi (the ratio of the circumference of a circle to its diameter) to be 9.2376. . ., which, Beckmann wrote, "probably represents the biggest overestimate of pi in the history of mathematics" (p. 174). The bill was actually passed by the Indiana House of Representatives, and was about to be voted on by the Senate when the fact came by sheer chance to the attention of a professor of mathematics at Purdue University; he "coached the senators," Beckmann says, and the Senate voted to postpone further consideration of the bill. It may seem strange that those persons to whose hands the welfare of the state of Indiana was entrusted should believe a geometrical or physical fact to be susceptible to legislation, but I should mention that in recent years, articles have appeared in psychological journals and in journals devoted to the philosophy of science in which physical facts such as the acceleration of gravity have been claimed, if I understand the authors correctly, to be no more than conventions or matters of "social reality"—that is, an agreement among a large number of people that objects approach each other in that way.

Some time in the 1940s, the Illinois legislature passed a bill to establish a statewide testing program for high schools. The bill specified that 70 should be the passing score for the test! In contrast to the Indiana case, that specification by the Illinois legislature could actually be carried out, although it was completely meaningless, since the bill made no specification about the nature of the test items, how many items the test should contain, how the items should be weighted in the scoring, or anything else that could affect the meaning of "70" or its effect on the lives of students and teachers. I cannot imagine, either, what the legislators could have meant by "passing." As far as I know, and I was associate director of that program for seven years, no one ever used the test as a gate through which students were to "pass" from one condition into another; educators used it chiefly for academic counseling.

When I was teaching an introductory course in social psychology (a good many years ago), I formed the students into groups of four to six persons and asked them to think of something they would like to know about the social world on campus but would not likely find in books. I wanted them to learn how one could go about getting observable information directly from the observable world. One group told me they would like to find out whether belonging to a fraternity or sorority caused students to get lower grades, on the average, than students who did not belong to those organizations. I told them that sounded feasible for research, and I asked them to come back in a few days with a plan for finding the answer to that question. They returned in a few days and told me that their plan was to go to some fraternities and sororities and ask the members whether they (the members there) thought they were getting lower grades than students who did not belong to fraternities or sororities. I don't remember any more of the conversation, but if I had asked them what they proposed to do about the differences in opinion they would inevitably gather, I suppose they would have said they would count the responses in the manner of a vote and declare the winner. I think it is sad, by the way, that people can get to be sophomores in college and still have no other conception of getting knowledge from the observable world than asking somebody else for the answer (or reading some author's answer). It is possible, of course, that when a professor asks college students to get some information, almost all students immediately think of asking someone for the information (or asking a book), because that is the way almost all professors and other teachers have almost always told students to get information.

I had an instructive experience when I was one of a faculty of a high school. At the opening of the school year, we learned that the superintendent wanted us and the faculty of the other high school in the district to discuss curriculum revisions once a month and make recommendations for change at the end of the school year. As the meetings came and went, it became clear that one member of the other faculty and I were together in disagreeing with all the other teachers on a fundamental point or two. At the end of each monthly meeting, a committee would put before us, for a vote, a proposed recommendation that seemed to sum up what the majority found pleasing. That other fellow and I would often vote against the proposal. At the last meeting of the year, when all the recommendations were bundled together to be forwarded to the superintendent, we two said we would submit a minority report. At that, one person stood up huffing and puffing in outrage. After we had been outvoted at every vote, he asked rhetorically, how could we possibly still hold to our opinion? As far as I could tell, he did honestly believe that any normal person, seeing that he or she was in opposition to a firm majority, would be convinced that his or her opinion was simply wrong. I am not sure whether that fellow thought we were physically or morally defective. Maybe both.

What happens in traditional psychological research seems to me something like that. A majority of participants, or enough to be beyond mere chance, act as the experimenter predicted they would, and the experimenter then reports, typically, that "the subjects" acted that way. Or the experimenter says that the participants were "tending" to act as predicted. That way of talking (and subsequent acting) seems to me very much as if each participant's act is taken as a vote for or against the experimenter's hypothesis. Some of my colleagues, upon hearing my dissent from that method of coming to a conclusion from data, react with very much the same outrage as the faculty member at the high school.

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SHIFTING PROPORTIONS

The fact that psychological experiments continue, decade after decade, to turn up behavior that goes contrary to prediction has of course been bewailed by many researchers. Here I will quote only Cronbach's (1975, p. 123) lament. He remarked about the fact that the conditions under which observations of behavior are made keep changing. He offered this analogy:

> The trouble, as I see it, is that we cannot store up generalizations and constructs for ultimate assembly into a network. It is as if we needed a gross of dry cells to power an engine and could make only one a month. The energy would leak out of the first cells before we had half the battery completed.

A good example of the kind of change Cronbach had in mind is exhibited in an ingenious study by Urie Bronfenbrenner (1958), who reviewed the studies that had been made of child rearing practices in the lower and middle classes between 1932 and 1957. The earlier studies had found that lower-class parents were more permissive with their children, in several ways, than middle-class parents. Bronfenbrenner said that researchers in the earlier years typically characterized "the working class . . . as impulsive and uninhibited, the middle class as more rational, controlled, and guided by a broader perspective in time" (1958, p. 422). Later studies, however, found the differences between the two classes to be less than the earlier studies had found, and by the middle 1940s, the differences had vanished! Was this finding, so confidently proclaimed during the 1930s, merely one more social-science mirage? Was it perhaps merely the product of sloppy research? No. Bronfenbrenner showed that the direction of change was a reliable one, and as the years went by, studies increasingly showed that the middle class had become more permissive than the lower! The change, however, was not one of exchanging positions. Parents in *both* classes had become more permissive, but parents in the middle class had changed the more rapidly. Here are excerpts from Bronfenbrenner's summary:

> Over the past quarter of a century [1932–1957], American mothers at all social-class levels have become more flexible with respect to infant feeding and weaning.
>
> Class differences in feeding, weaning, and toilet training show a clear and consistent trend. From about 1930 till the end of World War II, working-class mothers were uniformly more permissive than those of the middle class. . . . After World War II, however, there has been a definite reversal [of the difference].
>
> Shifts in the pattern of infant care—especially on the part of middle-class mothers—show a striking correspondence to the changes in practices advocated in successive editions of U.S. Children's Bureau bulletins and similar sources of expert opinion.
>
> . . . socialization practices are most likely to be altered in those segments of society which have most ready access to the agencies or agents of change (e.g., books, pamphlets, physicians, and counselors).

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In brief, what Bronfenbrenner's study showed was that at one period, lower-class parents were more permissive in certain of their child-rearing practices than middle-class parents, at another period there was no difference, and at another period the reverse was true. The research did not show, as most researchers in the 1930s and early 1940s mistakenly thought, that being in a certain social class caused parents to adopt certain child-rearing practices. It did not show the reverse, either—that being predisposed to certain child-rearing practices caused persons to move, by the time they had children, into a certain social class. The research showed that parents in both classes were capable of choosing their child-rearing practices, and they did so partly with the aid of what they read and heard from presumably knowledgeable people. Research of this head-counting sort is useful for discovering the current balance of opinion (which is what Bronfenbrenner did with impressive skill), but (as Cronbach properly pointed out) it tells us nothing that we did not already know about the nature of humans.

The mistaken conclusion that most psychologists (and some sociologists, too) adopted in the 1930s about child-rearing practices illustrates another way we often fool ourselves. We ascertain the present practice or state of affairs and then conclude that what we observe to be the case now is what *must* be so at every time and place—or at least in many times and places that we think are similar in some way to the present case. In the example I am using, the wrong conclusion was that certain child-rearing practices were *characteristics* of social class. The attitude at the time had the flavor of: Look at those people; that's the way those people *are*.

That kind of reasoning, combined with the assumption that the cases going contrary to the researcher's prediction somehow do not count, produce a strange conclusion that I have often found in the journals on business management. For example, a researcher might classify thirty companies according to their style of management and then look at their profit record during a relevant period. The researcher predicts that those using management style M will show higher profits than those using style Q. Let us say that the researcher then finds nineteen of the thirty companies conforming to that prediction; nine companies using management style M have above-average profits, whereas ten companies using style Q have below-average profits. The researcher then recommends to managers that they *not* use management style Q. But we also see in the data that six companies (let's say) using style Q also have above-average profits! (This is the sort of data-pattern and conclusion I have found every now and then in journals such as *Administrative Science Quarterly, Group and Organization Management, Academy of Management Journal, Organizational Dynamics,* and the like.) In such an array of results, the plain fact is that some of the companies (nine) are highly profitable while using management style M, and some of them (six) are highly profitable while using style Q. I see no reason to tell managers to stay away from style Q. If six companies can profit from it, maybe others can profit also. Maybe style Q fits your company better than style M. It might be better to judge by what you know about the capabilities of your company than by the "vote" of nine to six reported by the researcher.

SIMPLE SCIENCE

The word *science* is used in many ways. Sometimes people use it to label any body of knowledge, as *social science* or *library science*. Sometimes people use it to label any repeatable, systematic endeavor ("She has it down to a science"). One meaning my 1982 American Heritage Dictionary gives is "the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena." That, I suppose, is the meaning preferred by most people who call themselves scientists. Some scientists say that no description is scientific that is not stated in mathematics. I certainly do not want to argue about what science "really" is. I will be satisfied to claim that the kind of endeavor most of us call science is shaped by the urge many people feel *not to fool themselves about what they think they know*. In a communication to the CSGnet of 13 February 1995, Wm. Powers wrote the following:

> For me, science is simply trying to know about things in a way that is influenced as little as possible by what I want to be true, hope is true, or believe is true. Scientific methods are mainly tricks and techniques that help to keep us from fooling ourselves, which even the most famous scientists have done quite frequently. People who don't take precautions against fooling themselves, of course, do it even more frequently.
>
> The real pay dirt in science comes when you try to *disprove* a theory, particularly your own theory. You say "If this theory is true, then by its own logic if I do X then Y HAS TO HAPPEN." So you immediately arrange to do X, and you look very critically to see if Y happens. If it doesn't, you're finished: you've at least put the theory into deep trouble, and at best have destroyed the theory. I say "at best" because if a theory can be so easily disposed of we should do so immediately to avoid wasting any more time on it.
>
> The problem is that doing this doesn't come naturally to human beings. . . . Once we start to BELIEVE a theory, it becomes very difficult to get up the motivation to try to disprove it.
>
> One thing you can do is to keep it as simple as possible. If you can think up a simple theory like PCT in which you can do tests involving only a few variables, and make predictions in a way that clearly shows failures if they occur, and if no test you can think of (within the rules of the theory) is failed, then you're more or less forced to accept the theory, for the time being, because you just don't see any way out of it.

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HISTORICAL AND AHISTORICAL METHODS

One claim found in many books on psychological research method is that many causes of present action lie in the past—psychoanalysts are especially wont to say that. If you bought yourself a hat yesterday, or a month ago, does that fact cause you to wear a hat today? Well, if it is a cool day today, and you want to go outside for a while, you are much more likely to wear a hat than you would be if you had no hat. Statistically, people who buy hats are somewhat more likely to wear hats at a later date than people who do not buy hats. But, at that later date, the hat owner is under no causal necessity to wear a hat. The hat owner, on that fateful day, is free to choose whether to wear it or not.

On the average, gun owners are more likely to fire guns than people who do not own guns. But the gun owner is not physically caused, pushed, fated to pull a trigger.

Some sciences devote a large amount of attention to the history of the materials with which they deal. Geology, for example, discerns what is possible and what is impossible by finding evidences of changes in the earth's crust over billions of years. The Himalayas exist because an antarctic continental plate moved northward during millions of years and crashed (so to speak) against the Eurasian continental plate. (When I said "because" in that sentence, I did not mean anything about causes. I meant only to mention the sequence of events that ended with the Himalayas where they are. What causes went on during that plate movement, I do not know.) The geologic history of plate movements tells geologists, by extrapolation, the kind of large-scale movements that are likely and unlikely now. But that history cannot tell us where or when in the Himalayas to expect a landslide this year. The geologists can predict landslides better by examining the rocks, soils, interfaces of strata, ground water, and rainfall in a particular locality and judging from those *present* conditions the threat of landslide.

In January of 2000, for example, a landslide occurred on the coast a few miles north of Florence, Oregon, that blocked the coastal highway, U.S. 101. The Department of Transportation immediately began clearing the highway, but when the workers got the highway cleared, the engineers did not permit traffic to resume. From what they knew of the stability in wet weather of strata of that local sort, they judged that further slides were likely before long. They were correct; further slides did occur. The first traffic was not allowed through that stretch until about five weeks after the slide in January. I doubt very much that the engineers, before they made their judgment, looked up the history of the northwest coast a million years ago.

To predict the functioning of a person—that is, to model the functioning—PCT does not require us to know anything about the person's history. The ever-ready research method for PCT is, of course, The Test for the Controlled Quantity (for which see Chapter 7). The person's history may give us a hint or two about the nature of an internal standard the person may have formed in the interim, but it can never tell us unequivocally what the internal standard is like or whether there is a disturbance acting on the controlled variable at this moment. To ascertain the standard with any precision, we must use The Test, and we can use The Test effectively without any knowledge of the person's history. As for predicting *action* on the part of the person, actions always depend on the Requisites for a Particular Act that I set forth in Chapter 1. To simplify, the act that will be taken depends both on the variable being controlled by an internal standard and on the opportunities available in the environment for controlling it. Neither of those conditions can be ascertained by inspection of the person's history. What a person can do right now depends wholly upon the person's present state: on the perceptions being controlled right now and upon the environmental opportunities present right now for controlling them.

Suppose you have come to believe that Woodrow has a strong internal standard for neatness among his physical surroundings. (Maybe you have consciously used The Test, or maybe you have observed him informally for a long time.) If you move something on his desk, he soon moves it back. The clothing in his closet is stored in meticulous categories. The food in his refrigerator is arranged in rows and columns. You are confident that you can predict pretty well the kinds of situations in which he will be happy and unhappy. For example, you know that he likes to be courteous to friends and colleagues. Therefore, if Woodrow visits a friend whose parlor or office is messy, he will simultaneously want and not want to begin straightening things up. (Notice that we are not predicting particular actions here; we are predicting what Woodrow will *want* to perceive.)

Now let ten years go by. Here you are with Woodrow again. Are you going to use your knowledge from ten years ago to predict Woodrow's behavior today? Yes and no. Knowing that Woodrow controls the neatness of things around himself, you know that he will take action to bring things closer to his standard for neatness *when the environment and his other*

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internal standards permit him to do so. One answer to the question, then, is yes, you do know something useful for predicting Woodrow's behavior. But what you know is the kind of perception he *wants* to obtain. You do not know what particular acts he will use to bring about the perception nor when he will have the opportunity to use those acts. (Again, I refer to the Requisites for a Particular Act listed in Chapter 1.) Furthermore, one should always be cautious about the stability of internal standards; it is possible that Woodrow's standard for neatness has changed its character in ten years. Finally, my chief point in talking about Woodrow is that you didn't know how his standard for neatness came into being or when; all you needed to know was whether it was there, and you found out by using The Test. Ten years later, you got no help from knowing that it was there ten years earlier; still all you needed to know was whether it was there now.

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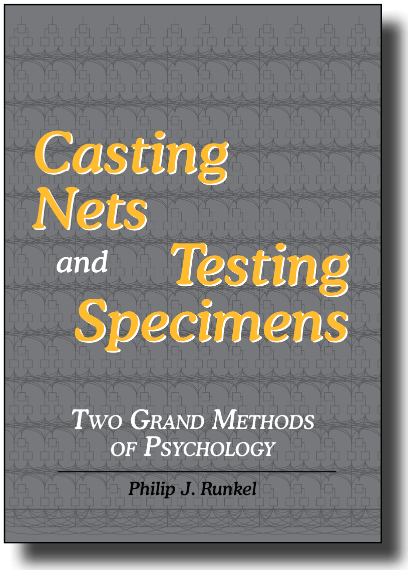
CODA

Perceptual control theory claims that behavior controls perception—at every time, in every place, in every living thing. The theory postulates that control operates through a negative feedback loop—neurally, chemically, and both. The theory postulates the growth of layers of control both in the evolution of the species and in the development of individuals of the "higher" animals. Those are the crucial postulations of invariance in PCT. They are asserted to have been true for the single cells floating hither and thither a billion years ago, which might have had only two layers of control, and they are asserted to be true for you and me with our many layers. They are asserted for all races, nations, sexes, and indeed all categories of humans—and indeed all categories of creatures. Furthermore, if *one* creature is found reliably to violate any one of those postulations (and yet go on living), the theory will immediately be revised.

Do you know of another theory of such sweep anywhere in the sciences of living creatures?

Casting Nets and Testing Specimens:
Two Grand Methods of Psychology



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By Philip J. Runkel

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Chapter One

Overview

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We all gather information, every day, every moment, squirreling it away in our memories. We gather information whether we are reading, crossing a street, digging in the garden, interviewing a political candidate, painting a picture, or conducting a psychological experiment. Sometimes we use the information in the next split second, sometimes next year.

We use various methods to gather information and so to come to beliefs about the behavior of ourselves and others. Our methods are often very sophisticated when we act as social scientists, and are often rough and ready when we act in ordinary life, but we all use methods of some sort, and we often cite them to justify our beliefs. We say, "I saw her do it," or "We queried 1,500 randomly selected households." This book is about the methods we choose by means of which to reach conclusions. It is about how we come to beliefs about the nature and behavior of humans and other living creatures.

Despite the long list of particular methods and the names social scientists have given them, almost all fall into one of two grand classes that I will call the *method of relative frequencies* (to be explained in Chapters 2 through 8) and the *method of specimens* (to be explained in Chapters 9 through 12). Both methods can deliver useful information about human behavior. The main point of this book, however, will be to show that for a long time now most social scientists have been using the method of relative frequencies for the wrong purpose—to discover how the human animal, as a species, functions. The method that can do that is the method of specimens. To assert once more, however, my claim that both methods have their suitable uses, I will explain *action research*, in Chapter 13, as a very useful amalgam of the two methods.

Though I think all the methods that have names and self-conscious procedures turn out to be varieties of either the method of relative frequencies or the method of specimens, I think the greatest amount of information-getting, if we count by person-hours, is done simply by finding out whether something can happen—whether something is possible. We can do that without adhering to any rules and without any intent to "generalize." I call that kind of information-seeking the *method of possibilities* and explain it in Chapter 13.

I will say, as I go along, that the secrets of the behavior of humans and other living creatures will not be uncovered by counting noses—by the method of relative frequencies. They will not yield to the sophisticated procedural apparatus that statisticians and social scientists have built during this century on the foundations laid by Galton, Pearson, and Fisher—the apparatus that includes random sampling, control groups, correlations, analysis of variance, factor analysis, discriminant analysis, and multidimensional scaling. The secrets of behavior will continue to emerge, as they have in the past, from the method of specimens.

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I will not say that information gathered by random sampling, counting noses, and statistical analysis has no use. The method of relative frequencies is very good indeed for making catalogs or maps, so to speak—for making good guesses about where or under what conditions certain kinds of behavior are likely to occur and the proportions in which they are likely to occur. That is a valuable thing to be able to do.

If I take more space in this book explaining what the method of relative frequencies *will not* do than I take telling what it *will* do, I do so to redress the balance. I think most of the books on the library shelves about polling and social surveys are largely right in what they say. But I think that most texts offered for academic courses in research method in psychology and other social sciences are largely wrong, including the book that I wrote with my friend Joseph McGrath (Runkel and McGrath, 1972).

I am not the only one, of course, to complain about the current canons of research method. For several decades, the literature has included declarations of discontent. For example, Gergen and Morawski in 1980 gave a concise review of several lines of thought about the inadequacies of method in social psychology; their core comments applied equally well to other social sciences. In 1986, Thorngate and also Cairns gave cogent examples of some ways that widely used research strategies lead researchers into wrong conclusions about individuals.

Many social scientists nowadays seem to believe that good theory will be built if only we can sufficiently refine the current canons of research method and persuade enough colleagues to cling to them rigorously. But the assumptions underlying the current canons do not fit the purpose to which many social scientists try to bend the canons. No matter how carefully you sharpen the teeth of a saw or how neatly you fit it with a new handle, it will remain a poor instrument for driving nails.

I will also argue that we can conceive causation in two ways: as linear input-to-output or as circular. By circular, I do not mean repetitive or cyclic. I mean cause and effect in a fully connected loop such that at any moment any event in the loop can equally well be called a cause or an effect. I will explain these matters in Chapters 8 and 9. The method of relative frequencies typically rests on the metatheory of linear causation. The method of specimens typically requires the metatheory of circular causation.

TWO METHODS

It is easy to find highly predictable phenomena by looking either at (a) an individual's control of bodily purposes or (b) statistics of masses of people. We can predict that every person not suffering internal damage or disorder will maintain an internal temperature between very narrow limits. We cannot usually, however, predict very well the particular actions the person will take to maintain that temperature—whether the person will take in more fuel by eating and if so what or when, whether or when the person will put on a coat or a blanket or snuggle against another warm body or build a shelter or make a fire, or whether the person will exercise to increase the flow of warm blood to the bodily extremities. We cannot predict particular actions very well, but we can predict with certainty that *every* person will act to maintain a particular temperature. We can predict confidently that under the threat of cold weather, *everyone* will take *some* sort of easily visible action to aid the body in maintaining the desired internal temperature.

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Statistics about mass phenomena, too, are often very reliable. The increases and decreases in traffic flow over the arterial streets of a city as rush hours come and go are highly predictable. So are seasonal change in retail purchasing and in visits to the Grand Canyon. The reliability of a mass phenomenon does not, however, enable us to predict well the behavior of any element of it. We are not helped to predict the time Clarence Berquistson will drive to work, what arterial he will choose, or whether he will visit the Grand Canyon this year. The proprieter of a drugstore cares little who comes in to buy vitamins, but does care how many do so. On the other hand, though the proprietor does not need to know much about the average pharmacist, he does need very much to know how to deal reliably with his own pharmacist, Clarence Berquistson.

Social scientists exhibit two needs similar to those of the drugstore proprietor. First, if social scientists want to know the proportions of individuals who will, with some specifiable probability, exhibit one sort of action in one sort of situation, they can then simply count anonymous cases, as do the druggist and the National Park Service. Culture and geography make it easier for people to carry out their purposes through certain uses of the environment instead of others. We can, therefore, predict not only that people in cold climates will do something to keep themselves warm, but also predict the proportions of people in a certain culture who will keep themselves warm by certain methods. This is the method of relative frequencies. Some of the success that researchers have in predicting frequencies of behavior at rates better than chance even among relatively small collections of subjects is due, if the researchers are careful to sample randomly, to this cultural predictability of mass behavior.

Second, if social scientists want to know how any and every individual functions, they must study the ways a neural net deals with sensory input, since sensory input is the only path through which a human or other living creature can know the environment and therefore initiate selective acts upon it. (By "neural net," I mean all the neural tissue in the body.) Psychophysicists, physiological psychologists, physiologists, neurologists, and other biological scientists do indeed study those neural functions that are the same over long periods of time in every undamaged individual. This is the method of specimens.

Both methods deliver useful information. Both enable us to get ready for future events. They do so, however, differently. The method of relative frequencies enables us to anticipate statistics about collections of people. The method of specimens enables us to anticipate the perceptual inputs that a particular individual will act to maintain and the invariant processes by which individuals maintain their unique perceptual inputs.

The two methods deliver different kinds of information. The method of frequencies enables us to estimate behavioral trends in the mass—such as how many anonymous lemmings will run into the ocean this year. The method of specimens enables us to discover how a species "works"—how its internal workings enable it to do what it does.

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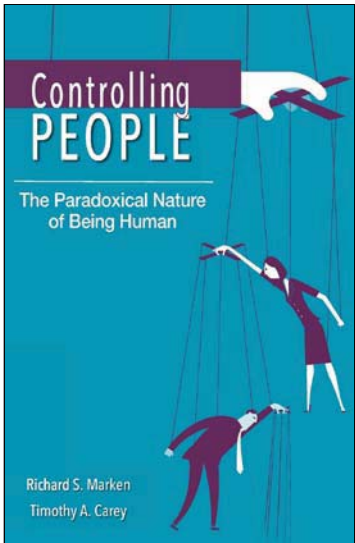
SUMMARY

I think we use two grand methods or strategies to get information from experience—to get ready to perceive future events and deal with them. I call one the method of relative frequencies. Using it, we count cases and estimate statistics. We look for ways in which conditions and actions cluster. In Chapters 2 through 8, I will show what I think the method of relative frequencies can do and what it cannot do.

The other method I call the method of specimens. Using it, we treat persons as members of a species. We look for features of behavior—the "rules" by which people choose behavior—that are invariant within an individual over time and that are the same from one person to another. We do not expect to find invariants in repeated particular actions, but in the inferred internal functioning that controls perceptions. I will say more about invariants in Chapter 9, and about circular causation, too. In Chapter 12, I will explain how the method of specimens can actually enable us to make working models of human behavior. Over the course of Chapters 9 through 12, I will show what I think the method of specimens can do and what it cannot do.

In Chapter 13, I will describe action research as a melding of the methods of relative frequencies and specimens. Also in Chapter 13, I will argue the merits of the "method" of possibilities—an informal but very useful strategy that lies outside the two main methods.

Controlling PEOPLE
The Paradoxical Nature of Being Human



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By Richard S. Marken and Timothy A. Carey

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Preface

When you hear that a person is 'controlling' what might first come to mind is someone who is very manipulative, such as an authoritarian parent or an overbearing boss. But what might also come to mind is someone who is very skillful, such as a baseball pitcher with 'good control', or a race car driver expertly steering their high performance vehicle through a tight turn at the limits of adhesion.

What these people have in common is that they are doing the same thing — they are all controlling. The authoritarian parent and the overbearing boss are doing what the skillful pitcher and the race car driver are doing. They are trying to get things to be the way they want them to be by *controlling* things such as the behavior of a child, the work habits of an employee, the location of a pitch, or the tightness of a turn. Indeed, they are trying to get these things to be the way they *should be*, from their perspective of course. And this is what we all do, all the time, is it not? We are all trying to have the things we care about be the way they *should* be. This book, then, is about the fact that we are all controlling people and that it is completely normal to be one. Indeed, it is just human nature.

But we didn't write this book just to say 'you are a controlling person but that's okay' (although we are going to eventually say that!). We wrote it mainly because we want you to know that your controlling nature can actually work against itself, causing you to *lose control*. This is a paradox, and a challenge for our lives, because our feeling of wellbeing depends on staying in control. We want things to be the way they should be and when they are not — when we lose control — we feel stressed, depressed, or anxious. Yet our efforts to be in control are often the reason we lose it.

Losing control happens when we try to control what we shouldn't control, which is usually people's behavior (including our own, since we are people too). This paradox is reflected in the title of this book, which refers to people who are controlling and to people who control people. The paradox of being a controlling person is that when we try to control people (both ourselves and others) we risk losing control because other people are also seeking control over what they care about (including themselves and us).

The obvious solution to this paradox would seem to be to stop trying to control people. But we will see that this is not in fact a solution. It won't work because controlling is as essential to our existence as breathing. That's why there is a paradox. We can no more stop trying to control people — especially people who are doing everything wrong from our perspective — than we can hold our breath indefinitely.

So how do we cope with the paradox we are placed in by our controlling nature? The aim of this book is to show you how. The short answer is that you do it by coming to understand and accept yours and other people's controlling nature. Doing this involves knowing what controlling is, how it works, and why you can lose control when you try to control other people who are trying to be in control just like you are.

The first chapters of this book explain what controlling is. We will show you that controlling is just a more technical way

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of describing what you are already familiar with as purposeful or goal-oriented behavior. People who are controlling are simply acting to achieve their purposes or goals. But viewing purposeful behavior as controlling makes us aware of the fact that we are consistently achieving our goals in a constantly and unpredictably changing world that should make such consistency impossible. So we will see that purposeful behavior, *controlling*, involves varying our actions in just the right way so that we are able to achieve our goals in a world that sometimes seems to be working against us.

The next chapters are about how this controlling works. They describe how the brain and nervous system allow you to act appropriately to consistently achieve your goals in an unpredictably changing world. We will show that your brain does this by specifying the goals to be achieved rather than the actions that should be used to achieve them.

Chapters 6 and 7 explain why people lose control when they try to control other people. The basic problem is conflict, where people literally end up at 'cross purposes' with each other (or themselves) so that no one is able to achieve their goals. We then describe a way to get out of conflicts when you find yourself in them. We will show that while it is virtually impossible to avoid all conflicts, it is possible — and rather easy — to 'rise above them' and get them to literally disappear. When conflicts disappear your ability to be 'in control' and your sense of wellbeing suddenly reappears.

In the final chapters of the book we speculate about how groups of controlling people — societies — can organize themselves in ways that maximize everyone's ability to be in control and minimize the conflicts that prevent this.

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The ideas presented in this book are based on the work of William T. Powers, who was the first to recognize that we are all controlling people. Powers developed a theory to explain the controlling that people do. The theory, which is now called Perceptual Control Theory (PCT), is described in his classic text *Behavior: The Control of Perception*[1]. PCT is an explanation of how controlling people 'work' but it can also be considered a theory of human behavior in general because, as we shall see, behaving *is* controlling. PCT explains how we do everything we do, from balancing on two sticks attached to rubber bands (our legs) to solving differential equations; from taking a sip of tea to writing a book about controlling. But most importantly, given the aim of this book, PCT explains why it is human nature for people to want to be in control and why controlling itself can result in the loss of control.

PCT is an important and revolutionary approach to understanding human nature. Therefore, it should be of interest to anyone who wants to achieve a more effective and fulfilling life through self-knowledge. But PCT is a scientific theory, so most of what is written about it is fairly technical and, thus, accessible only to those with the technical skills that are required to understand it. This book is an attempt to bring PCT to a more general audience. And to do so in a way that shows its very practical implications. We believe that the level of understanding of PCT that you can get from this book will provide you with the basic tools needed to be a more effective controlling person who better understands, and is more tolerant of, your own controlling and that of the controlling people around you.

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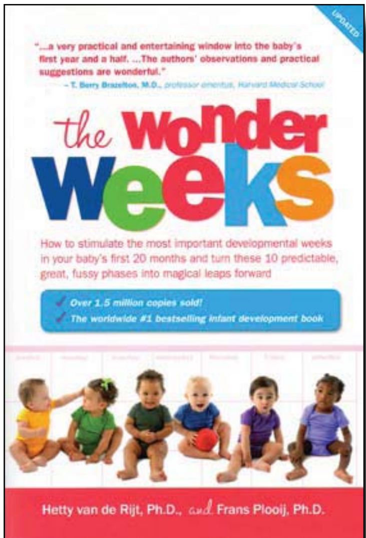
The Wonder Weeks:

How to stimulate your baby's mental development and help him turn his 10 predictable, great, fussy phases into magical leaps forward



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By Hetty van de Rijt and Frans Plooij

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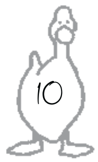

Growing up How Your Baby Does It

Watching their babies grow is, for many parents, one of the most interesting and rewarding experiences of their lives. Parents love to record and celebrate the first time their babies sit up, crawl, say their first words, feed themselves, and a myriad of other precious "firsts."

But few parents stop to think about what's happening in their babies' minds that allows them to learn these skills when they do. We know that a baby's perception of the world is growing and changing when she suddenly is able to play peek-a-boo or to recognize Grandma's voice on the telephone. These moments are as remarkable as the first time she crawls, but even more mysterious because they involve things happening inside her brain that we cannot see. They're proof that her brain is growing as rapidly as her chubby little body.

But every parent discovers sooner or later that the first 20 months of life can be a bumpy road. While parents revel in their children's development and share their joy as they discover the world around them, parents also find that at times baby joyfulness can suddenly turn to abject misery. A baby can seem as changeable as a spring day.

At times, life with baby can be a very trying experience. Inexplicable crying bouts and fussy periods are likely to drive both mother and father to desperation, as they wonder what's wrong with their little tyke and try every trick to soothe her or coax her to happiness, to no avail.

Crying and Clinging Can Simply Mean He's Growing

For 35 years, we have been studying interactions between mothers and babies. We have documented—in objective observations, from personal records, and on videotape—the times at which mothers report their babies to be "difficult." These difficult periods are usually accompanied by the three **C's: Clinginess, Crankiness, and Crying.** We now know

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that they are the telltale signs of a period in which the child makes a major leap forward in his development.

It is well known that a child's physical growth progresses in what are commonly called "growth spurts." A child's mental development progresses in much the same way.

Recent neurological studies on the growth and development of the brain support our observations of mother and baby interactions. Study of the physical events that accompany mental changes in the brain is still in its infancy. Yet, at six of the ten difficult ages we see take place in the first 20 months, major changes in the brain have been identified by other scientists. Each major change announces a leap forward in mental development of the kind we are describing in this book. We expect that studies of other critical ages will eventually show similar results.

It is hardly surprising, when you think of the number of changes that your baby has to go through in just the first 20 months of life, that he should occasionally feel out of sorts. Growing up is hard work!

The Fussy Signs that Signal a Magical Leap Forward

In this book, we outline the ten major developmental leaps that all babies go through in the first 20 months of their lives. Each leap allows your baby to assimilate information in a new way and use it to advance the skills she needs to grow, not just physically but also mentally, into a fully functioning, thinking adult.

Each leap is invariably preceded by what we call a fussy phase or clingy period, in which the baby demands extra attention from her mother or other caregiver. The amazing and wonderful thing is that all babies go through these difficult periods at exactly the same time, give or take a week or two, during the first 20 months of their lives.

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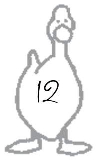

These ten developmental leaps that infants undergo are not necessarily in sync with physical growth spurts, although they may occasionally coincide. Many of the common milestones for a baby's first 20 months of development, such as cutting teeth, are also unrelated to these leaps in mental development.

Milestones in mental development may, on the other hand, be *reflected* in physical progress, although they are by no means limited to that.

Signs of a Leap

Shortly before each leap, a sudden and extremely rapid change occurs within the baby. It's a change in the nervous system, chiefly the brain, and it may be accompanied by some physical changes as well. In this book we call this a "big change." Each big change brings the baby a new kind of perception and alters the way that she perceives the world. And each time a new kind of perception swamps your baby, it also brings the means of learning a new set of skills appropriate for that world. For instance, at approximately 8 weeks, the big change in the brain enables the baby to perceive simple patterns for the first time.

During the initial period of disturbance that the big change always brings, you may already notice new behaviors emerging. Shortly thereafter, you most certainly will. In the 8-week example, your baby will suddenly show an interest in visible shapes, patterns, and structures, such as cans on a supermarket shelf or the slats on her crib. Physical developments may be seen as well. For example, she may start to gain some control over her body, since she now recognizes the way her arms and legs work in precise patterns and is able to control them. So, the big change alters the perception of sensations inside the baby's body as well as outside it.

The major sign of a big change is that the baby's behavior takes an inexplicable turn for the worse. Sometimes it will seem as if your baby has become a changeling. You will notice a fussiness that wasn't there in

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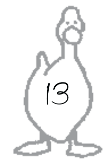

the previous weeks and often there will be bouts of crying that you are at a loss to explain. This is very worrisome, especially when you encounter it for the first time, but it is perfectly normal. When their babies become more difficult and demanding, many mothers wonder if their babies are becoming ill. Or they may feel annoyed, not understanding why their babies are suddenly so fussy and trying.

The Timing of the Fussy Phases

Babies all undergo these fussy phases at around the same ages. During the first 20 months of a baby's life, there are ten developmental leaps with their corresponding fussy periods at onset. The fussy periods come at 5, 8, 12, 15, 23, 34, 42, 51, 60 and 71 weeks. The onsets may vary by a week or two, but you can be sure of their arrival.

In this book, we confine ourselves to the developmental period from birth to just past the first year and a half of your baby's life. This pattern does not end when your baby has become a toddler, however. Several more leaps have been documented throughout childhood, and even into the teenage years.

The initial fussy phases your baby goes through as an infant do not last long. They can be as short as a few days—although they often seem longer to parents distressed over an infant's inexplicable crying. The intervals between these early periods are also short—3 or 4 weeks, on average.

Later, as the changes your infant undergoes become more complex, they take longer for her to assimilate and the fussy periods may last from 1 to 6 weeks. Every baby will be different, however. Some babies find change more distressing than others, and some changes will be more distressing than others. But every baby will be upset to some degree while these big changes are occurring in her life.

Every big change is closely linked to changes in the developing infant's nervous system, so nature's timing for developmental leaps is actually calculated from the date of conception. In this book, we use the more

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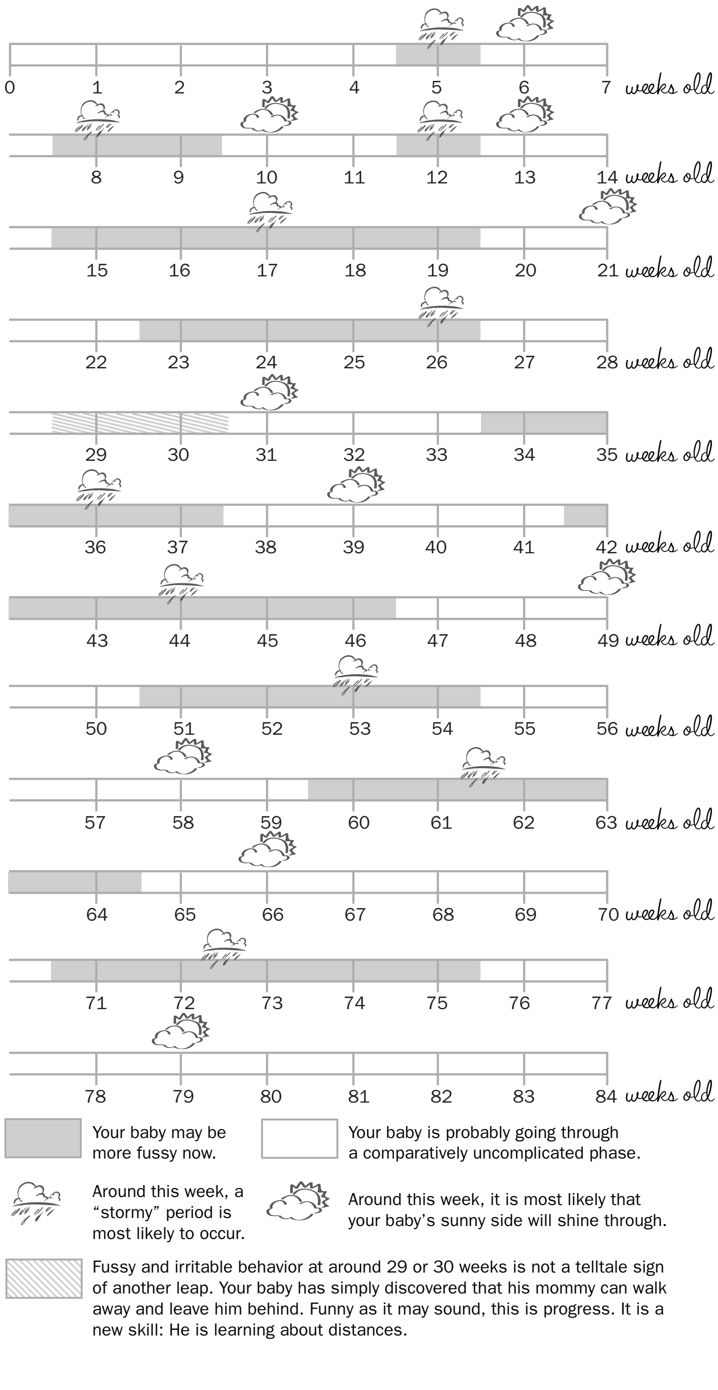
Growing up **How Your Baby Does It**

Your Baby's 10 Great Fussy Phases



Your baby may be more fussy now.

Your baby is probably going through a comparatively uncomplicated phase.

Around this week, a "stormy" period is most likely to occur.

Around this week, it is most likely that your baby's sunny side will shine through.

Fussy and irritable behavior at around 29 or 30 weeks is not a telltale sign of another leap. Your baby has simply discovered that his mommy can walk away and leave him behind. Funny as it may sound, this is progress. It is a new skill: He is learning about distances.

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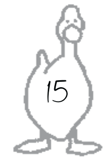


Not a Single Baby Gets Away

All babies experience fussy periods when big changes in their development occur. Usually calm, easygoing babies will react to these changes just as much as more difficult, temperamental babies do. But not surprisingly, temperamental babies will have more difficulty in dealing with them than their calmer counterparts. Mothers of "difficult" babies will also have a harder time as their babies already require more attention and will demand even more when they have to cope with these big changes. These babies will have the greatest need for mommy, the most conflict with their mothers, and the largest appetite for learning.

conventional calculation of age from a baby's birth date. Therefore, the ages given at which developmental leaps occur are calculated for full-term babies. If your baby was premature or very late, you should adjust the ages accordingly. For example, if your baby was born 2 weeks late, her first fussy phase will probably occur 2 weeks earlier than we show here. If she was 4 weeks early, it will occur 4 weeks later. Remember to make allowances for this with each of the ten developmental leaps.

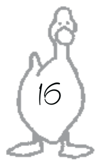
The Magical Leap Forward

To the baby, these big changes always come as a shock, as they turn the familiar world he has come to know inside out. If you stop to think about this, it makes perfect sense. Just imagine what it would be like to wake up and find yourself on a strange planet where everything was different from the one you were used to. What would you do?

You wouldn't want to calmly eat or take a long nap. Neither does your baby.

Papers

Books



All she wants is to cling tightly to someone she feels safe with. To make matters more challenging for you and your baby, each developmental leap is different. Each gives the baby a new kind of perception that allows him to learn a new set of skills that belong to the new developmental world—skills he could not possibly have learned at an earlier age, no matter how much encouragement you gave him.

We will describe the perceptual changes your baby undergoes in each developmental leap, as well as the new skills that then become available to him. You will notice that each world builds upon the foundations of the previous one. In each new world, your baby can make lots of new discoveries. Some skills he discovers will be completely new, while others will be an improvement on skills he acquired earlier.

No two babies are exactly the same. Each baby has his own preferences, temperament, and physical characteristics, and these will lead him to select things in this new world that he, personally, finds interesting. Where one baby will quickly sample everything, another will be captivated by one special skill. These differences are what makes babies unique. If you watch, you will see your baby's unique personality emerging as he grows.

What You Can Do to Help

You are the person your baby knows best. She trusts you more and has known you longer than anyone else. When her world has been turned inside out, she will be completely bewildered. She will cry, sometimes incessantly, and she will like nothing better than to be simply carried in your arms all day long. As she gets older, she will do anything to stay near you. Sometimes she will cling to you and hold on for dear life. She may want to be treated like a tiny baby again. These are all signs that she is in need of comfort and security. This is her way of feeling safe. You could say that she is returning to home base, clinging to mommy.

When your baby suddenly becomes fussy, you may feel worried or even irritated by her troublesome behavior. You will want to know

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Quality Time: An Unnatural Whim

When a baby is allowed to decide for himself when and what sort of attention he prefers, you'll notice this differs from one week to the next. When a big change occurs within a baby he will go through the following phases.

- A need to cling to mommy
- A need to play and learn new skills with mommy
- A need to play on his own.

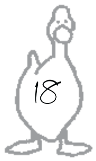
Because of this, planned playtimes are unnatural. If you want your baby's undivided attention, you have to play when it suits him. It is impossible to plan having fun with a baby. In fact, he may not even *appreciate* your attention at the time you had set aside for "quality time." Gratifying, tender, and funny moments simply *happen* with babies.

what's wrong with her, and you will wish that she would become her old self again. Your natural reaction will be to watch her even more closely. It's then that you are likely to discover that she knows much more than you thought. You may notice that she's attempting to do things you have never seen her do before. It may dawn on you that your baby is changing, although your baby has known it for some time already.

As her mother, you are in the best position to give your baby things that she can handle and to meet her needs. If you respond to what your baby is trying to tell you, you will help her progress. Obviously, your baby may enjoy certain games, activities, and toys that you, personally, find less appealing, while you may enjoy others that she does not like at all. Don't forget that mothers are unique, too. You can also encourage her if she loses interest or wants to give up too easily. With your help, she will find the whole play-and-learn process more challenging and fun, too.

Papers

Books



Growing up **How Your Baby Does It**

When your baby learns something new, it often means that she has to break an old habit. Once she can crawl, she is perfectly capable of fetching her own playthings, and once she can walk quite confidently on her own, she can't expect to be carried as often as before. Each leap forward in her development will make her more capable and more independent.

This is the time when mother and baby may have problems adjusting to one another. There is often a big difference in what baby wants and what mother wants or thinks is good for the baby, and this can lead to anger and resentment on both sides. When you realize what new skills your baby is trying to exercise, you will be better equipped to set the right rules for each developmental stage and alter them as needed as she grows.

Papers

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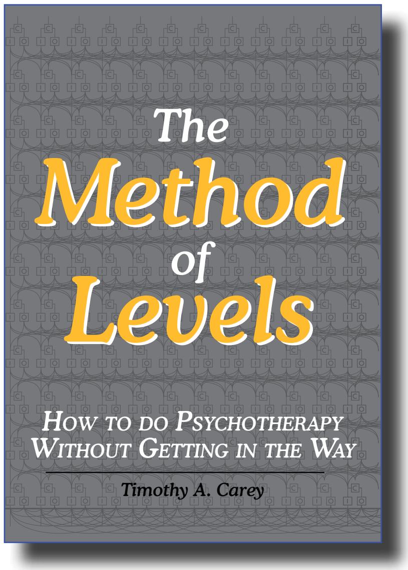
After the Leap

The troublesome phase stops just as suddenly as it started. Most mothers see this as a time to relax and enjoy their babies. The pressure to provide constant attention is off. The baby has become more independent, and she is often busy putting her new skills into practice. She is more cheerful at this stage, too. Unfortunately, this period of relative peace and quiet doesn't last long—it's just a lull before the next storm. Nature does not allow babies to rest for long.

The Method of Levels:
How to do Psychotherapy Without Getting in the Way



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By Timothy A. Carey

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Chapter Two

A look at where we are

People who are itching to know more about the practice of MOL might be inclined to skip ahead a few chapters. I don't explain *how* to do MOL until I've explained *why* MOL is what it is. It is the why of MOL that will be important when things don't go as they should. If you do race ahead to learn more about the "doing" of MOL, remember that these early chapters will be helpful to you when you want to improve your effectiveness with MOL.

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MOL differs from current practices. It differs in method because it also differs in underlying theory. Furthermore, it differs in the way it conceives of psychological problems. In the rest of this chapter, I will describe the ways that psychological problems are conceived in the psychotherapies pervasive today. You can find further thoughts about conceiving problems in the reading list at the back of this book, particularly the authors I mention explicitly in this chapter. The ideas in this chapter can be considered a synthesis of the material contained in many of the references listed.

As I said in the last chapter, people get themselves better. Getting better happens within individual heads.

Perhaps it is because people get themselves better that psychotherapists have so much latitude for the practices they employ. Very few methods of psychotherapy have plausible rationales about how their methods work. We might know that someone will be less depressed if they think more functional thoughts and fewer dysfunctional thoughts, but a compelling account of how a dysfunctional thought changes into a functional thought is absent from the descriptions of psychotherapy methods that use these techniques. The same applies to any other psychotherapy approach. No one can say precisely how a traumatic memory becomes less traumatic, or how a state of panic transmogrifies into a state of calmness, or how a phobic response becomes an ambivalent one.

Just knowing that something works is fine while the something continues to work. However, when problems in psychotherapy occur, attempts to fix the problems will necessarily be random and haphazard if there is no clear idea of how psychotherapy works. It is only when you know how something works that you can fine-tune it systematically to ensure optimum performance.

Maybe the fact that people get themselves better is the reason that those who create psychotherapy programs have been able to leave out the explanation of how their particular technique facilitates change. Possibly, since people get themselves better as long as they are not hampered too much, it doesn't matter greatly what methods psychotherapists employ. However, when the process of getting better does not proceed satisfactorily, such things *do* matter, and the scope for creativity is narrowed.

Engineers who understand the principles that allow planes to fly, boats to float, and buildings to stand know that they have limits in what they can do. Certain things must always be present if planes are to take to the skies. Once these things are in place modifications and adaptations can occur as long as these changes don't interfere with the things that are necessary. There is much less variability in something like the airplane industry than there is in the psychotherapy industry. It seems that when people in any given field are confident that they know what works they just do that.

If a law was suddenly imposed which restricted psychotherapists to the use of only one technique regardless of the people they saw, which one would you keep and which ones would you discard? In this book, MOL is presented as the only approach necessary to help people with psychological troubles get better as efficiently as possible while getting in the way as little as possible.

Papers

Books

By way of context, it might be useful to consider what other authors have said about the area of psychotherapy. In 1994 Professor Robyn Dawes provided some conclusions from an extensive analysis of the psychotherapy research literature. Dawes maintained that, even though psychotherapy seems to work in general, there is no suggestion as to how it works since vastly different approaches can work equally well for the same problem. Moreover, it seems that an individual psychotherapist's training, credentials, and experience are irrelevant to his or her success as a psychotherapist (Dawes, 1994).

For the treatment of depression "the range of psychological treatments found to be as effective as CBT [Cognitive Behavior Therapy] suggests that any kind of psychotherapy will probably be effective if a positive therapeutic relationship is developed." (King, 1999, p. 16).

Asay and Lambert (1999, p. 24) summarized the results of a meta-analysis conducted by Smith, Glass, and Miller (1980) and concluded that "the average treated person is better off than 80% of the untreated sample." They did not define what they meant by "average" (a common oversight in articles about psychological research), but it is fair for us to guess that they mean 50% of treated persons are better off than 80% of untreated ones. To understand statements like this Bourbon often draws a little table. In this example, the table would look like:

	Better	Not Better
Treated	50%	50%
Untreated	20%	80%

With the results in a table like this you can see that, the other side to the coin of Asay and Lambert's conclusion is that the 20% of people who get no treatment at all (the rest of the untreated sample) are better off than half of those who do get treatment.

You could also say it like this: 50% of treated people remain about as well off (or as poorly off) as the 80% of people who don't get treatment.

After reviewing the psychotherapy effectiveness research Dineen (2000, p.117) concluded that "85 per cent of clients would improve with the help of a good friend and 40 per cent without even that." Dineen goes on to report that only 15% of the effectiveness of psychotherapy treatment can be attributable to the specific effects of any particular treatment protocol.

Let's stop there. My point is not to bludgeon you with heavy statistics or weighty conclusions. To be sure, there are other authors who write about how effective some treatment or another is. These writers only serve to emphasize the point that a great deal of confusion exists in the area of psychotherapy. Psychotherapists believe strongly in the programs they provide and the explanations behind these treatments. At the moment, however, no one can predict what treatment will be effective for which person and under what conditions. More importantly, the many different explanations of peoples' problems that exist cannot all be correct.

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In some respects psychotherapy could be seen as being analogous to witchdoctory. Witchdoctors often have elaborate stories to explain a person's current condition. A person who feels hot to touch and is sweating may have angered the sun god. Witchdoctors also have their own particular ways of treating the person. The treatment conjured up by the witchdoctor often has many different ingredients. And yet, witchdoctors have success with a proportion of the people they treat. Was it the witchdoctor's treatment that was responsible for the improvement in the condition? If some part of the witchdoctor's treatment was responsible, which part was it? Was it the combination of all the parts or were some parts only there to color the water? Did some parts of the mixture actually interfere with the healing properties of the useful bit?

Psychotherapists have many elaborate stories about why people experience the problems they have. Sometimes it's because their child self and their adult self are having a spat. At the same time it could be because their bucket of needs has run dry, or their emotions can't get out of wherever it is they are locked up, or they have little things called dysfunctional thoughts in their heads like worms in an apple. Perhaps the spookiest story of all is that people's problems are caused by chemical "imbalances" in their brains. The balances of chemicals in an intact human brain are currently as immeasurable as the wrath of the sun god. Yet many people hold on to the chemical imbalance story just as tightly as sun worshippers grip their story.

At this point let me say loud and clear I am definitely *not* attempting to minimize or devalue the psychological problems that people experience. Obviously, many people have serious psychological problems from time to time that can be very distressing both for themselves and for their families and friends. It's precisely because the distress of psychological problems is so serious that it's important to get it right when we try to understand what's going on.

Some of the stories in psychotherapy attempt to explain the existence of the "mental disorders." Current ideas of mental disorders, however, are as preposterous as the stories that explain them. The notions of mental disorders such as schizophrenia, depression, and ADHD, are as fanciful and chimerical as a "sun god malady." People do not have problems because they have "got" schizophrenia, or depression, or ADHD, or any other psychological disorder. To be diagnosed with depression you simply have to tell someone with the authority to make diagnoses that for the past little while you've felt sad, you haven't done much, you've slept too much (or too little), you haven't eaten enough (or you've eaten too much), you've felt like crying, you've felt irritable, and you've lost interest in things. If you say this to someone who can diagnose, they will tell you that you've "got" depression. But depression is *defined* by things like "a sense of inadequacy, a feeling of despondency, a decrease in activity or reactivity, pessimism, sadness and related symptoms" (Reber, 1995, p. 197). So by telling you that you've got depression, the diagnoser has told you just exactly what you've said!

For the most part, the current so-called mental disorders are arbitrary constellations of behaviors. The stars that form Orion only do so because someone once said that those stars should go together. Similarly, inattention and impulsivity contribute to ADHD, irritability and inactivity contribute to depression, and delusions and disorganized speech contribute to schizophrenia simply because someone said they should. Inattention and impulsivity are not symptoms of some underlying organic problem in the same way that fever can be symptomatic of malaria and tremor can suggest Parkinson's Disease. The constellations in the night sky do not point to any underlying order of the universe. The constellations in the sky were invented, not discovered. So too, the behavioral constellations in mental disorders were invented, not discovered. There is no identified organic problem that characterizes things like depression, schizophrenia, and ADHD.

Papers

Books

Or, to say it another way: There is no "thing" called ADHD that causes the symptoms of inattention and impulsivity, there is no "thing" called depression that causes inactivity and irritability, and there is no "thing" called schizophrenia that causes delusions and disorganized speech. And people don't stop being impulsive or irritable or deluded by being cured of these "diseases." And psychotherapists do not help people by curing such "diseases."

The U.S. Congress Office of Technology Assessment Report of 1992 stated that "Mental disorders are classified on the basis of symptoms because there are as yet no biological markers or laboratory tests for them." In fact, for many of the disorders listed in the *Diagnostic and Statistical Manual of Mental Disorders (4th ed., 1994)* such as depression and schizophrenia, a specific qualifier exists along the lines of "the symptoms are not due to the direct physiological effects of a substance or a general medication condition" (e.g., pp, 286, 327, 366, 402, and 432). Therefore, if an organic "thing" ever is found that causes depression and schizophrenia then, *by their own diagnostic criteria*, they could no longer be considered mental disorders.

Have you been having thoughts like "so what?" running through your mind as you read the information above? Did you wonder things like: "So what if there are lots of different stories lying about on the psychotherapy bookshelves?" or "So what if mental disorder diagnoses are based entirely on symptoms?"

These questions can only be answered by your own personal standards. Is it important to you to become more effective at what you do? Even witchdoctors are helpful some of the time. For witchdoctors who want to be more effective at what they do, however, it is extremely unlikely that they will improve by working harder to appease the sun god or the spirit of the forest. It doesn't matter how many offerings they make or how many ingredients they put in their medicine. Without an accurate explanation of how people get better, some of the people they treat will improve, some will stay the same, and some will get worse. And they won't know which people these will be or why people will respond differently to their charms. The reason the people get better, stay the same, or get worse, is, for the most part, unrelated to what the witchdoctor does. People get better serendipitously when a witchdoctor treats them. If witchdoctors want to have a more direct impact on the well-being of people they treat, they will need a different story.

A similar situation exists in psychotherapy. Cognitive therapy and applied relaxation, for example, have been shown to produce equally effective results in the treatment of panic disorder (Ost & Westling, 1995). If these treatments really are equally effective, then clearly neither the specific techniques of cognitive therapy nor those of applied relaxation can be held responsible for the reduction in the symptoms of panic. It is neither the specific potion of cognitive therapy nor the concoction of relaxation that can be identified as the curative agent. This means that psychotherapists who do cognitive therapy or applied relaxation are not doing what they think they are doing in terms of helping people get better. This also means that if psychotherapists such as cognitive psychotherapists want to help more people more often, it will be pointless to invent more cognitive strategies or to improve the way they employ their existing strategies.

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No psychotherapeutic procedure should be spared from this analysis. To the extent that people get better in psychotherapy, it is not because of any specific strategy from any particular method. It is not because people talked to chairs, or disputed their dysfunctional thoughts, or wiggled their eyeballs, or released their emotions, or were desensitized systematically, or shook hands with their adult and child, or met their needs, or controlled their behavior.

I *am not* suggesting that people fail to improve in the context of various psychotherapeutic activities. Many clearly do improve. I *am* suggesting that it is not the activities that got them better. Learning to relax doesn't get them better, doing homework doesn't get them better, talking to chairs doesn't get them better, disputing irrational beliefs doesn't get them better, and integrating parts of self doesn't get them better. These activities are not bad or dreadful or wicked. In terms of helping people get better they are probably circuitous at best and distracting at worst. Fundamentally, they are not *necessary* for people to get better.

Much psychotherapy research suggests that the most important ingredient in effective psychotherapy is establishing a warm, caring relationship. The specific activities that are undertaken, therefore, are largely irrelevant as long as the appropriate relationship is established. Researchers still can't tell what it is about a warm, caring relationship that seems to help, however, so this relationship shares the same status as other factors, characteristics, and procedures of psychotherapy.

The reasons that people get better are not the reasons that psychotherapists say they do. This is only troublesome for people who want to help more people more of the time. For witchdoctors who want to secure their place in the tribe by curing lots of people, it won't help at all to add more of their favorite ingredients to the brew. If psychotherapists want more of their clients to improve, it is futile to get better at understanding the id, or disputing irrational thoughts, or identifying unmet needs. None of these things put the clients where they are and none will bring them back.

Generally in fact, most current psychotherapy amounts to little more than giving people advice. If you're afraid to go out of the house, try to go out just a little bit for just a little while. If you feel sad, start doing some things you enjoy. If you think you're unlovable, think you're lovable. If you're feeling tense, take some deep breaths. In many cases, very little of the advice or suggestions that are provided seem exceedingly profound. Rather, they amount to, "if you can't do a whole lot of something, just do a little bit of it." Or, "if you're thinking things you don't want to think, then try to think things you do want to think." Since many people who visit psychotherapists are probably about as smart as the psychotherapist, it is interesting to wonder why they didn't think of these suggestions themselves. And since some people are helped by the advice and some aren't, it can't be the advice that makes the difference.

Papers

Books

In the previous chapter I suggested that much of what is currently done in psychotherapy may well interfere with peoples' abilities to get themselves better. Perhaps what a witchdoctor does that is really effective is to recommend that sick people spend five days resting in their huts. For many people, after five days of rest they might feel better. Everything else the witchdoctor does is just for the spectacle of witchdoctoring. Witchdoctors would not experience the status or prestige they enjoy if other people in the tribe discovered that all they really did was recommend a period of rest.

I would be disappointed if the idea you took away from my comparison of witchdoctors and psychotherapists was that I was trying to humiliate, belittle, or demean witchdoctors and psychotherapists. My purpose in providing the comparison is to demonstrate that, as deliverers of psychological remedies, we are perhaps not as sophisticated as we might think we are. It is not uncommon to hear people talk about the science of psychotherapy without a second thought, yet people would not often describe witchdoctoring as a science. The two practices, however, are currently perhaps more similar than they are different.

I don't think witchdoctors and psychotherapists are conniving charlatans any more than I think a child who writes a letter to Santa Claus is a rogue. I just think they are mistaken. There have been lots of mistaken ideas throughout history. People who believed the world was flat were mistaken. People who thought the earth was at the center of the universe were mistaken. People who believed that other people were witches and that they should be dunked or burned were mistaken. People who believed in phlogiston and ether were mistaken. People who thought lead could become gold were mistaken.

While it's easy to see the foolishness of ideas of the past, for some people it seems to be intolerable to entertain the notion that we might currently be mistaken. In fact, I am probably breaking one of the unspoken cardinal rules of psychology. There appears to be a general agreement in the community of the social sciences that we won't say anything is wrong. "I won't say your theory is wrong if you won't say my theory is wrong." It's as though the "wrong" word stings peoples' ears. The thinking seems to be that no theory or idea is wrong; some are just better than others. Well, that doesn't seem to be much of a way to improve. At times, some things are wrong, that's all. Acknowledging the wrongness of an idea paves the way for the exploration of new, more accurate ideas. Accommodating wrong ideas in a patchwork of "anything goes" impedes the development of accuracy and delays progress.

And I don't think that the psychotherapy of MOL is exempt from the judgment of right and wrong, nor that perceptual control theory (PCT) is—the theory that underpins MOL. Actually, I'm hoping like heck that some of the ideas in this book will be shown to be wrong in the future. I definitely do not intend this book to be the final word on MOL or on the conceptualization of psychological problems from a PCT perspective. The ideas that I describe here are as right as I can make them at the moment, and I think they're a pretty good start, but that doesn't mean they shouldn't continue to be scrutinized, evaluated, and revised when results of rigorous testing suggest that modification is called for. I am not enamored with any particular idea I've written about … except for the ideas of accuracy and precision.

Papers

Books

While I've suggested that there seems to be a *general* agreement to avoid saying that anything is wrong in the social sciences, the agreement has not been endorsed unanimously. Since I am making such a strong case for the problems with the way psychological troubles are currently conceptualized and treated, I would be remiss not to point you in the direction of at least some of the sources I know of that explore these problems, or elements of them, in more detail than I provide here.

A few pages back I mentioned Professor Robyn Dawes. The subtitle of his fascinating book *House of Cards* (1994) is *Psychology and Psychotherapy Built on Myth*, and throughout this book he makes it clear that he hasn't signed the "don't say it's wrong" agreement. Dawes says things like:

> …we have no insight into exactly why some people get better while others don't. (p. 38).

and

> One particularly distressing aspect of the professional therapy field is the doggedly persistent but sincere belief that whatever the current practice is, it is "enlightened," while past practices were deficient if not outrageous. We learn the specific faults of the past but seem immune to learning the general principle that decade after decade, great new insights and great new therapies turn out to be anything but great. (p. 192).

Dawes suggests the phrase "tyranny of childhood" (p. 223) as a label for all those beliefs that are based on the idea that childhood events somehow pervasively and dramatically affect adult functioning. Dawes goes on to point out, however, that "our belief in the tyranny of childhood has little more foundation than a belief in a mountain god." (p. 223).

Dr. Thomas Szasz is a psychiatrist who writes prolifically about the problems with current notions of psychological troubles. Perhaps his best known book is *The Myth of Mental Illness* (1974, revised edition). In this book Szasz explains at length the fallacy of comparing mental illness with physical illness. He points out things like:

> … whereas in modern medicine new diseases were *discovered*, in modern psychiatry they were *invented*. (p. 12).

and

> "Mental illness" is a metaphor. Minds can be "sick" only in the sense that jokes are "sick" or economies are "sick." (p. 267).

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Books

Psychology and psychotherapy are the concerns of this book, but they are not the only areas where mistaken ideas flourish concerning problems of mental health. Dr. Peter Breggin is a psychiatrist who is an outspoken critic of pharmacological approaches to treating mental health difficulties. He and Dr. David Cohen wrote *Your Drug May be Your Problem: How and Why to Stop Taking Psychiatric Medications* (1999), in which they say:

> The public is told that a great deal of science is involved in the prescription of psychiatric drugs, but this is not so—given that we know so little about the way the brain works. … We simply do not understand the overall impact of drugs on the brain. (p. 5).

and

> … there's no substantial evidence that any psychiatric diagnoses have a physical basis … (p. 93).

Elliot Valenstein is Professor Emeritus of Psychology and Neuroscience at the University of Michigan. Valenstein is another of the few who is not afraid to break the "don't say it's wrong" rule. In his enthralling and engaging book *Blaming the Brain: The TRUTH About Drugs and Mental Health* (1998), he meticulously scrutinizes the use of medication to treat psychological difficulties. A conclusion he reaches in the book is that none of the biochemical theories of mental disorder are right, but researchers are at a loss to know what to put in their place (p. 94). He also suggests that influences from politics and fashion have more to do with shaping diagnostic labels than scientific considerations do (p. 147), and that prescribing drugs is basically done by trial and error (p. 146). He points out that we know nothing of causes:

> In pursuing the biochemical approach to mental disorders an enormous amount has been learned about neurochemistry and drug action, but it is questionable how much has been learned about mental illness. We do not really know if a biochemical imbalance

> is the cause of any mental disorder, and we do not know how even the hypothesized biochemical imbalances could produce the emotional, cognitive, and behavioral symptoms that characterize mental disorder. (p. 138).
>
> The now overwhelming evidence that experience can alter neuronal structure and function should make it clear that it is dangerous to assume that any distinctive anatomical or physiological characteristic found in the brains of people with mental disorders was the cause of that disorder. (p. 128).

There is much hocus pocus in psychology at the moment. A robust statistical package here, a powerful software program there, a neuropsychological assessment someplace else, and an evocative brain image in another corner. Psychologists (and others working in the mental health area) want so desperately for their wrong ideas to be accepted that they'll do almost anything to find new ways of making things appear to be the way they want them to be. Acceptance seems more important to psychologists than accuracy. Or perhaps Professor Valenstein is right … we know the ideas are wrong but we don't know what to replace them with.

Papers

Books

But there is an alternative to existing notions of behavior. There has been ever since the 1950s. This alternative idea is as different from current explanations as the heliocentric model of the universe is different from the geocentric model. This idea is the one that I outline in Chapters Four and Five and the one that Powers has already explained in the foreword. (Check out www.livingcontrolsystems.com if you'd like still more information.) Some people have had bits of this idea from time to time, but Powers was the first person to accurately and precisely figure out how it all fits together. The basic idea is that humans (and indeed all things that live) don't behave, they control. Behaving is not what humans do. Controlling is what they do. If the idea that living things control is on the money, and there is compelling evidence that it is, then this means that—gulp!—ideas that don't recognize or explain this fact are wrong. Thanks to Powers we do have something with which to replace all those wrong ideas.

Living things control. This simple fact has profound and pervasive implications for the sciences of life. Having the right idea at our fingertips, however, does not mean that all our questions can be answered. What this new idea means is that many current questions are irrelevant, so we can stop searching for answers to them. The new idea suggests new questions and new avenues for investigation. Just as knowledge of a heliocentric universe won't help us answer questions about a geocentric universe, knowledge of the process of control won't help us answer questions about the causes of behavior.

The idea that behavior is caused by particular things is wrong. Believing that grades, or jail, or bonuses, or stickers, or relationships, or bombs, or a withering glance, or "employee of the month," or any other "stimulus" can make people act in particular ways is an appeal to magic. And it doesn't help to shift the stimulus from outside the head to inside and insist that thoughts or needs or goals or mental disorders or genes or emotions or personalities or traumatic memories or neurotransmitters make people act in particular ways. That requires a similar appeal to magic. When we're trying to understand how something works, it's not very helpful to invent magical solutions. There's enough magic already in the world. We couldn't figure out how to turn lead into gold, but nature turns coal into diamonds and shell grit into pearls. Things like gravitational and electromagnetic forces seem pretty magical. The creation of life and the phenomenon of control have a sense of magic too. There's magic aplenty in nature without creating more whenever we find something that's a bit tricky to figure out.

In time, the idea that some things (like bad circumstances or bad thoughts or out of balance chemicals or dodgy personalities) cause other things which we call mental illness (such as agoraphobia or bipolar disorder) will arrive at the Mistaken Ideas Hall of Fame and will take its rightful place beside phlogiston and flat worlds and all the other ideas that have been proven wrong. Advances in science won't reveal the secrets of ADHD, depression, schizophrenia, and all the other psychological disorders to us. Advances in science will show us that we've been looking at things the wrong way.

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I imagine a front porch of the future. Two old-timers have their chairs leaned back against the wall. They are gazing out upon the world and reminiscing about the good ol' days:

> Shoot, Hal, remember the time when we used to think that people could get something we called social phobia?
>
> Sure do, Marv. And what about the one that people had faulty cognitions that made 'em ill.
>
> That was a goody too. But my favorite, Hal, was the one about neurotransmitters makin' ya crazy.
>
> Oooh ee! There was craziness happenin' back then all right. We was just confused about where the craziness wuz!
>
> Yessir … sure were.

Throughout this explanation I have been unashamedly displaying my bias for accuracy and precision. Some people, however, are not seduced by the exactitude of an idea. Instead, they prefer their favorite ideas to have other qualities such as popular appeal, or ease of understanding, or marketability. People have all sorts of ways of deciding whether or not an idea is one they are prepared to run with. Perhaps they like ideas to nestle snugly into their existing network of beliefs, or perhaps they like ideas that are generally accepted by most other people, or perhaps they like ideas that are entertaining and can keep people amused. Undoubtedly there are still more ways to choose ideas. No doubt some ideas have more than one of these qualities. I'm being extreme for the sake of the lesson. In this book I'm presenting an idea that I think is pretty exact (this is the first half of the book). If you're not that bothered by a lack of exactness of ideas, this book probably won't be to your liking.

It is not always easy to accept that the stories you hold strongly to are erroneous. Many people at one time believed stories about Santa Claus and the Tooth Fairy. People also once thought the earth was at the center of the universe. There is nothing wrong with a good story. The botheration arises when stories are required to do things they cannot do. The Santa Claus story won't get Grace her new bike unless she knows the bit about making sure her mum and dad see the letter to Santa before she sends it. The geocentric story of the universe won't help Nicholas understand what seem to be little stutters that celestial bodies make in their otherwise orderly march across the sky, nor will it help him search for new stars and planets that are as yet undiscovered.

Current psychotherapy stories seem to be best appreciated for their entertainment value rather than their scientific accuracy and plausibility and explanatory power. Entertainment is a fine activity to participate in. Understanding the condition of being human and figuring out how to help when problems come along, however, will not be improved through entertainment. If understanding and improvement is the goal, then accuracy, not entertainment, must take center stage.

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What's been said

Many different explanations exist to explain the presence of psychological problems, but these stories lack scientific plausibility.

Diagnostic labels are just arbitrary summary terms to group together the symptoms that people report—not indicators of some underlying pathology.

By and large, people don't get better because of the different techniques they are introduced to in psychotherapy.

An inaccurate story will not be of any help when problems need to be corrected.

Papers

Books

The big deal

Current ideas about psychological problems are wrong, and the reluctance to acknowledge and address their wrongness is delaying progress.

Coming up

What is a psychological problem?

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Postscript

Questions & Answers

As this book was nearing completion I had the opportunity to co-facilitate an MOL training workshop with Powers. About 15 people attended the workshop which ran from Sunday evening until Wednesday lunch time. The workshop was discussion and activity based and often headed in directions that were surprising and intriguing. Participants had many opportunities to practice MOL and with diverse backgrounds and enquiring minds they poked and prodded in pursuit of a greater understanding of conducting MOL psychotherapy. Through their searching for greater clarity I found myself pondering new ideas and growing in my appreciation of this method. The workshop appeared to be such a valuable experience for all of us who attended that I thought collating some of the insights and sharing them here would be a perfect finishing touch to this book. I hope you think so too.

Can I use MOL with myself?

Given how useful the workshop participants found MOL when they were guided through it with someone else, the issue of self-MOL was raised. The idea of being able to conduct self-MOL is appealing. MOL would obviously be a lot more accessible if it turns out to be a procedure that can be done independently of any guide. It is, therefore, certainly a direction that warrants closer scrutiny.

I have experimented with self-MOL in various ways. Initially, I just tried to catch background thoughts when I noticed them and spend some time mulling them over. Then I made a little "chime tape" that I had first learned about during my behavior management advisory visiting teacher days. On a blank tape I recorded, every 30 seconds, a little "ding dong" sounding chime (my "ding dong" was produced by tapping the side of a glass twice, quickly and gently, with a teaspoon but how it is produced is not important). When I had something that was bothering me and I found some alone time (often this occurred while I was driving in the car) I would switch the tape on and start talking about my concern. Every 30 seconds the little chime would sound and that was my cue to check for any background thoughts. When I heard the chime I would think "What am I doing at the moment?" or "Do I have any background thoughts just now?"

For some of the issues that I considered in this way I found the technique really useful. Over time, however, I began to expect the sound of the little chime and then I'd become distracted from discussing the topic and would begin to think "Is the chime about to go now?" Then I would think about being distracted and also about thinking about the chime. Sometimes I would still get to some interesting places but it wasn't always connected to my initial topic. I did discover that, in some cases, simply talking out loud about a problem, rather than talking it over in my mind, leads to some useful and interesting perspectives.

So my feeling at the moment is that self-MOL may have some application but ultimately I still think having a guide such as a psychotherapist is best. With a guide, people are free to talk about their thoughts without also having to keep track of them. The guide can pick up on things that the person might not have noticed or might actually be avoiding. With the assistance of a guide people can begin to explore areas of their minds that they might otherwise stay away from. These might very well be the areas that hold the key to the resolution of their conflict. It may, in fact, be the staying away from these areas that is perpetuating the conflict.

Self-MOL is interesting, fun, and sometimes even useful. Even so, I think there will always be a place for MOL psychotherapists and their curious guiding.

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To use MOL effectively, do I have to be less caring than I can be with other approaches?

This may well be a pivotal issue for psychotherapists to reconcile as they undertake to learn MOL. In Chapter Seven I suggested that psychotherapists might reorganize as they are learning MOL. What it means to be a caring psychotherapist may well be one of the areas where reorganization occurs.

For some psychotherapists being caring might mean helping clients out of their difficulties by comforting them, advising them, and demonstrating that they are being heard and understood. When clients are upset they might tell them things to help them feel better and when clients are stuck they might give them suggestions for moving forward. In MOL, however, being caring means helping clients shift their awareness to a useful higher level and keep it there long enough for reorganization to do its job. When clients are upset or stuck this means helping them explore these experiences in detail and providing them with opportunities to shift their attention up.

The differences in approach probably boil down to the different theories that are used to explain what is happening. From a PCT perspective, when someone is upset or stuck as the result of internal perceptual conflict, the most direct way of helping them through this is to provide them with opportunities to move their attention to higher perceptual levels. Their upsetness or stuckness will dissolve once higher-level systems reorganize so MOL psychotherapists are interested in going for that higher level directly.

Perhaps psychotherapists' attitudes to caring can be summed up by the way in which they answer this question: Do you see it as caring to provide to others your ideas and opinions about how they should be living their lives or do you see it as caring to provide to others opportunities to figure out for themselves their most satisfactory ways of conducting the business of living?

Can I use other methods or must I use MOL exclusively?

When considering what approach to use, it may be useful to keep in mind that the real name of the game is to help people resolve distress as efficiently as possible. People sometimes wonder if they must use MOL exclusively or if they can use other techniques from time to time. My answer is that you should use whatever you think you need to use as a psychotherapist to help people as well as you want to help them.

In my clinical work I've found that, so far, all I've needed to use is MOL. I'm not saying that there haven't been times when I could have done things like advised, or suggested, or interpreted, or diagnosed, or introduced skill-building activities, or given educative information, or provided explanatory diagrams. There have been bountiful opportunities for me to unleash any one of a number of common psychotherapeutic strategies. I just haven't needed to. That is, I've found that these routine psychotherapeutic strategies were not necessary for me to use in order to help people.

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Up to this point I've not needed to adapt MOL or adopt other methods, but psychotherapists are different. If you have a technique which is more efficient than MOL, less stressful, theoretically defensible, and both ethical and legal, then of course you should use that! We are not in the business of MOL for MOL's sake. We are in the business of helping people. The reason I have gone to such lengths to describe MOL is because, at the moment, it seems to me to be the most efficient and direct way of helping people in distress and it has the most plausible scientific rationale I know of. In fact, I cannot understand how another technique would be justified theoretically but my lack of understanding should not be a barrier to your exploration. As I said in Chapter Two, I hope this book is not the final word on MOL. What a wonderful position we would be in if, through the introduction and application of MOL, we encouraged the discovery of more efficient methods of helping.

Perhaps the most useful question to consider then is not "Can I use other methods or must I use MOL exclusively?" but, rather, "Why do I want to use methods other than MOL?" Exploring the answers to that question that lie within your own perceptual hierarchy might be instructive.

Is it really the case that the content the person describes is unimportant?

Like answers to so many other questions, the answer to this question depends on your point of view and how you understand the "content" you hear another person producing. Is there a tendency perhaps to assume that words you hear from another are descriptors of some "real" state of affairs? Based on this assumption, it is your job to understand this real, but unsatisfactory, state of affairs and then to take it, and mend it, so that it is once again satisfactory.

I know from my own experience that the words I utter at any given time are often only a slice of the totality of the experiences I'm aware of at that point. When I'm asked at work how my weekend was, I give an edited version of the events that transpired, and what I describe will differ depending on whether I'm talking to a boss, or a friend, or a client. Similarly when I'm asked for my opinion on a new piece of art, or a new item of clothing, or a lavishly prepared dinner, or a lovingly drawn stick figure, I select one from the many opinions I might have at that time.

I assume that the clients I work with are built like me, and so I understand the words that they push my way are only a part of their attempts to control some of their experiences at that time. I don't ascribe any exalted status to the particular words they utter. When I work as a psychotherapist, however, I do need something to work with, just as when Margaret makes bobbin lace she has particular equipment that she uses. The "equipment" that I use in psychotherapy is the information provided to me by the client I am working with. So it is probably necessary to have some content for at least some of the psychotherapy session, but the specific details and the accuracy of the content are less important. No matter what you hear coming from the mouth of the client, ask for more detail, watch for disruptions, and then ask about the disruptions as a way of shifting the client's attention to a background thought and perhaps to a relevant higher perceptual level.

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To demonstrate the inconsequentiality of the content that is spoken, I introduced an activity at the workshop. People formed psychotherapist/client pairs to begin the activity. We had seven pairs on one occasion and eight on another. The client began talking and the psychotherapist began MOLing. After approximately 90 seconds I summoned my most commanding presence and said sternly "ding ding." This was a signal for each psychotherapist to stand up and move along to the client on their left. The client continued to talk about their problem and the MOL psychotherapist continued to ask about foreground thoughts, spot disruptions, and ask about them. It took about ten to fourteen minutes to complete the activity with each psychotherapist MOLing each client for about 90 seconds.

Each psychotherapist only heard a snippet of each client's story, yet the psychotherapists reported that they were able to pick up the conversation and keep MOLing as they had been. Perhaps even more interestingly, the clients said that they were able to go up levels and some even came to helpful realizations and insights. More than one of the clients said that initially they felt the need to recap for the incoming psychotherapist, but after two or three psychotherapists they just kept talking and were able to continue the process without recapping. For the people involved, this was a dramatic illustration of how unimportant the particular content that the client provides actually is.

Can I use MOL with couples or groups?

Conducting couples psychotherapy and group psychotherapy is a common way of helping others. However, since MOL is a technique for helping individuals explore their individual perceptual hierarchies, I can't conceive how MOL would work with a couple or with people gathered in a group. Of course, limitations to my imagination should not stop creative psychotherapists from exploring MOL applications with couples and groups. My thinking, however, is that people who are experiencing internal perceptual conflict benefit most from the focused attention of a one-on-one interaction.

In the case of a couple, it seems to me that it would be exceedingly difficult to ask each member of the couple to talk about whatever is at the front of their mind, to look for disruptions, and then to ask them about these when they occur. An MOL psychotherapist is spontaneous, flexible, and responsive to the immediate goings on of the client. I can only see this process being compromised if the psychotherapist needs to oscillate between two clients at the same time. This difficulty, to my way of thinking, would be increased markedly in a group situation.

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Another complicating factor is that, for MOL to work, clients need to be able to talk freely about the happenings of their mind. If Abiola and Malika are having difficulty in their relationship, then it is at least possible that each of them has thoughts about the other from time to time that they would find difficult to talk about with the other present. Certainly, in some situations, it helps couples enormously to learn how to talk to each other openly about the matters that concern them. If Abiola doesn't know how to talk about his feelings then perhaps some instruction on emotional expression would be useful. It may be the case, however, that Abiola wants his wife to make her own decisions in life but also wants her decisions to be the same as his. In this case Abiola would be in conflict and the way for him to resolve this conflict is by shifting his attention to higher perceptual levels. Abiola, however, is unlikely to allow his awareness to drift unrestrictedly if he is concerned about offending or hurting or otherwise disappointing Malika.

Maybe the time to do couples psychotherapy is after each member of the couple has had the opportunity to resolve whatever perceptual conflicts they are experiencing individually. Once this has happened, however, perhaps the couple would be able to resolve whatever difficulties remained between them without the help of a psychotherapist.

The same thinking that I've applied to a couples situation applies to group situations. The likelihood that each member of the group would be prepared to talk freely and the psychotherapist would be able to help each of them shift their awareness up their individual hierarchies is slim to say the least. This is not to say at all that couples therapy and group therapy is not helpful for some people. It's just to say that MOL is not the way to be helpful in these situations.

How important are the questions I ask?

A constant theme throughout the workshop centered on the fact that it was the intent behind the questions that were asked, rather than any particular sequence of words, that was important in MOL. Still, some participants wanted to make sure that they were asking useful questions and weren't continually saying the same thing. In anticipation of this concern I endeavored to provide a variety of questions throughout this book.

An illuminating lesson was learned, however, when participants at the workshop commented on their experiences when they experienced MOL as the client. Almost without exception, these clients said that they couldn't remember what questions they had been asked by the psychotherapist. Even when they could remember a particular question it wasn't that they remembered being asked the same question repeatedly but that that particular question caught their attention because of the way it was phrased or the area it asked about.

It seems then, that adding variety to the questions you ask may be more for the psychotherapist's benefit than for the efficient provision of MOL. In one of my first experiences with MOL I remember explaining the process to a friend of mine and telling him that I wanted to experience it from the client's perspective. I said to him that I wanted to just talk about a particular topic and after listening for a little while I wanted him to say "What do you think about __________?" and to insert a little bit of whatever it was I had just said. To my surprise the activity worked well. I was able to shift my perspective to what seemed a broader point of view and I developed an attitude I hadn't thought of before. I certainly wouldn't recommend adopting the "one question" approach to MOL but my experience, along with the reports from the clients in the workshop, seem to indicate that compiling a vast repertoire of questions to deliver might not be one of the important aspects to learning MOL. It's more important to know when to ask and why you're asking than it is to know what to ask.

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Can MOL techniques improve your normal daily conversations?

MOL is a specific method of helping people shift their attention to higher perceptual levels. It seems especially useful for resolving internal conflict and is also a neat means of self-discovery. There is nothing magical about MOL, however, (apart from the magic of an accurate theory underpinning it) and I don't think of it as a way of helping people win friends and influence others. Since learning MOL, I think I have become a much more effective psychotherapist. I'm certainly much clearer about my role as a psychotherapist and what I can do when I am in this role.

Outside of psychotherapy, however, I think I communicate in pretty much the same way I always did. I probably notice people's disruptions in routine conversations where I didn't before, but I don't ask people about them in an effort to direct their attention away from our current conversation. I think of MOL as a specific kind of conversation and I would need to obtain people's permission before engaging them in this way of talking. When people turn up for psychotherapy I can accept that they are implicitly giving their permission by initiating the psychotherapeutic relationship (and if I am unsure I explicitly ask them before beginning MOL), but when I chat with friends on the phone, or ask the lady behind the counter for an olive and goats cheese ciabatta, or explain to the mechanic that my brakes seem spongy at the moment, I'm not thinking about what they might find as they explore their perceptual hierarchies.

MOL is not a way of talking generally. It is a way of helping those people who want to be helped to shift their attention to places that will bring about a resolution to their conflict or an experience of increased self-understanding.

Can MOL be used to manage people more effectively?

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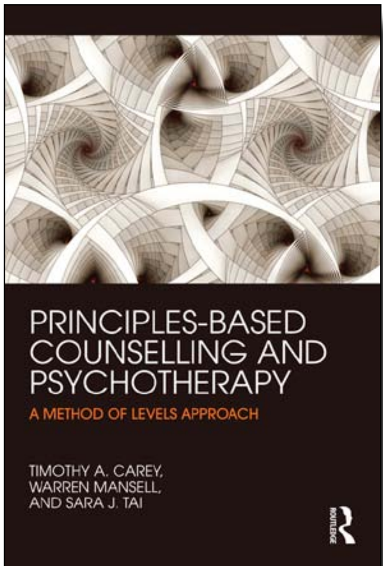
Much of what I wrote about in the section above will be relevant here. I don't think of MOL as a way of managing people—I think of it as a way of helping people resolve internal conflicts. It is certainly the case that people who are being managed experience conflicts from time to time. Perhaps Marcus wants to apply for a promising promotion but doesn't want to leave the happy and productive team he is a part of. MOL may well help Marcus resolve this conflict. Given the nature of many managerial relationships, however, and the fact that if people experiencing MOL are concerned about what they say to the person conducting MOL, it may be the case that managers are not the best people to conduct MOL with those they are managing. If Marcus thinks it's important to present himself in a particular way to his manager, then he will be limiting the things he talks about and the places in his mind he explores during the process.

In some cases, perhaps it is the manager who could benefit from MOL. Perhaps Kylie wants her team to increase their productivity but also wants to maintain the friendly relationships she has established with them. In this situation, Kylie might find it very useful to reorganize her way to a different point of view.

MOL is a process for helping people develop their own new perspectives and insights. It is not a method for convincing others to act in particular ways or persuading people to adopt attitudes and mindsets that appeal to others. MOL will help people live their own lives more contentedly. It won't help people live the lives that other folk have decided they should live.

These are some of the topics that we discussed and explored at the MOL workshop. Perhaps some of them have prompted you to think of other issues or scenarios that haven't been covered here. I would be delighted if you were able to use what I have described throughout this book to scrutinize and clarify these topics for yourself.

Principles-based Counselling and Psychotherapy:
A Method Of Levels Approach



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http://www.routledgementalhealth.com/books/details/9780415738781/

Introduction

It is a tremendous privilege to be able to provide counselling and psychotherapy services to people experiencing psychological distress. We are continually humbled at the strength of the human spirit that people with psychological troubles demonstrate through their resilience and endurance. People place an enormous amount of trust in counsellors and psychotherapists when they bare their souls to them during programmes of psychological treatment. Sometimes, in only just a few minutes of meeting them, these people tell their counsellors or psychotherapists things that they have told no one else.

Given how debilitating psychological distress can be, we think it is important to constantly seek to improve the services provided by counsellors and psychotherapists. Unfortunately, despite the regular appearance of new and seemingly innovative approaches on the psychotherapy scene, there has not been a steady advance in the effectiveness or efficiency of our treatments. Many innovations are often only innovative at a superficial level and actually turn out to be recycled versions of well-established, more fundamental methods. Exposure is a good example of this. Exposure, in its broadest sense, occurs when people maintain an awareness of distressing images, thoughts, feelings, and objects for a prolonged period of time, and arrive at a different, less upsetting, understanding of these experiences than they had previously. Much of the stock available in the marketplace of psychotherapy techniques is, at its core, a way of promoting exposure, even though it might be packaged very differently (Carey, 2011a).

The approach we offer in this book is an invitation to focus less on the tools you might collect for your toolbox and to focus more on the principles behind why you might use each tool, and when and how it is used. We invite you to do this regardless of your therapeutic orientation – whether it originates in psychodynamic therapy, client-centred counselling, or cognitive behavioural therapies, for instance. We also recognise that the principles we describe will have relevance to wider disciplines that are concerned with mental health and well-being, such as psychiatry, nursing, social work, occupational health, and education. The principles will provide new insights and directions for working with people experiencing distress even for those who are not directly providing psychological therapies – such as support workers or advocates.

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The aim of our book is to help to distil the underlying principles of alleviating psychological distress, rather than to add yet another therapy to the plethora of approaches available. There is a strong reason to believe that most psychotherapies 'work' on average (in the sense of helping people reduce psychological distress). Our goal is to distil the key principles of any form of counselling or psychological therapy that help it maximise its effects for each client. In this way, our book is designed to enhance reflective practice. For more than 40 collective years, we have been studying an explanation of behaviour that we think provides the key to significant and sustained improvements in the provision of counselling and psychotherapy treatments. The explanation is perceptual control theory (PCT; www.pctweb.org). We outline PCT in detail in this book, as well as its relevance to addressing human misery and internal mayhem.

Three fundamental principles are at the core of PCT, and our contention is that by understanding these principles, counsellors and psychotherapists will be able to work effectively and efficiently with a wide range of people experiencing a variety of manifestations of psychological distress. We think that successful approaches can be built from these principles, and we describe the Method of Levels (MOL; www.methodoflevels.com.au) that can be considered a transdiagnostic therapy that is based entirely on the three principles we present in this book.

The initial idea of MOL was suggested by William T. Powers (the originator of PCT), but this idea was then developed and refined in routine therapeutic practice. It has now been used successfully in different health-care contexts by different therapists with different clients and in different countries with different health systems. On the one hand, MOL lends itself particularly well to services in which there is an impetus for an effective and efficient method to get started earlier without a long assessment period, such as clients in primary care or in acute inpatient psychiatric wards, often where people might only attend a small number of sessions, or may wish to use therapy as a 'drop-in' service. On the other hand, it is particularly flexible for people who want therapy to be available for longer than the 'average' client (e.g. people with long-term conditions or complex interpersonal problems) or for people who wish to use therapy to make a long-term recovery and circumvent the problems of mental health diagnoses (e.g. recovery from psychosis). It is an intervention that can be used for everyday problem-solving, irrespective of mental health problems, and therefore also serves as a model for settings such as therapy supervision, teacher training, and co-counselling. In this book, we particularly focus on how a principles-based approach can refine clinical practice and serve as a training resource. It helps us to think about *why* we ask our clients a question at a particular moment about a particular topic, and *how* might be the most pertinent and simplest ways to ask these questions from the clients' perspectives.

Evaluations of MOL have consistently demonstrated that it is experienced helpfully by many clients. We provide detailed explanations of MOL throughout this book, as well as an abundance of examples from therapeutic practice to demonstrate and highlight important features of the approach.

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In Chapter 1, we begin with a broad overview of mental health generally, and we present our rationale for why we think a principles-based approach to counselling and psychotherapy is overdue. We explain what we mean by a 'principles-based approach' and we describe some of the advantages of this way of working, as well as some of the difficulties that might be encountered in adopting this approach. When you get to the end of Chapter 1, you will be in a good position to assess how ready you might be to undertake working from this perspective.

We explain and explore the three fundamental principles that form the basis of the book in Chapter 2. Our stance is that control is what people do, conflict is what interferes with control, and reorganisation is what resolves conflict and restores control. Control, conflict, and reorganisation, therefore, are the cornerstone principles of our approach. The control that is the basis of PCT has a robust scientific foundation but, conceptually, it is nothing more than the process of making things be the way you want. Despite its conceptual simplicity, the phenomenon of control has profound implications for the life sciences, and none more so than in the area of understanding and treating psychological distress.

Some of the implications of these principles are explored in Chapter 3. PCT and its approach to control, for example, influences the way that ideas such as 'empathy' and 'objective' are understood. PCT also helps to clarify the change process in therapy and, in doing so, permits a more nuanced understanding of both the role of the therapist and the role of the client in facilitating change. 'Relativity' is not often discussed when psychological distress is being considered, but we explain its importance and relevance to any form of distress.

After discussing some of the general implications for therapeutic practice, we begin to focus on the specifics of therapy provision. In Chapter 4, we spend time clarifying the roles of both the therapist and the client from a PCT perspective. We illustrate, with a simple activity, how therapists might be able to become more aware of their own motivations in therapy by examining their inclination towards the different techniques and routines they use. We also describe the two fundamental goals an MOL therapist focuses on in each session and we consider the experience of the client in a programme of MOL therapy.

In Chapter 5, we extend the discussion from the previous chapter by shifting from considering the therapist and the client individually to focusing on the relationship they create together. We explain how the therapeutic relationship can be understood from a PCT perspective and we offer what might be the minimum requirement for therapeutic success in the context of the therapeutic relationship. To assist in learning, we also provide some short scripts of what a therapist might say to explain different points and we spend some time addressing how you might deal with potential difficulties in the therapeutic relationship.

Chapter 6 discusses some practicalities of therapeutic service provision in terms of how appointments are scheduled. We advocate for a client-led approach to appointment scheduling and we explain the benefits of this approach as well as how it can be implemented. While the way in which we decide how appointments are scheduled might seem like a fairly mundane aspect of therapy provision,

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it can uncover important assumptions and beliefs that therapists hold about how much therapy a client should have and who should decide when enough is enough in terms of therapy provision.

The thesis of Chapter 7 is that the therapeutic value of any technique can be enhanced by an understanding of the three principles we expound in this book. We illustrate this point using well-known examples such as activity scheduling, thought diaries, and mindfulness. Each of these techniques is helpful and meaningful for some people and inert for others. To magnify therapeutic potency, we suggest four components that we maintain are the necessary and sufficient ingredients whenever any technique is effective therapeutically. By focusing on these components rather than the strategy itself, therapists will be able to become more effective more of the time.

As we near the end of the book, we spend some more time addressing the nature of psychological distress and the general unhelpfulness of the current diagnostic categories in understanding disruptions to psychological functioning. Our contention in Chapter 8 is that it is important to focus on the distress underlying any particular symptom constellation rather than the symptoms themselves. We demonstrate, by reference to some widely used questionnaires, how implicitly symptoms are assumed to be distressing without this assumption ever really being verified. Formulation can be a valuable alternative to a diagnostic approach but formulation has problems of its own, so we propose that the principles-based approach that is offered in this book can even help to improve formulation.

While change is the basic remit of all approaches to counselling and psychotherapy, it is very difficult to find unambiguous definitions of change. Understanding change more clearly and then considering how it might be promoted most efficiently and effectively is the purpose of Chapter 9. We explain change from a PCT perspective that characterises the change process as non-linear and unpredictable. Lasting and satisfying change is not constrained by the time frames that counsellors and psychotherapists devise. Persistent psychological distress can be thoroughly resolved in any number of sessions. Sometimes a successful reorganising occurs after only a session or two, and on other occasions it takes many more sessions. A principles-based approach understands this and accommodates it. Recognising change as reorganisation has serious implications for counselling and psychotherapy, and we explore some of these in this chapter.

In the final chapter, we discuss some practicalities such as monitoring client progress and self-reflection but we also synthesise the information from previous chapters by providing an example of what an actual programme of MOL might look like. We discuss how MOL might be introduced in the first session and the way questionnaires might be used and integrated into therapy. We then discuss subsequent sessions and explain, in practical terms, how aspects such as client-led appointment scheduling can be implemented.

We hope you like this book but, more than that, we hope you are intrigued by it, challenged by it, and excited by it. For us, learning PCT and providing MOL has been a professional trip like no other. We think MOL is an excellent

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demonstration of what can happen when the principles of robust, accurate, and elegant scientific theories are applied with sensitivity and diligence. While it is exhilarating to be standing on the shore, with our backs to the familiar world of mental health disorders and psychological treatments, and to be contemplating the brave new PCT world of psychological well-being and human relationships, we have but yet dipped our toes in the water. The destination is clear but the journey is not. We would love it if we met up with you along the path.

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Chapter 2

The principles

Control, conflict, and reorganisation

By reading this chapter, you will learn:

1 what control is and why it is important;
2 how control can be disrupted;
3 just how common conflict is and why it can lead to problems; and
4 about a fundamental learning mechanism that helps keep everything in order.

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In the first chapter, we explained the rationale for a principles-based approach to counselling and psychotherapy. We also explained that in our approach, we use a single, robust theory of psychological functioning that provides a small number of clearly defined and interrelated principles, rather than adopting a pragmatic collection of both general and specific principles from existing research (as carried out by Castonguay & Beutler, 2006b). We define our three principles in operational terms and in a significant amount of detail, but not as specific recommendations or instructions for particular therapeutic activities. The implications for conduct in therapy become apparent when the principles are considered in relation to individual clients and therapeutic situations. As you will see, the principles we use to guide therapy do not apply only to mental health and human beings; they are principles for how all living organisms function, survive, and thrive. Through a sequence of interviews across a wide range of contexts, we have found that these theoretically derived principles match closely with people's lived experiences of mental health problems and recovery (Alsawy & Mansell, 2013; Carey *et al.*, 2007; Gianakis & Carey, 2011; Higginson & Mansell, 2008; McEvoy, Schumann, Mansell, & Morris, 2012; Stevenson-Taylor & Mansell, 2012). We will define each of the principles in turn. The principles are: control, conflict, and reorganisation.

Control is ubiquitous in nature. It is unfortunate that, in recent times, the term 'control' has come to be associated with manipulation or coercion or the activity of tyrants. Although manipulation and coercion are forms of control, we mean something much more commonplace when we use the term. Cooperation and benevolence are just as clear examples of control as are bullying and intimidation. Standing upright is a control process, chopping tomatoes is a control process, cleaning teeth is a control process, tying shoelaces is a control process, blowing out birthday candles is a control process, and catching a bus is a control process. Autonomous control is a characteristic of living things. Tyrannical behaviour will certainly be included in our understanding of control, but so will admirable, altruistic, and even absent-minded behaviours. Winnie the Pooh is every bit as controlling as Attila the Hun.

What is control?

A colloquial understanding of control is conceptually very similar to a formal definition of the phenomenon. In everyday terms, 'control' could be thought of as: 'Making something happen the way you want'. Sometimes, that involves persuading other people to do things in a particular way, but it also includes keeping your car where you want it to be on the road, making sure your DVD player records your favourite show while you work late, and ensuring your lounge room stays as dust- and clutter-free as you prefer.

A formal definition of control is: 'Achievement and maintenance of a pre-selected perceptual state in the controlling system, through actions on the environment that also cancel the effects of disturbances' (Powers, 1973, p. 283). While this sentence might seem very different to the more casual definition offered in the paragraph above, three essential elements are the same. Two of these elements are directly stated and the third is implied.

Although we need to talk about these elements in a sequential way, it is important to realise from the beginning that the three elements all occur simultaneously. This realisation is important in order to accurately understand the process of control. Control is not a start-stop, cause-effect process. It is an ongoing, dynamic process in which the separation of causes and effects is often arbitrary and even unnecessary. The humble eye-blink reflex in relation to a puff of air illustrates the tightly coupled nature between effects and causes that reveals a process of circular, rather than linear, causality. In order for a puff of air to be followed by a blink, some preconditions need to be in place. First, the eye needs to be a living eye – dead eyes do not blink. Second, the puff of air needs to land on the surface of the eye. A puff of air on the elbow or ear lobe will not produce the same effect as a puff of air aimed directly at the eye. Why are these two preconditions important for the puff of air to 'work' in terms of producing a blink? It turns out that the surface of the eye has a particular moisture level that is maintained by blinking. When the puff of air lands on the surface of the eye it has the effect of changing the moisture of the eye's surface. The blink, however, has the effect of restoring the surface moisture to the pre-blinked level. So is the blink a cause? Well, yes. It is *both* cause and *caused*. It is *caused* by the puff of air and it causes a change in the moisture level on the surface of the eye. Is the blink an effect? Well, yes. It both *is* an effect and it *produces* an effect. The blink is the effect of the puff of air and the effect of the blink is a change in the moisture level on the surface of the eye.

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Understanding the three elements of control enables us to make sense of the way in which the effects of causes and the effects of effects can actually be the same effects. With circular causality, something can be both a cause and an effect depending on your point of view and how you decide to analyse an event. Often, in order to identify causes and effects, one has to draw arbitrary lines that specify when a particular event starts and stops. On occasion, this can be helpful in analysing different aspects of behaviour, but in order to understand the behaviour as accurately as possible, the extracted segment must, at some time, be placed back into the context of the behaving creature. By focusing on the three elements we are introducing here, it becomes unnecessary to isolate samples of behaviour in order to identify causes and effects.

The first element that is obvious from both the colloquial and formal definitions is some 'desired state of affairs'. One definition calls it 'the way you want' and the other definition calls it 'a preselected perceptual state'. It is known by other names too. We could think of this element as a need, want, goal, dream, outcome, benchmark, desire, ideal, value, hope, directive, rule, standard, expectation, and so on. Each of these everyday terms implies subtly different kinds of 'wants'. For example, a 'hope' might be one that we feel strongly about but may struggle to achieve, whereas an expectation is typically achieved but not necessarily desired so strongly. A goal, such as to win a race, may be achieved over the space of a few hours whereas an 'ideal' may never be met fully over a lifetime. Yet, in every case, these words relate to the way in which some aspect of the world *should be*. Even the term 'should' is too restrictive, but we will use this term to stand for all of the above terms. The reason that we can include all of these different terms under one umbrella term is because of a focus on the mechanics of the process to which each of these terms point. Our stance is that the acts of observing a rule, maintaining a value, and chasing a dream all unfold the same way. Different actions will undoubtedly be involved in each case but the underlying process will be the same. For us, it is the way a process 'works' that is critical rather than the particular word labels used to name the process.

The second obvious element describes effort or activity. The casual definition specifies 'making something happen' while the formal definition describes 'actions on the environment'. Both statements therefore suggest that control does not happen serendipitously or by accident. Desired states of affairs are sculpted, fashioned, and hewn. So, control involves specifying the way in which we think some aspect of the world should be and also effort or activity to bring about this desired state of affairs. By the time we become adults, we are usually so good at controlling that we seldom notice the actions we use to maintain control. As a thought exercise, imagine what your appearance would look like in a week from now if you took absolutely no action whatsoever between now and then to affect your appearance. Spending time reflecting on the image that would greet you from the mirror in seven days' time if you suspended all appearance-directed activity might help you appreciate the subtle and ongoing ways in which we use actions to produce control.

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The implied element that has been left unspecified so far is that of detecting, noticing, perceiving, sensing, or experiencing. In order to be able to act to make the world be as it should be, we have to know how the world currently *is*. Control, in fact, could be described as a process of making what *is* match what we think *should be* – or keeping the difference between *is* and *should be* as small as possible. So, we have to remain aware of how the world *is* – or at least that aspect of the world we are controlling – constantly. If we take our eye off the ball, control will be compromised. We cannot control the volume of the television or the al dente-ness of pasta if we cannot tell what the volume of the television is or how firm the pasta currently is.

The process of acting to make the world we experience match some internally specified standard is, quite literally, a matter of life and death, for all living things. Even a single cell will only survive for as long as it can keep its internal state stable in the midst of fluctuations in the external conditions surrounding it. The phenomenon of control is so fundamental it can be thought of as a defining feature that separates living from non-living things. Living things control autonomously – that is, their standards are internally calibrated – whereas non-living things do not.

Some non-living things, such as temperature control systems in buildings or cruise control devices in cars, are organised to control, and mimic very closely the way living things behave. Non-living control systems, however, have their standards set by an external controller. When you push on a rock, it moves in direct proportion to the force applied to it. When you push on a living creature, however, the result is not nearly so predictable. Non-living things do not care what happens to themselves, but living things do.

A temperature control system does not decide for itself how warm or cool it will be inside the doors of the Grand National on the corner of 16th and Main, and a cruise control device does not have its own preference for the speed at which the Volkswagen Eos 155TSI motors down the M5. Living things, however, set their own standards for those things they like to experience. Brand new babies have preferences for how dry or how fed they like to feel, and adults have their own unique standards for how fast they like their car to travel, how long they like their fingernails to be, how overdrawn they like their bank account to be, how tanned they like their skin to be, and so on.

All living things control, and they control using the three essential elements we have described. For single cells to exist and to continue existing in the chemical soups they inhabit, they have to be able to act on their very limited environments to ensure that certain internal quantities and conditions remain in particular states. Even a single cell has a *should be*, a way of detecting what *is*, and the ability to keep the difference between the two at a minimum. The Princess cichlid that swims around its tropical aquarium has to be able to control the way it experiences the variable states of its aquatic environment, such as the speed with which it locates and ingests food and the distance between it and its aquatic cohabiters. If the cichlid is not able to control these important variables, or if the conditions of the tank change so that control is impossible, the fish will perish.

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Emperor penguins at the South Pole control, Bactrian camels of the Gobi Desert control, giraffe-necked weevils of the Amazon rainforest control, and cats and rats and elephants control. In fact, all living things control for as long as they continue living.

How does control work?

Given the importance of control, it is not surprising that the topic is discussed widely in the psychology and mental health literature. In 1996, for example, Ellen Skinner published a paper listing over 100 different constructs of control. Included in the list were terms such as behavioural control, instrumental control, and control beliefs, as well as less obvious control-related concepts such as expectancy, agency beliefs, responsiveness, and learned helplessness (Skinner, 1996).

Noticeably absent from Skinner's (1996) paper, however, was any suggestion of how control works. We think understanding how something works is an essential prerequisite to using that something effectively and efficiently. Since we are in the business of helping people solve problems and reduce psychological distress so that they can live their lives more as they would like to, and since 'living their life more as they would like to' is fundamentally a control process, we think it is important to understand how control works. In fact, we think it is important to understand how anything works when one is attempting to modify or improve that thing. A car mechanic who did not understand how car engines worked would not be able to fix cars regularly and routinely. A computer repairer who did not know how computers worked would not be able to address the problems of a broken computer efficiently. An electrician who did not have a sound knowledge of the way in which electricity worked would actually be a dangerous tradesman to have in your house. Because these people understand the workings of the objects to which they apply their trade, they are able to work systematically and successfully to restore optimal functioning. Much of the field of psychotherapy and counselling, however, is not based on an accurate understanding of how people function, so while many therapists are very successful with their clients, we think they are successful serendipitously rather than systematically. We say serendipitously because, when therapy does not go according to plan, we do not have a robust and uniform approach to analysing and correcting the problem. The many hundreds of different therapies that are currently available is strong evidence of the fact that we currently have no clear idea of the best way to go about helping people experiencing psychological distress. If we are to help people systematically to resolve psychological distress and live more of the life they would like to, we think it is important to understand the way in which the process of living actually 'works'. In this sense, we think of the process of living as a process of control.

Although control is discussed just as frequently in the mental health literature as it is in the more general psychology literature, an explanation for how control works is also missing here. It is widely recognised that attentional control, behavioural control, emotional control, impulse control, and so on are all important aspects of mental health. What is not so clear is how control actually occurs.

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The working explanation of control that we use is described in perceptual control theory (PCT; Powers, 1973, 2005; Powers, Clark, & McFarland, 1960a, 1960b). PCT explains the way in which the three components we have described – specifying the way the world *should be*, noticing the way the world *is*, and acting to make sure *is* matches *should be* – fit together to produce the phenomenon of control. Figure 2.1 (from Carey, 2008b) illustrates the way in which these components are connected to produce a negative feedback loop. This little loop is known as a control system and is regarded as the basic building block of life from a PCT perspective.

Figure 2.1 is a particular kind of diagram, and not the kind we might be familiar with from clinical formulations – it is not based on self-reports, for example. In Figure 2.1, you will also notice single letters such as '*r*' and '*e*' and '*p*', as well as two simple equations: $e = r - p$; and $qi = a + d$. We will not go into the technical details here (and there are many more details such as 'leaky integrators' and 'delays'), but it is important to realise that the diagram in Figure 2.1 is regarded as the beginnings of a blueprint for making something that works. When an

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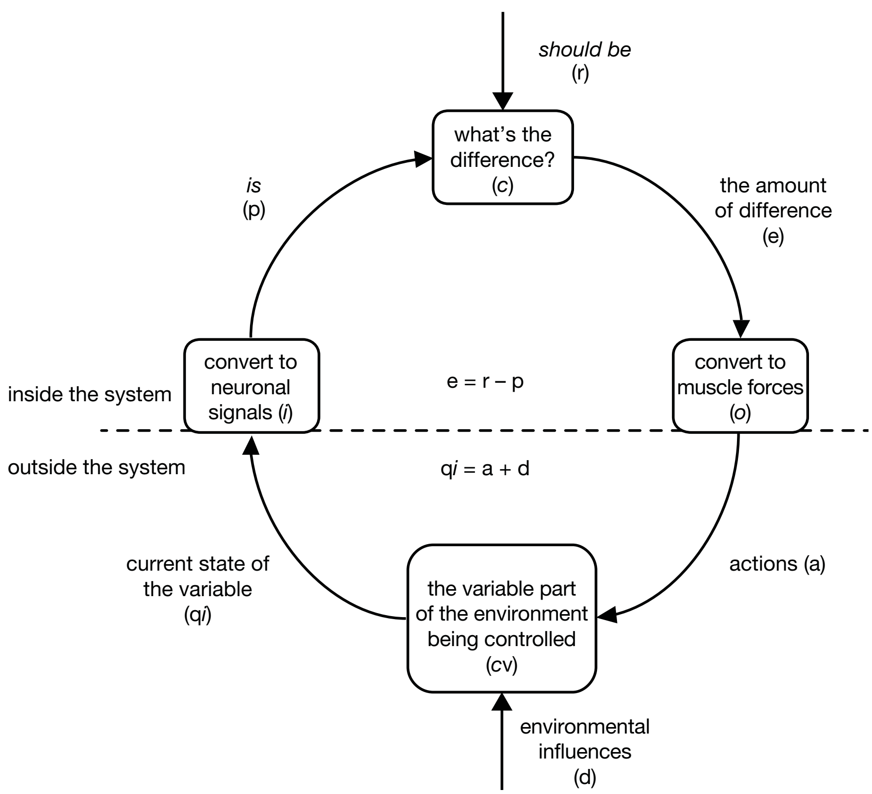

Figure 2.1 The basic unit of PCT: a closed causal negative feedback loop
Source: Copyright © *International Journal of Cognitive Therapy*, 2008, reproduced with permission

architect draws a plan of a house, it is with the intention of constructing an actual dwelling from the plan. This is a very different perspective from the way models and diagrams are usually considered in psychology. Models in psychology are generally hypothetical – *conceptual* or *statistical*, but they are hardly ever *functional*. Functional models have to resemble what actually happens in real life, so they are much more robust and are tested far more rigorously than conceptual or statistical models (Marken & Mansell, 2013). A functional model is more accurate and more precise. It is this exacting and stringent nature of model building that is the primary reason that we prefer the PCT model to other models that might try to explain one or more aspects of control. In this sense, it is even hard to compare PCT with other theories because it requires comparing a functional model to a statistical or conceptual model. A comparison of that nature is a bit like comparing a teaspoon with a satellite. Once other theories are expressed in functional terms, then useful comparisons could be made by considering which functional theory provides the model that most closely simulates the phenomenon under investigation.

Also, because the important terms in the PCT model are defined precisely and quantitatively, there is the opportunity to be very clear when communicating. The '*r*' in the diagram is the 'should be' that we described by various terms. In a sense, it does not matter whether someone uses the word 'goal' or 'objective' or 'dream' or 'plan' or 'hope' or 'expectation', as long as what they mean when they use the word is the '*r*' in $e = r - p$. In PCT, it is important to understand the relationships between variables; the particular word terms that are used to label the variables are not of fundamental importance.

The equations in this model describe the process of negative feedback. In this context, 'negative feedback' does not mean critical opinions or harsh judgement. The 'negative' refers to the process of acting in the world to *reduce* the error or the difference between *should be* and *is*, so that goals are achieved, needs met, and ideals realised. It is also important to note that Figure 2.1 describes the working of a basic building block in the nervous system. A mature human may have billions of these neuronal control systems arranged hierarchically and in parallel, rather like the branching, entwined roots of the trees in a forest. The '*should be*s' at the trunk of the trees are deeper and more fundamental (e.g. to be a kind person) whereas the '*should be*s' at the fine root tips are those that apply to the current moment (e.g. to hold a child's hand to cross the road). They are interrelated, and the way we control experiences in the present moment are guided by the longer-term ways we want ourselves and the world to be. This dynamic, layered process is control in action.

The other benefit of paying attention to a functional model rather than a conceptual or statistical one is that the results can be surprising and illuminating. It turns out that, in order to make a model function in a way that controls like a living creature controls, it is the input that must be controlled, *not* the output. In practical terms, this means that when we control (which is all the time), what we control is what we sense or experience, and not the way we act. Our actions are

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the variable means by which we keep our experiences in their *should be* states. This principle might seem counterintuitive at first, but is easily demonstrated by an example. When you are driving your car, the actions could be thought of as the way you move the steering wheel and the way you apply pressure to the accelerator, brake, and clutch pedals. Your experiences or senses would include what you see as you look through the windscreen and look down at the speedometer and fuel gauge, and also what you hear and what you feel as you travel along. Clearly, when you set out in your motor car, you do not have strong preferences about how much pressure to apply to the accelerator or where your hands should be on the steering wheel. You do have strong preferences, however, for where your car is on the road, how far behind the car in front it is, what the colour of the traffic lights are, how fast your car is travelling, and so on. Driving could be summarised as a process of making your car travel at the speed you want it to and in the direction you want it to. Certainly, what your hands and feet are doing will influence this, but so will the conditions of the road on which you find yourself. On a busy road, you will produce different actions than on a quiet road. In fact, if you drive to work, you will produce different actions every day you drive *exactly the same route* because the route is never exactly the same. It was, apparently, Heraclitus who first put forward the idea that 'You never step into the same stream twice', and this sentiment captures well the nature of the variable environments we inhabit. We are, in fact, so good at controlling that we do not notice the amount of variability there actually is. It turns out that our actions are in a very precise and intricate relationship with the environment so that the way we act at any point in time is *jointly determined* by both the difference between *should be* and *is* and the current circumstances in the environment. These are the types of learnings that are possible from a functional model developed from a robust theory, and it is the implications of learnings such as these that have informed the therapy described in this book.

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A model of normal functioning

So, control is the natural state of play for living things. It is the standard of 'normal functioning', if you like to think of it that way, from which models and explanations of disrupted functioning can be developed. This highlights another advantage of the PCT model. Most current models in mental health are models of disorder or dysfunction, but the model of normal functioning that people might return to after engaging in some effective psychological treatment is not specified. When therapy is effective, does it mean that people will never have any more negative automatic thoughts or dysfunctional assumptions? Will they constantly be mindful and 'in the present moment'? Will all of their doubts and worries be forever removed and will they always be motivated to achieve their goals? These questions are difficult to answer without a benchmark of routine functioning to refer to.

From a PCT perspective, normal functioning occurs when people are able to control the things that are important to them about as well as they would like to.

Control is not always perfect and life is never problem-free, but we would consider routine day-to-day living to be a process of creating and maintaining desired experiential states. People who function 'normally' experience hassles and, sometimes, even serious problems from time to time. Normal people get anxious and worried and frightened and despondent and forlorn, as well as exhilarated and playful and chirpy.

We find this perspective helpful in approaching the provision of psychological treatment because we are not trying to turn people into superheroes. Neither are we saying that there is a set 'prototype' specifying exactly how people should function. Successful therapy does not mean a problem-free life. It also does not necessarily mean people will 'self-actualise' and never think another bad thought or that they will score zero or in the 'normal' range on some symptom measure of depression or anxiety or some other problem. We think therapy is successful when people are able to resolve their psychological distress and re-engage in the life they are creating for themselves. More than anything, we think that the people who are accessing the treatment are the best judges of when treatment has been effective and when they have had enough. So, from the principle of control, implications for how therapy is applied and delivered begin to emerge. We will elaborate on these important aspects of therapy throughout the book.

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Disruptions to normal functioning

There is no doubt that life has more downs than ups for some people some of the time. Because we understand life to be a process of control, we conceptualise problems from that perspective too. An event or experience, therefore, will be a problem to the extent that it interferes with someone's ability to control. There are a limited number of ways that this can happen. One obvious way is through physical damage to the system. If control systems are damaged or destroyed, such as by accident or disease, a person can lose the ability to control things that are important to them. Paraplegia and multiple sclerosis would be examples here. Apart from physical damage, there are three other general ways in which control can be compromised. Figure 2.1 provides some clues. Satisfactory control will be prevented if there is an absence of *r* or if *d* becomes too great. Having no *r* would mean not having a standard or goal or expectation of what should occur. If you are invited to a traditional wedding by a friend from another culture, you might be unsure about the correct procedures to follow. What should you wear? Should you take a gift? What do you do when you arrive at the ceremony? All of these queries relate to not being able to set standards or goals for yourself. If you are not able to set a *should be*, you will not be able to reduce the difference between *should be* and *is*. On the other hand, if you are driving to the wedding and you suddenly encounter some black ice on the road and your car starts moving independently of your efforts with the steering wheel, this is an example of a situation where the forces of *d* (environmental influences) can be overwhelming. Both absent *r*s and insuperable *d*s will interfere with control.

These effects, however, tend to be rather transitory. Once you arrive at the wedding, you might ask people what you need to do, or you might ask your friend before the wedding for a 'briefing' on the correct procedures, or you might have even done some reading on the Internet to find out what might be expected. Similarly, when you realise you are driving on ice, you might employ different driving strategies, and once you get to a safer stretch of road you might choose a different route or apply some other action. This may mean that some inabilities of control never reach clinical proportions. In terms of *r*, most people become able to hold conversations, requiring all kinds of references in the social world (language, rules, etiquette) despite there being a time in childhood when this was impossible for them. In terms of *d*, the majority of people recover from acute traumas over time. We would propose that when recovery does not occur, this is either because the environment continues to be overwhelming (e.g. hostage situations) or that the next principle plays a pivotal role.

The second important principle is conflict. Conflict can retard control processes far more chronically, pervasively, and debilitatingly than the problems we have described so far. Control will be impaired when two interconnected control systems attempt to create two incompatible experiences (i.e. two opposing *should be*s are specified) simultaneously. This type of conflict can have devastating consequences.

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Conflict

Conflict is the main psychological problem for control systems (Carey, 2006a, 2008c; Mansell *et al.*, 2012; Powers, 1973, 2005; Powers *et al.*, 1960a, 1960b). Conflict occurs when, as one control system decreases the difference between *should be* and *is*, this has the effect of *increasing* the *should be/is* discrepancy for another control system. As the other control system responds to reduce its *should be/is* separation, it inadvertently pushes apart the *should be* and *is* of the first control system. Figure 2.2 (Carey, 2008b) provides an illustration of this arrangement.

An important point to notice about Figure 2.2 is the hierarchical arrangement that is necessary for the creation of intrapersonal conflict. We mentioned earlier that the single control system is regarded as a building block. These building blocks are organised in parallel and hierarchically to form the neural network of individuals. Any control system in the network receives its reference signal from one or more systems at the level above and it control its own perceptual signal by varying the references of systems at the next lower level. In Figure 2.2, it is clear that a system at the highest level is sending signals to two systems at the next lower level and these systems are sending signals to a still lower level. Thus, from a PCT perspective, conflict is considered to occur across at least three levels of the hierarchy: the lowest level is where erratic and unstable behaviour manifests; the middle level is the level of the incompatible goals; and the highest level is the level that is actually establishing the context for the conflict by generating the incompatible references.

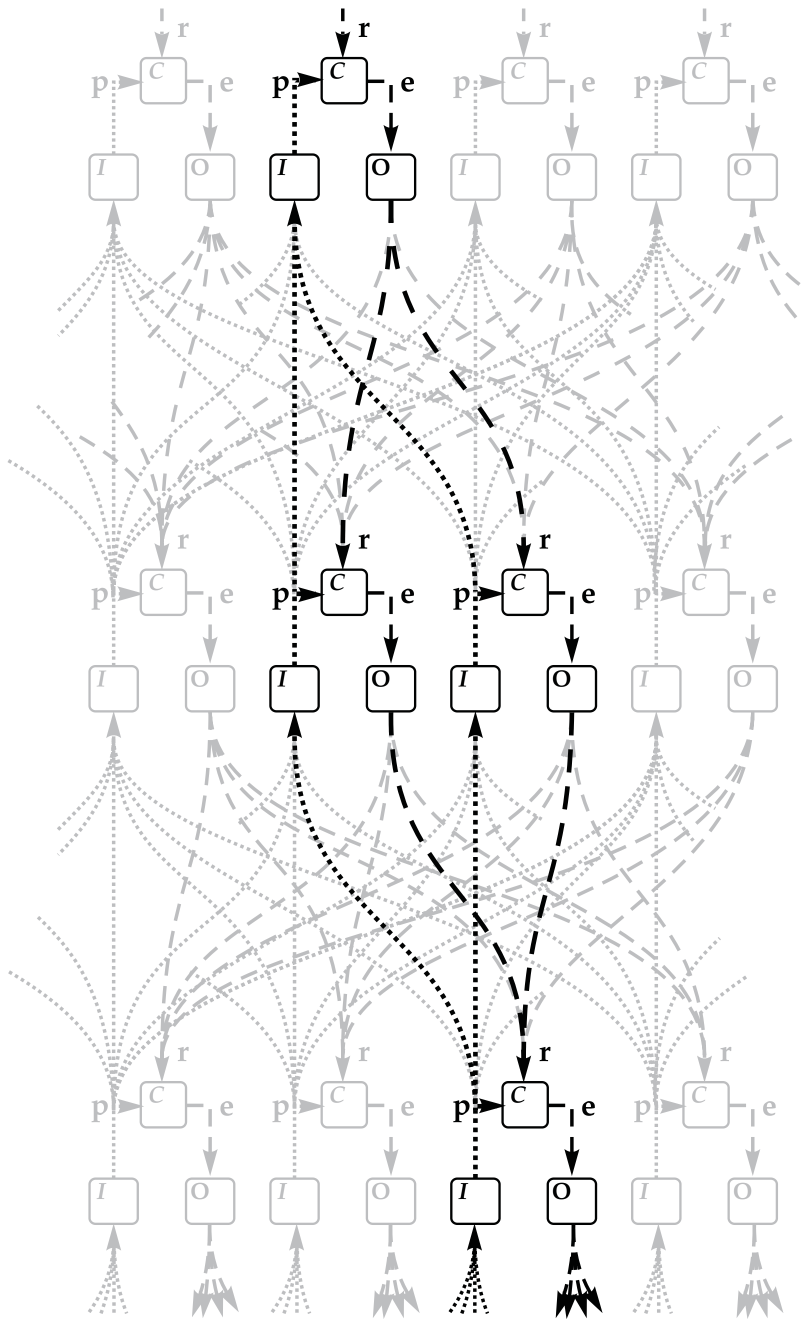

Figure 2.2 A PCT model of conflict
Source: Created by Dag Forssell for *The Method of Levels*, 2006, reproduced with permission

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Despite the devastating effects it can have, conflict is actually an extremely common occurrence. In fact, from a PCT perspective, any choice situation is, by definition, a conflict. If you have the option of holidaying in an apartment by the beach in Dubrovnik or a summer alpine holiday in a chalet in La Clusaz, it might be difficult to choose between the two. You might think about the advantages of both and spend time weighing up the pros and cons. For as long as the holiday destination remains undecided, these two options will be on your mind. You might find holiday thoughts 'popping' into your mind at different times throughout the day. Sometimes, it could seem like you cannot stop thinking about it. Your friends might even complain that all you seem to talk about these days is your holiday. As the period of indecision draws out, other considerations might come into play, such as missing the best deal if you do not book the holiday soon.

Some people would easily be able to choose between a holiday at the beach or one in the mountains. In fact, for some, it might not even be a choice at all because the options are so unevenly weighted. For others, though, having these two options before them presents a period of indecision and quivering inactivity. From a conflict perspective, it is easy to understand why people who have trouble making decisions are sometimes described as 'dithering'. The immobility of conflict produces exactly that state of oscillating within the confines of the two choice options.

If this conflict scenario concerns not a holiday, but issues such as the sort of life that should be lived, then it might be easy to appreciate how much more devastating the consequences can be. For example, if a person stays at home away from people to feel safe, but also wants to leave home to experience the acceptance and affirmation of social relationships, this significant conflict would be likely to generate distress on a daily basis. One client described having a 'thirst for life' and a 'desire for oblivion'. It might be easy to appreciate how completely the battle between these two states would usurp the ability to live a life of meaning and value.

There is a psychotherapy based on the principles of PCT, known as the Method of Levels (MOL), which targets conflict directly. The importance of the word 'levels' in this therapy can be appreciated by examining Figure 2.2. It is understood from a PCT perspective that, despite the different manifestations that psychological distress can have, it has a common basis – chronic internal perceptual conflict. Conflict is the ultimate 'wanting to eat your cake and have it too', 'being caught between a rock and a hard place', and 'biting the hand that feeds you' with regard to important values and life goals:

> *'I want to achieve great things and be better than other people but I also want to just let things happen and go with the flow.'*
>
> *'I want to forget the past and move on, but the past was important in making me who I am and I want to make sure I never forget where I came from.'*
>
> *'I want people to like me and think I'm fun to be around but I also want people to take me seriously and agree with my opinions.'*

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'I know there's no point but I still want to know what the point is.'

'I want to let go and move on but what we had was really special and I don't want to let go of it.'

Conflict is the 'double-edged sword' that so often confronts us in daily life. From the conflict perspective of psychological distress, there are always two sides requiring attention. One gloomy thought will not lead to despair on its own. We think there is a *relativity* to psychological distress that is often not fully appreciated (Carey, 2006a, 2009). The concept of relativity is discussed further in Chapters 3 and 8. A thought that 'life is meaningless' is itself meaningless on its own. If the thinker of this thought belonged to a spiritual or religious group that emphasised the power of an interconnected universe and the insignificance of humans, then a thought that life was meaningless might be entirely appropriate and bring solace and comfort. If, on the other hand, the thinker had been pursuing an existence of purpose and worth, then a thought that life was meaningless could be a shattering experience. The point here is that it is not the thought on its own that produces particular feelings. It is the thought *in the context of other thoughts* that will be associated with contentment or despair.

A person who had an uncomplicated 'thirst for life' might be passionate about what they do and involved in a variety of activities. They might have a fulfilling career, participate in community activities, and enjoy engaging and challenging hobbies. Similarly, a person with a 'desire for oblivion' would take the necessary steps to end their life successfully and completely. It is when both these specifications exist in the same head at the same time that neither one is able to be satisfactorily achieved.

It is, therefore, the juxtaposition of dichotomous yet equally important beliefs, attitudes, and values that sows the seeds of psychological distress. It is having a thirst for life *relative to* a desire for oblivion that generates despair. When this configuration remains in place chronically, mental health disorders in their myriad of manifestations can flourish. Hating your parents for the abuse you suffered at their hands when you were a child but also believing that it is a sin to hate your parents will produce despair and discontent until these opposing mind states can be reconciled.

Far from being a model of 'dysfunction', however, the conflict formulation of psychological distress requires robust, well-functioning control systems to achieve its most debilitating effects. Powers (2005, p. 266) points out that the 'worst aspect of conflict between control systems is that the higher the quality of the control systems, the more violent and disabling the result of the conflict'. For example, people describing themselves as perfectionists are often highly skilled at noticing the mistakes in their own and other people's work because they believe this is important for self-improvement. Couple this perfectionistic tendency with a natural desire to be unconditionally accepted by others, and there is a potential for conflict to occur within the individual as they apply their own stringent standards of perfectionism to an unrelenting desire to be accepted by others at all times.

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Given how common conflict situations are – for the most part, benignly disguised as daily choices – there is every reason to conclude that we are normally very adept at resolving conflict. We do not stand jittering in front of the fridge deciding between the Chardonnay or the Sauvignon Blanc. Nor do we fail to turn up for work because we are immobilised in the bathroom unable to choose L'eau D'issey over Coco Mademoiselle or the other way around. We do not even delay our children's entry to school because we are unable to decide between a private or a public education. Fortunately, we have a range of well-learned and well-used strategies that enable us to prioritise and sort choices into satisfactory results. Even when conflict seems intractable, however, according to PCT, we have an inbuilt learning mechanism that restores order to the system. So, how exactly is order restored?

Reorganisation: the change that occurs when you do not know what change to make

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Clearly, mature humans are not born with their repertoire of values, beliefs, and attitudes already established and intact. While the propensity to build neuronal control systems might be part of our genetic inheritance, the specifics of what precisely these control systems control is added in as we grow and develop. A learning mechanism, therefore, must also be part of what we inherit. It is self-evident through observing newborn and very young children that humans know *how* to learn long before they know *that* they are learning – or even *what* they are learning. That is, they learn before they know they know how to learn. In fact, some of the most important skills they will ever learn – locomotion and language – are learned before any formal teaching or learning programmes are provided.

The learning mechanism offered by PCT is called reorganisation (Marken & Powers, 1989; Powers, 1973, 2005, 2008). It has particular features that make it unique from the learning processes with which you may already be familiar (such as conditioning). Reorganisation involves random change and reduction of error (the difference between the *should be* and *is*) that remains unresolved within conflicted control systems. Although error reduction is business as usual for control systems, sometimes, particularly in conflict scenarios, error persists. When error is not reduced by the routine operation of the control system, reorganisation activity begins to increase. Reorganisation introduces random changes to the control system and monitors the changes. If the change has the effect of reducing error, then that change stays in place until error once again increases, at which time another random change is made. So reorganisation is not switched on and off, but is always active in the sense of monitoring error in the system. If error can be minimised by the routine operation of the control system, then the reorganising system delays making any further changes. If a situation arises where error persists, then the activity of reorganisation increases and alterations begin to be generated.

Reorganisation, therefore, is value-neutral with respect to the types of changes that are introduced and the decision as to which changes linger. The only criterion is error reduction. We think a lot of the seemingly 'crazy' ideas that occur to people when they are extremely distressed, including ideas of suicide, could be the effects of reorganisation generating random changes to be considered. If a change occurs and error is not reduced, another change will be generated. If a particular change does reduce error, that change is retained. Timing, therefore, is very important when reorganising. If reorganisation is too slow, changes will not be generated in enough time to restore effective functioning to the control system. Reorganisation that is too rapid, however, will have a similarly impotent effect. If reorganisation occurs too swiftly, then a new change will be introduced before the error reducing effects of the previous change can be properly assessed.

Obviously, different parts of the control system hierarchy will need to be reorganised at different times, so mobility must be a feature of the reorganising system. There must also be a way of safeguarding effective functioning control systems so that reorganisation does not introduce changes where they are not needed. A creature would not survive very long if it possessed a reorganising system that changed control systems arbitrarily and haphazardly. As early as the end of the 1950s, Powers considered that what we call 'awareness' or 'consciousness' could be closely related to the location at which reorganisation occurs (Powers *et al.*, 1960b); reorganisation and awareness are linked such that it is the systems in awareness that are reorganised. From this perspective, it makes sense that our attention is naturally drawn to the things that are a problem in our lives more so than the things that feel OK. Being aware of those areas where sustained error is occurring means that reorganisation will follow.

The process of reorganisation seems to match well with what we now know about change in psychotherapy. We know, for example, that change is a non-linear process where, sometimes, things can seem to get worse before they get better (Carey, 2011a). The time needed for effective change to occur varies from individual to individual with some people changing quite quickly and other people taking much longer. Even the timing of reorganisation might have clinical implications. Could the manifestation of some of the experiences currently labelled 'psychosis' be the effects of a reorganising system that is operating too rapidly? Similarly, might severe inactivity and catatonia be the consequences of a reorganising system that has drastically slowed?

Building a therapy

Our contention is that an effective psychotherapy can be built on the three foundational principles of control, conflict, and reorganisation. Control is the process of living. Control is what people do all day every day. Control for humans is hierarchical and multilayered. It ranges from experiences we control in the moment, to a concept of ourselves and the world that we may strive for over a lifetime. Control occurs whether our attention is focused on it or not. Dropping the kids off at school is a control process, getting to work on time is a control process, putting a stamp in the right place on the envelope is a control process,

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digestion is a control process, checking on the daily news headlines is a control process, and visiting Grandma for Christmas is also a control process. We are so good at controlling, we rarely realise that all of our activity is designed to make the world as we are currently experiencing it match the way we have specified it *should be*.

The main psychological problem for controllers is enduring conflict. Conflict occurs when two equally weighted, highly valued, but incompatible *should be*s are pitted against each other. The longer the conflict exists, the more devastating and pervasive the consequences can be. From a PCT perspective, there is nothing wrong or 'dysfunctional' with control systems in conflict. Actually, it is exactly the reverse. As mentioned earlier, Powers (e.g. Powers, 1973, 2005; Powers *et al.*, 1960b) suggests there is a positive relationship between the quality of the control systems and the viciousness of the conflict. When people are in conflict, we should expect erratic, sometimes contradictory, behaviour. They might seem to be trying very hard to behave in a particular way or to keep themselves in check or to control some aspect of their behaviour. At times, they might seem to do exactly the opposite of what they were saying just a few minutes before. Such is the experience of a conflicted mind. Relapse, irritability, and unpredictability may all be indicators that a conflict still lurks within a person's neural network.

Reorganisation is an innate and powerful learning mechanism that can resolve conflict. If reorganisation occurs in those places on which a person's awareness is focused and their problem is still present, then logically, awareness is not illuminating the precise place in which reorganisation can have its best effects. Thus, reorganisation needs to happen in a different place to produce a more effective result. Therapy, then, has the purpose of helping people who are distressed shift their awareness – and thereby their reorganising system – to new places in the hierarchy where reorganisation might have some ultimately satisfactory impact on the conflict. The configuration in Figure 2.2 suggests that the conflict is being generated from a system above the two opposing systems within the branching hierarchy we described. So, the suggestion in therapy is that people need to become aware of a higher order *should be*, so that reorganisation can make changes at these superordinate levels and, thus, alter the conflict that is occurring.

A therapy based on these ideas has important implications for the roles of the therapist and the client, as well as aspects of therapy such as how appointments are scheduled and for how long therapy should last. Important areas such as the therapeutic relationship are also able to be usefully understood from a PCT perspective. PCT even provides a framework for reconsidering well-worn psychotherapeutic problems such as co-morbidity, complexity, non-compliance, and treatment resistance. After discussing the implications of these principles in the next chapter, we will elaborate on the information we have provided here about these principles and demonstrate their therapeutic application throughout the rest of the book. Some aspects of the therapy informed by these principles might fit with insights you have already developed from your own therapeutic practice but there might be some surprises as well.

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Summary of main points

- *Control is what we do.* It is a process common to all living things and cleverly mimicked by some non-living ones. Routine and satisfactory daily functioning is a process of control.
- *Conflict is an extremely common occurrence.* Essentially, any choice situation is a conflict in terms of having to select one option from a range of two or more similarly desirable alternatives. People are usually pretty adept at resolving conflicts but, when conflicts endure, mental health is compromised. Rather than mental health problems being generated from *dis*ability or *dys*function, however, chronic conflict often occurs between well-functioning, 'high gain' control systems.
- *Reorganisation is the natural learning you have when you do not know how to learn.* It is the learning mechanism we were born with that helped us walk and talk before we knew of any other learning strategies such as brainstorming, rehearsal, or cost-benefit analysis. Reorganisation is based on random change and error reduction.

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Topics for discussion

1 Every choice is really a conflict. Discuss.
2 Control is a paradox because, for the most part, we never notice the controlling we are doing. Ironically, we mostly only notice control when it is compromised and we have to try extra hard or do something different. Are you comfortable thinking of yourself as a controlling person? Why or why not?

Activities for learning, consolidation, and fun!

1 Write down a recent choice you made. What were the two alternatives? How did you decide on one of them?
2 Can you find references to control and conflict in other therapies? How are they discussed and how do you compare them to the concepts presented here?
3 How would you sum up the principle of control in a sentence? Can you do the same for conflict and reorganisation?

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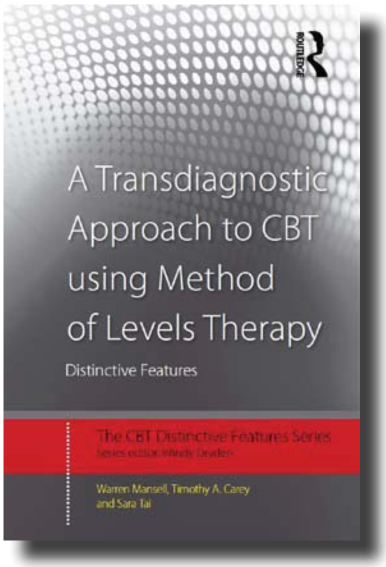

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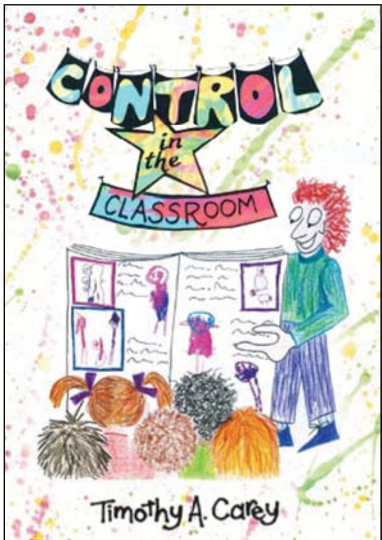

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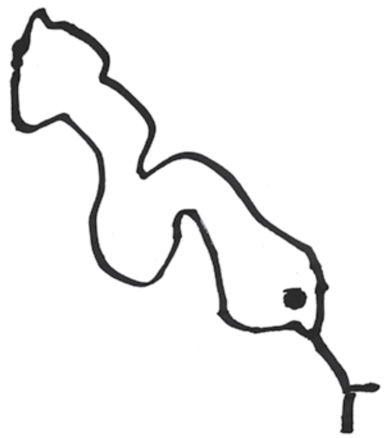

3

Learning From a Control Perspective

If you read this chapter
you'll find out about
the important elements to
building networks of PCAs

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Learning From a Control Perspective

If it really is the case (and there's some pretty good evidence to suggest it is) that what we call learning is the construction or reconfiguring of PCAs, then, when people learn, they must learn to perceive, compare, and act with respect to the subject matter they're mastering. When young children learn to reach out and grab things they must learn to perceive, compare, and act with regard to the experience of seeing and feeling their hand wrap around an object that has caught their attention. When people learn to play the piano they must learn to perceive, compare, and act with regard to hearing a particular combination of notes occur in a particular way. The same thing applies when someone learns a second language or how to differentiate and integrate.

When someone learns to drive a car they learn to create and then maintain a particular speed of the car and a particular position of the car on the road and a particular distance behind the car in front. When people learn to walk they learn to maintain their body position in a particular posture and move it around their environment. Have you ever noticed the way someone changes the way they lean if they walk up a hill or down a hill. They don't have to be told to do this, they just do it. Such is the wonder of control with PCAs – once they're in place, they look after all the tedious details for you. So, once you've established the particular orientation to the ground that you'd prefer (let's call it "vertical"!), the PCA will make sure that happens regardless (across some pretty broad changes in scenery) of the lay of the land.

The same applies for pianists when they learn to create particular sounds. Pianists learn to perceive the position and movement of their fingers on the keyboard in relation to the sounds that

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they hear. They learn to compare the sounds they are producing with the sounds they intend to produce and they learn to act in order to make what they are hearing match what they want to hear. Through good teaching they put together a PCA that can cope with different contexts and settings.

The same process occurs whether the learning involves riding a bike or baking a cake or writing a novel or any other activity. People take art classes because they cannot create the strokes on a canvas that they have imagined in their mind's eye. People take tennis lessons because they cannot make the tennis ball do what they want it to do. People hire math tutors because they cannot manipulate symbols as precisely as they would like to. The extent to which the art teacher or the tennis coach or the math tutor is helpful will depend on the extent to which they are able to help the individual in each case construct a PCA which allows them to make things happen the way they want. The result of good teaching is that learners achieve greater control of something: greater control of the production of visual images, greater control of the movement of the tennis ball, greater control of the manipulation of math symbols, and so on. Greater control from their perspective that is.

This approach to learning – helping people construct PCAs – raises some very helpful questions for teachers.

Is Jim able to notice (or perceive) what he is learning to control?

If Jim has a severe hearing impairment he will have difficulty learning to produce the sounds of speech because he cannot hear the sounds he is making. If Lauren has an extensive visual impairment she will not learn to discriminate colors the way sighted people do because she is not able to sense different colors visually. In order to control something we first have to be able to notice or detect that particular thing. Have you noticed the way that food loses its flavor when you have a cold? Imagine if you were like that permanently – it

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would be very difficult to create culinary masterpieces with the right blend of secret herbs and spices if you couldn't taste the brew you had mixed. If Jim has a visual impairment, even if it is less severe than Lauren's, he may not be able to see the chalkboard clearly from where he is sitting. Sometimes, the first step in helping people learn is just making sure they can notice or detect the thing they are trying to control. Perhaps there is some specific and important detail they're missing because they're looking at the big picture. People who are very expert at something can forget the particular things that are important to pay attention to at the novice stage. In order to know what to point out to a learner, it might help to devote some thought to all the necessary elements of a task.

When problems occur, figuring out what people see or recognize can be helpful. Some people have trouble reading or calculating, for example, because they do not see written symbols the way many other people see them. Similarly, if we're interested in students controlling things like respect and cooperation it's good to find out what they know about these things. Would they recognize respect if it showed up in front of them? Would they know when someone was cooperating with them?

Can Sophia remember what she has perceived?

If Sophia is to learn to control the amount of meaning she derives from printed matter she will need to be able to remember what letters look like. She will need to be able to differentiate letters from nonletters. If she wants to control the correctness of a mathematical solution she will need to be able to remember the sequence of steps involved in solving the problem. She will also need to be able to remember acceptable steps from steps that are not permissible. Prompts, guides, and cue cards can be very useful for students when they are learning something that requires them to remember a sequence of steps or some important symbols.

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Issues like these can be important to keep in mind in situations such as testing (I have more to say about testing and assessment later in the book). When we're testing students, and when we're considering the results of testing, one factor that might help make sense of some of the results is the extent to which students are able to retain the concepts that are being tested. If you have some doubts about their memory have a quick check about other tasks at school. Do they remember your name and their friends' names? Do they remember where their desk is? Do they remember when it's time for lunch? If you offer them a treat (just something they like) after a particular activity, do they remember the deal you made? Answers to these questions will give you some sense of the capabilities of their memory. Sometimes the machinery is working appropriately but what we're asking them to learn is so different from all the other PCAs they currently have that the new PCA has trouble fitting in. Finding out about the student and the ways in which they understand their world can often give you some clues about where a new PCA might fit best.

Does Ben have a preferred state of what he is controlling?

The idea of a preferred state of something is a crucial aspect of the whole PCA game. The preferred state is important during the comparison phase. In the morning before work when you're looking in the mirror, you're comparing what you see reflected back at you with what you want to see. When your hair is just right (or right enough) and your outfit is just right (or all you have time for at the moment) you'll set off for work (or at least move away from the mirror). I mentioned just-rights before and said they were important. The just-rights are the things that tell the PCAs what the current standard or goal is. Essentially, the just-right says to its PCA "make it be *this* way". The just-rights cover all that we do – make my relationship be this way, make my coffee be this way, make the speed of my car be this way, make the report I'm writing be this way, and so on.

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A young child, for example, might know that the letters "d", "g", and "o" can be connected in a just-right way to create a written representation for their favorite pet. If they want to communicate their ideas effectively with other people they need to establish a standard of "d-o-g" when they connect these letters. Other combinations like "d-g-o" or "o-g-d" or g-d-o" just won't cut it. If Ben has trouble spelling "dog" one way of checking whether he has established the appropriate standard or not would be to put all the different combinations on different cards. You could show him a picture of a pooch and ask him to pick out the card that tells you what it's a picture of. Can he do it? If not, maybe he needs more practice at establishing the appropriate standard for the way the letters are combined. Spelling provides a clear example of the idea of a standard or benchmark for variable combinations of letters. Imagine all the ways that the letters "supercalifragilisticexpialidocious" might be combined. There is only one combination of these letters, however, that will be correct if you want to sing along with Mary Poppins.

When I first began communicating over the internet via email I noticed a particular configuration of symbols that regularly appeared in the printed messages I received from other people. The symbols varied slightly but would often be a colon ":", followed by a dash "-", followed by a bracket ")", so that the whole symbol looked like ":-)". As I was new to the game of internet communication I was unaware of the meaning this symbol had and I was puzzled as to why so many people kept making the same peculiar typographical error. It was only one day in casual conversation with an internet veteran that I discovered that the symbol ":-)" was actually ☺ (a "smiley face") on its side. Once I understood what this symbol represented the meaning of a lot of what I read over the internet was different. I now had a benchmark or reference for the symbol.

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Is Bianca able to compare her standard or benchmark with the way things currently are?

Essentially, once Bianca has set a just-right state she needs to be able to compare this state with the state she perceives or notices on a moment to moment basis. She needs to be able to tell the difference between what she wants (her just-right) with what she is currently getting. Tom, for example, might regularly misunderstand sarcastic comments. The comments to Tom might not sound different from the comments that he likes to hear. Socially some students may have difficulty telling whether their peers are being nasty or nice. Perhaps this difficulty enables students to be set up in pranks and high-risk activities by peers whose motives are not clear to them. Or perhaps having their peers notice them *is* their just-right. If Sharelle has a just-right for hearing a certain amount of laughter from the other students in the class, this just-right might be more important to her than just-rights about learning and achievement with regard to curriculum material. While this situation remains, Sharelle will do things to achieve the amount of laughter she has specified even if this interferes with her ability to complete set tasks.

An important point to take from this example is that we are always achieving *something*. Our PCAs are always switched on. Sometimes students won't be achieving what you would like them to achieve but that doesn't mean they're not achieving. Figuring out what's going on in terms of what students are achieving at any point in time and gaining some understanding of what PCAs are important to particular students is an important step in knowing what to do next.

Persuasive writing is another example of the importance and relevance of an internal standard or benchmark. When students learn to write persuasively they are learning to control the degree of influence conveyed in their essay. They need, therefore, to be able to compare the degree of influence they would like to communicate with the degree that currently

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exists in their written work. An inability to compare what you are getting with what you want to get will severely compromise your ability to control.

Is Elizah able to act on the environment in order to change what she is perceiving so that it is like what she intends?

Elizah might know she has got the wrong solution to a math problem but she might not know what to do to correct the problem. Being unhappy with the number of friends you have or the way you are treated by other people does not necessarily mean that you will know how to change that situation. Knowing that you cannot move through water satisfactorily does not automatically imply knowing how to become a more efficient swimmer.

Generally, in order for one PCA to do its job properly, it needs to be able to call upon the services of other PCAs. I mentioned earlier that our PCAs are arranged in parallel and hierarchically to form a large and intricate network. Some PCAs control the same kind of thing and some PCAs control different things. Making sure your car stays the right distance behind the car in front and putting the right flowers beside each other in a flower arrangement might seem like very different things but, in a sense, they're the same *kind* of experience. "Near to" and "beside" are both relationships so these experiences require PCAs that control relationships (not relationships like "friend" or "partner" but spatial relationships like "in front of" and "under"). On the other hand, getting your coffee as hot as you like it and being as honest as you want to be are different kinds of experiences. The coffee experience requires a PCA that controls sensations (you want *this much* hotness) whereas the honesty experience requires a PCA that controls principles or rules (you want *this much* honesty). The hierarchical setup of the network means that the "Ps" at one level combine in different ways to form a more complex "P" at the next level up. That's just a convoluted way of saying that some things we experience are made

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up of simpler experiences. You can recognize the categories of things like "ball" and "net" without playing a game of tennis but you can't play a game of tennis without some balls and a net. Also, the "As" at one level set the standard for one or more PCAs at the level below. You could think of it like floors in an office building. It's like sending a memo down to the next floor telling them what you want to see on your desk.

Perhaps you have a PCA related to friendship. That PCA might create for you the sense of being a good friend. In order to give you that warm glow inside, the PCA might send a "how often" standard down to the PCA concerned with staying in touch with people. Perhaps the standard is "weekly". The staying in touch with people PCA might use the dialing a telephone PCA to get what it wants. The dialing a telephone PCA will need to use the PCA that distinguishes telephones from televisions and telescopes. This kind of analysis can be continued right down to the PCA that produces the right amount of pressure from your finger to dial the number. And this kind of coordination of PCA upon PCA is involved with all of our activity. Such is the marvel of a hierarchical network of PCAs. It really is wondrous isn't it? You just think "Oh, I'd better give Isaac a call" and the legion of PCAs get to work making it happen. Are you even more impressed now at the amazing job you do when you help people learn?

Even tasks that might seem simple to us require the use of layers and levels of PCAs. For Hannah to control the steps of a math problem, for example, she will need to be able to vary an array of lower level PCAs. Some of the tasks required will be producing the correct sequence of steps of the problem, performing the calculations required at each step, being able to distinguish reliably the categories of "tens" and "units", and being able to produce shapes that look like standard numbers. To control something even more simple such as the shape of a written letter Jack's PCA for correct letter shape will need to use PCAs related to muscle tension in his arm and hand.

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Finally, has Eloise had sufficient practice to be able to control this variable smoothly and efficiently under a range of different conditions? You could think about this part as "grooving". When people are learning something new they need to be able to go through the activity over and over. Repeated attempts will groove their PCA connections and iron out the bumps. Have you ever seen a baby when it first reaches for something? Its movements are jerky and unsteady. Over time, however, the babe learns to reach out and grab things sometimes seemingly without even paying attention. I am amazed at how much time a young child will spend doing the same thing over and over again. They seem to know what they need to do to get in the groove. Can you remember your first efforts at driving a manual car? It's difficult at first to coordinate the accelerator and the clutch but gradually, with sufficient time and practice, your efforts become grooved to the point where the driving examiner is satisfied enough to give you your license. Students need sufficient time and practice too if they are going to groove. "Sufficient" is likely to be different for different students. What is a sufficient amount of practice for Tom might be just getting started for Rachel. One day "What PCAs did you groove today?" might become another question around the dinner table.

Perhaps, for example, Maurice can control the variability of the letters "d", "o", "g" to produce the word he intends but he runs into problems when the letters look like "D", "O", "G". When Lucy is learning to swim she will need lots of opportunities of swimming in different conditions in order to become a proficient swimmer. She could swim in still water and surf, in shallow water and deep water, by herself and with lots of different people. All these different swimming experiences will help her groove her abilities so that she can move around in the water the way she wants. It's a shame that "play" seems to have acquired a frivolous, kind of non-essential connotation. "Oh, he's just playing". Perhaps, from a PCA perspective we could think of playtime as a very necessary and "groovy" activity.

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Learning then is what happens when people put together PCAs so that they perceive and control things in a way that they couldn't before. Sometimes this requires a PCA that wasn't there before. When a young child learns to walk or talk or when a student learns to read they may need to create entirely new PCAs.

At other times, however, learning might simply be a change in one of the components of a PCA or a change in the connections between PCAs. When I discovered that this symbol ":-)" was a smiley face on its side it is likely that I just established a new benchmark or standard for that particular combination of symbols. I already had PCAs in place concerned with communicating in written form and I already knew what a smiley face was. The learning in this instance then, may simply have been connecting already established PCAs in ways that had not been established previously. As children progress through school this second type of learning will probably be the most common. Rather than building PCAs they didn't have before they'll be learning to put PCAs together in different ways. PCAs higher up the chain will send different standards down to other PCAs or hook up with PCAs they hadn't used before. This might explain why the learning in the younger grades is so crucial to success later on. You can't make castles in the air if you didn't gather enough bricks to start with.

When young children increasingly refine their labels of animals they are developing an ever-increasing number of animal categories. Initially they may call all animals "dog" but gradually they learn to call non-dog animals by their appropriate labels such as "cat", "pig", and "armadillo".

As Lachlan learns to paint in a cubist rather than an impressionist style he is learning to send different "As" down to lower level PCAs. He is already able to perceive different art styles, he has a reference for the kind of artwork he wants to see, and he has no trouble comparing what he is seeing with

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what he wants to see. What he needs to learn is to perceive himself moving the brush *this* way not *that* way. That is, he is learning to set new standards for his brush-stroking PCAs.

To learn is to construct and maintain new PCAs. It is likely that the students you teach will all differ in terms of the PCAs they have in place as they interact with the material you provide. Regardless of where they start, they will be learning to do the same thing. They will be learning to control the tasks they undertake with respect to the standards, goals, and benchmarks they have set for themselves. They will control the matching of animal pictures to animal labels, or the persuasiveness of an advertisement, or the detail in a scientific model, or the clarity and confidence in their oral presentation. Redefining learning as a process of acquiring new PCAs or reconfiguring and reconnecting existing PCAs provides us with exciting opportunities for considering curriculum delivery in schools.

It is my suggestion to you in this book that teachers will best help learning to the extent that they are able to provide students with opportunities to improve their control abilities. While students are at school they learn to control in ways that they couldn't before. To do this they need to build or mold PCAs. That is, they learn to perceive, compare, and act.

Treating students as though they are creatures who act on their environments to control perceived states of that environment is to treat students the way they are designed. When students are treated the way they are designed, more satisfying relationships are possible and greater student learning outcomes can be realized. A student's task at school is to learn to control certain perceptual variables. A teacher's task is to provide the opportunities whereby this might happen. With a clearer idea of what is actually occurring during the learning process you might be in a better position to help both your students and yourself undertake the business of learning and teaching more proficiently.

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So, now that I have unpacked PCAs a little bit, for the remainder of the book I will describe how teachers might best promote student learning from this perspective. I will continue to assume throughout the book that control is all there is. Classrooms are places where a number of people are all controlling. In order to understand this environment more clearly, the notion of PCAs is all you need. The idea of a network of PCAs is what I use to inform the strategies and procedures that I describe in subsequent chapters. So, let's get on with it.

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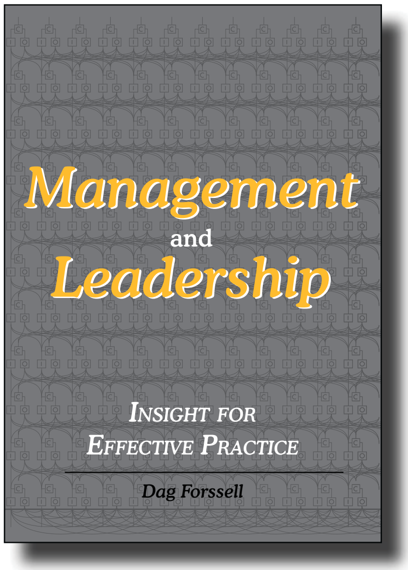

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Read ***Details and comments*** first, continue with ***Management insight for problem solving***.

Perceptual control — management insight for problem solving

ABSTRACT

This article suggests that managers focus on the wants and perceptions of their associates instead of their behavior in a questioning approach to problem solving. This recommendation is based on the first successful, demonstrably valid concept of the basic operation and structure of our nervous system. A discussion of the nature of the concept, a do-it-yourself demonstration, and detailed instructions on how to solve problems are included.

INTRODUCTION

This article applies Perceptual Control Theory (PCT) and Hierarchical PCT (HPCT), introduced in the first article, to problem solving situations. The architecture presented in exhibit 4, (page 21), is a representation in principle of Hierarchical Perceptual Control Theory. The idea of a person as a hierarchical system of control systems seems both preposterous and incomprehensible unless some of the underlying principles are understood. Out of context, the demonstration in this article of a person acting as one control system may be dismissed as a curiosity. If so, conflict resolution by means of mapping and influencing wants and perceptions becomes just another unfounded prescription for action. The purpose of this article is not to provide an exhaustive technical description of HPCT, but to explain conflict resolution. I shall limit the technical content to a few comments about the nature of the theory on which the recommendations are based.

Focusing on one of the many control systems active within the hierarchy, you can perform a do-it-yourself demonstration with a friend. This will show you how invisible control is (because people have never learned to recognize it) and provide an "A Ha" experience for both of you. You can illustrate

> It is not necessary to understand.., because people *are* control systems and control whether they understand it or not. But if you *do* understand, you can solve problems more effectively.

conflict and cooperation. From an understanding of control and conflict follows insight into organizational interaction and lessons about how conflict can be resolved.

The careful student will find this a fully integrated, useful explanation of how thoughts (perceptions and purposes) become actions, results and feelings. It has much to say about how we grow up, live our lives, interact, and manage organizations effectively.

Understanding the nature of HPCT

If nature had evolved Personal Computers, a society of non-technical people would most likely suggest that computers are too complicated to understand. A non-technical scientist researching how computers function would press keys on the keyboard, observe what happens on the screen or with the printer, and try to make sense of it through many experiments, using statistics if results were inconsistent. It would be extraordinarily difficult to learn anything about the internal organization of the computer that way.

To understand and reverse-engineer a computer, it would be necessary to

a) Understand the physical sciences.
b) Make a lucky guess about the nature and structure of the computer's various parts.
c) Test the resulting functional model against the function of an actual computer.

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With such an understanding, borne out by successful tests, the user could do more with the programs that run on the computer, change some of the programs, and thus could accomplish far more than other computer users.

We have been told for centuries that the human brain is too complicated to understand. Research results have been so inconsistent that statistics are employed to indicate the validity of observations made.

Perceptual Control Theory successfully attempts to reverse-engineer our nervous system, create functional models to simulate it, demonstrate that the basic concept is valid, and point the way to more effective research methods.

Levels of perception and control

The *vertical dimension* in exhibit 4 is "Levels of perception." Starting from the bottom, a low-level input—a neural current created by a nerve ending "tickled" by some physical phenomenon in the environment, such as light falling on a single cell in the retina—is combined with other inputs, creating a perception signal at a higher level, in turn combined to create a signal at a still higher level. At the higher levels, a branch of the perceptual signal can be stored in memory and later played back as a reference signal. (HPCT incorporates distributed memory to explain imagination, automatic control and passive observation).

Perception and control starts with intensity signals from neuron sensors and develops successively higher level perceptions, presently thought to be intensity, sensation, configuration, transition, event, relationship, category (language fits here), sequence, program, principle and, at the highest level, systems concept (the way the world is). Each successively higher level of perception builds on the immediately lower ones.

The *horizontal dimension* is "Examples of perception." At the lowest levels, we perceive light, vibration, pressure, temperature, joint angles, tendon stretch, smell, taste and physiology (which we sense as a part of feelings). At higher levels, we form perceptions of things and concepts like clothing, food, personal relationships, honesty and employment. These principles and system concepts are descriptions, explanations and mental models of the world, in many areas of knowledge, which we learn and decide to believe in.

Taken together, they constitute what we call culture, science, religion, ethnicity and so forth. The insight HPCT offers is that these principles and systems concepts are perceptions in themselves. In daily language we talk about understanding, belief, or generally "the way the world is or should be."

Based on the *systems concepts* we have internalized, in comparison with the world as we see it, we select *principles* to live by: priorities, values, standards. These in turn—again in comparison with perceptions of the current world, determine the *programs* or action plans we carry out. From these follow *sequences*, or methods made up of *events*, work elements needed to carry out the programs we have chosen. Events require control of muscles and body chemistry at the lowest levels.

Validation of HPCT is found in numerous experiments and in the development of infants (Rijt-Plooij, 1992). The Plooij's have identified 10 highly predictable periods of mother-infant crisis in the first 18 months of life. They have found that the newborn infant controls at the second level, with perception of configuration emerging at 7-8 weeks, perception of transitions at 11-12 weeks, events at 17 weeks, and so forth. The principle level emerges at 14.5 months and the systems concept level (including the notion of self) towards 18 months.

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> Your action illustrates plainly the phenomenon of perceptual control—we act in opposition to disturbances to develop and maintain perceptions we want.

With this brief outline, I hope you can see how your own perceptions "behave" from your highest systems concepts level down to the lowest levels. You do not have to have a detailed outline of HPCT to realize that what you really want—what is important to you—you make come true as best you can. We control our world as we perceive it from the time life began until we die.

The demonstration that follows shows how you can focus your attention on control of something, in this case a single visual relationship, and how your mind makes it come true, working through your hierarchy of control systems, physiology and muscle fibers.

A demonstration of control

You can perform a practical demonstration, wherever you are, with the simple prop of two rubber bands joined by a knot. Just get a friend to help you play a game. This game will illustrate all the elements of human control, their interactions and functional relationships. This description follows Runkel (2007, pp. 103-106).

I am hopeful that placing this demonstration in the context of the larger hierarchy gives it more meaning in your mind. When dealing with every aspect of your own life—requesting water instead of juice to drink; insisting on telling the truth because that is honorable, for example—you are specifying and controlling complex perceptual variables, just like you or your friend control a rather simple one in this demonstration. The rubber band is a very simple environment, where disturbance and action have a direct, obvious influence on the variable.

This rubber band demonstration becomes a functional representation of how we live our lives. The visual relationship you select represents anything you want at the moment, and this variable, as you perceive it, instant by instant, represents your perception of the world, corresponding to your want.

Join two rubber bands by a knot. You hook a finger into the end of one rubber band and your friend hooks a finger into the other (Exhibit 5).

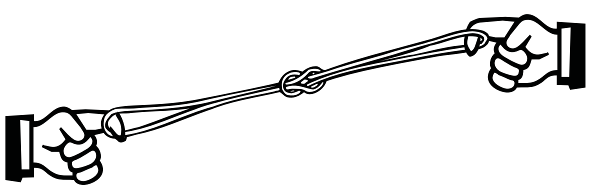

Exhibit 5. The rubber band demonstration.

Tell your friend something like: "You are the experimenter. Move your finger as you like. Watch what I do. When you can *explain* what is *causing* me to do what I do, let me know."

When you sit down with your friend, place yourself so that the knot joining the rubber bands lies above some mark you can see but which your friend probably will not notice—a small mark on a table top or paper, a piece of lint on your knee. As your friend's finger moves, move yours so that the knot remains stationary over the mark.

By deciding to keep the knot over a target, you have adopted a particular visual relationship as your want. When something disturbs this relationship, you will restore it. You will move in any way necessary to do that.

Of course, you cannot keep the knot stationary if your friend moves faster than you can act. Some people playing this game seem to want to move abruptly, too fast. If that happens, ask your friend to slow down. The lessons to be learned will be much more obvious to both of you if you are able to keep the knot continuously over the mark. You might say: "Don't move so fast. I can't keep up with you."

Your friend will soon notice that every motion of her finger is reflected exactly by a motion of yours. When she pulls back, you pull back. When she moves inward, you move inward. When she circles to her left, you circle to your left. You must do that, of course, to keep the knot stationary in this particular environment. Your action illustrates plainly the phenomenon of perceptual control—we act in opposition to disturbances to develop and maintain perceptions we want.

Notice that you perform many different acts to maintain your perception of the visual relationship. You move your finger to the left, to the right, forward, backward, and diagonally at varying speeds.

Most people, when they announce that they can explain what is causing you to do what you do, will say that you are simply mirroring what they do, or imitating it, or words to that effect. Some will put it more forcefully: that whatever they do, you are acting in opposition to it. Almost all will say or imply that *they* are the *cause* of your behavior.

A few people will notice that the knot remains stationary. That is an excellent observation, but not quite an explanation of cause. Agree, but keep asking: "What is *causing* me to do what I do?" Most people will say that your intent is to do something in reaction to them. But then you deny that. They will eventually give up and ask: *"All right, what is causing your behavior?"* You explain that you have been keeping the knot as close to the mark as possible, and that any *difference* caused you to do what you did.

You moved to oppose any motion of the knot away from the mark, not to oppose her. Your motivation had nothing to do with what your friend might have been trying to do; you did not care. *You watched only the knot and the mark.* Indeed, if you had not been able to see your friend's moves, your

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actions would have been identical. Watching the knot and the mark carefully, you cannot pay close attention to her movements at the same time. There is no need to.

Reactions of experimenters will vary widely. A few will accuse you of being devious and go away grumbling. Most will be surprised, even dumbfounded, to have missed the obvious. A few will find many of their previous ideas so shaken that they will think about it for days afterward.

Play the game with your friend. Play it with several friends! This game is an important part of this introduction. It only takes a few minutes. Please be sure to actually do the demonstration with another person. If you just visualize it, you will miss the insight of just how invisible the phenomenon of control is.

Suppose you played this game with 10 of your friends. Let us say that one was in fact able to explain (without coaching) that you were only holding the knot steady over the mark and acted to keep it there. That still means that 9 out of 10 failed to recognize the phenomenon of control when it was right in front of them. They have never been shown what control is or how to recognize it. Without an understanding of control, they are literally blind to a phenomenon that is fundamental for all living organisms.

Repeat the game with visibility for both of you. This time you are the experimenter. When your friend has seen the simple explanation: that the action is a function of the experimental setup—the rubber bands—and follows from her want to keep the knot over a mark, ask your friend to do it once more and use a pen to trace the action.

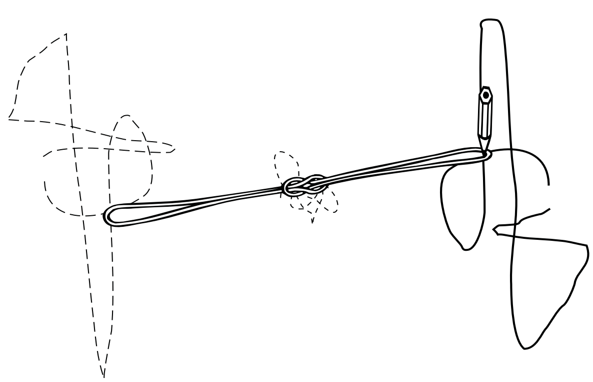

Exhibit 6. Tracing the rubber band action.

Exhibit 6 shows what the trace might look like. Notice that the knot moves a bit, erratically, about the target. If you think of this as a production process, this movement might represent variability of production quality. The slower you perform this demonstration, the better quality you can achieve, because your control will be better.

Now we focus on your friend's visible behavior and ask: "What can a reasonable observer conclude about your friend, based on what the observer can see of your friend's behavior?" What is your answer? Now that you have acted out this demonstration and considered the question, would you agree that you cannot draw any conclusions about your friend from her behavior? Your friend's behavior is clearly a product of what your friend wants (a visual relationship, specified in her mind), combined with the disturbances (your pulling on your band) acting on what she is controlling (her current perception of the visual relationship) . Her behaviors are what they have to be under the circumstances, given all the functional elements, their influences and interactions.

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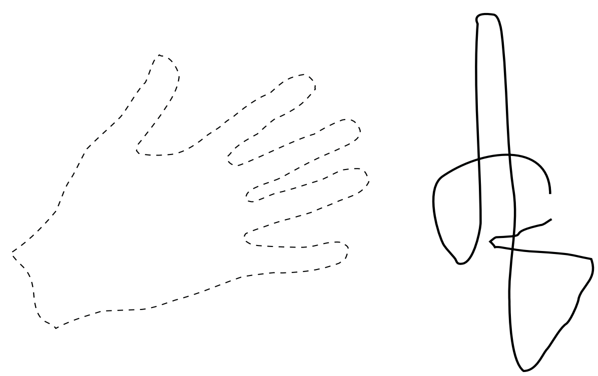

Exhibit 7. Only muscle action is visible to an outsider.

Exhibit 7 suggests that the only part of everyday behavior an observer can see is the action. Hidden from view by the hand are: 1) your friend's want, 2) the disturbing influence the experimenter has on what your friend wants, and 3) many aspects of the environment. What your friends and associates want at any moment, how they perceive it, and what disturbs it is seldom visible to an observer.

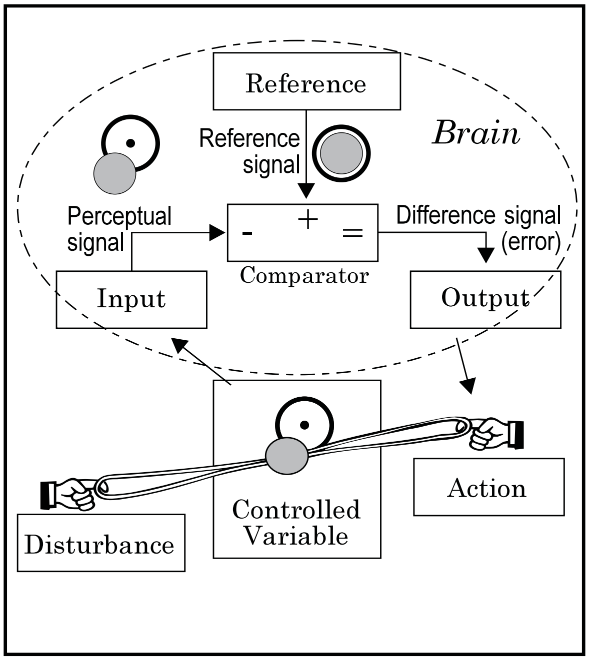

Exhibit 8. Rubber band diagram.

Compare with exhibit 12. Taken from a classroom illustration, this diagram shows a ping-pong ball over the knot, making it more visible.

This demonstration and the diagram in exhibit 8 clearly illustrate wants (reference signals) and perceptual signals, the difference between them, output signals that provide instructions for action, the actions themselves, which influence the variable we control, and other influences (disturbances) on the variable.

This demonstration is more easily appreciated when you can be face-to-face with the person doing it, talk about it, see the diagram as it unfolds and ask for clarification. Notice that everything is apparent. You are able to see, question, and discuss the elements and their relationships.

This is a simple but complete way to understand what is going on. The control model provides complete diagnostic tools for any interaction between people—whether in cooperation or conflict.

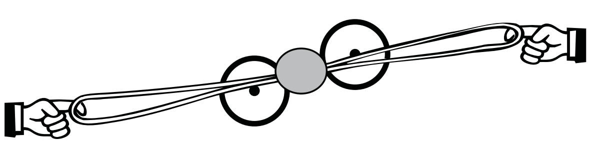

Exhibit 9. Rubber band illustration of conflict.

Conflict

Repeat the experiment with your friend, but this time with both of you controlling your own visual relationship (Exhibit 9). Your target is the one closer to you. The moment you start, you will both pull as far and hard as you dare (not wanting the rubber band to snap and hurt you) in your own direction. If you repeat the experiment with a rope instead of rubber bands, you will find that the stronger person can reach her target, while the weaker is frustrated. The waste of effort is obvious. Conflict can arise in other ways, for example if the two players perceive a single target differently, from different angles.

Cooperation

With a three-part rubber band and three players, you can demonstrate cooperation (Exhibit 10). Two players can both influence the knot with one agreed-upon target, with the third player providing a disturbance. The cooperating players can pull in different directions and with different forces (one can even slightly counter the other), in such a way that the net result compensates for the disturbance, or they can work completely in parallel to compensate with a minimum of total effort.

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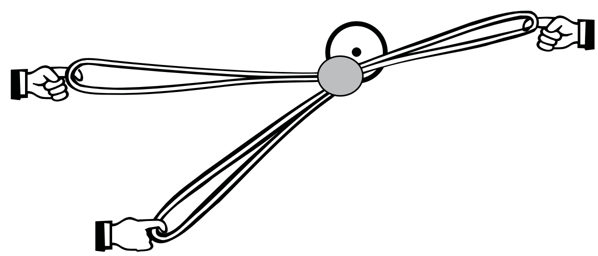

Exhibit 10. Rubber band illustration of cooperation.

An assertive person

The concept of assertiveness intuitively recognizes our nature as control systems. In exhibit 11, an assertive person claims the right to control his own perceptions in several different ways. If you claim these rights for yourself, how about granting them to others? That means recognizing your fellow man as a living control system, just like yourself. Depending on just exactly what it is your fellow man understands and wants, you may be happy to work side by side, or want to put great distance between him and yourself. As shown in the demonstration of conflict and cooperation, what we want and how we look at the world do make a difference.

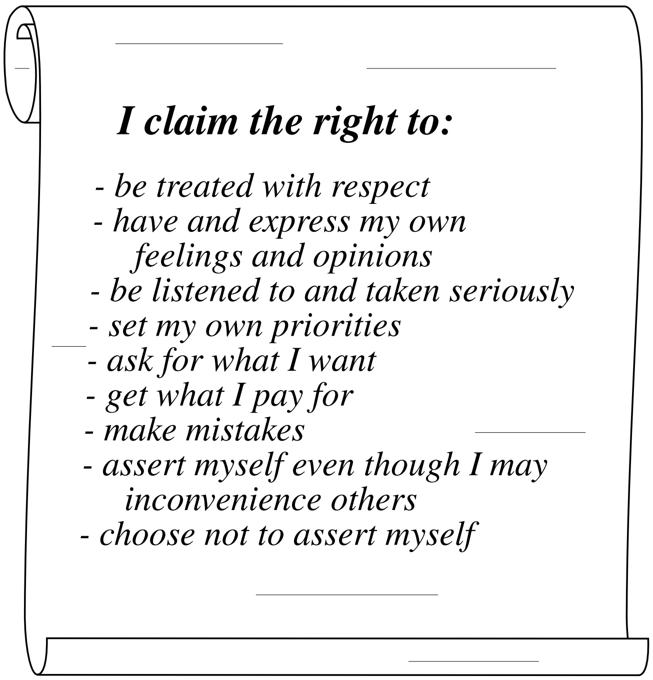

Exhibit 11. An assertiveness bill of rights (Zuka,

An effective person

While all people are equal in that we all control, some people are more equal than others in that they control *well* most of the time. Exhibit 12 is my attempt to summarize the qualities of a well balanced, productive person as one control system. In the reference box, I have shown the concept of levels of perception collapsed to the statement: Informed understanding ➔ Considered priorities ➔ Selected wants, indicating that a person's wants (right now, in relation to present circumstances), are not selected at random in a vacuum, but derive from higher understanding. The wording in the other boxes must also be read as a composite of the capabilities of the entire hierarchy. My point in offering exhibit 12 is to suggest that a person who is cool, calm and collected in most circumstances, is a pleasure to deal with and very productive, can properly be portrayed this way—a very capable system of control systems.

This "portrait" allows for a great variety of wants and perceptions. It is easy to see how people can be labeled as having different "personalities," classified in popular books as "difficult people," and stereotyped as "dysfunctional." People develop different understandings, priorities, wants and ways of perceiving/interpreting their experiences. The entire structure of perceptual functions and stored perceptions is our individually subjective *reality*. (See *We can never know REALITY*, page 63). Our ability to control our lives varies, depending on how effective this subjective *reality* is in helping us deal with the REAL world outside our minds.

Thinking of a person this way gives the manager obvious diagnostic tools: In any situation, ask questions about what the person wants (and which wants are more important), what the person does *not* want, how the person perceives the situation, including alternative interpretations, how satisfactory the comparison appears and what actions the person has considered in imagination.

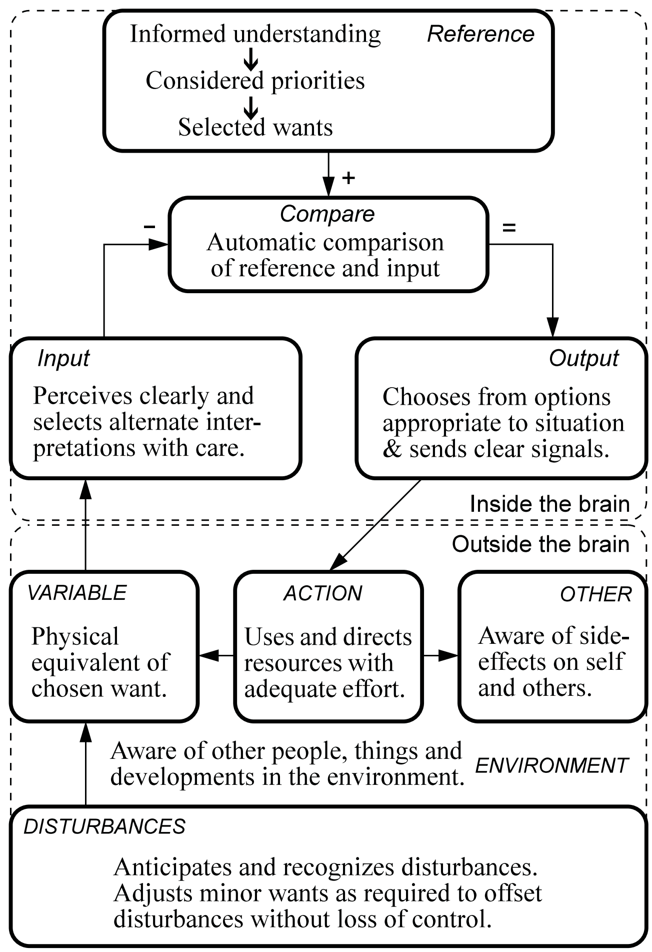

Exhibit 12. An effective person

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People interacting

Exhibit 13 shows a framework for understanding the interaction between people, whether in conflict or cooperation. Here, two brains are shown, acting in a common environment (outside the body, of course). Each person is controlling a perception of some physical variable as that person wants to, by acting on it. If the chosen variables are related or even the same one (say the balance of a tandem bicycle), it quickly becomes obvious that a variable is subject not only to disturbances from the environment in general, such as crosswind, but also that each person's action becomes a disturbance to the other. Even side effects of independent actions become disturbances to the other. (The balance is affected/disturbed if one turns around to enjoy the view).

In this illustration, person #1 can represent your associate or a prospective customer. Person #2 can represent another associate or yourself or your prospect's associate. You can readily extend this illustration with Person #3 in another department, Person #4, #5 etc., all interacting in the same physical environment. Exhibit 13 provides the framework only; the boxes are not filled in with specific understandings, wants, perceptions, output options etc. Each person in exhibit 13 lives in a personal "world" of wants and perceptions. Besides personal variations, these worlds can be very different because of professional specialization, studies, experience, and responsibility.

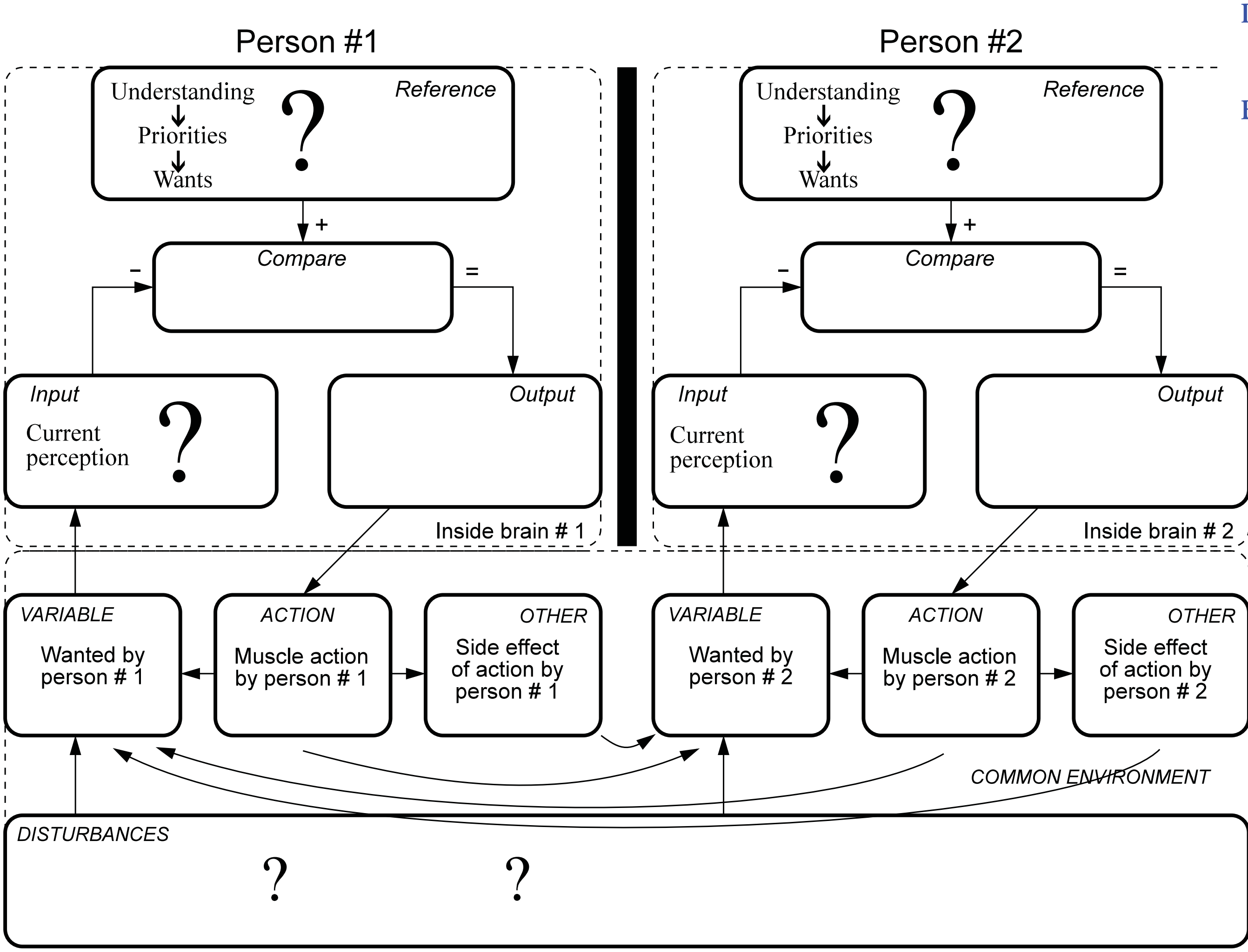

Exhibit 13. Two people interacting.

Organization

Exhibit 1 portrayed how we often think of a hierarchical organization and how we develop specialized goals for individuals in different parts of the organization. Note the visual similarity between that hierarchical goal structure and the hierarchical control structure shown in exhibit 4.

Exhibit 13 shows how, once those goals have been communicated and accepted, an entire company can more properly be portrayed as individuals working side by side in a common environment. Development, communication and agreement on goals is not easy. Telepathy between brains is not possible. (The black line represents a barrier between brains). Everyone must interact through the environment, as exemplified by the order giver and taker on page 23, even if the controlled perception is a high level mental construct such as "honesty," that has no physical equivalent in the environment.

Respect

Respect, ethics, morals—a sense of right and wrong—follow naturally from an understanding of HPCT. You realize that you are a living control system, and assert the right to control your own perceptions as freely as possible within the constraints of nature. In fairness, you accept that your fellow man deserves and asserts the same right.

If you want to not only "live and let live," but also want to support your fellow man, HPCT shows 1) what supports effective control, 2) what defeats it, and 3) what disturbs it.

1 a) Offer the best possible, validated, factual information for consideration. This helps your associates develop understanding and select appropriate wants.
   b) Allow them to perform freely and experience the results.

2. a) Misleading information can create unattainable wants and frustration.
   b) Too much help does not allow your associate to perform—to experience effective, satisfying control and to learn from it.
   c) Promises or threats distort purposes and can create conflict.

3. Judgements of, remarks about, and criticism of action/behavior focus on the incidental means, not the purposes and perceptions of a living control system. This does not help at all, but disturbs your friend and creates conflict. It is impossible to convey a sense of respect when focusing on the action/behavior of another.

Lessons for managers

It is not necessary to understand how control works to live, because people *are* control systems and control whether they understand it or not. But if you *do* understand, you can solve problems more effectively.

From the detailed insight of HPCT, managers can learn this most important insight: *Judging action/behavior is next to useless.* It tends to cause conflict, not solve it. Wants and perceptions are what should be discussed so they can be reconsidered. When they change, action changes automatically. The interactions (horizontal arrows in the environment) portrayed in exhibit 13 change when the wants and perceptions of either or all parties change.

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Mapping and influencing wants and perceptions

We have seen how exhibit 13 represents people working side by side; brains living in separate personal "worlds" of wants and perceptions in a common environment. We understand that actions are the result of an automatic comparison between current perceptions and related wants. Exhibit 13 shows clearly that if we want to understand (and influence) the actions of others, we must "map" the blank spaces in the areas of wants and perceptions. We know that people have wants and do perceive. The question is: What are the wants? What understanding and priorities are they based on? How does the person interpret inputs?

By *mapping and influencing wants and perceptions* you can explore the unknown territory of other minds. Ask questions. Where a person is unclear, your questions help her consider where her wants come from and alternate ways of perceiving a situation. You can ask what actions she has considered in her imagination, and what she thinks the results would be. *Mapping* can range from gentle exploration to challenging questions which help her consider and revise her wants and perceptions as they are being mapped. You can use the mapping approach in a professional discussion, in a sales presentation, in a performance coaching review, and in a firm but non-judgemental discipline session. (This will be discussed more in the third article).

The result of mapping is self- and mutual understanding. Every person involved in a cooperative task will clearly understand the relationships between their various wants, perceptions, actions, results and side effects. They can work things out and support each other.

Mapping can involve a whole team. Let me show how you can facilitate a simple conflict resolution between two people. A male associate may ask for your assistance in order to resolve some problem, or you, as his manager, peer or friend may approach him. You can work one-on-one with him alone. Your questions help him think through both sides of his conflict and draw his own conclusions.

A basic methodology might be as follows:

1) He asks for a meeting (or you do).
2) Ask him what happened and concerns with the other.
3) Ask him about his own wants in relation to the other.
4) Ask him what he thinks the other's wants, perceptions, and possible choice of actions are.
5) Ask him to compare. Does he see any conflict between his own wants and perceptions and those of the other as he understood them (or you clarified them)?
6) If yes, ask him if he wants to commit to work on a way to resolve the conflict.
7) If yes, coach and support him as he develops a plan to change wants, perceptions, capabilities and the environment to eliminate the conflict.

The point of this approach is to ask about goals and any conflicting goals and ask him to consider outcomes of his different options until he decides on a course of action that is best for him in the context of his agreement and capability to support the organization. You can renegotiate if you represent "the other" and support as appropriate.

Things to avoid when asking him to map himself and others:

- Do not dwell on the action that may be the reason for mapping. At no time do you criticize him. You conduct the entire session by asking questions, offering advice only when it is welcome.
- Do not *ever* tell him what you think, but ask if he would like to have information when you have something relevant to say. If you impose your opinion on him, he perceives your message as an attempt to control him and he will resist. He is concerned about what he wants, not about what you are saying.
- Do not dwell on his feelings, (it is not productive) but ask about what *causes* them, namely his goals and how they compare with his perceptions. (That gives him a way to deal with his feelings).
- Do not take over his responsibilities and try to do his thinking for him. Living control systems must do their own thinking in order to function effectively. Your role is only to ask questions (and teach when asked).
- Do not ask him why he has behaved in a certain way. He must now defend ineffective choices in the past.
- Do not bring up a negative incident from the past. It is beyond his control at this point.

As you explore the things he wants, you are not limited to things he mentions. As an experienced person, you can ask about related wants or reasons for these wants. For instance, if he has an internal conflict—incompatible wants—you can ask him about his priorities, which will help him to resolve his conflict. If he does not tell you what he wants, you can employ "the test." You guess what he wants, then disturb it and watch to see if he resists the disturbance consistently. (Runkel 2007, p. 115 & 150).

This approach is not soft and wishy-washy, leaving everything up to your associates, and you powerless. You will find that the approach outlined here is more effective than telling people what goals to adopt, assuming that they do, and talking to them about what they *do*—their actions.

Through careful and persistent questioning, you help your associates focus their attention on issues (you can raise issues related to company goals) that are important to them and help their mind to come up with solutions to what they agree are their problems. Over time, you become their trusted friend, someone who cares.

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How is this different?

Conventional psychology teaches us that the only thing we can legitimately study and deal with is peoples' behavior. It is widely understood that the purpose of conventional psychology is the prediction and control of behavior. This behavioristic point of view encourages managers to think of people as something to be manipulated. What can we do to get our people to be the way we want them to be? How can we motivate them? How can we get them to come on time, work harder, show more loyalty to the company, pay more attention? In short: How can we control their behavior?

When we are unhappy with the results of the performance of another, we ask: Why did you do that? Can't you do something better? We tell people: You can't do that; your behavior is unacceptable! Here is what I would do if I were you... This is the accepted method in that situation. If you say this..., the customer will do that... We focus on and try to reinforce, reward, train and modify *behavior*.

The questions above often lead to defensive excuses, conflict and resentment. Only accidentally may they lead to a productive discussion of wants. It does not make matters easier that the term behavior itself is poorly defined and confusing. Behavior refers to action, but is invariably defined by the result: harassing behavior, loving behavior, cooperative behavior, leadership behavior, etc..

HPCT explains how we develop our own understanding, make our own choices based on our values and standards, and act freely to control our own perceptions. The last thing we want is for someone else to control our behavior.

PCT shows that *action is a normal by-product* of wants, perceptions and circumstances. When we are unhappy with the results of the performance of another, it is best to ignore the action/behavior—the by-product or symptom—and ask instead about wants, perceptions, and disturbances, which are the causes. (Exhibit 13).

You stimulate creative thought through questions rather than manipulative coercion. Respect for your associates' internal world of wants and perceptions is critical.

When you change from trying to control your associates' behavior to asking them to deal with both their own and their organization's wants and perceptions, your associates learn to think, sort out internal conflict, and develop effective plans. You allow your associates to control well: to satisfy personal and company wants at the same time. You are seen as a leader and teacher rather than as a controlling agent.

Old habits die hard. This change in focus may feel awkward for a time, but the payoff will be great.

Summary

In this application of the PCT and HPCT models, I have illustrated the basic concept. I have shown a questioning approach to problem solving which fully respects the other person as an autonomous living control system; facilitating the development of trust, cooperation and high productivity.

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> ..you help your associates focus their attention on [work] issues that are important to them... you become their trusted friend, someone who cares.

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Perceptual control — details and comments

INTRODUCTION

These comments provide more background and perspective on how PCT is different from contemporary psychologies, and develops the architecture of HPCT suggested in the first article, exhibit 4.

How is PCT different?

Let us contrast PCT with the linear cause-effect perspective of contemporary schools of psychology.

First, let me ask you: What is the most common explanation for why people behave? People respond to stimuli in their environment, right? How they respond depends on how they have been shaped or conditioned by their environment. This means that what happens to people determines what they do.

Some management programs tell you how to push people's "buttons" so they do what you want them to do. Some programs advise you to assess what situation you are in to know which behavior to use.

Some sales training gives you a choice of "17 different ways to close," depending on how you read the customer's situation and attitude. Of course, you must know what situation you are in and what buttons to push.

Would you agree this doesnt work all the time?

Another explanation is that our thoughts, our plans and decisions determine what we do. As an example, think of how you play solitaire. You sit quietly and think. There is no stimulus from outside you. You decide to place an ace on a king and do it. This is a cause-effect perspective too, only with an internal cause. This, too, appears true some of the time, but does not work all the time, because it is not the whole story either.

> The basic postulate of PCT is this:
>
> *it's all perception*
>
> We experience the brain's perceptual activities, not the world itself.

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PCT gives you a complete picture of how both the environment and internal goals relate to action. PCT provides diagnostic tools that help you see how a system of perceptions, goals and actions is working continuously. This means that you can always understand the structure of functional interactions in yourself and in others, and can figure out what questions to ask to learn details at any time.

If you do something that works well, PCT explains **why** it works. If you are doing something that does not work well, PCT will indicate why and suggest new approaches. For example, if you use a wise, principle-based management program, PCT will make it more understandable and easier to teach. If you use a respectful, non-manipulative sales approach, PCT will make that more understandable too.

There are many natural leaders, successful salesmen, wise parents and good communicators. But they cannot explain what they do in any depth. Their insights and skills are intuitive. PCT provides the missing explanation.

> Without an understanding of control, [people] are literally blind to a phenomenon that is fundamental to all living organisms.

Hierarchical Perceptual Control Theory

Exhibit 17 shows more of the architecture first presented in exhibit 4. The two dimensions of this model of the human mind are:

1) Levels of perception and control and
2) Examples of perception.

You will find that thinking in terms of these two dimensions is very helpful when counseling associates and resolving conflict. A control system at the center of exhibit 17 ( ) has been highlighted. The demonstration that follows shows how you can focus your attention on control of something, in this case a single visual relationship, and how your mind makes it come true, working through your entire body. But first, let us examine how the proposed architecture works.

Levels of perception

The *vertical dimension* in exhibit 17 is “Levels of perception.” Exhibit 18 shows more detail. Starting from the bottom, a low-level input—a neural current created by a nerve ending “tickled” by some physical phenomenon in the world, such as light falling on a single cell in the retina—is combined with other inputs, creating a perception signal at a higher level, which is in turn combined to create a signal at a still higher level. At the higher levels, a branch of the perceptual signal can be recorded in memory and later played back as a reference signal. (It is beyond the scope of this article to suggest an integration of distributed memory in HPCT, with suggested explanations for imagination, automatic control and passive observation).

Levels of perception are central to HPCT. They were introduced by Powers (1973), and have been further described in detail by Robertson and Powers (1990). Some of the DOS computer demonstrations (PCT demos and texts available from the author) show how hierarchical control of perception works, and the file percept.lvl explains how to think about the levels. I will not describe the proposed levels in detail in this introduction, but the basic postulate of PCT, simply put, is this: *it’s all perception.* We experience the brain’s perceptual activities, not the objective world itself.

Levels of perceptual control

Exhibit 19 incorporates exhibit 18, and completes the picture with control at the same levels as perception. This arrangement is shown in exhibit 17 in the two areas of muscle action and physiology, but not in the other senses. All the control systems shown in exhibit 17 act on the body outside the brain through both muscles and physiology, and on the world outside the body through muscles.

You can think of the chain of control systems in exhibit 19 as an organization with a worker at the lowest level, a supervisor at the second level and a manager at the third level. An equivalent metaphor is to think of a driver and two rows of backseat drivers. The driver (control level 1) sees the road through a TV screen and does the steering. The driver at level 2 gets a summary report passed on from an interpretation of the driver’s TV, combined with summary reports from other TV’s. The driver at level 3 has similar options. You can easily imagine that this third level driver combines wants of his own superiors of different “Examples of perception,” then shows where to go by selecting a map in memory. The second driver reads the map and specifies which streets to use. The first driver converts these more detailed instructions into control of positions through action—turning the wheel. If the communication is fast and reliable enough, this arrangement will work fine in real time.

The human body has about 800 muscles. Therefore, the muscle tension control chain in exhibit 17 represents at least 800 interconnected control units at the first level. When you walk, you may address a memory stored at the event level, which holds a certain walking pattern. This memory plays back a reference signal which is converted with additional inputs at the transition level into a certain speed of this walk. The configuration level converts this reference signal into smoothly varying leg positions, which result in changing velocities at the sensation level. Changing velocities require changing accelerations, which the tendon reflex loop*, at the intensity level, accomplishes by varying muscle contraction. If your toe hits an obstacle, the limb acceleration, velocity and position are disturbed. Within fractions of a second, the tendon reflex loop compensates by changing the muscle force. This explains why you recover from a

* See exhibit 25 in *Are All Sciences Created Equal?*

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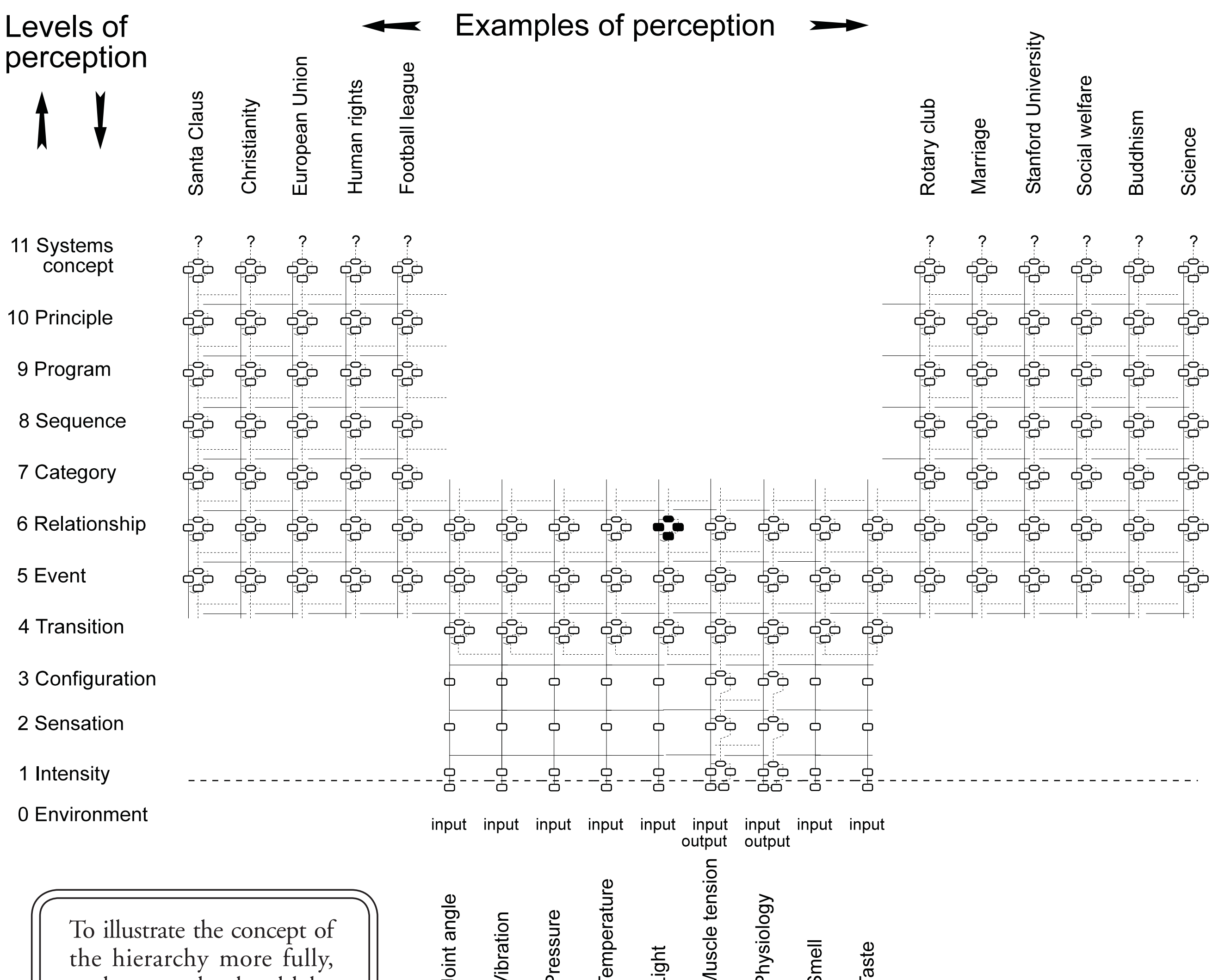
stumble even before perceptions of the stumble have been combined and reported all the way up your internal "chain of command"—as shown in exhibits 2 and 3. You don't just react with some mysterious reflex—all your body's muscles are under exquisite control at all times. When you specify a perception at a high level, the hierarchy delivers a real time perception very close to what has been specified, by acting on your environment. The HPCT term for this is that perceptions behave. *The Hierarchical Behavior of Perception*, (Marken, 1993) reports on this in greater detail including response times in humans.

Examples of perception

The *horizontal dimension* in exhibit 17 is "Examples of perception." At the lowest levels, we perceive light, vibration, pressure, temperature, joint angles, tendon stretch, smell, taste and physiology (which we sense as a part of feelings). The highest perceptual levels are called systems concepts. These are descriptions, explanations and models of the world, in many areas of knowledge, which we learn and decide to believe in, as exemplified in exhibit 17. Patterns of principles and systems concepts taken together constitute what we call culture, science, religion, ethnicity and so forth.



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To illustrate the concept of the hierarchy more fully, each example should be labeled at each level.
For an early suggestion of such labeling, see Living Control Systems I, p. 206.

Exhibit 17. Conceptual illustration:
A person as a hierarchy of interacting control systems.
(Inspired by an illustration created by Mary Powers.)

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The insight HPCT offers is that these principles and systems concepts are perceptions in themselves. In daily language we talk about understanding, belief, or generally "the way the world is or should be."

Based on the *systems concepts* we have internalized, in comparison with the world as we see it, we select *principles* to live by: priorities, values, standards. These in turn, again in comparison with perceptions of the current world, determine the *programs* or action plans we carry out. From these follow *sequences,* or methods made up of *events,* work elements needed to carry out the programs we have chosen. Events require control of muscles and body chemistry at the lowest levels.

With this brief outline, I hope you can see how your own perceptions "behave" all the way from your highest systems concepts down to muscle fibers and chemistry. You don't have to have a detailed outline of HPCT to realize that what you really want—what is important to you—you make come true as best you can. We control our world as we perceive it from the time life began until we die.

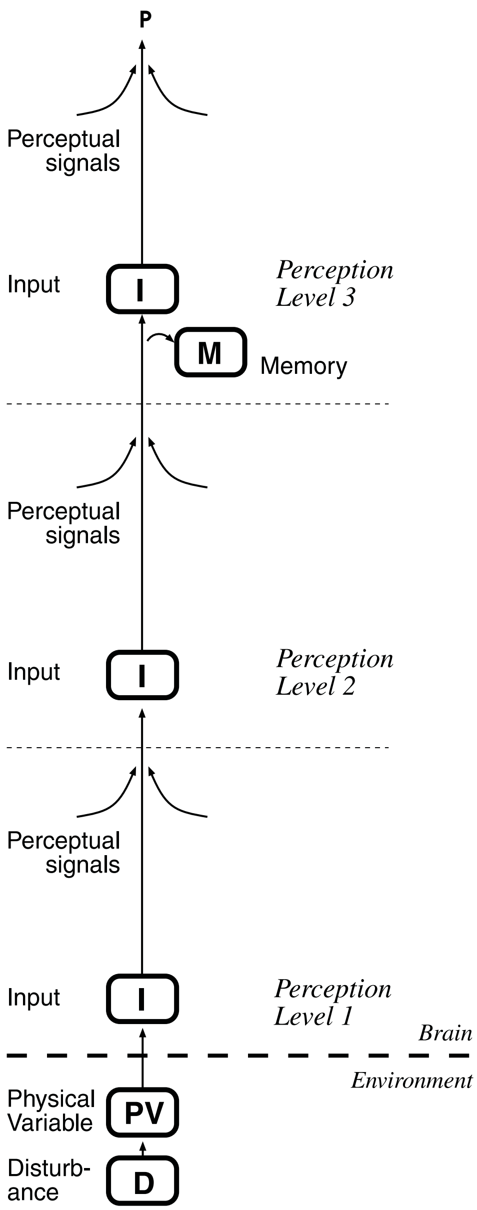

Exhibit 18. Levels of perception

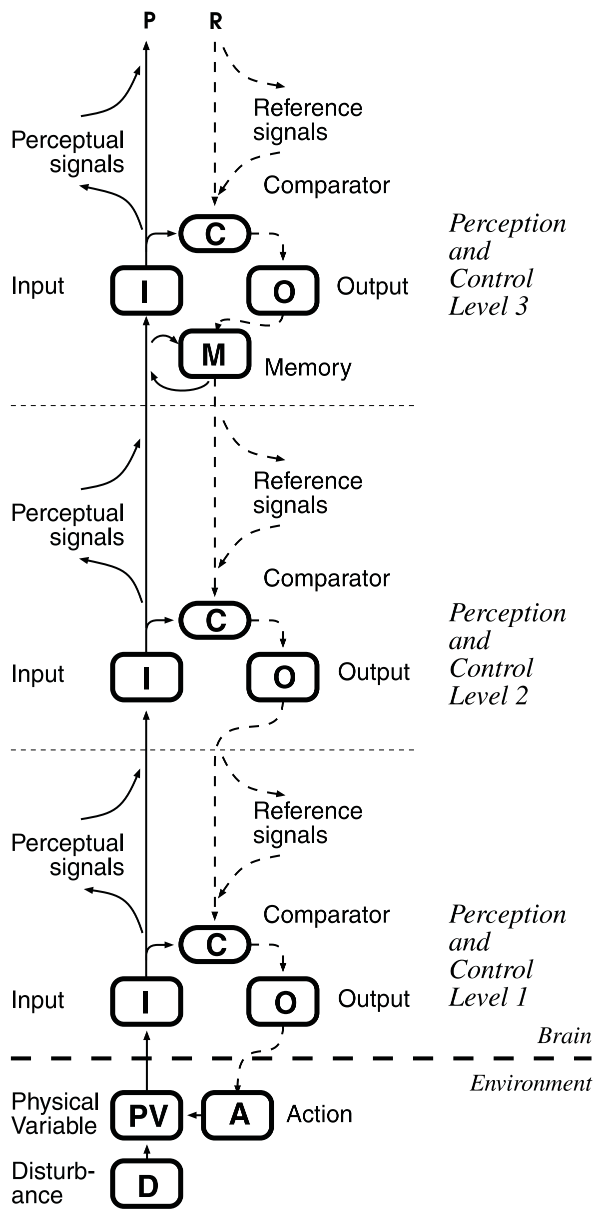

Exhibit 19. Levels of perception and control.

> When you specify a perception at a high level, the hierarchy delivers a real time perception very close to what has been specified, by acting on your environment.

When as manager, teacher, parent or friend, you want to help people control their world better, to be more effective and satisfied, exhibit 17 suggests that one of the things you can do is to help people improve and expand on their internal control capability by clarifying and developing their perceptions at higher levels, in relevant subject areas (see *mapping and influencing wants and perceptions*, page 34). The world portrayed in exhibit 17 is internal to a person's mind. A person is the **only** one who can question the validity (from her own point of view, of course) of the perceptions stored in her own mind. Therefore, a good way to assist people is to ask them questions about their systems concepts, principles, and programs in the areas or subjects of knowledge that is relevant to their problem or conflict; questions which help them talk to themselves.

When you respect people as autonomous living control systems, you realize that you cannot impose your opinions. You will not be surprised if they ignore you when you try. You gain trust when people they realize that you are helping them control their lives more effectively. *Freedom From Stress*, (Ford, 1989) is a very readable introduction to PCT that illustrates these principles with a counseling story and roleplays that touch on work, marriage, family, and school.

Early development

An exciting aspect of HPCT is that it provides a rational, consistent explanation for our development all the way from conception to adulthood using the same basic building block of control. An infant has developed some ability to control both muscles and physiology. The fetus has been able to hear, taste, touch, smell and move about, and thus practice these perception and control capabilities, but has not experienced vision, nor coordinated it with eye and body movement.

In their article: *Developmental Transitions as Successive Reorganizations of a Control Hierarchy* (Marken, 1990), Dutch researchers Frans X. Plooij and Hedwig C. van de Rijt-Plooij report their observations of mother-infant development among free-living chimpanzees. They identify and describe progressively higher levels of control capability (giving examples all the way up to the emergence of the principle level at about 18 months of age), with short periods of regression and crisis between them, as if the infant takes one step back and two forward to develop. They note that movements are rapid in the beginning, as when the newborn roots for the nipple on the mothers breast, and slow down as higher levels of control develop and the infant no longer searches by means of sensing temperature of the skin and nipple (second level control—sensation), but instead perceives the visual image of breast and nipple (third level control—configuration), then moves directly to the nipple, but more slowly. This is consistent with the engineering requirement that higher control systems be slower than lower ones. If they were not, the hierarchy could not be stable.

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The Plooij's have later studied human infant development (Rijt-Plooij, 1992 and 1993), and have identified 10 highly predictable periods of mother-infant crisis in the first 18 months of life. They have found that the newborn infant controls at the second level, with perception of configuration emerging at 7-8 weeks, perception of transitions at 11-12 weeks, events at 17 weeks, and so forth. The principle level emerges at 14.5 months and the systems concept level (including the notion of self) towards 18 months. Their book *Oei, Ik Groei! (Wow, I Grow!)*, based on this work, is written for all parents and reports both on infant development and the mother-infant conflicts that go with it. It is easy to understand, very practical and became the top nonfiction book in Holland in 1993. Available in German *Oje, Ich Wachse!* and English *The Wonder Weeks: Eight predictable, age-linked leaps in your baby's mental development.* See www.livingcontrolsystems.com for more details.

> You gain trust when people realize that you are helping them control their lives more effectively.

Reorganization

When an organism (young or old) fails to control its world well, perhaps due to conflict, large differences (error signal, dissatisfaction) arise between what the organism wants and what it experiences. This large error signal creates large neural and biochemical signals**. HPCT postulates that such chronic error signals are undesirable and that they are perceived by a very basic, "dumb" biochemical control system which as its output causes random changes in the organization of the control hierarchy. This is called *reorganization*. It is thought to take place at a basic neurological and biochemical level as well as at the high levels of principles and systems concepts, and explains both the development of infants and changes in adults, even dramatic ones. The idea is that chronic error and reorganization (being random, it can be good or bad) continues until some change happens to rearrange the control systems in a way that works better. At that point, the chronic error and reorganization both stop. The process of reorganization manifests itself as crisis, frustration, and discomfort. Many different neural and biological rearrangements may be tried until something serves to restore control or the person eventually dies. We recognize mild reorganization when we have a complex problem that troubles us. Our mind churns ideas and we say: "Let me sleep on it, a solution will come to me." A manager can support an associate who is reorganizing by explaining the process, reassuring the associate that (most of the time) there is light at the end of the tunnel and, if asked, offer more effective ways to perceive the situation and more effective choices to make, thus reducing the randomness of the process.

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** See also *PCT explains feelings* (page 71).

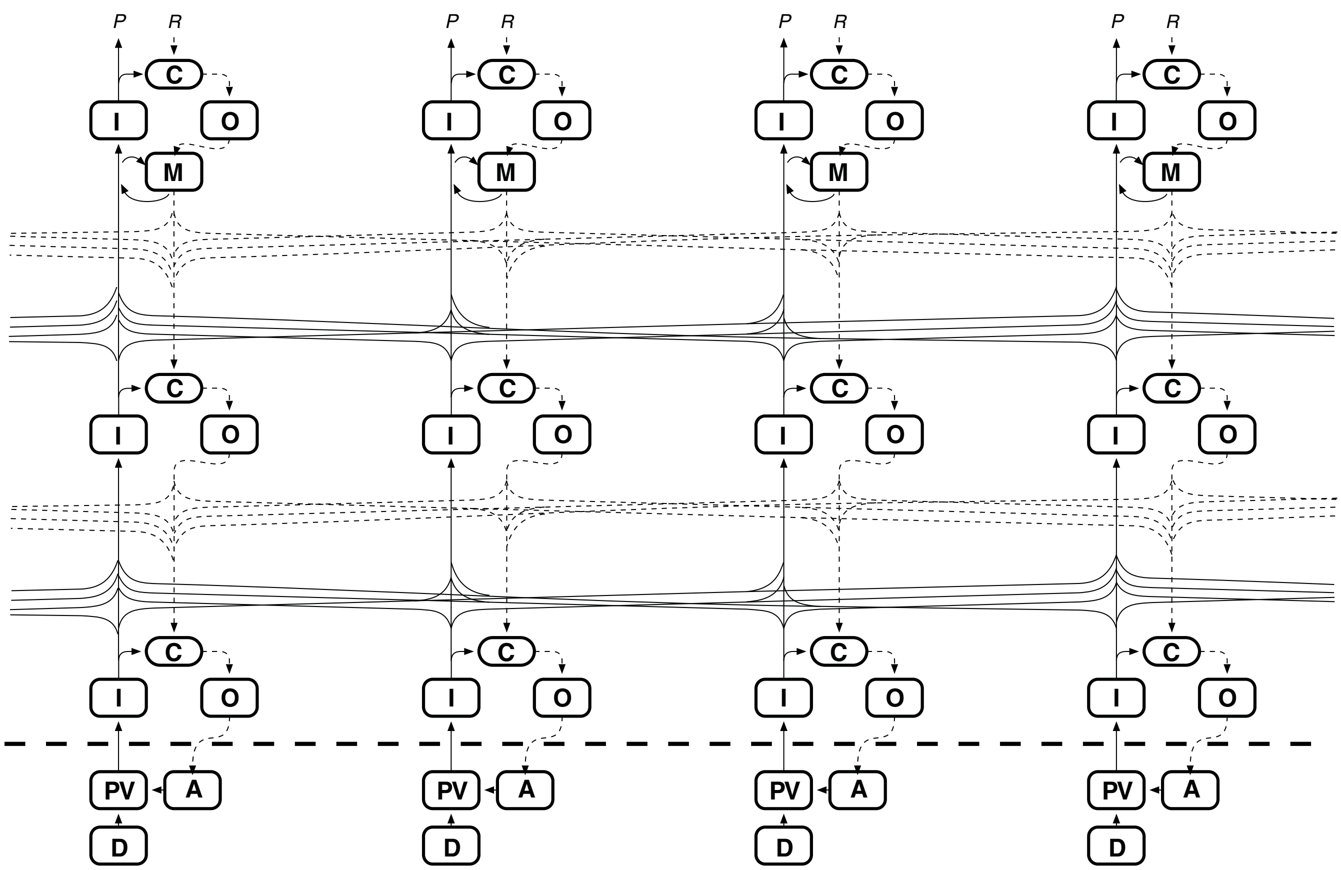

Exhibit 20. Interconnections among control systems.

Interconnections

The horizontal lines shown in exhibit 17 represent connections with other control systems, both adding perceptual signals together as higher-level perceptions are formed, and distributing reference signals to several lower-level control systems. Exhibit 20 suggests the full complexity of such interconnections. Such hierarchies can both be stable and satisfy many different high-level specifications. In this illustration, each of the four low-level "workers" work on a different process to satisfy the combined demands of four different intermediate "supervisors" who in turn satisfy the combined demands of four different "managers." This sounds like an impossible nightmare in terms of a matrix organization in business, but is clearly illustrated by the "Spreadsheet" demonstration on the DOS demodisk. This demonstration shows that the control systems either

a) converge on a stable "worker" solution that satisfies the disparate demands of both "supervisors" and "managers" quickly and efficiently, or
b) develop severe internal conflict with large outputs which cancel one another, maintain chronic errors, and waste energy.

One real world application of this kind of capability in a human being is the maintenance of physical balance. We don't usually think of a human being as a tower made of sticks, swivel joints and active rubber bands carrying out a balancing act all day long, do we? When you stand at a blackboard and write, you focus on your hand movement. But hand movement upsets your balance, so in order to maintain that specification at the same time, most of your skeletal muscles are continuously compensating. You cannot stretch out your hand without the muscle in your big toe getting involved, can you? Exhibit 20 illustrates the Spreadsheet demo which provides an active demonstration of how smoothly a hierarchy of control systems can take care of multiple demands without your giving it any conscious thought at all. While you are still at the blackboard, select a memory that specifies some rhythmic changes in your balance and position, and you find yourself dancing, still maintaining harmony and cooperation among all 800 muscles in your body. A hierarchy of control systems is simple and does the job out of sight and (most of the time) out of mind.

A demonstration of control

You are now turning your attention to the highlighted control system in the center of exhibit 17. Notice how all the control systems in your hierarchy connect your visual experience and difference signals to your muscular control systems, which move your hand while maintaining your balance.

Here ends the original draft for the first half of the second article. The rest of the article continues on page 29, right column:

A demonstration of control

For more demonstrations, I suggest *Portable PCT Demonstrations* (Greg Williams, ed) in *Closed Loop*, Spring 1993, Vol 3 No 2.

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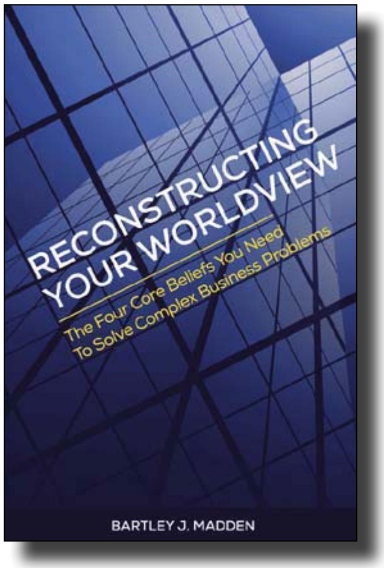
> We control our world as we perceive it from the time life began until we die.

Reconstructing Your Worldview:

The Four Core Beliefs You Need to Solve Complex Business Problems



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INTRODUCTION

THIS BOOK HAS developed over a thirty-year period beginning with my curiosity about how we know what we think we know. It's an ongoing project dealing with how we perceive the world, analyze problems, make decisions, and build knowledge. The overriding goal is to improve the handling of complex problems.

In 1991 I published an article in the *Journal of Socio-Economics* that included a section highly critical of Milton Friedman's famous methodology of positive economics. His approach dictates an extreme focus on how well a theory predicts, disregarding any skepticism concerning how reality-based its assumptions are. I sent the article to Friedman, and he replied in a letter that, pertaining to my critique of the methodology of positive economics, "I have no criticism of it, and it has no criticism of me." Apparently, Friedman agreed with my point that researchers could use this methodology to justify building fanciful and elegant mathematical models while ignoring the lack of realism of underlying assumptions; but, he implied, he himself did not do that.[1]

While my work on the topic of how we know what we think we know was progressing, my professional career was focused on investment research. My aim was an improved understanding of the causes of levels and changes in stock prices worldwide and how one could make better investment decisions for buying and selling stocks. I spent a lot of time researching systems thinking—a subject I discuss in Chapter 4—and that influenced my finance work. My 1999 book, *CFROI Valuation: A Total System Approach to Valuing the Firm,* describes a valuation framework that differs from mainstream finance in important ways, and today is used by institutional investment firms worldwide. My 2010 book, *Wealth Creation: A Systems Mindset for Building and Investing in Businesses for the Long Term,* made the case that knowledge-building and wealth creation are opposite sides of the same coin. That book contained an early version of the knowledge-building loop that I describe here in Chapter 3.

For many years I've enjoyed exploring diverse fields with the intent of formulating insights that could help with improving the handling of complex problems. This led me to the work of Bill Powers, who developed perceptual control theory (PCT), which is described in Chapter 5.

The table of contents shows what might appear to be an eclectic, unrelated group of chapters. To the contrary: I've specifically written these chapters because their very diversity supports the widespread usefulness of a reconstructed worldview. I hope to make a convincing case that the worldview-oriented material in this book leads to genuine insights for solving problems, especially complex problems in managing a business. For example, why did Sam Walton's worldview versus that of his competitors lead to Walmart's becoming the world's largest retailer? How can business schools change in order to better equip their students to solve real-world problems? What is it about a worldview that can help you solve your tough problems the same way that smallpox was eradicated and the cause of cholera discovered? This will be explained in subsequent chapters.

At the heart of this book are four core beliefs. Ideally, these core beliefs work in tandem and facilitate new, improved habits of thought. In an academic sense, I could refer to these core beliefs as propositions or hypotheses. Instead, I use the term "core beliefs" because their adoption can deliver extraordinary improvements in our thinking.

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The first core belief is that past experiences shape our current assumptions. Through our assumptions about how the world works, we participate in creating what we perceive as our reality.

The second core belief is that language is perception's silent partner—silent in the sense that we are mostly unaware of the powerful influence of language. A creative use of language can generate new opportunities for a future unshackled from the past.

The third core belief is concerned with systems thinking: how to improve system performance by identifying and fixing a system's key constraints. Systems thinking helps overcome the limitations of linear cause-and-effect thinking. People often make presumed improvements to one component of a system without regard to whether this helps performance of the overall system; or they fail to identify and focus on the key constraints that are degrading system performance.

The fourth core belief is that human behavior is purposeful, and that it can be productively analyzed as a living control system. Instead of viewing behavior as a response to an external stimulus, an alternative perspective is that we compare our *actual* experiences to our *preferred* experiences and take actions in an attempt to create new experiences closer to what is preferred. The control-system perspective explains, among other things, why compensation/incentive systems often do not work well.

You may initially think that these core beliefs are a bit too philosophical, and be unconvinced as to their practical value. In this regard, I offer more detailed explanations of the four core beliefs in Chapters 2, 3, 4, and 5, and include many examples that I believe clearly illustrate their practical nature. For example, you'll gain insights about the Toyota engineer's worldview that eventually gave birth to the much-admired Toyota Production System and to the related "lean thinking" that has spread worldwide, and about Eli Goldratt's Theory of Constraints, which has been popularized in his best-selling book *The Goal*.

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Chapter 6 explains the application of the core beliefs in developing a public-policy proposal of mine—Free To Choose Medicine—that could fundamentally restructure the drug-testing and approval process in the United States, much to the benefit of patients now and in the future.

Chapter 7 describes how leaders in education are shaping curriculums that address the ideas fundamental to this book, so that students are equipped with a worldview that greatly improves their innovation and problem-solving skills. This new direction isn't about conventional learning that merely looks for the right answers to textbook questions. Rather it is about creating experiences in which students learn how to ask the important, penetrating questions; how to pinpoint faulty assumptions that can be the root causes of problem situations; and how to quickly, efficiently evaluate new ideas—all critical steps for those interested in developing wealth-creating insights.

So as to present the ideas in this book in straightforward language and to avoid excessive technical details, the extensive notes serve as source material for those who want to dig deeper.

A significant portion of this book builds upon my 2012 article "Management's Worldview: Four Critical Points about Reality, Language, and Knowledge Building To Improve Organization Performance," which was published in the *Journal of Organizational Computing and Electronic Commerce.* I am grateful to Professor Mark Frigo of DePaul University for inviting me to make a series of presentations to his MBA students, who provided valuable feedback on these ideas. Two presentations were filmed and are available on YouTube, titled "Capitalism and Management's Core Responsibilities" and "Reconstructing Your Worldview." The former explains how management can run their businesses in ways that both create wealth and earn the moral high ground. The latter is an overview and application of the four core beliefs central to this book.

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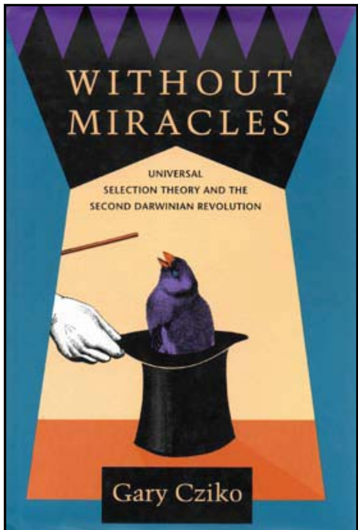

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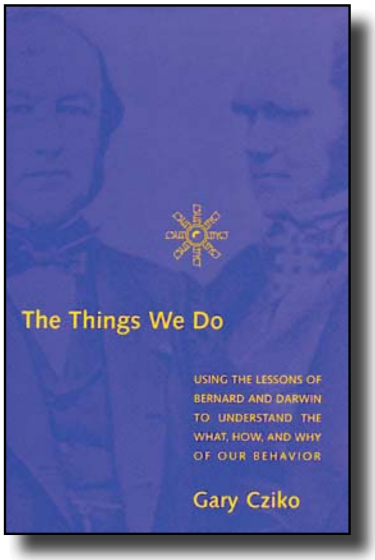

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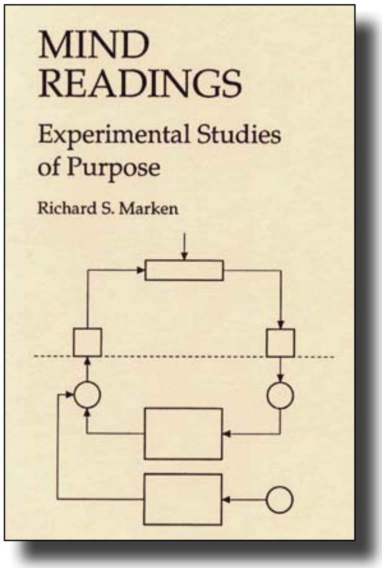

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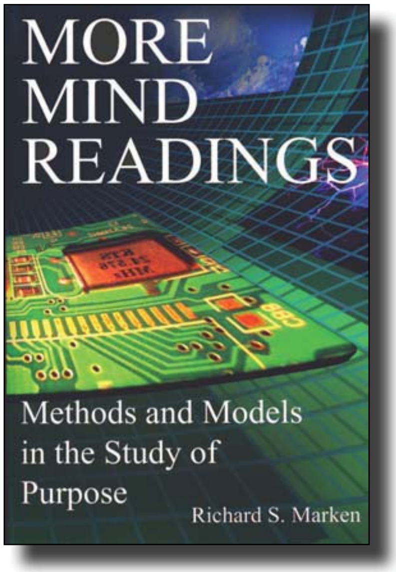

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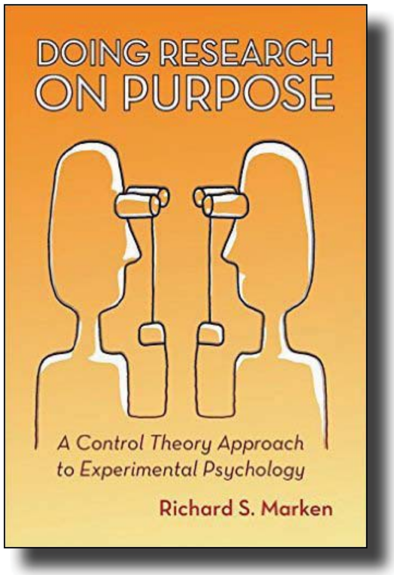

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Foreword

This book is the third collection of papers from Richard Marken. Together these three volumes represent a body of scientific work that has secured their author a permanent place in the history of psychology, a unique distinction among living psychologists.

I urge readers to read this book, above all because it is a valuable introduction to the science of psychology. My emphasis is on the word science because in traditional psychology what you find is not so much science as a promise of a science. But if you wish to learn what a mature science of psychology is like and how it can help you achieve an understanding of the behavior of living organisms, yourself included, then this book is a good place to start.

Some may wonder why after so many centuries psychology as a science is still not quite ready to be launched. The answer is found in this book. As Marken explains, psychologists have unwittingly strayed from the right path by abandoning the study of purpose. Over a century ago the idea that behavior is purposeful was still popular. But although these early psychologists, such as William James, had the right intuitions about purpose, they did not understand it well enough to launch a true science. Marken's aim in this book is to provide the understanding they lacked. The foundation of this understanding is Perceptual Control Theory (PCT), a model of purposeful behavior first proposed by William T. Powers. PCT provides a scientific explanation of folk psychological notions of purpose in terms of a hierarchy of negative feedback control systems. Psychology, thus, is shown to be a teleological science – a science of purpose – as rigorous as the non-teleological sciences of physics and chemistry.

Some might object to the claim that psychology has neglected purpose since the term "purpose" (or related terms like "goal" and "intention") appears in the titles of many publications in the field. As Marken shows in this book, however, psychologists typically use these teleological terms incorrectly and informally, with no description of what they refer to or how they might work. The papers in this book describe what goals, intentions, and purposes are in terms of observable behavior and explain how they work using quantitative working models of purposeful behavior.

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In restoring purpose Marken has also restored the other concept missing in psychology—the individual. Of course traditional psychologists would often pay lip service to the individual. But as soon as we read any article in psychology carefully the individual disappears as the statistical average emerges. If the individual ever appears it is in the idealized form of the group average, a Gaussian person whom nobody has ever met before.

The challenge to any true individualistic psychology is to develop a scientific method, just as rigorous as those in the physical sciences, that does not rely on averaging across individuals. How can we use a single subject as the basis of a science? How can we make statements about individuals that are always quantitative but not statistical? Again this book offers the answers. Marken explains the test for the controlled variable and the method of modeling, tools that can be applied to individuals—and actually predict the details of the individual's behavior with great accuracy. I believe the experiments that Marken describes here are similar to the experiments using pulleys and inclined planes from the early days of physics. In the future they will become standard classroom demonstrations in a psychology laboratory course.

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One day, I hope in the not too distant future, the methods introduced here will become standard practice in experimental psychology. Future readers will look upon everything described in the papers herein as obvious and correct, perhaps even with the boredom that school children today associate with balls rolling down inclined planes. But future generations might not remember how such work was accomplished or the price paid for independent thinking. What might not be apparent to them is a story of courage. For although it is only natural for the current generation to accept that the earth is round, it was not always so.

Imagination is needed to appreciate the courage needed to say that the earth is round for the first time, when all around you say it is flat. It is with such courage that Marken has produced the work included in this book, laboring in obscurity and against the prevailing dogma of our time. Future generations will face new challenges, and once in a while courage will again be required to defy the compact majority. On such occasions, I hope some will also find inspiration in the remarkable intellectual journey documented in this book.

Henry Yin
Duke University
December, 2013

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Introduction

The title of this book refers to the somewhat paradoxical situation of the experimental psychologist. Such psychologists are living organisms who have the purpose of studying the behavior of other living organisms whose behavior is as purposeful as their own. They are "doing research on purpose" in both senses of that phrase; purposefully doing research on behavior that is purposeful. Yet experimental psychologists have carried out their research purposes as though the behavior they study is not as purposeful as their own. Indeed, experimental research in psychology is based on a model that assumes that behavior has causes but no purposes; the apparent purposefulness of behavior is either ignored or treated as an illusion.

But the behavior of organisms is, indeed, purposeful, a fact that many experimental psychologists claim to be aware of even though their approach to research suggests otherwise. The feeling among these psychologists seems to be that simply being aware of the purposeful nature of behavior is a sufficient basis for saying that one is taking purpose into account in one's research. This book can be considered a rebuttal to this point of view. The papers collected together here have one central theme: It is not enough to simply be aware of the purposeful nature of behavior in order to properly do research on purpose; one also has to know what purposeful behavior is and how it works. Once this is known, research on purpose will be done in a way that is rather different than the way most research in experimental psychology is currently done. In particular, the focus of research will be on determining the purposes rather than the causes of the behavior under study.

A scientifically rigorous description of what purposeful behavior is and how it works was given by William T. Powers in his classic book *Behavior: The Control of Perception* (Powers, 1973). Powers makes a convincing case for viewing purposeful behavior as equivalent to the phenomenon of control since both involve the production of intended (goal) results in the face of unpredictable (and often undetectable) disturbances. Powers goes on to show how control theory – the theory of how control works – can be used to explain how purposeful behavior works. When applied to the purposeful behavior of living organisms, control theory has come to be called Perceptual Control Theory (PCT) to emphasize the fact that what living organisms control is their perceptual input, not their behavioral output.

Powers discussed the implications of PCT for experimental psychology in only one short chapter of *Behavior: The Control of Perception*. He later published a more detailed discussion of the topic in *Psychological Review* (Powers, 1978), a journal that was (and probably still is) regarded as the premier journal of scientific psychology. It was this article that sparked my own interest in the experimental study of purpose and led me to do the research that is described in the papers collected in this book. Thus, this book can be considered an elaboration of the main argument of that *Psychological Review* article: that an understanding of purposeful behavior as a process of control requires a new approach to doing experimental research in psychology.

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Control Theory Psychology

The first section of the book contains two papers that describe the PCT approach to understanding purposeful behavior. The first, *Looking at Behavior through Control Theory Glasses*, describes the control theory view of purposeful behavior as a process of control. It gives several examples of behavior that demonstrate what control is and how it can be seen in the behavior of living organisms.

The second paper in this section, *Taking Purpose into Account in Experimental Psychology*, gives a fairly detailed description of the PCT model of control (purposeful behavior) as it applies to experimental psychology and introduces the central concept of this model: the *controlled variable*. A controlled variable is a perceptual aspect of the environment that the behaving system is acting to bring to a pre-selected or goal state. Controlled variables are the attributes of behavior that are missed by approaches to research that ignore purpose. But they are the central focus of research based on PCT: research on purpose.

Looking for the Purpose of Behavior

The papers in the next section of the book describe the basic methodology used to study purpose as control. This methodology, called the Test for the Controlled Variable or TCV, is aimed at determining the perceptual aspects of the environment – the controlled variables – around which purposeful behavior is organized. The first paper in this section, *Making Inferences About Intention:*

Perceptual Control Theory as a "Theory of Mind" For Psychologists, describes the basic logic of the TCV and an experimental approach to carrying it out.

The next paper in this section, *Testing for Controlled Variables: A Model-Based Approach to Determining the Perceptual Basis of Behavior*, describes an approach to doing the TCV that is based on the use of computer simulations – models – to evaluate the results of experimental studies of purpose when the identification of controlled variables cannot be made using experimental manipulations alone.

The last paper in this section, *Optical Trajectories and the Informational Basis of Fly Ball Catching*, shows how the TCV can be used to determine the controlled variables around which a more "ecologically valid" behavior – object interception, in the form of catching fly balls – is organized.

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Illusions and Confusions

Perhaps the main reason experimental psychologists have felt comfortable doing research in a way that ignores purpose is because this kind of research seems to work. In a successful psychology experiment, variations in the experimental conditions – the independent variable – appear to cause concomitant variations in behavior – the dependent variable. Results like these provide what appears to be convincing evidence that behavior is ultimately caused by the circumstances in which it occurs; purpose does not seem to be involved at all. The PCT model of purposeful behavior suggests that the apparent causal relationship between circumstance (independent variable) and behavior (dependent variable) seen in psychological experiments is likely an illusion (Powers, 1973a). The nature of this illusion, what Powers called the *behavioral illusion*, is explained in the next section of the book.

The first paper in this section, *The Illusion of No Control: A Perceptual Bias in Psychological Research*, explains the nature of the behavioral illusion and why it occurs. The illusion is that behavior is caused; that there is no purpose (no control) involved. It results from paying attention to only one aspect of control – the actions (dependent variables) that protect controlled variables from disturbances (independent variables) – while ignoring the controlled variables themselves.

The next paper in this section, *The Power Law: An Example of a Behavioral Illusion?*, describes a quantitative example of one aspect of the behavioral illusion; the fact that, in a control system, the form of the function relating independent to dependent variable reflects characteristics of the feedback connection between an organism's output and its input rather than characteristics of the organism itself.

The last paper in this section, *Control Theory for Whom*, is a review of a book that describes a control theory-based approach to understanding behavior yet succumbs to the illusion that purposeful (control) behavior can be studied by looking for causal relationships between independent and dependent variables.

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A Methodological Revolution.

Clearly, PCT represents a very new approach to experimental psychology. Some would say it is revolutionary. But unlike previous revolutions in psychology – and there have been several, the latest having been the so-called "cognitive revolution" – the PCT revolution requires not only a new way of understanding behavior but also a new way of studying it. PCT implies that there must be a methodological as well as a theoretical revolution in psychology if the nature of purposeful behavior is to be properly understood. This is the subject of the two papers in the next section of the book.

The first paper in this section, *You Say You Had a Revolution: Methodological Foundations of Closed-Loop Psychology*, discusses why PCT requires a new approach to psychological research. It also discusses the difficulties this has presented for the development of a science of purposeful behavior based on PCT. These difficulties stem mainly from the existence of the huge edifice that is the scientific psychology "establishment" consisting of the textbooks, curricula and intellectual capital which support an approach to studying behavior that ignores its purpose. Tearing down and rebuilding this edifice will not happen overnight but this paper suggests steps that might be taken to start the process.

The other paper in this section, *Methods, Models and Revolutions*, is a comment on an article that described an analytical revolution that was occurring in psychology. My reply simply makes the distinction between an analytical revolution, which doesn't change the way psychological research is done, and a methodological one, which does. And, again, I argue that what psychology needs is a methodological as well as an analytical (theoretical) revolution in order to approach the study of purposeful behavior properly.

The Future of Experimental Psychology

In the final section of the book I allow myself to muse about what experimental psychology might look like once the accepted view is that behavior is purposeful and that the aim of research in psychology is to understand how purposeful behavior works. The paper, *Looking Back over the Next Fifty Years of Perceptual Control Theory*, was presented at a Festschrift for Bill Powers on the thirtieth anniversary of the publication of *Behavior: The Control of Perception*. It was based on the pessimistic assumption that it could take another fifty years until the PCT view of behavior becomes the default view of the nature of behavior and how it works. Ten years have passed since I presented that paper and in that time there have been many positive developments in PCT science – the science of purposeful behavior – not least of which is the addition to the PCT "team" of several very competent young researchers. So I now have hope that it will be considerably less than 40 years until there is a critical mass of experimental psychologists who are "Doing research on purpose".

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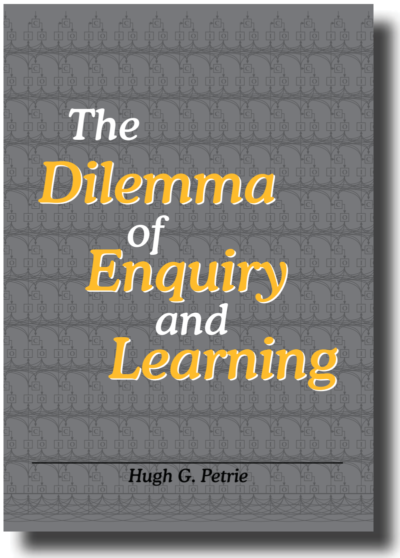
The Dilemma of Enquiry and Learning



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By Hugh G. Petrie

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Enjoy! ➡ Conclusion

8. Conclusion

This work began with the question "How are enquiry and learning possible?" The answer I have given is that it is only if we focus on the processes of learning and coming to know rather than on the products of learning or knowledge structures will we be able to answer this question. This means that much more emphasis must be placed on processes of knowing than on structures of knowledge. In a fundamental sense, we need to know more about how people reasonably change their knowledge structures than we need to know about what those knowledge structures look like at any given time. A static snapshot of a knowledge structure in the process of transition is useful primarily for what it can tell us about the transition and not so much for what it can tell us about the structure. I think this emphasis on knowledge processes is useful for epistemology in general, but it is absolutely crucial for educational epistemology.

Once the shift is made to focusing on knowledge processes rather than knowledge structures, an interesting picture emerges. There are two quite different types of knowledge processes corresponding to the two horns of the *Meno* dilemma. The knowledge process that adds to and fleshes out an existing conceptual framework I have called assimilation. Those who would grasp the old-knowledge horn of the *Meno* dilemma tend to try to assimilate all coming to know to elaboration of existing conceptual schemes. On the other hand there is the knowledge process that involves changing our conceptual schemes. The knowledge process that changes our existing conceptual framework I have called accommodation. Those who would grasp the new-knowledge horn of the *Meno* dilemma tend to try to assimilate all coming to know to changes in conceptual schemes. Neither approach tells the whole story, and what I have been urging throughout this book is that learning and enquiry are possible only by attaining a reflective equilibrium between assimilation and accommodation.

These two knowledge processes are not well recognized in current educational thought. Still less recognized is the necessity for dealing with them simultaneously, i.e., for slipping between the horns of the *Meno* dilemma. What educators must begin to do is ask what knowledge process is of concern in any given situation. The answer may well dictate quite different educational practices and policies. If the process is assimilation, there still remains the necessity for understanding the ways in which experience is processed by existing knowledge structures. A great deal of adaptiveness can be found simply in how we deal with situations which are similar to but never quite the same as

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situations we have dealt with before. Behaviorism seems bankrupt in this regard. Control system theory looks promising, especially in that it gives a radically new view of how to test for learning. Look not at the outputs of the student but at what disturbances to inputs the student resists. If, on the other hand, the process of concern is accommodation, the problem becomes one of how we rationally change our cognitive structures to account for recalcitrant experience. Here I have urged a much greater reliance on variation and selective retention processes. From the student's point of view it will be logically impossible in cases of accommodation to specify in advance in terms intelligible to the student what it is that is to be learned. Rather we must concentrate on getting the students to try out knowledge variants which have as their sources the students' current knowledge structures and arrange the educational ecology so that the reflective equilibrium the student reaches is roughly what is required by our collective understanding. The autonomy of the students' reason is necessarily respected in this approach, for it is the student's equilibrium which will control the knowledge processes of that student.

The problem in educational thought is that this reflective equilibrium is seldom maintained, and the educational pendulum oscillates wildly between new- and old-knowledge approaches. Not so many years ago, we were inundated with cries for the reform of dull, drab, irrelevant schooling. The curriculum of the schools was outmoded and uninspiring; we were told that we needed to open up our schools and classrooms and allow far more student participation. I have no doubt that this reform movement was reacting appropriately to schools and schooling that seemed to deny that conceptual structures were ever rationally alterable. In our time, however, the reform is "back to the basics." I have no doubt that this movement is reacting appropriately to excesses of open schools that seem to deny that the human race has collectively learned something of value that should be passed on to our children.

But neither the new- nor the old-knowledge horn of the *Meno* dilemma can be grasped to the exclusion of the other. I confidently predict, that the "back to the basics" movement will effectively deny that concepts do change and will ultimately be challenged for its inability to integrate conceptual change with the movement's emphasis on conceptual continuity. Not until we recognize the necessity for a reflective equilibrium between assimilation and accommodation will education avoid impaling itself first on one and then on the other horn of the *Meno* dilemma.

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An unfriendly critic might accuse me of having said nothing new about learning and enquiry. Indeed, we knew all along that the *Meno* dilemma was solvable—we see it solved every day as people learn new things all around us. It might also be said that I have not really added anything to our knowledge except perhaps some technical jargon we could easily do without. Surely we have always known that we must start with the student's current cognitive state, that new conceptual structures are occasionally necessary, that rule-governed activity is central to education, that trial-and-error learning does sometimes take place, and even, perhaps, that there is such a phenomenon as conceptual change.

One might raise such an objection, but to do so would be to miss the central point of this work. And that is that we do manage to move, collectively and individually, from current knowledge and ways of knowing to new knowledge and ways of knowing, and it is that movement which must be of central concern to education. Of course I have utilized what is already known about learning and ways of knowing. One must not deny the old-knowledge horn of the *Meno* dilemma. But neither have I simply summarized what we already know. I have pointed to some new and different directions; I have suggested a new conceptualization, if you will, for understanding how our existing knowledge and ways of knowing can and do change. The ideas presented here have implications for future study and research in education which are significantly different from the directions of much current educational thought. In that sense this book is at least a sketch of a new educational theory.

The central thrust of that theory can be seen by returning to the *Meno* itself. Most scholars have focused on Plato's theory of recollection as his intellectual answer to the *Meno* dilemma. Such a focus presupposes that knowledge *structures* are the chief area of concern. What has recently been done in the context of Platonic scholarship has been to look at the *activity* that the dilemma engendered in the dialogue, namely, the active searching for and trying out of knowledge variants (see, for example, Sternfeld and Zyskind, 1978). The theory of recollection is followed in the *Meno* by Socrates' active demonstration of its truth with the experiment with the slave boy. The Socratic method as exemplified within the experiment with the slave boy itself makes essential use of the *activities* of the slave boy in propounding new ideas, correcting them, and iterating the process. As Klein (1965, p. 172) anticipated, "It is *the action of learning* which conveys the truth about it. The answer to the question about the possibility of learning is not a 'theory of knowledge' or an 'epistemology' but the very *effort* to learn."

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Near the end of the *Meno* Plato says (98A):

> True opinions are a fine thing and do all sorts of good so long as they stay in their place; but they will not stay long. They run away from man's mind, so they are not worth much until you tether them by working out the reason. Once they are tied down, they become knowledge, and are stable. That is why knowledge is something more valuable than right opinion. What distinguishes one from the other is the tether.

This book has attempted to work out the tether for a new theory of education. It is a tether that requires us to alternate in a constantly adaptive way between what we already know and what we do not yet know. It requires us to act in the world as well as think about it, and in that way we shall be able at last to step between the horns of the *Meno* dilemma of enquiry and learning.

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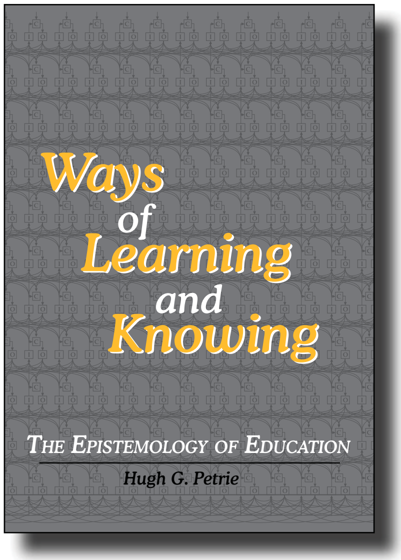
Ways of Learning and Knowing
The Epistemology of Education



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By Hugh G. Petrie

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Preface

I have spent my entire professional life as a philosopher, philosopher of education, and educational administrator fascinated by the questions of how we learn and how we know what we learn. My attempt at putting my views on these subjects into a coherent whole is my book, *The Dilemma of Enquiry and Learning* (1981) Chicago: University of Chicago Press; revised and expanded (2011) Hayward, CA: Living Control Systems Publishing. However, as Dag Forssell, the editor of Living Control Systems Publishing, was putting out the revision of that book, he commented that there were quite a few of my articles and book chapters over the years that had both prefigured the book and later expanded in more detail on a number of its themes. He suggested that we put together an anthology of those articles and chapters and this volume is the result.

This anthology begins with my intellectual autobiography where I trace my path from a small town high school student through my higher education and on to my first position as a philosopher at Northwestern University. It was there that I met the two most important influences in my professional life. Donald Campbell taught me to appreciate and embrace evolutionary epistemology and William T. Powers taught me the revolutionary psychological theory that behavior is the control of perception, not the other way around. Those two influences profoundly permeated the rest of my professional life.

Even before these two influences had fully informed my thinking, I wrote *Why has Learning Theory Failed to Teach us How to Learn.* I there criticized behavioral psychologists for being unable to communicate their stimulus-response theories to educators who firmly believe that we do act to achieve our goals—an insight later beautifully explicated with the aid of perceptual control theory.

In *Theories are Tested by Observing the Facts—Or Are They?* I argued for the then emerging thesis of the theory-dependency of observation which has since become a staple of epistemology. I was also already

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anticipating the perceptual control theory insight that the same action, e.g., driving to work, or getting the food in a rat's puzzle box, could be accomplished in an indefinite number of ways with an indefinite array of muscle movements, etc. Behavior is the control of perception. We try to maintain our perceptions in the state we want to see and this can be accomplished in a dizzying array of environments.

Action, Perception, and Education is my first short attempt to explain perceptual control theory to educators. The main problem with any abbreviated attempt to explain perceptual control theory is that, as Kuhn has pointed out so well in The Structure of Scientific Revolutions, people resist scientific revolutions as hard as they can and stubbornly continue to try to explain the new paradigm in terms of their old familiar paradigms. So it is with perceptual control theory. One really has to study it at length with an open mind in order to appreciate its real revolutionary appeal.

In many of my writings, I had a penchant for catchy titles. This is evident in *Can Education Find Its Lost Objectives Under the Street Lamp of Behaviorism.* The continuing critique of behaviorism to be found there is part of the groundwork for looking elsewhere for a coherent theory of human behavior. Since behaviorism is as totally incoherent as its critics argue, it should be easier to understand and accept perceptual control theory.

As I was thinking through the implications of evolutionary epistemology and perceptual control theory, I was privileged to participate in an interdisciplinary faculty seminar at the University of Illinois examining the role of the social sciences and humanities in an engineering curriculum. I found a number of my ideas, especially the theory-dependency of observation to be clearly relevant to my experience in that seminar and *Do You See What I See? The Epistemology of Interdisciplinary Inquiry* was the result. In perceptual control theory the test for whether someone is perceiving something is to introduce a disturbance and see if it is counteracted. Thus there is a test for when someone has learned the observational and theoretical categories of a new discipline.

Given that observation and understanding are dependent on a given conceptual scheme, how is it that we can ever learn anything new; for we must always start with what we have? In *Metaphorical Models of Mastery: Or, How to Learn to Do the Problems at the End of*

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the Chapter of the Physics Textbook I sketched an early answer to the complete treatment I gave in *The Dilemma of Enquiry and Learning*. Metaphors and concrete examples allow us to bridge the gap between what we currently believe and the new material we are to learn.

In *A Rule by Any Other Name is a Control System* I examined the ubiquitous concept of "rules" in a variety of psychological theorizing. I argued that even behavior in accordance with so-called "descriptive" rules presupposes norms and require judgments as to the appropriateness of the norm. I then showed how an analysis of rule-following behavior using perceptual control theory meets all of the criteria for norm-regarding behavior in a completely transparent way.

Evolutionary Rationality: Or Can Learning Theory Survive in the Jungle of Conceptual Change? prefigured the use of evolutionary epistemology to account for conceptual change in my book, *The Dilemma of Enquiry and Learning*. I used the central idea of blind (not random) variation and selective retention to show how concepts can rationally change. This change occurs both in the growth of knowledge generally and in the growth of knowledge for individual students.

The *Metaphor and Learning* chapter by Petrie and Oshlag is a revision of the original chapter by Petrie which appeared in A. Ortony (1979). (Editor). Metaphor and Thought, First Edition. Cambridge. Cambridge University Press. It is the most extended of my treatments of metaphor as the key bridge accounting for rational change between conceptual schemes in the growth of knowledge, both in science and for individuals. Thus metaphors are not only useful in the educational process, they are epistemologically necessary.

The use of traditional paper and pencil tests in education is as ubiquitous as it is mostly misguided. I argued this point at length in *Against Objective Tests: A Note on the Epistemology Underlying Current Testing Dogma*. I showed that the "objectivity" obtained through interpersonal agreement, e.g., machine scoring, both limits what we can learn about what someone knows about a subject, and falsely leads one to believe that "subjective" tests, e.g., interviews, are somehow biased. Analyzing testing through the lens of perceptual control theory shows how interviews and other "subjective" tests often are the most reliable indicators of what someone knows. Introduce a disturbance to an hypothesized controlled variable and see if it is counteracted.

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In my presidential address to the Philosophy of Education Society, *Testing for Critical Thinking,* I elaborated on the perceptual control theory analysis of finding out what someone knows and can do. Again the key is to introduce a disturbance to an hypothesized controlled variable and see if it is corrected. The doctoral oral is a paradigm example of how one can apply this notion and follow it up with additional probes and disturbances to determine if the candidate really can think critically.

In 1992 I updated my earlier work on interdisciplinary education in *Interdisciplinary Education: Are We Faced With Insurmountable Opportunities?* I considered the "disciplinary paradox"—the idea that the fragmentation of knowledge into disciplines calls for an interdisciplinary approach, but can only receive epistemic justification from the established disciplines. This paradox is a close relative to the Meno dilemma I dealt with in *The Dilemma of Enquiry and Learning*. And the solution is similar. Once one recognizes that knowledge is both theoretical and practical, attention to thought and action as justification allows one to avoid the paradox. Both disciplinary and interdisciplinary knowledge are justified because they allow us to pursue our human purposes in an ever-changing, but broadly stable, world.

By the time I wrote *Knowledge, Practice, and Judgment* I was increasingly utilizing my epistemological insights in the service of educational policy analysis. In this piece I criticized the notion that teachers should "apply" research to practice. The argument is the familiar one that the theories and categories of the researcher are largely incompatible with the concepts and perceptual categories of the teacher. The concept of professional judgment, on the contrary, allows for the fact that teachers can and do adapt their knowledge and action to constantly changing situations to further their goals.

I continued the emphasis on educational policy in *A New Paradigm for Practical Research.* I elaborated on how perceptual control theory with its insistence that behavior is the control of perceptions provides a real underlying model of how human action works. It provides a physically plausible explanation both for the consistency of outcomes of human action and the variability of means utilized to achieve those outcomes in a constantly changing environment. I urged that the then emerging concept of professional development schools provides the perfect real world laboratory for research using a perceptual control theory model of human behavior.

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Finally, in *Purpose, Context, and Synthesis: Can We Avoid Relativism* I commented on several articles by evaluators worrying about the validity of evaluations that take into account the purpose of the evaluation and its context. Once again with a perceptual control theory model of evaluation, these concerns disappear. By sensing the various nuances of context, we are in effect comparing the actual context with our concept of that which is being evaluated and we need not know in advance what the context might be. We need only describe the extent to which the actual situation meets or fails to meet the reference concept in order to make warranted evaluative judgments.

Hugh Petrie
Tucson, Arizona, 2012

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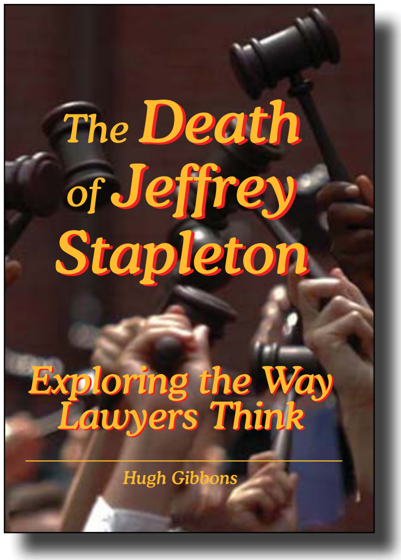
The Death of Jeffrey Stapleton:
Exploring the Way Lawyers Think



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By Hugh Gibbons

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Preface

Introduction to the 2013 edition

Law is the institution that is based upon the assumption that human beings are responsible for their own behavior and the effect of their behavior on others. Perceptual Control Theory, PCT, is the science that explains what behavior is and how it works. The relationship between law and PCT is that simple.

In this volume I will use a tragedy—the death of a musical prodigy at the hands of a reckless driver—to explore the way our minds work when we "think legally." All of us think legally many times each day, often so automatically that we are largely unaware of it: Who was responsible for the breakup of a family, the collapse of a corporation, the failure to investigate a crime? When is it permissible to use force, to lie to achieve our ends, to take credit for another's work, to download something from the internet without permission? These questions roll through our minds with little effort, and the answers to them shape how we think about our behavior.

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To get a sense of our thinking, I will slow it down, hopefully not to the point of tedium. From four decades of teaching law to students from a great many other countries, as well as my own, I'm quite confident that our thinking will be very similar regardless of where we've come from. When we've resolved the case, I will turn to PCT for a theoretical account of our thinking, which I will present in words and diagrams.

Let me give a quick illustration. One of the classic mysteries of law is the fact that it requires jurors and judges to make an assessment of the inner state of the defendant's mind: How on earth is one person ever to know what's going on in another's mind? Every interesting legal question requires us to do that. Consider the firefighter who is crushed by a person falling out of a building. The firefighter's estate might bring suit against the estate of the falling man, which instantly raises a question about why the man fell. Did he leap to his death to commit suicide, failing to check out the area where his body would land? Or was the building on fire and he leaped out in a desperate attempt to avoid the heat? Or was he thrown off the roof of the building by someone who intended him ill? Or was there a longstanding conflict between him and the firefighter?

The answer to those questions will let the jury determine the mental state of the defendant. The jury will have no way to determine it with certainty, but certainty is not required. They will debate the issue, reevaluate the evidence, and finally get "comfortable" with one assessment of the defendant's inner state or another. In a truly difficult case, there may not be enough evidence to allow them to get comfortable with any assessment, but those are rare.

Perceptual Control Theory gives us a framework for explaining where purposive behavior comes from (for example, from a desire to enter a world in which there is no fire at one's back), thereby explaining the way that law works. PCT explains a lot more, from the mechanics of controlling an automobile to understanding what happens to a person whose purposive powers have disintegrated due to an addiction. Here, we will satisfy ourselves with an understanding of the way we think through a legal problem.

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Chapter Seven

The control system model

We have resolved Jeffrey's case. The question now is, How did we do it? What was going on in our minds as we evaluated the facts of the case, made inferences about what had happened, and applied law to the case as we came to understand it?

Why do we need to understand how we did it? Is it not enough to realize that we did do it? Legal thinking is just something that we humans are good at. Why not leave it at that? There are many good reasons to understand the way we think, but I will mention only one: As you thought through the case you made a number of mistakes. You ignored facts that later proved to be crucial; you misunderstood some of the norms that applied to the case; you got confused on some points, many of which are may still be a bit of a muddle in your mind.

Papers

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Legal thinking is something that we are good at doing badly. Legal thinking comes naturally, all right, but it is not something that we naturally do well. Biases distort what we see; emotions intrude upon the way we feel about the parties to the case; short term memory fails us as we lose track of loose ends; laziness prevents us from looking deeply enough into the law. If we understand what "bias" and "laziness" are, if we understand the way that emotions affect our thinking, perhaps we will be aware of them, more able to spot their effects and avoid them.

Whatever our minds were doing as we thought through Jeffrey's case, it is clear that that thinking took place in our brains. To fully understand our thinking we would have to describe what is going on in our brains. What is an *inference* in terms of brain activity? When we say that we "inferred" that Timothy dropped his keys in the street, what neuronal activity was entailed in that thought?

It is not possible to explain thinking in terms of brain activity. During each minute that we thought about the case many, many billions of neurons fired off in our brain. Most of them had nothing to do with thinking about the case. Some controlled our heart beat, others our body temperature and breathing. We are many decades, perhaps centuries, away from understanding what all that brain activity does, let alone how something as simple as an inference is actually done in biological terms.

To explain thinking we must simplify the problem by modeling thinking with abstractions. A model railroad, for example, is very different from a real railroad. Missing are the dirt that coats everything in a real railroad, the sheer size and weight of the cars and engines, the thrill of traveling over the countryside. What is left in the model is the part that the one who builds the model finds *interesting*—the tracks and switches and cars running through a make-believe countryside.

The aspect of legal thinking that I think is interesting is the *organization* of legal thinking. I cannot account for the *content* of legal thinking, for the feelings that you have for the parties or for the decisions that you made. It seems to me that we all differ in those feelings and values, and differ in a way that I cannot account for. But we are similar in the way our thinking is organized. We organize data about a case into things that we call "facts." We draw "inferences" from the facts. We base our decisions on those inferences and adduce "reasons" to support our conclusions.

Legal thinking is systematic. That is to say that, whatever the flow of thoughts actually going through the lawyer's head, those ideas fall into regular patterns. It is that fact that allowed you to understand what I was talking about as we went through Jeffrey's case. My thinking, however different from yours, fell into patterns that you could "understand." It is those patterns that this model of legal thinking will account for.

To say that legal thinking is systematic implies that it evinces the properties of a "system." A system is a set of things that are *causally related.* Your hand is a system that translates physical tension on the tendons that connect it to the muscles in your arm into the movements of gripping, holding, and letting go. Your hand moves systematically, which is to say that tension on a tendon produces coordinated movement in a bone and in the skin that is connect to it. Were the first joint on your index finger to move in a different direction from the second joint, you would be rightfully distressed, for that is not a permitted movement of the hand system.

Papers

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Your thinking is similarly systematic, though like your hand it can break down. If you feel, for example, that Timothy did nothing to cause Jeffrey's death, it would be a violation of your mental system if you concluded that he should nonetheless be made to pay for it. Ideas, in this case the idea that a person is only responsible for that which he causes, exert a pull on your thinking just as the muscles in your forearm exert a tension upon the bones of your hand. Those ideas *cause your* behavior. In this case, presumably, that behavior would be a verbal statement to the effect that, "I don't think that Timothy should have to pay damages to Jeffrey's estate."

Modeling thought, however, will require a more complex system model than the one that would model your hand. Your hand is a mechanical device. It could be modeled with a physical model that showed how physical tensions on tendons caused changes in the position of the bones. Where your hand *accepts* control from the rest of your body, your mind *exerts* control on the rest of your body. To account for that we will have to model your mind as a *control system,* a system that exerts control over things like hands. The control system model that I will use is the work of William Powers. See References: Powers (1973). For tutorials and models you can run on your Windows computer, see Powers (2008).

To get a sense of how Powers' control system model works, try a little experiment. Put your right hand palm down on a flat surface with your fingers close together. Now move your index finger to the left until the tip of the finger is an inch away from your middle finger. Try it.

What is going on in that experiment? The movement of your hand and finger were controlled by the muscles in your forearm. Those muscles, in turn, were controlled by signals from your brain. You were not conscious of those signals, which is very fortunate, for it took many thousands of nerve signals to move your hand and finger. If you were aware of them, your mind would have been so flooded with information that you would have lost track of my instructions. What you were conscious of was my instructions, which established a *desire* in your mind to move your index finger until it was an inch away from your middle finger. My instructions created a desire in your mind, which generated without conscious effort the signals necessary to carry out that desire.

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Powers' model explains thought and behavior as a system that translates desires into actions; that is what is meant by "control." Your mind controlled the behavior of your hand to bring it into alignment with the standard that I established, namely, that the tip of your index finger be an inch from your middle finger. That standard exerted what I called in Part I a "tension" on your mind, a sense that there was something that needed to be done. Your behavior eliminated that tension. Or did it? How close did you come to the standard? You might want to do the experiment again, this time with a ruler in your left hand so that you can check to see how close you actually come to a one inch separation.

Legal thought and behavior are a good deal more complicated than that involved in the hand movement experiment. In Part II I intend to explain what was going through our minds as we thought through Jeffrey's case in Part I. Our thinking in that case will serve as the experience that I will attempt to explain. First, however, we must place legal thinking within the context of thinking in general. Legal thinking, as you have seen is pretty much like any other kind of thinking. To see how it differs, we must first gain a sense of what it differs from. That is the text of the next three chapters. In Chapter 10 we will apply Powers' model of thinking to our own experience of Jeffrey's case.

Understanding thermostats

To get a grip on the control system model we will begin by considering a control system —the home thermostat—that is a good deal simpler than our minds. Understanding how it works will give us a sufficient understanding of control system theory to get on with the job of understanding legal thought.

If you were to pop the cover off of the thermostat in your home you might see something that looks like this:

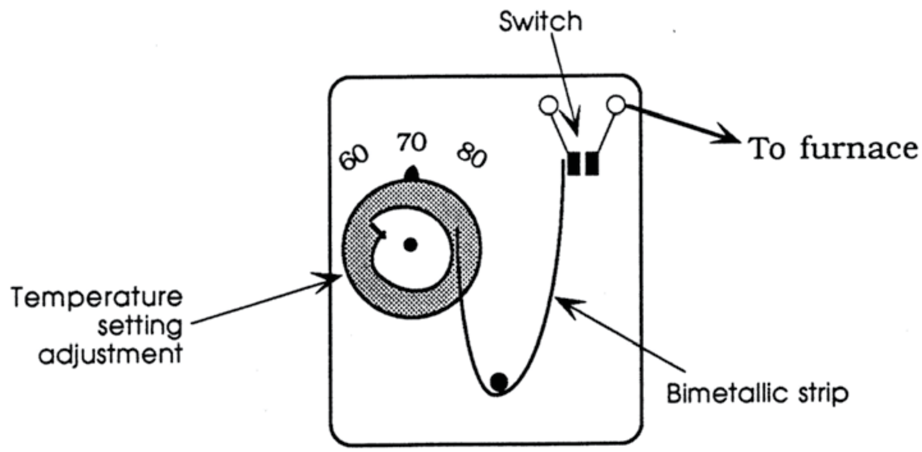

Figure 7.1. The innards of a home thermostat.

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There are several types of thermostats, but the type shown here is quite common. You set the temperature by rotating the knob on the left to the temperature that you desire. That applies a pressure to the left end of the bimetallic strip that is proportional to the temperature that you have set (the higher the temperature, the greater the pressure on the strip).

The other end of the bimetallic strip pushes against a spring-loaded switch. When it pushes against the switch with enough force to overcome the spring, the contacts on the switch close, sending a signal to the furnace which tells the furnace to deliver heat.

The bimetallic strip is the active component of the thermostat. It is made up of two strips of metal that are bonded together (hence, “bimetallic”). Each of the strips expands at a different rate when it is heated, which means that as the strip changes temperature it bends. In Figure 7.1, the right end of the strip bends to the right as it cools, exerting greater pressure on the switch, until the pressure is great enough to close the switch. As the temperature of the room rises, the bimetallic strip warms up and the right end of the strip bends to the left, relaxing the pressure on the switch and allowing it to open when the temperature of the room reaches the level set on the adjustment wheel, thereby shutting off the furnace.

As simple as it is, the thermostat illustrates all of the functions of a control system. Those functions can be diagrammed in this way:

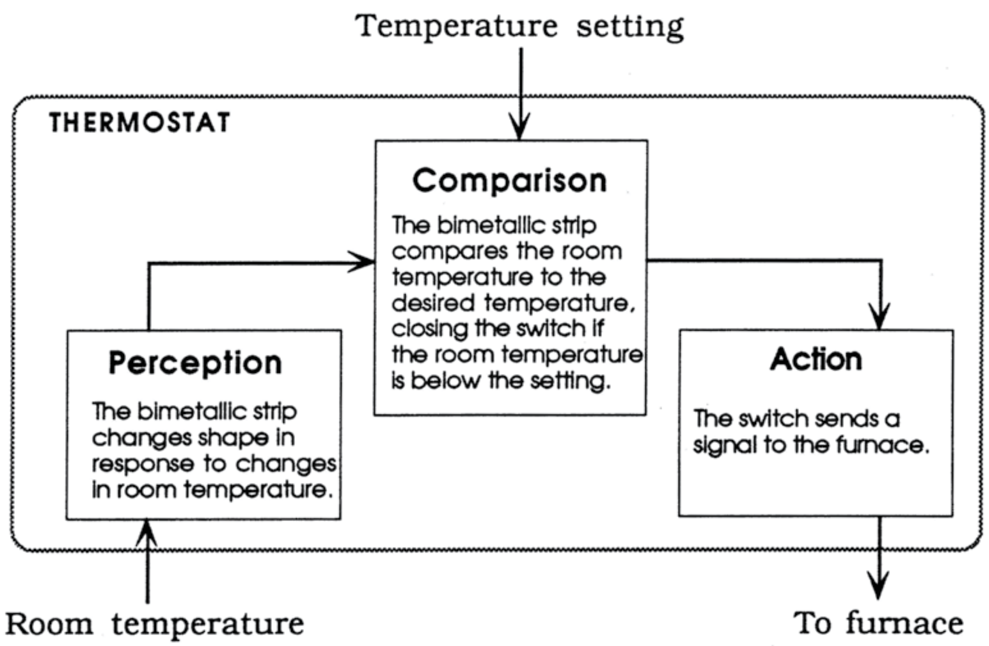

Figure 7.2. A functional diagram of the working of the thermostat.

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The thermostat takes in two types of information from its environment: the temperature of the room, which it senses through the bimetallic strip, and the desired temperature setting, which it registers on the adjustment wheel. It compares those two values, and if the room temperature is below the level set on the adjustment wheel it closes the switch, sending current to the furnace. The switch stays dosed until the room temperature rises enough to bend the bimetallic strip to the left, relaxing the pressure on the switch and letting the contacts on the switch open.

Notice that the thing that animates the thermostat is its detection of a difference between the temperature setting and the room temperature. In control system theory that difference is called an "error." If the room temperature is different from the temperature that has been set, the room temperature is in "error," and the control system acts to eliminate that error by telling the furnace to generate more heat.

Notice also that the action of the control system is quite dumb—all it does is tell the furnace to turn on or to turn off. It does not tell the furnace how long to burn or how much heat to deliver. It just tells the furnace to turn on, and, when the room temperature has reached the desired temperature, to turn off. It is quite a simple mechanism, but in that simplicity resides its power.

A control system is a "negative feedback" system. Its action, turning on the furnace, generates a response—a rise in room temperature—which it in turn perceives. The perception of its own actions is called "feedback." If that feedback reveals a level of temperature that departs materially from the desired temperature, an error signal is generated, hence the term "negative." The error, when sufficiently strong, drives the action, which acts to eliminate the error.

Figure 7.2 is a functional diagram of a control system. A functional diagram describes the functions of the system—the way that it acts—in the abstract. The actual system can be *implemented* in a variety of ways. The thermostat pictured in Figure 7.1, for instance, is just one implementation of a thermostat. In other thermostats a mercury switch is used instead of the spring-loaded mechanical switch in Figure 7.1, or a tube of temperature-sensitive liquid is used instead of the bimetallic strip. However they are implemented, all thermostats are functionally equivalent; they all perform the functions diagramed in Figure 7.2.

I will use functional diagrams like the one in Figure 7.2 to describe the inner working of human thought. I am suggesting that human thought is a lot like a thermostat. If that seems inherently unlikely, even insulting, pause for a moment to consider what you are doing at this instant. You are reading this line of text. To do that, your neck and eye muscles must move, pointing your eyes ever rightward on this line of text, until you get to the end of the line and must return to the left. How do you make them do that?

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You don't actually *make* them do that in any conscious sense, do you? (There *are* people who must consciously make themselves do it and use their finger as a guide to their eyes.) All you know is that you have a desire to read the text—you *want* to read it. Everything else follows unconsciously from that. I am suggesting that your desire to read this text is, in a sense, like the temperature setting on the thermostat. Once you have set that desire (that is, once you have decided to read this line, rather than closing the book and getting on with something else), a process very much like the thermostat takes over and issues commands to your neck and eye muscles (as well as to your eyes and to your hands, if you are holding the book) to carry out your desire.

Occasionally your neck and eye muscles make a mistake. They may make your eye skip some words, or skip a line of text. That may generate an error signal—at that point you become aware that your eye controllers have made a mistake and act at a higher, conscious level to rectify it. Your perception that you have skipped a line generates an error signal ("Woops, where am I?"), which you rectify by finding the correct line of text. I can let you feel what that where am I?"), which you rectify by finding the correct line of text. I can let you feel what that is like by duplicating the line of text above. That messes up your eye control system, creating an error and forcing you to take conscious control to get back on track.

Tricks like the one I just played on you are irritating. Your first perception was probably that the printer had made a mistake. Then you realized that I had repeated the line on purpose to demonstrate what an en¯or signal feels like.

You are now operating under the control of the purpose of reading this book. You can change that purpose, for example, by deciding to "skim" the book, rather than reading it thoroughly. Do that right now. Tell your eyes to skim the balance of this paragraph. (Then reread it to see what you missed.) Changing your desire from a desire to read the text to a desire to skim the text is like a change in the setting on the thermostat. It changes the commands that your brain sends to your neck and eye muscles, causing them to jump greater distances between the chunks of text that your eye focuses upon.

There are several important differences between a human and a thermostat which require us to further develop the general control system model described in Figure 7.2. The first difference lies in the fact that a thermostat cannot generate its own desires, while a human can. Notice that in Figure 7.2 the *value* of the temperature setting comes from outside the thermostat, from the setting put on it by a person. Humans have their own values, their own purposes, desires, norms, standards, aspirations. They are self-animated in a way that a thermostat cannot be. That requires an addition to the control system model.

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Making lemonade

In his seminal work on control system theory William Powers used an illustration which in its sheer simplicity and homeliness conveys the main idea of the theory clearly. He explored the process of making a glass of lemonade. If you have never made lemonade, think of it in terms of mixing any beverage for which you have a refined sense of the way it should taste.

Making lemonade from scratch involves mixing water, sugar, and lemon juice into a satisfying drink. Most commercial lemonade is, to my taste, not satisfying—it is usually too sweet. As a result, I only drink lemonade that I have mixed myself. Here is my approach. Since lemons come in lumps, one lemon at a time, while sugar and water can be added little by little, I begin by squeezing a whole lemon. Then I add some water and sugar, and taste the mixture. I expect that the first taste will be too strong (not enough water) and too sour (not enough sugar) because I cannot take out water or sugar if I have added too much. Occasionally I get it right the first time, but usually I have to add more water and sugar. Eventually, the taste of the lemonade conforms to the taste that I am after and the task is complete.

As you can tell from that tale, I don't make lemonade often—perhaps once every two or three years. If I did it more often I would probably have a recipe in mind that would set out the proportions and speed up the task. The interesting thing, however, is that, as rarely as I do it, I *never make a mistake* (well, hardly ever; occasionally I add a bit too much water and have to cut another lemon). The lemonade always turns out right. Since I can test it continually, I can always produce a glass of lemonade that is exactly "right."

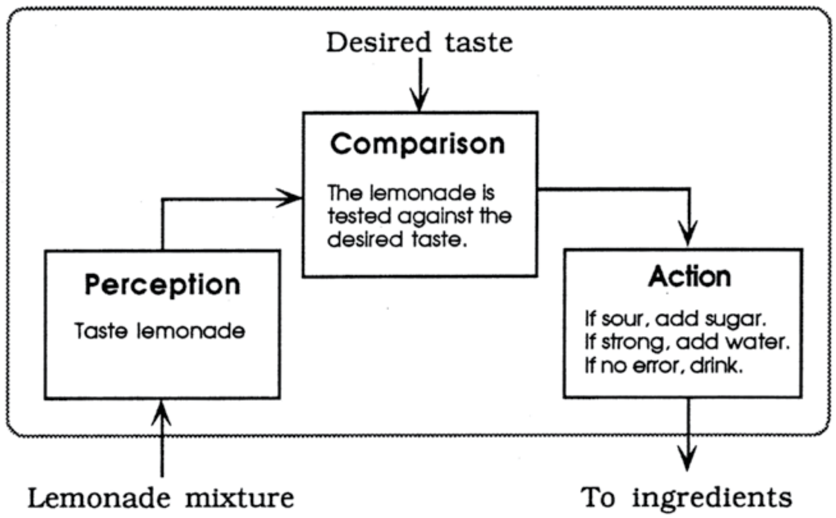

Figure 7.3. A functional diagram of making lemonade.

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As with the thermostat, there are two inputs into the lemonade making system: the actual taste of the lemonade and the desired taste of the lemonade. As with the thermostat, those two inputs are compared. If the taste departs from the desired taste, an error signal is generated that directs my action to eliminate it by adding water or sugar. If the actual taste conforms to my desired taste, the procedure is at an end and I am ready to get on to the drinking stage.

Unlike the thermostat, the value that drives this system—the desired taste of the lemonade—is contained within the larger system, the person, himself.

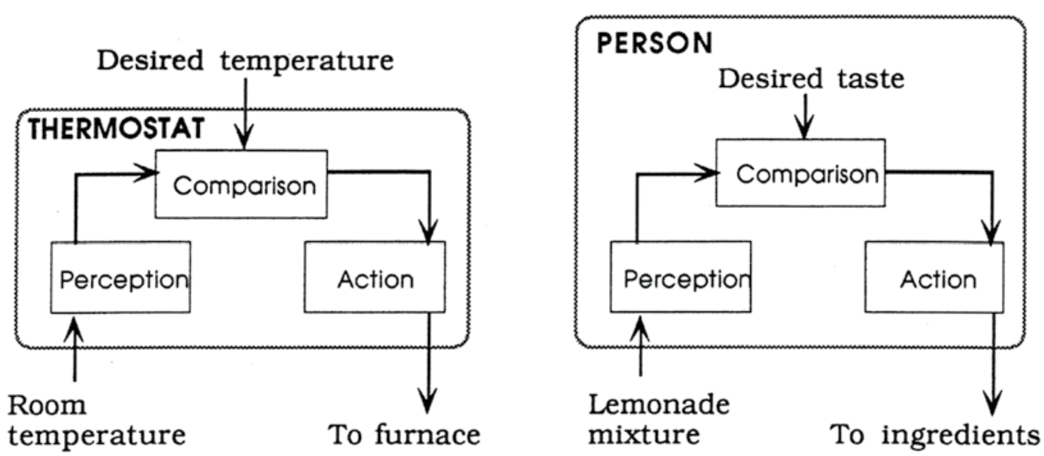

Figure 7.4. A functional comparison between a thermostat and a person, showing the difference between them in the source of the desires that animate them.

The desired room temperature set on the thermostat comes from outside the thermostat, from the same place the desired taste of the lemonade comes from—namely, from me. Unlike thermostats, human beings are *self-animated* control systems.

As humans pursue their desires, they have at their disposal dumb control systems, like thermostats. Consider your situation as you read this. You are presently pursuing a desire to read this book. That desire is generating a great deal of behavior—page turning, eye and neck movement—that is presumably allowing you to satisfy the desire; you are perceiving the book, line by line.

At the same time, however, other perceptions are pouring into your mind that have nothing to do with the book. The chair that you are sitting on is pushing up against your body, generating a constant flow of signals that you are largely unaware of (until I mention it), which your mind uses to interpret that all is well as far as body position is concerned. The temperature receptors in your skin are also sending a stream of messages to your brain that let it make constant minor adjustments to your body temperature without any thought on your part.

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If those adjustments get out of hand—let's say that, in order to keep you warm enough, your brain is sending strong messages to your muscles to contract, which you feel as shivering—you may become consciously aware that all is not well on the body temperature front: "Hmm. I am freezing." That is an "error signal," a notice that there is a difference between the temperature that you would like to be and the temperature that you are. That error signal generates the feeling that I referred to in Part I as *tension,* a feeling that something more must happen. That tension drives you to action.

You have at least two possible strategies for eliminating the error, and its attendant tension: (1) put on more clothing, or (2) raise the temperature of the room by setting the thermostat to a higher level. You have, in other words, a *repertoire* of alternative actions, both of which will bring about the desired result.

How do choose from your repertoire? Control system theory does not, at the moment, have a very good answer to that question. Economists think that economics has as good answer, so let's ask for a moment how an economist might explain your choice between putting on more clothes and turning up the thermostat.

To the economist, every choice produces *costs.* If you decide to turn up the temperature of the room, you will burn more fuel. In fact, since the thermostat will raise the temperature of the entire house (unless you have multiple heating zones), it will burn a lot more fuel than what you need to stay warm while you read. That is a big waste, unless there are other people in the house who are also cold or unless you anticipate that you will soon be moving to other parts of the house.

On the other side of the ledger (to use a metaphor that economists resonate with), the decision to put on more clothing is not costless either. You will have to stop reading the book and move to get a sweater (which you would presumably rather not do), but you will have to do that with the thermostat as well. The extra clothing might be somewhat uncomfortable to wear. Worse, the extra clothing will not be as effective at producing exactly the right body temperature as setting the thermostat. Putting on a sweater will raise the temperature of your torso, but perhaps leave your legs too cold. If the sweater is a little too heavy, you may find that you have to take it off in a few minutes. To make the decision an economist would compare the costs of the alternatives:

LEDGER

COST OF RAISING THERMOSTAT		COST OF PUTTING ON MORE CLOTHES	
Time and effort needed to make the adjustment	10	Time and effort needed to don more clothing	25
Cost of excess fuel	65	Discomfort of added clothing	5
		Cost of expected further fooling around with clothing to produce the desired temperature	55
TOTAL COST	75		85

Figure 7.5. Cost analysis of decision about warming up.

To decide between the alternatives, you compare the costs of each and choose the action that will impose the least costs. If your cost analysis was like the one in Figure 7.5, you would choose to raise the thermostat rather than put on more clothes, though the costs of the two alternatives are so close that you might do the worst of all possible things (in economic terms), namely, sit for minutes in a dither as you tried to make the decision.

To the economist, people are *rational maximizers* (if they are sane), which means that they always try to get the most of that which they value for the smallest sacrifice in other things that they value. The "costs" of an action are the perceptions that must be sacrificed in order to pursue a given perception. If you are cold, pursuing a better perception (i.e., the perception of getting warmer), means that you will have to give up other things that you could do with that time and effort. That is a cost. You will try to minimize that cost.

To make this explanation work, economists posit some kind of internal accounting system. In Figure 7.5, the costs of each alternative are represented in numbers. But what do those numbers mean? They are a measure of the sacrifice that a given behavior will entail. From introspection it surely does not feel as though we do this calculation between alternatives numerically, though it is a convenient way of quantifying the decision-making process. Perhaps control system theory will one day explain how it is that we actually make decisions without the need to posit numbers.

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As we apply the control system model to legal thinking in later chapters we will find that decision-making in law is a subtle process, far more subtle than the decision between raising the thermostat or putting on more clothes. At this point, however, we will assume that you have decided to bring your body temperature into alignment with your desired body temperature by raising the setting on your thermostat. Doing that creates a relationship between two control systems—you and the thermostat—in which you generate the desire that the other control system will pursue. That relationship can be pictured this way:

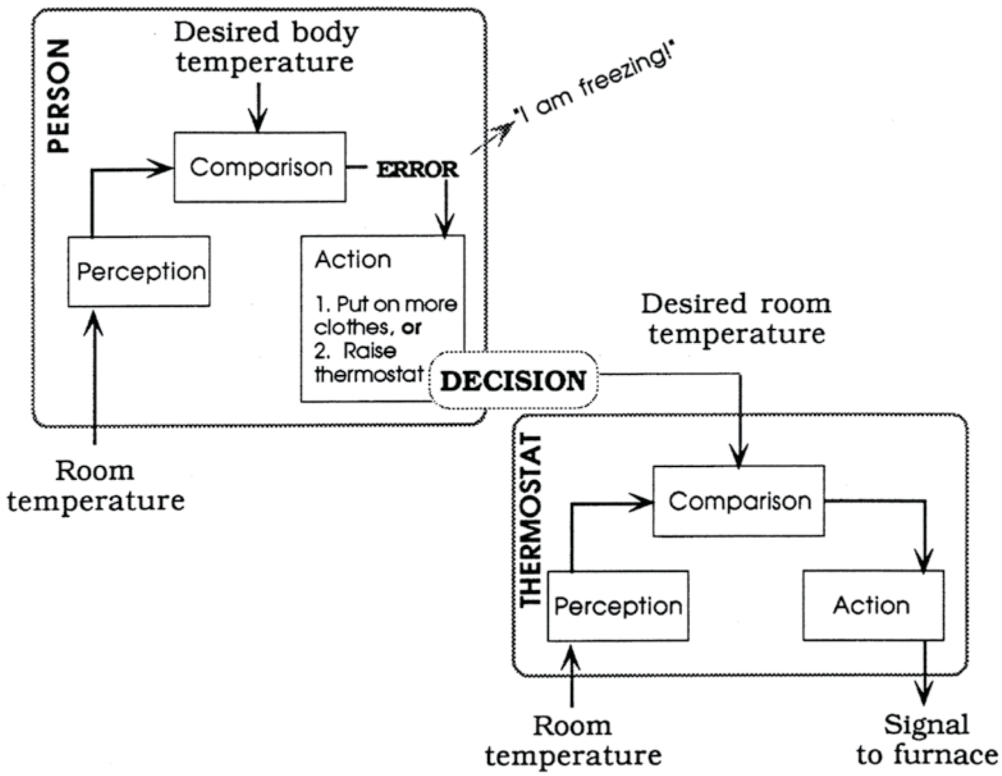

Figure 7.6. The relationship between a human and a mechanical control system.

Notice that both control systems will sense the same feedback—the temperature of the room. But each will compare that temperature against a different standard. The thermostat will compare it against the value that you have set, keeping the furnace going until the desired room temperature is reached. Your body will use the room temperature to change its internal response to temperature change, none of which you will be aware of. You will be aware of the general level of your body temperature, of the measures that your body is taking to warm or cool itself. If the thermostat and furnace are working well, the temperature of your body will recede from consciousness and you will turn all of your attention to the purpose of reading this book. If you

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were not artful, if, for example, you turned the temperature up too high in an effort to get a quicker fix, you will get too hot and have to go through the procedure again.

Getting along with others

The thermostat is your slave. Were the only control systems that you had to deal with in your life dumb ones like the thermostat, there would be no need for law. Lacking their own sense of purpose, dumb systems wait obediently until a control system that has its own purposes, like you, comes around to animate them with new settings. It has been suggested that a large part of the success of personal computers is that they are so rewarding to control. They are themselves control systems, controlling such things as printers, modems, and disk drives. But they lack a purpose. They sit around until they are animated by a person. They reward the person with an uncritical willingness to do whatever is desired. Because they are so willing, however, when they fail to deliver because of a software or hardware failure, they can produce outrage.

Papers

Living with other human beings is altogether different. Each human being is a self-animated control system; each person is up to something. The actions of a person pursuing a purpose can enhance or diminish the ability of another person to pursue her own purpose. The ability of our actions to enhance the desires of others is the foundation for social interaction; their ability to diminish the desires of others is the foundation for law.

Books

There is no need to spell this out at any length; we all have vast experience with social life. But I will point out the way that control system theory applies in the social context (that is, in control system theory's terminology, in the context comprised of multiple, interactive, purposive control systems). Return to the example of setting room temperature, but now put another person in the room with you.

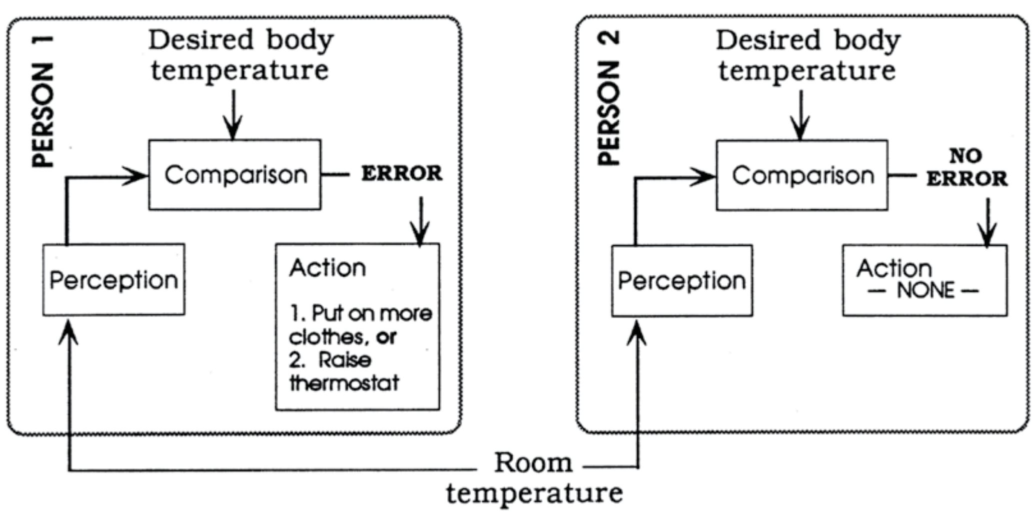

Figure 7.7. The relationship between two humans who are in the same room, one of whom feels comfortable while the other is too cold.

Each of you is experiencing the same room temperature, but you ("Person 1") are cold, while the other person ("Person 2") is comfortable. You are in a state of tension derived from the error signal from body temperature, while the other person is not. What to do? You could proceed as before, ignoring the other person. Doing that, however, will raise the room temperature, which is likely to create an error signal in the other person ("Isn't it getting awfully hot in here?"). Ignoring other people's error signals is, in fact, typical of young children, as they struggle with each other over their individual pursuits. But you are no child, so you will take the effect of your action upon the other person into account.

Why would you do that? Here are three possible reasons, each with a profoundly different implication for the legal system.

FEAR If I raise the temperature of the room, that will create an error signal in the other person ("It is getting to hot in here!"), who is likely to remonstrate with me about it ("Turn down the heat!"), creating an error signal in me and forcing me to act.

LOVE If I raise the temperature of the room, that will create an error signal in the other person ("It is getting hot in here!"), the mere contemplation of which creates an error signal in me ("Oh oh, I have made someone unhappy!"), causing me to eliminate it from my action repertoire. I'll put on a sweater.

RESPONSIBILITY If I raise the temperature of the room, that may create an error signal in the other person, so I'd better ask whether or not it is OK.

NOTE: In Part II I will use statements like the ones in parentheses above to illustrate what the particular error signals I am referring to feel like.

Figure 7.8. Three different reasons to take another into account in one's decisions.

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You might not raise the thermostat because you fear the consequences. Doing it would have two effects: raising the room temperature and possibly provoking discomfort in the other. The first would remove the error signal stemming from your desire for a comfortable body temperature, but the second would create an error signal, even if all it did was interfere with the peace and quiet that you need to have to continue reading this book.

Conversely, you might not turn up the temperature because the mere thought of causing discomfort to the other person itself creates an error signal in you. I have termed this "love," for love appears to enable one person to appreciate another person's mental state as if it were her own. One person empathizes so strongly with another that his discomfort is her discomfort, her joy is his joy. In such a system, purposes and perceptions are shared in a way that each person's error signals incorporate the other's perceptions, and action is taken only if it will reduce the error of both people.

If Person 1 "loves" Person 2, Person 1 will put on a sweater without making a fuss (unless Person 1 also needs appreciation from Person 2 for the "selfless" act).

Fear and love are powerful motivators, but neither offers a perfect solution to the problem of integrating the behavior of independent actors. Love seems to have its own agenda independent of social control, which even the repetition of the duty to love one's neighbor seems impossible to affect. By contrast, fear is subject to social manipulation. Law can provide and enforce penalties for improper behavior. But enforcement is costly, both to those who must do it and to those whom it is directed at. And fear is not reliable: some people seem to act to spite the promised penalty, while others take consequences into account only if penalties are uniform and reliable. To them, the chance of getting caught every tenth time they do something wrong produces little fear.

Fortunately, there is a form of control that avoids the weaknesses of both love and fear. As you sit shivering with this book, considering whether or not you should put on more clothing or raise the thermostat. you will be aware that raising the thermostat will affect the other person. That is, you will recognize your *responsibility* for the discomfort that the other might feel if you raised the temperature setting. You will see yourself as the *cause* of that person's error signals. That recognition will induce you either to avoid that behavior or to ask the other person for his acquiescence to your desire to raise the room temperature.

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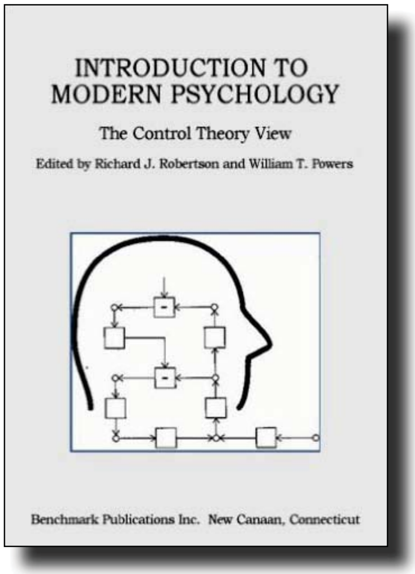
Notice that responsibility operates in a self-contained way. It doesn't matter whether or not you know the other person. love him or hate him. The golden rule of responsibility extends to all persons. In the lilting terminology of control system theory, the idea of responsibility could be put this way. "Never take an action that will induce an error signal in another without gaining the other's acquiescence."

I would suggest that that principle was, though you were probably unaware of it, the basis for your evaluation of Jeffrey's case. It is what enabled you to identify the injury to Jeffrey (who suffered a terrible set of error signals until his very existence as a control system terminated), the potential problem of Margaret's behavior (the failure to protect her son from error signals), and the difficulty with the case against the Newlands (did their actions *produce* an error signal in Jeffrey?).

We talk about injuries, risks, and responsibilities in everyday terms without making explicit their underlying dynamics. In this book, however, we are seeking to understand how it is that we think about law. Seeing human beings as control systems gives us the opportunity to model both our own thought and our concept of ourselves and others as moral beings who are entitled to respect. Control system theory enables us to use a single model to describe both the way we are and the way we think we are.

In this chapter I have described how it is that a fundamental moral principle (i.e., Never take an action that will induce an error signal in another without gaining the other's acquiescence.) derives from the very process by which we *think about law.* I have yet to show, however, that control system theory offers a framework for understanding normative thought. In the next chapter I will describe a simple way in which our values and desires generate thought.

Introduction to Modern Psychology:
The Control-Theory View



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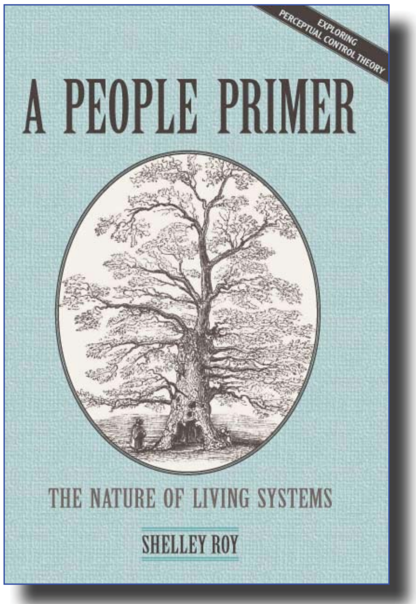

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CHAPTER 3

Dear Jodene,

Controlling is what living is all about

CONTROL

One of the individuals who inspired me to write this book as a series of letters is Jodene. When we first met at a training session, I was partnered with Jodene for a small group exercise in which participants were asked to try out some of the language of PCT. In fact it was his first opportunity to "try it on," to try asking questions in the ways we had learned about in training. Many people would have been intimidated when asked to partner with one of the instructors, but Jodene wasn't.

Besides being an art teacher in a rural middle school, he is a recovering addict and an addictions counselor. His personal and professional interest in the treatment of addictions and his never-ending quest to enhance his skills as a teacher brought him to the training. His understanding of the Twelve-Step Program for Alcoholics Anonymous played a key role in his quick grasp of the ideas he was learning in the training.

Jodene is dedicated to being the change he wants to see in the world and to living one day at a time. By modeling successful life skills for black male youths and helping individuals become more of who they want to be.

Many of our discussions have led to how PCT is different than what he already knows and does. This has not been easy to sort out. When he first asked me for my insights, I was reminded of something in Eric Jensen's work on brain compatible instruction: some learners learn by figuring out how what they are being taught is unlike what they already know. In the classroom, it may seem like these learners are challenging the teacher, but it is their way of making sense of the world. Jensen refers to this type of learner as a "mismatcher." Viewers of television shows that feature crime scene investigations are already familiar with this idea. Effective investigators look for what doesn't fit. One of my favorite TV detectives is the character Monk, played by Tony

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Shalhoub. Monk is so obsessed with order that he quickly figures out what doesn't fit.

Understanding PCT has helped me see that the "mis-matchers" label might be true of all of us. We are all going about the world looking for what's not working or what doesn't fit. What is working is not the focus our attention. This ongoing dialog about how PCT is different from other models of human behavior and how PCT practices differ from other "helping" practices is the basis for this letter.

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Dear Jodene,

I know you are the kind of person who likes practical, real life examples, and you don't like to be buried in all that *technical lingo*, so I'll do my best to keep it practical. I also know that you are really trying to understand how Perceptual Control Theory fits or doesn't fit with what you know. One thing I keep hearing you struggle with is the understanding that PCT is not a program or something we do. This is a very common problem when people first learn about PCT. They'll say things like "I tried *it*, and *it* didn't work," or "I wish I was more fluent in doing *it*!" What I hear you doing is comparing *it* to other programs you know and understand. PCT is an explanation of human behavior. It isn't something you do, and it is not another program. Like other scientific theories, it attempts to help you better understand what is happening in the world. I'm hoping that learning more about PCT will help you to be more effective and more efficient in everyday life. PCT can also help explain why certain programs, like the Twelve-Step Program and peer mediation programs have a good chance of being successful, but don't always work. Just keep in mind that PCT is not a program, it's a theory.

I'll see if I can find an example from the art world. I'll also try to keep my explanation relevant. I'm asking you to change your paradigm of human behavior, which will be much easier if I use examples that are familiar to you. You asked me to help you understand what I meant by *controlling*, and what makes it such a big deal. Well, let me address the last part first.

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What's the big deal about controlling? The big deal, simply put, is that *controlling* is what distinguishes living things from non-living things. Controlling is required to keep people, plants, and animals alive. You see, controlling is a phenomenon that only living systems do. It is a process of reducing error in the system. Non-living things like rocks, sand, paint, or water respond to external stimuli, which means that they operate based on events outside of themselves. They act consistently, according to basic principles, with predictable results. You can use physics and linear thinking to describe the basic principles by which non-living things respond to their environments. Let me give you an example: if I mix the exact same proportions of a specific pigment to paint base, I will always get the same color. Rocks, paint, sand, and water are predictable. Living things, on the other hand, are not predictable. Living systems are able to create identical results by varying means or varying results with the same means. When is the last time you met a totally predictable person? This seems like common sense. Living systems are not predictable, but how many people live by this understanding?

Living things are flexible, not static. Non-living things can be controlled from the outside. They can be pushed, shoved, and manipulated in the same manner time after time with the same results. And they operate based on stimulus-response. You may think, well that's true of people, too. You may think they can be pushed, shoved, and manipulated. The difference is that you cannot predict what will happen when a living system is the "thing" being stimulated. When we are talking about exerting external force on non-living things, we are evoking the laws of physics. Acceleration is inversely proportional to the mass of the object. If I kick a ball with my foot, the ball moves. How far and how fast and in what direction can be predicted using the laws of phys-

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ics and conditions in the environment at that moment. On the other hand, because you are a living system, if I kick you, I'm not sure what will happen. That's because you are controlling, not being controlled. With a living system I can never be sure that if I do "this," I'll get "that." I don't know that if I pet the dog, the dog will lick my hand. Even though for the past three years every time I've petted the dog, the dog has licked me, today may be the day the dog won't.

The big deal is this: living systems control, they are not controlled by either internal or external forces. As living systems, we just "do it." We control. There is no direct link from something inside of us or outside of us that makes us do what we do. This is why learning strategies and applying specific programs doesn't necessarily work. No one can guarantee that they can get a living system to do something they want it to do all of the time. There is a very old joke that illustrates this: "How many psychiatrists does it take to change a light bulb?" The answer: "One, but the light bulb has to want to change." That's one of the major differences between living and non-living things: living systems have to want to!

Most people believe that we do what we do to meet a need, and if you understand this you can control people and animals through the effective use of punishments and rewards. Provide what they want to get them to repeat an action, or deny what they want to get them to stop an action. The belief is that people and animals are being controlled from the outside, and something in the environment or some internal need is "making" them do what they do. Both of these ideas represent a linear stimulus-response way of thinking about behavior. Take a minute and think about how often this paradigm of external control bubbles up into how you think and act.

Unlike the stimulus-response explanation of behavior, PCT is not linear. It is circular, and it is about relationships.

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Specifically, controlling is about the relationship between a perception (a have) and a reference (a want to have). Both pieces of information are vital, but knowing them is not enough. You also need to understand how they are related. You can't just look at a reference, what a person wants, or a perception, what they think they are getting. You have to look at both and understand the relationship between the two. Is the "getting" enough, too much, or too little compared with the "wanting."

That brings up another issue: "What are we doing?" A lot of folks think of behavior as the "actions" we observe, but that isn't what I mean by the word *behavior*. This idea of our observable actions being equivalent to behavior is archaic. Actions are only what I can see of you and you can see of me, and most of what I think of as behavior is happening inside a person and is not observable to the naked eye. Behavior is a process. To add to the confusion, we don't always do the same thing (take the same action) to get the same results. I don't always wave when I want to get someone's attention. Sometimes I whistle, sometimes I send flowers, sometimes I raise my hand, sometimes I write a letter, sometimes I instant message, sometimes I toot my car horn, and sometimes I say hello. Sometimes when I do these things, I'm not trying to get anyone's attention. For example, today a six-month-old baby was at my house, and she began to use her muscles to stiffen her body and cry. There were three adults present, and none of us could figure out what she wanted. We could clearly see the actions she was taking. We could observe what is commonly called her "behavior," but it gave us very few clues about what she was doing or how to help her. The situation illustrates the fact that neither you nor I nor anyone else can tell what someone is doing by watching what they are doing. Even when it comes to my own actions, I am not always fully aware of what I'm doing

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and what it's all about. I often catch myself about to pop a piece of chocolate candy in my mouth and wonder, "What am I doing?" PCT is different because it takes into account the unpredictability and variety of living in an ever-changing world, and it describes behavior as a circular process of feedback, not simply the observable actions of a person. The big deal about controlling is that it is the process that defines living systems.

Now for the more technically difficult question: What does a person who uses PCT lingo mean when they say "controlling"? Let me use an example that everyone has experienced. From the moment you were alive you were controlling for things like a full stomach, a dry bottom, a feeling of security, and other "wants." When you were young, you depended a great deal on the actions of someone else to provide you with what you wanted, and you were also constantly engaged in a process of controlling. When you felt life wasn't the way you wanted it to be, you did what you could — cry, giggle, kick, scream, and cry some more — to try to get what you wanted. It didn't matter to you that your parents were trying to take a shower, get some sleep, or talk on the phone. Your world was all about you, just like their world was all about them. For you, it was and is about you getting your perceptions of the world to match the world you want. You knew how you wanted your bottom to feel, and you knew when it didn't feel that way. It was all about you getting that "just right" feeling. Controlling is the process by which living systems match a perception and a reference perception. It's about reducing the difference between the world I'm experiencing and the way I want the world to be.

Let's get back to the example of you as a baby. It may appear that you were controlling your parents by crying, kicking, and screaming, but you were not. There were times when you took action and no one changed you, fed you, or

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picked you up. This happened for several reasons. Those around you had to make their best guess as to what you were controlling for, what you wanted, and sometimes they were right, and sometimes they were wrong. And at the same time your parents were also controlling; for your parents it was about them getting their perceptions to match what they wanted. Luckily for you, that included feeding you, changing you, and picking you up, or just about anything to get you to stop crying.

We have all seen parents who do not want to help create the world their children want. They are busy creating the world they want, which may or may not include providing for their children. All parents have a reference for the kind of parent they want to be. Luckily for babies around the world, most people want to be the type of parent that provides for her children. What you need to remember is that it's all about everyone controlling for the world he wants. No two of us want the same thing, and no two of us go about getting it in exactly the same way. In fact, we usually don't go about getting the world we want in the same way twice.

The simple technical answer is this: control is about a living system reducing error by taking action to try to match a reference signal and a perceptual signal. Metaphorically we are always asking: Is P (perception) = to R (reference)? Take for instance a young child in a grocery store who wants a piece of candy. What action does she take to control for the piece of candy? What does she try? She may cry, whine, kick, scream, and cry some more, acting out in what most of us call a temper tantrum. For the child in the grocery store, the reference signal is "candy" and the perceptual signal at that moment is "zero" (what you think of as "no candy"). So the child, living system that she is, continues to control for the candy, because P does not equal R. In this case, the

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child may use crying, screaming, grabbing for some candy, or throwing something within reach to get that candy.

Let's say the parent hands the child a pack of gum. How does that change things? The child is now probably recording a perception other than "zero." So the question is, does P now equal R? Does the child have a "match"? We don't know. It depends on whether or not a pack of gum matches the child's reference for "candy." If it does match, the child probably stops controlling for the candy. If it doesn't match, the child probably keeps controlling for candy. The child may do this by crying louder, screaming more, or adding a few other creative techniques to get what she wants. Like the child wanting candy, we are all going about trying to get a match between our perceptions (haves) and our references (wants).

Remember that I once told you PCT can be simple, and then it gets complex really fast? Well, this is what I was talking about. It is tough enough when we are working with one control system, but in this example we have two: the parent and the child. Typically, the child wants the candy, and the adult wants the child to be quiet. So what do we see? If I'm thinking inside the stimulus-response box, I might see a power struggle in which the adult thinks, "I have to win! I need to punish or reward my child's actions so that she no longer behaves this way in public." What do I see if I'm thinking outside the stimulus-response box? If I'm thinking in terms of PCT, I see two living systems both controlling to get the world to match their personal specifications. I usually ask the child, "How's it working?" At this point many children stop, because they understand that what they are doing isn't getting them what they want. At this point most parents are stymied and silent. I'm never sure if this is because a perfect stranger butted into the situation or because the child is quiet. This simple idea of understanding

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that people are always controlling can be extremely helpful in taking more effective control of my own life.

If PCT explains all living systems, what's the difference between controlling in adults and babies? Not much! We adults seem to think we are different than children, but we are still all about controlling to get the world to be the way we want it to be — we adults just have a lot more we are controlling for. Adults have more wants. Think about it. Have you ever seen adults who aren't getting what they want? Do their actions look much different from those of a baby or a toddler or a teenager? As adults, we want a lot more, and many people become more creative about getting what they want as they age, but it is still the same process. Check it out for yourself. Watch people around you, and see what they try. Recently on a trip home from South Carolina, I was in a very small plane late at night. I don't think there were any empty seats. It was one of those planes that seats two people on each side. The man across the aisle was getting more and more agitated the longer we sat waiting to take off. He began to mumble under his breath. I won't say what he said as it wasn't very polite. Pretty soon he was complaining about everything the airline hostess said and did, even when she was making announcements that FAA regulations require her to make prior to take off. The longer it took us to get up in the air, the more he complained, swore and moved around in his seat, throwing his arms in the air and stomping his feet. I was very tempted to lean over and say, "How's it working for you?" or "Is what you are doing helping us to take off any faster?" Here's another example. The other day, I was sitting in McDonald's and overheard one of the workers complaining that she did not want to work the 4–11 shift, the shift she was currently working. On her break, I saw her walk across the parking lot to smoke a cigarette and call someone on her cell phone.

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She then walked back in and told the manager she had to leave because her mother had just had a heart attack. Now that's creative adult behavior in action.

Besides throwing a tantrum or lying when we aren't getting what we want, many of us have other problems controlling. For example, we keep using the same actions, thinking that this time they will get us something different. I'm guilty of this as well. About twice a week, I walk into my family room, and there is a mess on the coffee table. I say, "Guys, do you think you could pick up your mess?" and my boys almost always say the same thing: "What mess?" You'd think I'd learn that saying what I'm saying doesn't get me what I want, and I'd stop doing it. After all, my sons are 21 and 16, and this line hasn't worked yet. When I'm trying to be a little more creative, I say "I see 'not me' and 'I don't know' have been here. Do you suppose they could come back and clean up this mess?"

I really think this idea of doing the same thing and expecting something different is important to mention because I've noticed that as adults, it is hard for us to stop trying the same things we tried yesterday, last week, last year, or as a child. For some of us, learning that if we keep doing what we are doing, we will probably keep getting what we are getting can take a lifetime. If I base my life in the principles of PCT, I realize that action, perception, and references are all intricate parts of the process. I can take more effective control of my life if I really start thinking and being aware of *all three* parts of the process and how they fit together. I can try to be aware of what I want in every situation, question what information I am paying attention to, and attend to the actions I am taking. It doesn't hurt every now and then to ask myself, "How is that working for me?"

Remember that learning PCT is like learning new meanings for words you already know well. "Controlling" is one

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of those words. Living systems are engaged in a continuous process of controlling for a match between their perceptions and their references. Controlling involves action, perception, and comparison. Each of these terms has a very precise meaning that is critical if you are really trying to understand PCT. Controlling is how living systems create the same results by doing different things. Controlling is how the soccer player can get the ball in the net time after time even though he is in a different place on the field, or there are different conditions on the field, or the player is tired or fresh just coming off the bench. It is what you did when you were a baby and you didn't like your empty stomach or your wet diaper. It is what the child who wants candy is doing, and it's what the guy stuck on the airplane and the employee at McDonalds were doing. And controlling is what I am doing right now. It is what keeps us alive. Becoming more effective at controlling is what learning PCT is all about.

Let me see if I can pull this all together for you by using a painting example, since that's how you like to express your artistic side. Let's say you have in your mind's eye an idea for a specific color you want the sky to be in a painting. Do you simply go to your tray of colors and begin to put the paint on the canvas? No, you don't. Any good artist knows that colors are a blend of several pigments. This was a problem when you were in kindergarten and the school supply list said "Crayons, box of 8 colors." You couldn't get the colors to match the way you wanted them to be. Like an infant, your options for getting what you wanted were limited. Having more options can be very important when it comes to getting what you want. I know that you work two mornings a week with a group of black male youth and that much of what you are doing with them is helping them "gain options for getting what they want." You are helping them discover words, thoughts, and actions that can get them more of

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what they want, and much of this you do by modeling for them. Just as when you were that budding kindergarten artist, you now want more colors to choose from. You want your colors to look "just right."

So you have a "just right" for the color of the sky you want to paint. The "just right" is called a *reference*, a specific state of a perception; in this case a visual perception. And as you begin to blend colors (this would be your action) on your palette you constantly look at the color you've created (perception), and you keep blending and adding until you get a match between the specific color you had in mind (your reference), and what you see on your palette (your perception). In other words, you *controlled* for the color you wanted. That's what the term *control* means for someone who understands PCT. It is the process of creating a closer match between the reference (the specific perception we want) and the perception (the perception we are presently recording). Mathematically speaking, you are controlling for P to equal R. Sometimes you will accept "close enough," and sometimes you want an exact match. For you as a painter, the references you have for color and the other elements of art — line, form, shape, space, texture, and value — are much more specific and probably more important to you than they are to me as a mathematician.

As long as we are talking about painting I want to briefly introduce another PCT concept — levels of perception. I'd like to invite you to think about the relationship between the principles of art (a higher level of perception) and the elements of art. Specifically that the principles of art — balance, contrast, emphasis, proportion, pattern, rhythm, unity, and variety — are created by using lower level references that you think of as the elements of art.

All this talk about the exact color you want reminds me of another concept that I want to encourage you to apply to

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yourself: “Seek the reference.” It is important to be clear on what you want, to know in any given moment what you are controlling for. What experts in any field are good at is being very precise in the references they are controlling for. For you, it may be the color of the sky you wish to paint. For me, it may be having my checkbook balanced. This concept of being very clear on what you want — seeking the reference — is one that can change a whole lot in your life if you begin to practice it. Understand what you are controlling for by seeking the reference, and don’t stop at the first thing that comes to mind. Keep digging deeper. The same holds true when you are working with others. When you are asking questions, try to find out what the person wants, and keep digging. Sometimes we have to dig deep to clarify what we really want.

So all of us are living life trying to get what we want. This process is described in PCT as *controlling*. This is where the loop comes in. It is a diagram that shows the process of control. The trick is figuring out how I get what I want in a way that doesn’t hurt me or interfere with others. Now that’s tough. That’s a letter for another day.

I hope this helps you get more of what you want.

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In a nutshell

- Perceptual Control Theory isn't something you do; it is an explanation of human behavior.
- Control is important because it is what makes living systems unique; it's what life is all about.
- Understanding controlling is critical to understanding human behavior.
- Controlling is a process by which living systems bring about the perceptions they desire.
- Controlling involves references, perceptions, and comparison.
- Controlling allows living things to take different actions to get the same results.
- Understanding PCT can help you become more effective at controlling.
- "Seeking the reference" — knowing what you want — can be helpful.

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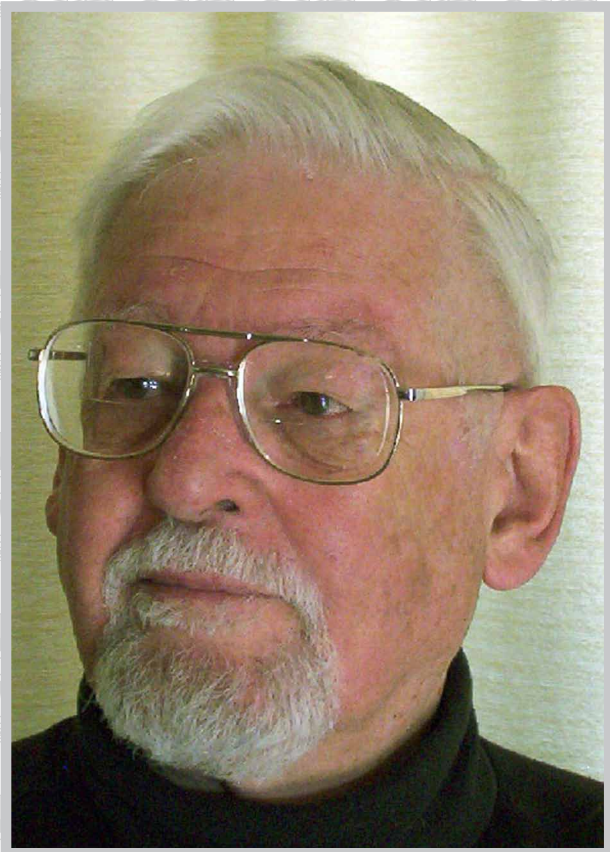
About the creator



William T. (Bill) Powers was in the Navy from age 17 to 19 (1944 to 1946), which is where he learned electronics, had his first experiences with repairing and maintaining various kinds of servomechanisms, and learned some basic feedback theory. He went into college in 1947 and graduated from Northwestern University in 1950 with a BS in physics and mathematics.

With a keen interest in human affairs, he began his development of Perceptual Control Theory (PCT) in the early 1950s by applying control engineering and natural science to the subject of psychology.

For many years he was chief systems engineer at the department of Astronomy at Northwestern University. Bill has been responsible for inventing a number of control devices, including a curve tracer for plotting isodose contours in the beam of radiation from a Cobalt-60 therapy machine, the automatic all-sky photometer for use on the moon (for Apollo 18), and he won the Marshall Field Award for his microcomputer system for receiving, formatting, and typesetting satellite-broadcast stock tables in real time.

About the resources presented in this volume

Perceptual Control Theory (PCT) results from one man's curiosity, expertise, creativity and determination. The papers, books, and computer tutorials sampled in this volume would not have been created, certainly not this way, if it were not for William T. (Bill) Powers's seminal insight and tireless efforts across sixty years.

These introductions and readings provide a comprehensive range of information for the study of Perceptual Control Theory—papers, books, book reviews, resources on-line, demos and tutorial programs for your computer.

The PCT explanation for what behavior is, how it works and what it accomplishes is well documented. It lays a foundation for a new natural science and can handle behavioral phenomena within a single testable concept of how living systems work. You can demonstrate it to yourself several different ways.

Whether you are interested in resolving chronic psychological stress, understanding what is going on with an inconsolable baby, getting a different take on what emotions are, resolving conflict in general, becoming a better parent, manager, sales person, friend or lover, you will find fascinating insight when you review these readings and study this new explanatory concept with care.

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