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SEMINAL HUMAN BEHAVIOR INSIGHTS

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ABSTRACT

This is a condensed version of a monograph I wrote in 2021. The objective is to explain Perceptual Control Theory (PCT) in sufficient detail so that you can make an informed choice about a theory to serve as your foundational understanding of human behavior. Over many years, I have accumulated myriad PCT books and journal articles. As questions concerned me, I have been fortunate to get answers from the leading researchers, including Bill Powers who developed PCT. This paper distills the work of Bill Powers and his colleagues in developing PCT and highlights the potential wide application of PCT.

A widespread belief is that human behavior is about responses to stimuli (e.g., carrots and sticks management approach often seen in business) and/or that our brain plans in detail with incredible speed our every action to deal with disturbances in the environment. In this paper, a strong case is made that these approaches are decidedly inferior to the PCT approach focused on controlled perceptual input.

We human beings live *purposeful* lives which can easily be ignored with a stimulus-response approach to understanding human behavior. Due to a continual stream of environmental disturbances, actions are varied in order to cancel the effects of these disturbances on our perceptions of controlled (important to our goals) variables. Behavior is control of perception.

Two sections at the end of this paper, PCT for Business Firms and Concluding Thoughts, may provide new ideas for improving culture and performance measurement at all levels of the firm leading to a higher level of sustained value creation.

SEMINAL HUMAN BEHAVIOR INSIGHTS

> You [William T. Powers] did not invent the [negative feedback] 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.
>
> —Philip J. Runkel[1]

Mainstream psychology ignores Perceptual Control Theory (PCT)

Systems in business entail coordinated activities in which people work to achieve a specified goal or purpose. This can range from a small team to a large complex organization. Systems can involve people inside and interactions with other outsiders (e.g., a manufacturing plant and its outside suppliers or a classroom using books written by outside authors). Moreover, managers of a system may have divergent views of how to make changes in order to improve performance. Is it not reasonable that a prerequisite to system analysis should be clarity about why we act in the ways we do. So much has been written about performance improvement that intimately involves people, but totally absent, or inadequately treated, is a foundational explanation of human behavior.

Readers of cognitive psychology textbooks are introduced to the power of our brains as calculating engines to issue commands to our muscles to take actions in response to stimuli in the environment. Even though cognitive psychology has replaced behaviorism, which ignored brain functioning, the basic sequence of a cause (stimulus) followed by an effect (response) is maintained. The cognitive revolution began in the 1950s as an interdisciplinary study of how the brain uses sensory inputs to guide behavior. The early developers of cognitive science believed that the brain acted as a computer that models the external environment and instantaneously calculates an appropriate response to a stimulus just experienced. This approach facilitates the stimulus/response framework that is so intuitively appealing to many. The appeal is that thoroughly understanding the cause presumably equips one to predict the forthcoming response. This linear (straight line or open loop) approach is extraordinarily useful for explaining the behavior of nonliving things such as billiard balls. The mass, velocity, and direction of the impacting ball (stimulus) can be used to predict the subsequent velocity and direction (response) of the impacted ball.

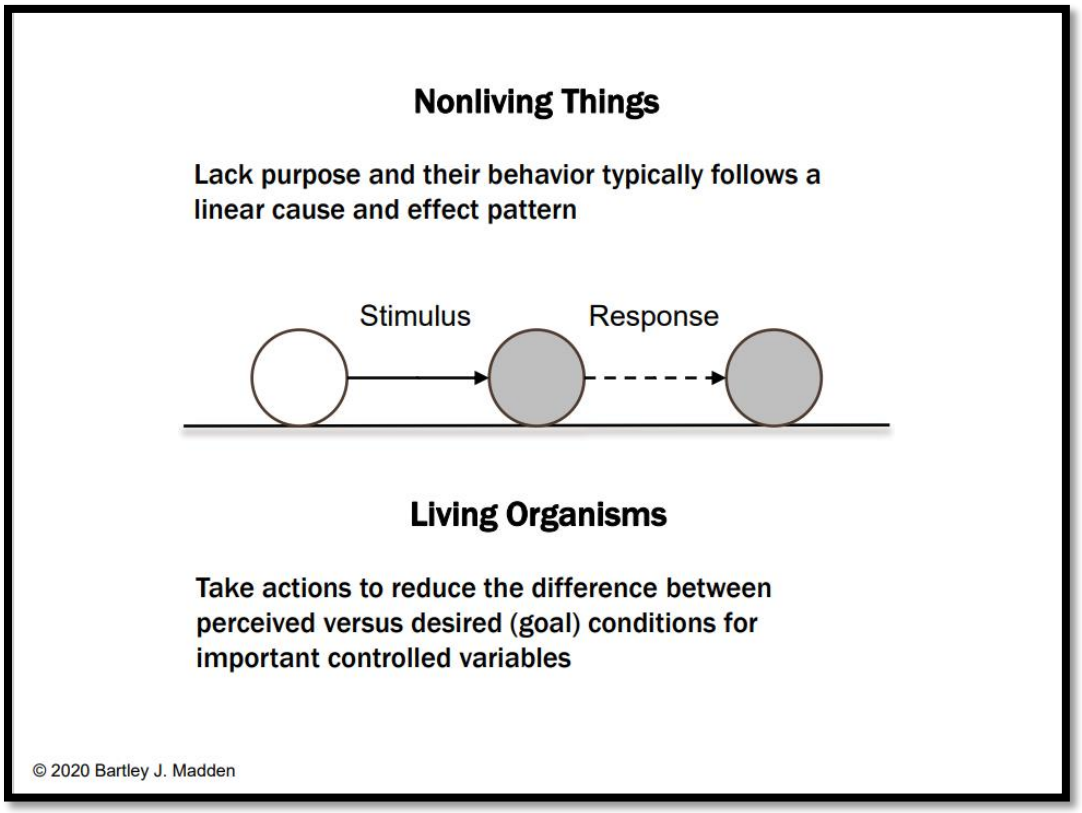
In 1960, William T. Powers and his coauthors wrote the first PCT journal articles and started an intellectual movement that has the potential to become a paradigm change regarding a theory of human behavior. Perceptual Control Theory asserts that, for living organisms such as people, it is misleading to view their actions (behavior) as a response to a stimulus. For example, imagine that you are driving a car in the rain on a windy day. The external environment is continually disturbing your driving via a multitude of stimuli. Do you continually respond using your brain to model the condition of the road, the wind speed, the weight of the car, the grip of our tires (new versus old), etc., and then

[1] Dag Forssell (ed.). 2016. *Perceptual Control Theory: An Overview of the Third Grand Theory in Psychology Introductions, Readings, and Resources.* Hayward, CA: Living Control Systems Publishing. p. *vii.*

send signals through your nervous system to activate muscles to adjust the steering wheel in the calculated manner?

A more plausible PCT-based explanation is that behavior is control of perception.[2] the developer of PCT. We humans are wired as hierarchical control systems (see Figure 2). Behavior is best viewed, not as response to a stimulus (disturbance), but actions to move a perception closer to its desired or "reference state," i.e., striving for a zero error between the reference state and the actual perception as will be explained in considerable detail in later sections.

Figure 2 The difference between nonliving things and living organisms

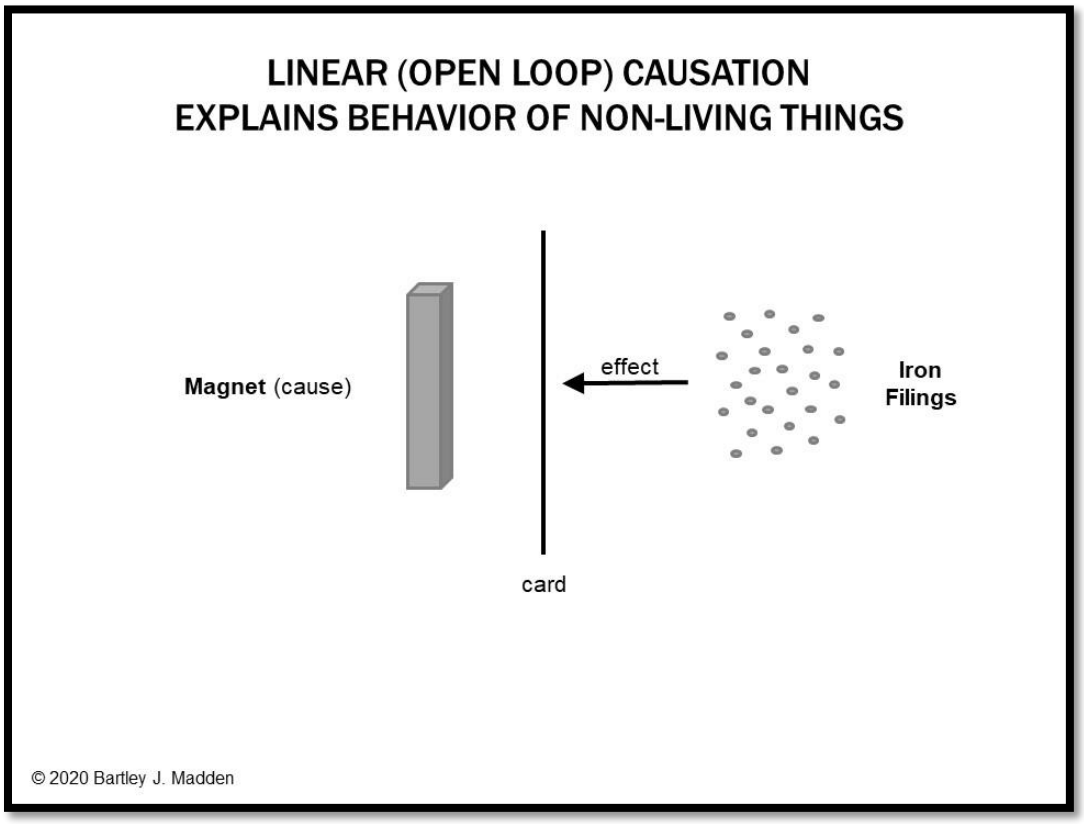


Instead of linear (open loop) cause and effect, we experience life as a closed loop where cause and effect simultaneously interact. At a point in time, your perception of the position of the car between lane markers is disturbed and this causes you to simultaneously act (move the steering wheel) which immediately changes your perception. This effect encounters new environmental conditions leading to a new steering wheel adjustment. We have a closed loop of cause and effect. With a closed loop, what people do impacts what they sense and what they sense impacts what they subsequently do (more on this later). The human system controls what it perceives and not what it does. In the late 1800s, William James and John Dewey got it right about behavior as control of perception with a closed loop of cause and effect.

[2] See William T. Powers, "The World according to PCT," in Warren Mansell (ed.). 2020. *The Interdisciplinary Handbook of Perceptual Control Theory.* London: Academic Press, Chapter 1.

In his 1890 textbook, *Principles of Psychology,* James noted the actions of nonliving things for which linear cause and effect thinking is sufficient. He contrasted human behavior to how a magnet attracts filings in a linear way which does not change if an obstruction (a card) is placed between the magnet and the filings.[3] Figure 3 illustrates the behavior of the iron filings.

Figure 3 Linear (open loop) causation



James described in his textbook a situation involving Romeo and Juliet:

> Romeo wants Juliet as filings want a magnet; and if no obstacles intervene, he moves toward her by as straight a line as they [can manage]. But Romeo and Juliet, if a wall be built between them, do not remain idiotically pressing their faces against its opposite sides like the magnet and the filings with [an obstructing] card. Romeo soon finds a circuitous way, by scaling the wall or otherwise, of touching Juliet's lips directly. With the filings, the path is fixed; whether it reaches the end depends on accidents. With the lover it is the end which is fixed, the path may be modified indefinitely.[4]

[3] The linear cause and effect examples I use throughout are for the world we experience, not the world for which quantum mechanics applies.

[4] William James. 1890. *Principles of Psychology.* Chicago: University of Chicago. p. 4. (1952 edition).

The above insight is the essence of PCT focused on purposeful behavior which involves overcoming obstructions that interfere with achieving one's goals. Why didn't the discipline of psychology incorporate this insight? Richard Marken and Timothy Carey, leading PCT researchers, explain that psychologists are typically uncomfortable with abandoning the temporal sequence of an explicit cause leading in a fixed linear manner to an explicit effect and psychologists invent many different theories to explain purposeful behavior in linear cause and effect terms. Marken and Carey point out:

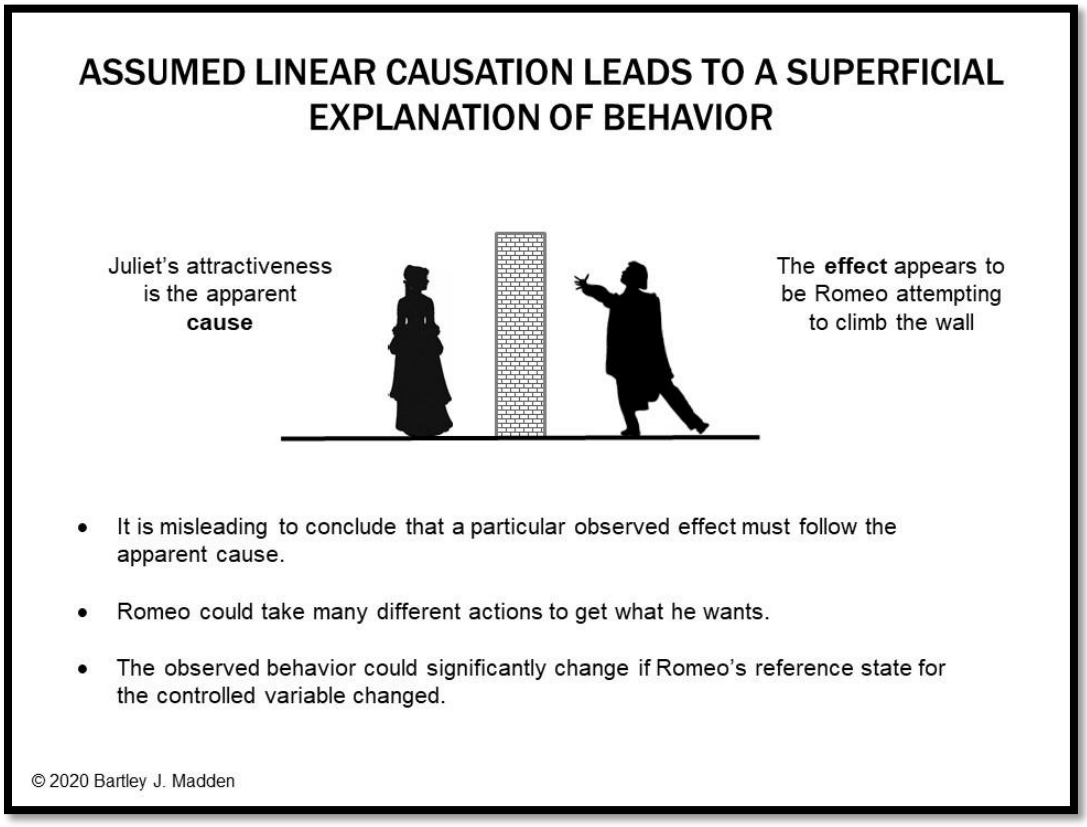
> Romeo's apparently purposeful pursuit of Juliet [may be] seen as being *caused* by Juliet's attractiveness just as the iron filings' apparently purposeful pursuit of the magnet is *caused* by the magnet's force field. But this cause-effect explanation of purposeful behavior works only if you ignore the part of James's parable about dealing with obstructions to goal achievement. Romeo finds a circuitous way around the obstructions, the filings don't. Juliet's attractiveness can no more *cause* Romeo to get around an obstructing wall than the magnetic field can cause the filings to get around the obstructing card.[5] (italics added)

To sum up, in a steady-state environment without continual disturbances, a psychological hypothesis that asserts an explicit cause (e.g., Juliet's attractiveness) that apparently explains what Romeo does can appear plausible. And Juliet's attractiveness (cause) comes before Romeo's actions (effect) thereby maintaining the conventional notion of a cause preceding an effect. But, if it is assumed that Juliet's attractiveness truly causes an explicit effect, is it not odd that Romeo seems to care little about which action he takes and a lot more about whether it gets him what he wants? What is important to Romeo is achieving his goal, not how he does it. Unlike the iron filings, living organisms can use variable means to get what they want. **The PCT explanation that applies to human behavior in general is that a person acts to keep the perception of a controlled variable as close as possible to the desired state or reference state**. **Behavior is the control of perception.** Technically, a perception refers to a sensory stimulation that gives rise to a perceptual signal (neural current) to the brain that represents some aspect of the outside world. As a practical matter, a perception is what we experience as the tasting of strawberry ice cream or seeing a friend walk across the room. Romeo is fundamentally trying to get his actual perception to match his reference state—his lips experiencing the touch of Juliet's lips.

Figure 4 illustrates how easy it is to label what we see in terms of linear cause and effect.

[5] Richard S. Marken and Timothy A. Carey. 2015. *Controlling People: The Paradoxical Nature of Being Human.* Samford Valley, Australia: Australian Academic Press. p. 24.

Figure 4 Romeo and Juliet



Extending the above example further, after Romeo discovered that Juliet had been unfaithful to him, the next day his reference state was to keep "far away" from Juliet. How well would the "attractiveness" variable then explain Romeo's disinterest in getting close to Juliet? Perhaps the conclusion is that most all stimulus/response empirical findings are context dependent and not representative of a foundational theory of human behavior. When researchers use a regression equation with a dependent variable and independent variables, they are accepting linear, or open loop, causation.

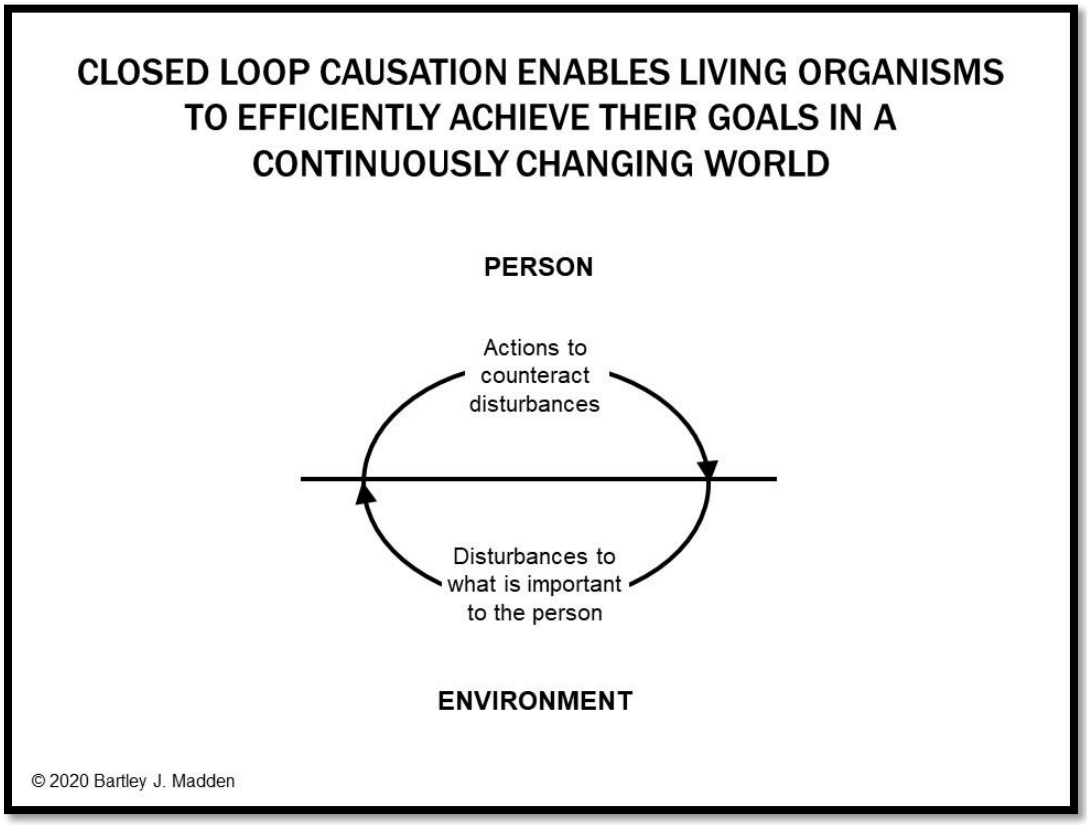
We return to the idea of a closed loop of cause and effect where actions for adjusting a steering wheel or for Romeo to surmount some obstacle involve a continual dance of controlling what is perceived. Along these lines, in 1896 John Dewey, with his typical wisdom, addressed the need for a sound foundation for psychology:

> What we have is a circuit [closed loop], not an arc or broken segment of a circle. This circuit is more truly termed organic than reflex, because the motor response determines the stimulus, just as truly as sensory stimulus determines movement.[6]

Figure 5 illustrates the closed loop concept.

[6] John Dewey. 1896. "The Reflex Arc in Psychology." *Psychological Review* 3: 357-370.

Figure 5 Closed loop causation



Here is an important takeaway: What we do (system output) invariably impacts what we perceive (system input). While the closed loop of causation is easily visualized for driving a car, even those behavioral situations that appear to be linear cause and effect are still better explained using closed loop viewpoint. Keep in mind, that the particular effect you observe is one of many possibilities. And the observed effect can vanish if a person changes (not visible to you) their reference state for the controlled variable.

PCT applied to living organisms

Building on the work of Claude Bernhard, Walter Cannon's 1932 book, *The Wisdom of the Body*, laid out the concept of *homeostasis* that focuses on how key variables such as body temperature and blood sugar levels are automatically maintained within narrow ranges in spite of continual disturbances. The key is negative feedback control of the physiological processes that control life-maintaining conditions inside the body. A case can be made that the negative feedback loop enabled the survival of species and their subsequent evolution.[7] That human beings control continual disturbances outside their bodies with negative feedback loops should not be surprising.

[7] For insights about the behavior of animals consistent with PCT principles, see Louise Barrett. 2011. *Beyond the Brain: How Body and Environment Shape Animal and Human Minds.* Princeton, NJ: Princeton University Press, Chapter 6.

The extraordinary utility of the negative feedback loop for living organisms is evident in how the bacterium *Eschericha coli* navigates. Marken and Powers built a PCT model with negative feedback that replicated the behavior of the bacterium. They also showed that human subjects, when their locomotion was restricted to mimic that of *E. coli,* behaved consistent with the negative feedback model.

> The biased random-walk chemotaxis [movement] of the bacterium *Eschericha coli* is a remarkably effective method of navigation based on random trial-and-error responding rather than steering. Humans restricted to the same mode of responding are able to navigate to target locations, just like the bacterium. *This mode of navigation can be modeled as an input control process that selectively retains favorable and rejects unfavorable consequences of the random responses*. The selection process is determined by the internal organization of the system rather than the external influence of the environment (as in natural selection or reinforcement).[8]
>
> (italics added)

While today's psychology textbooks discuss purpose (goal/motivation), they invariably focus on statistical averages (gross tendencies). These textbooks lack PCT's rigorous and comprehensive explanation of how an *individual person* achieves (or tries to achieve) his or her purposes. How did this come about?

The insights of William James and John Dewey for living organisms, such as people, were shelved most likely because a workable theory was not available at that time. Bill Powers began developing PCT in the 1950s. As previously noted, he first sketched out these ideas in articles in 1960. And he thoroughly explained PCT in a 1973 book.[9]

Meanwhile, the discipline of psychology marched behind the flag of *scientific research.* Develop a hypothesis, rigorously define variables, test how the hypothetical cause correlates with the observed effect, and verify that findings can be replicated; i.e., the scientific method. This approach led to a huge and continuing expansion of knowledge in the physical sciences focused on non-living things. For their empirical research, mainstream psychologists adopted the scientific method with independent variables manipulated by the experimenter and correlated with dependent variables.

Let's return to the situation where Romeo was trying to get his perception of the controlled variable to match the reference state. This is the inside view which is diametrically opposite the outside view of attempting to explain Romeo's behavior by *observing what he does*. After learning about Juliet's unfaithfulness Romeo's reference state for closeness to Juliet radically changed. His subsequent behavior may seem strange to an observer familiar with his past behavior around Juliet. Powers summarized this situation as follows:

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[8] Richard S. Marken and William T. Powers. 1989. "*Random-Walk Chemotaxis: Trial and Error as a Control Process.*" *Behavioral Neuroscience* 103(6): 1348-1355.

[9] W. T. Powers, R. K. Clark, and R. L. McFarland. 1960. "A general feedback theory of human behavior. Part I." *Perceptual & Motor Skills* 11: 71-88. W. T. Powers, R. K. Clark, and R. L. McFarland. 1960. "A general feedback theory of human behavior. Part II." *Perceptual & Motor Skills* 11: 309-323. and William T. Powers. 1973. *Behavior: The Control of Perception.* New Canan, CT: Benchmark Publications (2nd edition, 2005).

> [Perceptual] control theory bypasses the entire set of empirical problems in psychology concerning how people tend to behave under various external circumstances. One kind of behavior can appear under many different circumstances; instead of comparing all the various kinds of causes with each other while looking for objective similarities to explain the common effects, we are led by control theory to look for the *inputs* that are disturbed not only by the discovered causes but by all possible causes. For a thousand unconnected empirical generalizations based on superficial similarities among stimuli, I here substitute one general underlying principle: *control of input*.[10]

Ignoring control of input and singularly focusing on observed behavior (output) is at the heart of what Powers called the behavioral illusion. Consider a very cold winter day when your daughter embarks on a cause-and-effect experiment for her psychology class. Whenever a person leaves the front door open for at least two minutes, she observes that this *causes* the furnace to pump hot air (effect) into the room next to the front door. This empirical finding is repeatedly replicated by your daughter until she encounters a failure. Since empirical studies in the social sciences seek general tendencies, her average relationship is strong even though one observation shows no effect following the cause. What actually occurred is that, unknown to your daughter, your mischievous son decided to sharply lower the thermostat setting from 70 degrees to 40 degrees. Consequently, opening the front door was not immediately followed by the furnace pumping hot air. Stimulus-response analysis will fail to provide an insightful understanding when a system operates with a controlled variable.

This example is useful, at one level, because it deals, in a commonsense way, with a thermostat setting (reference state) and the perception of the controlled variable (room temperature). However, its oversimplification includes an outside observer being able to see and adjust the reference state (thermostat setting). For living organisms, outsiders can't see the organism's reference state and typically are not even aware of what the controlled variable is, and this lack of knowledge is magnified when multiple control variables are operating. Engineering control systems differ from living organisms because the users can set the reference (desired) values.

Consider the situation where a person points out to you that their teenage daughter just put a jacket on *because* the weather turned cold. With a PCT mindset, you silently think to yourself what is truly happening. The teenager put a jacket on in order to *experience* warmth; more specifically, she took action to get her skin temperature (controlled variable) close to the reference state for that particular sensory perception. She could have entered a car or a house if that were the more expeditious route to experience warmth—variable means for a fixed end as William James explained a long time ago.

I recently gulped a glass of water after taking an initial sip of some exceedingly spicy soup. (You know where this is going.) Did the soup "cause" my immediate swallowing of water? Some readers might push back and argue that, as a practical matter, I would not have gulped the water were it not for the very spicy soup. However, this represents a superficial explanation of behavior. The PCT explanation travels well for changing contexts; i.e., it represents a foundational understanding of human behavior. Example: My wife had the same soup and didn't blink. She grew up in a wonderful Mexican family and she was accustomed to enjoying eating red jalapeno peppers, which affect me like swallowing a small blowtorch. Concerning soup, my reference (desired) value for sense perception of food temperature on my tongue is considerably lower than my wife's. The important point is that, in contrast to empirical studies with regression-derived

[10] William T. Powers. 1978. "Quantitative Analysis of Purposive Systems: Some Spadework at the Foundation of Scientific Psychology." *Psychological Review* 85(5): 417-435.

statistics for central tendencies, **PCT explains how an individual person behaves and enables mathematical models to be constructed that can replicate specific types of behavior—a benefit not available to theories in psychology that lack PCT's precision.**

Boarding the PCT Train

Boarding the PCT train requires that you check off on six critical insights. The following insights work best as a package that helps you put together the major pieces of the PCT puzzle.

#1 Answering the question: Why do we act the way we do necessarily begins with understanding control. Otherwise, one is likely to view behavior as a continually repeating sequence of stimulus-response and be satisfied with what mistakenly appears to be commonsense logic. As noted earlier, this leads to a superficial understanding of human behavior. In contrast to nonliving things, we live purposeful lives, which is to say we continually try to get what we want in a world of continual change that yields disturbances that initially move us away from what we want.

In a very real sense, at any point in time, what we know about the world is what we perceive through our senses. These perceptions are guideposts that inform us as to how close we are to what we want. We act (behave) to control what we perceive as important to us. That's it—behavior is control of perception as reflected on the cover of Bill Powers' 1973 book. Control is maintaining a perceived variable at a reference or desired state in spite of continual disturbances.

Language matters. Once we begin using precise language for control and behavior, we have checked off an important step in understanding human behavior.

#2 We humans are living control systems that function with closed-loop causation. As pointed out earlier, with closed-loop causation, what the (human) system does impacts what it senses and what it senses impacts what it subsequently does. However, closed-loop causation happens so automatically that it can be missed. You turn your head to better see something of interest and the action of turning your head affects visual perception and subsequent action, and so it goes: closed loop causation all day long. With circular closed-loop causation, we can't speak of an independent cause of behavior.

#3 Open-loop (linear) cause and effect (stimulus-response) thinking is highly useful in many ways from manufacturing processes to the physical sciences; however, one needs to shift to closed-loop-PCT thinking when analyzing the behavior of an individual person. Getting comfortable with when to use open-loop or closed-loop thinking requires an especially clear understanding of control that illuminates what is going on with a stimulus-response worldview. Let's begin with Figure 6.

Figure 6 Stimulus-response worldview

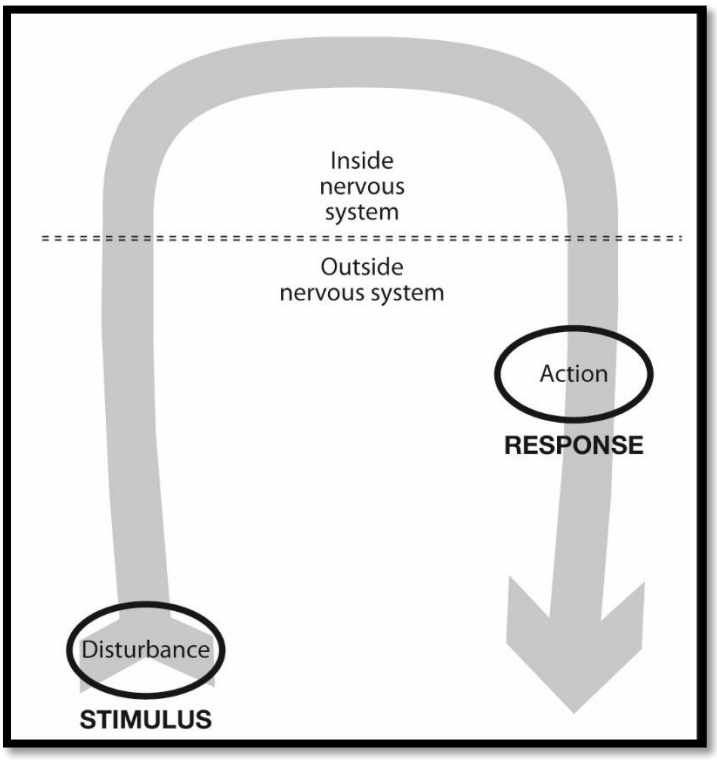


Figure 6 displays a stimulus as the input to the nervous system, followed by a response or output from the system. This is linear cause-and-effect logic in which the stimulus, after a time lag, is followed by a response. Cause precedes effect.

In Figure 6, the stimulus is labeled disturbance and the response is labeled action to conform to PCT terminology. A single response is shown although if many people experience a particular stimulus expect different responses dependent upon the specific environment coupled with people having different controlled variables and different reference states (Powers preferred the term reference signal).[11]

If you happen to observe a person's response following a particular stimulus, is it not easy (assuming that you never learned about PCT) to think that the stimulus "caused" the response (action)? Absolutely, which is why linear causation is so popular with explanations of behavior. We see what's easy to see. What observers fail to see because it is not visible to them is the person's control system. This is inside the nervous system, whereas the visible stimulus and response are outside the nervous system as shown in Figure 6.

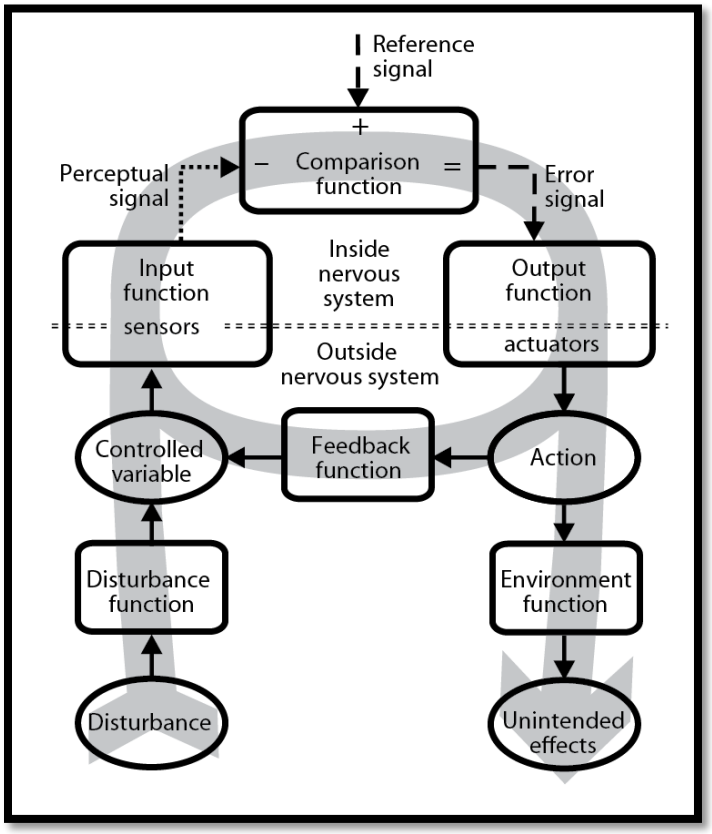
The existence of a control system obsoletes the validity of a stimulus being the cause of an observed response. What actually is happening is that when the disturbance affects a person's controlled variable

[11] The observed responses to a particular stimulus tend to be specific to the environmental context. Consequently, with a stable control system the outside environment, as opposed to what takes place inside the person, is likely to have the most influence on the responses.

(discussed later) that causes action to be taken to get the controlled variable back to a desired state. The action taken is not a response to the disturbance (stimulus) even though it is easy to conclude so. In fact, if an environmental disturbance had no effect on a person's controlled variables then no action results.

#4 The key to understanding control is to understand how a negative feedback loop functions. The result is a sharpened intuition about PCT and an appreciation for the preciseness of PCT that allows for researchers to build computational models. An iterative process of model building and evaluation of how well the model corresponds to actual human behavior is the same learning process that generated progress in the physical sciences. The loop is *negative* because actions taken *reduce* the existing error, as illustrated in Figure 7, and moves the system to being in control (approximate zero error).[12]

Figure 7 Negative feedback loop



Let's describe Figure 7 beginning with the *controlled variable*. As I am writing these words, one of my controlled variables is my sensory perception of noise level. My wife has turned on the TV in the adjacent room and the resulting noise represents a *disturbance.* That noise reaches my ears via a

[12] Figures 7, 8, and 9 were originally crafted by Bill Powers and Dag Forssell and I subsequently modified them slightly. Reprinted with permission from Living Control Systems Publishing, which contains a treasure trove of PCT material, some of which are free downloads. The figures were published in Dag Forssell (ed.). 2016. *Perceptual Control Theory: An Overview of the Third Grand Theory in Psychology Introductions, Readings, and Resources.* Hayward, CA: Living Control Systems Publishing, pp. 52 and 54.

disturbance function that determines what I actually sense (e.g., the walls of my office dampen the noise).

Inside my ears, the noise is sensed and the *input function* translates this sensed perception into a neural signal. This perceptual signal is one of two key inputs to the *comparison function.* The other input is the *reference signal,* which is my preferred environmental noise level while writing in my office. The difference between my current perception versus my preferred state (reference signal) represents an error that becomes a neural signal transmitted to the *output function.* It guides actuators (e.g., muscles) to initiate *action*, which can be ramped up (loop gain) to handle large errors. The purpose of the action undertaken is to move the controlled variable (noise perception) back to my desired state. The *feedback function* translates action into a new perception. In this situation, I walked to my office door and closed it thereby achieving my desired state and reducing error to zero. An action often produces *unintended effects* via the *environment function.* In this case, the environment in my office changed (now quiet); however, if my wife calls out for me to meet someone at our condo elevator, with the office door closed, I'll likely not hear her.

The loop from the controlled variable to the comparison function to action is a negative feedback loop because actions taken are intended to reduce error and keep the system in control, i.e., controlled variable matches desired state. This simple illustration hints at the intrinsic speed and efficiency in which negative feedback loops maintain control. The earlier discussion of driving a car provides a useful picture of the speed and efficiency of the negative feedback loop that employs a circular or closed loop of causation. The sensed perception of lane position leads to a comparison with the reference signal and any error gets translated into an action of our hands moving the steering wheel. Hence, what we sense affects what we do and what we do affects what we sense in a circular fashion.

The key to the PCT-version of control theory is the negative feedback loop, which Powers referred to as the basic principle of life.[13] The conventional view of behavior as "control" of actions needs to be replaced with PCT showing that the consequences of actions are actually controlled. In other words, a control system does not control actions; rather, the system controls what it senses. Getting comfortable with the prior sentence is another checkmark in understanding human behavior.

#5 Behaviorism, which is rooted in a stimulus-response view, lacks PCT's parsimonious and powerful theoretical underpinning that can explain so much with negative feedback, closed loop causation, hierarchical control systems (discussed later), and computational models that employ mathematical precision in place of the vague language so typical of mainstream psychology.

In the early 1900s, the focus of mainstream psychology was on introspection. That was a mistake and interfered with predictions about human behavior that could be evaluated experimentally, so argued John B. Watson. In a hugely influential article in 1913, "Psychology as the Behaviorist Views it," Watson asserted:

> Psychology, as the behaviorist views it, is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data

[13] William T. Powers. 1995. "The origins of purpose: the first metasystem transitions." *World Futures* 45: 125-138. Special issue on The Quantum of Evolution.

> dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness.[14]

Behaviorism has deep roots in the worldviews of those who believe actions are responses to environmental stimuli (disturbances) and those who believe that employees are best controlled via carrots and sticks. Behaviorists assert that stimuli are the *input* to the person whose brain and nervous system function to generate an *output* in response. While this view seems logical to many there really is a nagging problem with this simplification. Powers noted:

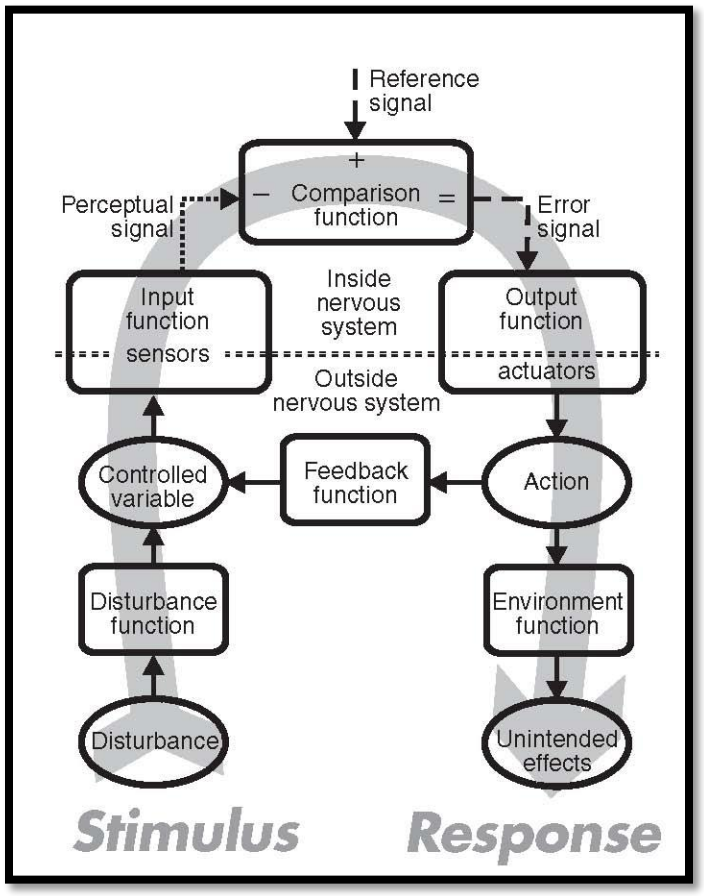
> There has, however, always been a nagging problem in the background. William James mentioned it nearly 100 years ago. It is that organisms seem to accomplish repeatable ends by variable means. Taken at face value, this observation means that *there can be no reliable chain connecting antecedent causes to consequent behaviors*. The chain is broken somewhere between the place where muscles contract and the place where we observe the consistent consequences of variable muscle contractions.
>
> … Of course actions are highly variable: they must be, because a natural environment is always disturbing the variables that organisms control. Of course the consequences of variable actions repeat: they are, or are closely related to, input quantities that organisms are controlling. What we mean by the word *behavior* is not the unpredictable fluctuations of muscle force and limb position that we can see, but the regular consequences that result. We mean controlled variables.[15]
>
> (italics added)

In Figure 8 below, depicting the Behaviorism worldview, the grey arrow shows an Input-Output system that fails to operationalize the role of purpose (reference signal) residing inside the nervous system.[16]

[14] John B. Watson. 1913. "Psychology as the Behaviorist Views it." *Psychological Review* (20): 158-177.
[15] William T. Powers. 1990. "Control theory: a model of organisms." *System Dynamics Review* 6(1): 1-20. pp. 13 and 14.

[16] William T. Powers. 1973. "Feedback: Beyond Behaviorism." *Science,* 179, No. 4071 pp. 351-356.

Figure 8 Behaviorism worldview



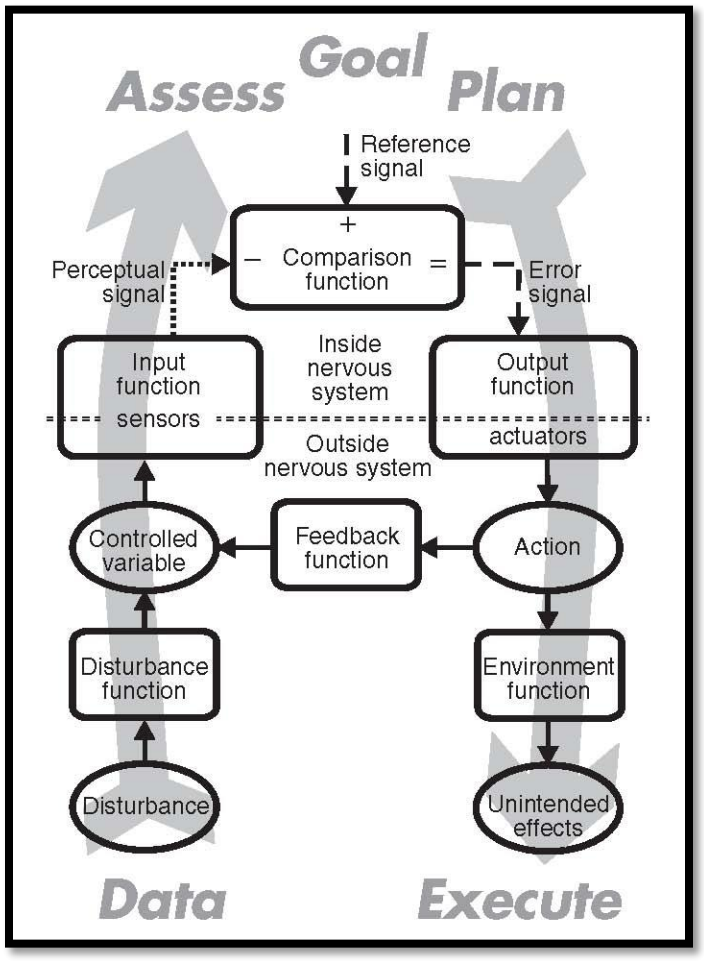
With an extreme focus on inputs, the environment is then the prime mover for understanding behavior. To no surprise, B. F. Skinner wrote: "It [Skinner's Behaviorism] offers, I believe, the clearest possible statement of the causal relations between behavior and environment.[17]

#6 What is critically missing from cognitive psychology, which utilizes the findings from cognitive science and is the centerpiece of modern psychology textbooks? In contrast to Behaviorism, with its exclusive focus outside the nervous system, cognitive psychology turned attention to inside the nervous system. As illustrated in Figure 9, processes in the brain became the focus for explaining stimulus and response.[18]

[17] B. F. Skinner. 1974. *About Behaviorism.* NY: Random House p. 273.

[18] Richard S. Marken. 2009. "You Say You Had a Revolution: Methodological Foundations of Closed-Loop Psychology." *Review of General Psychology* 137-145.

Figure 9 Cognitive psychology worldview



Data from the environment is the input to the brain which instantaneously analyzes the environmental situation, one's goals, and all relevant relationships. The optimum plan of action (output) is computed and commands are sent to the muscles in order to generate the appropriate response. Figure 9 illustrates the widely-held assumptions (especially in psychology textbooks) that behavior is the end result of environmental stimuli and cognitive plans.

Notably missing from cognitive psychology is the negative feedback loop mechanism so central to a hierarchical control system that enables actions to control perceptions in a way that is super-efficient in achieving one's purposes. Why are control system insights totally missing from psychology textbooks?

Here is a clue. Changes to textbooks follow highly cited articles in the top journals. Such articles typically bridge gaps in the existing paradigm with theory or empirical contributions. Articles reporting empirical findings typically employ linear cause and effect (stimulus and response) with dependent variables correlated with independent variables for two reasons. First, it facilitates doing the research and getting a paper accepted. Second, seriously engaging with PCT entails a fundamental break with their peers, learning a new research methodology, and facing increased difficulties in publishing in the top journals. For sure, this is a huge roadblock for young scholars seeking tenure. And the senior scholars on the editorial boards of the journals control the publication process and have built a legacy of work that

supports the existing paradigm. In addition, across the social sciences in general, there is the unspoken expectation that knowledge advancements will be produced by members in good standing in "the club." Club membership almost always requires a PhD and either being a professor or working at a prestigious research facility. Bill Powers was not a member of the club.

Nevertheless, if PCT brings major, *foundational* insights about human behavior, should we not expect that leading thinkers in cognitive science and the philosophy of the mind would eventually appreciate the usefulness of the PCT hierarchical control systems? Bill Powers may never get the recognition he deserves but his ideas may well come to occupy center stage. In the following quote, Andreas K. Engel, Karl J. Friston, and Danica Kragic, by any measure, leading-edge cognitive scientists, suggest shifting the direction of mainstream cognitive science in a way that is much more compatible with PCT:

> The insight that cognition may be fundamentally grounded in action [in contrast to the classical cognitivist approach of making models representing the world] seems to reinforce a radical change in how we conceive of the functional significance of neural patterns. Some argue that brain states prescribe possible actions, rather than describe states of the outside world. Thus, brain states might better be understood as "directives" that guide action, rather than as "representations."[19]

The influential philosopher and cognitive scientist Andy Clark has argued for the importance of the brain's ability to predict sensory perceptions and reduce predictive error, which is close to PCT thinking:

> Action is not so much a "response to an input" as a neat and efficient way of selecting the *next* input, driving a rolling cycle … We thus act so as to bring forth the evolving streams of sensory information that keep us viable … The largest contributor to ongoing neural response is the ceaseless anticipatory buzz of downwards-flowing neural prediction that *drives perception and action in a circular causal flow*.[20]
>
> (italics added)

The high-powered minds quoted above neither referenced Powers nor PCT even though PCT seems particularly relevant to their thinking. If they and other leading cognitive scientists used PCT as a foundation to build upon, or at least as a source for hypotheses to be tested, perhaps new useful knowledge could be produced at a faster pace. Alternatively, would we all not benefit from cognitive scientists and particularly the authors of psychology textbooks plainly explaining why they choose to ignore PCT? One can speculate that the answers would represent a defense of linear causation coupled to an input/output experimental mindset and wrapped in a defense of their existing research methodology.

Computational models, motor sensory tracking experiments, and controlled variables

As discussed in the above section, Perceptual Control Theory and cognitive psychology (the reigning view of human behavior) are radically different. Figure 10 summarizes these differences.

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[19] Andres K. Engel, Karl J. Friston, and Danica Kragic. 2015. *The Pragmatic Turn: Toward Action-Oriented Views in Cognitive Science*. Cambridge, MA: MIT Press. p. 5.

[20] Andy Clark. 2016. *Surfing Uncertainty: Prediction, Action, and the Embodied Mind.* Oxford: Oxford University Press. p. 52.

Figure 10 Two different views of human behavior

PERCEPTUAL CONTROL THEORY	TOPIC	COGNITIVE PSYCHOLOGY
Closed circular loop of causation functions so that what the system does affects what it senses and what it senses affects what it does. Cause and effect happen concurrently.	Time	Open loop (linear) causation with cause preceding effect
Purpose is center stage and operationalized as the reduction of error calculated as the difference between the perceptual signal and the reference signal.	Purpose	Recognized but not center stage.
People control the consequences of their actions in order to achieve their purposes.	Control	People control their actions to respond to environmental stimuli.
Actions feed back to offset disturbances	Feedback	Ignored
Controlled variable changes little even when encountering continual disturbances.	Controlled Variable	Ignored
Research would benefit from the use of a hierarchy-of-control-systems structure.	Brain and nervous system	Large scale research in progress (e.g., neuroscience)

As noted in the above figure, cognitive psychology ignores feedback and the controlled variable so prominent in Perceptual Control Theory. The key points noted in the above figure constitute a potential paradigm change as to the understanding of human behavior. Consider the last point about the brain and nervous system. Cognitive psychology employs an input/output mindset in which the brain (treated as a supercomputer) *receives inputs* about the environment and optimizes output (action). In contrast, the PCT mindset emphasizes how the *individual person chooses inputs*, i.e., what is important to them (controlled variables and reference states). The criticism that PCT is analogous to controlling a machine and ill-suited to human behavior is misinformed and reflects a lack of knowledge about PCT.

Tracking experiments, which are discussed below, are powerful tools in explaining how PCT works. However, those who have just heard about PCT most likely need some further "big picture" insights in order to be motivated to spend time with tracking experiments. They need to feel comfortable in replacing (at least, provisionally) the belief that we control our actions with the idea that we control the consequences of our actions.

We walk without falling down, safely drive a car, brew a pot of coffee, drink a cup of coffee and endless other tasks using variable actions that yield the same outcome. How so? This is explained by viewing behavior as control of perceptions such as your foot touching the ground in a way that maintains balance; the position of your car in its lane; the temperature, color, and taste of the brewed coffee; and adjustments in raising the coffee cup to your lips as the weight diminishes due to less liquid in the cup. Does it not make sense that you control the consequences of your actions such as the perception of the coffee cup touching your lips?

Adopt this PCT mindset and see where it takes you. The first step is to realize that observing what people do can easily lead to a superficial understanding of their behavior. Understanding flows from discovering controlled variables important to the person and then observing how their actions are attempts to keep their controlled variables where they want them to be.

Say you observe drivers who stop at a gas station and you further observe that, on average, the amount of money spent indicates a low amount of gas in the tank when they entered the station. You conclude that behavior in this situation is clearly understood. Not really. PCT is about explaining the behavior of an individual person not averages or central tendencies of people. A person with the same low amount of gas left in the tank may drive by this gas station when she is controlling for being on time for an important meeting. Controlled variables can be difficult to pinpoint. Was it more important to that particular driver who stopped at the gas station to get gasoline or to get a caffeine fix by buying a cup of coffee?

PCT views the person as doing the controlling and not mechanistically responding to environmental stimuli such as the gas gauge indicating one quarter full. A husband may fill up the tank in his wife's car when the gauge read half full. In this instance, he is controlling for his wife's feelings since she appreciates the help in avoiding a future visit to the gas station.

You may push back and say: "Look at that driver's gas gauge which is almost empty. Clearly, I *know* what caused him to pull into the gas station because I can *see* the almost empty gas gauge." Seeing an environmental stimulus coupled to a response gives us a false sense of certainty as to understanding behavior. A deeper analysis reveals that the controlled variable is safety. He is controlling for safety on the road and avoiding an empty tank on the expressway is a way to control for safety. Moreover, on another occasion he may stop at the gas station with plenty of gas in his tank. In this instance, he feels that one of his tires may be experiencing a slow leak and checking air pressure in the tire controls for safety—a different action to keep a controlled variable (safety) where he wants it. We control the consequences of our actions. The first step in understanding behavior is to discover a person's controlled variables relevant to the situation at hand.

We tend to be on automatic pilot every day in implicitly assigning cause to an environmental stimulus that is followed by a response (action). Keep in mind that this common experience of analyzing behavior begins with observing the stimulus and correlated action. *We almost never begin with a person's controlled variable, which often can be difficult to discover.* As previously noted, Powers labeled this noncritical and superficial way of observing what people do in apparent response to a stimulus as a behavioral illusion.[21]

PCT like any theory needs to be tested to observe if its predictions are verified and if it helps us understand what is really happening. A reasonable initial test would focus on motor sensory tasks in which the disturbances and actions are visible and quantifiable. The motor sensory experiments have provided the strongest support for the PCT explanation of human behavior and are definitely worth your time to personally experience.[22]

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[21] Richard S. Marken. 1992. *Mind Readings: Experimental Studies of Purpose.* A Control Systems Group Book, Chapter 1.

[22] See the following websites: The International Association for Perceptual Control Theory at iapct.org, PCTweb.org, LivingControlSystems.com, and especially MindReadings.com.

The basic idea behind a computational (software coded) model is straightforward. For example, a motor sensory task is studied and, based on PCT principles (or whatever theory the researcher relies on to explain human behavior), a model is constructed in precise mathematical terms and converted into computer code.[23] The mathematical precision of a computational model overcomes the lack of specificity in verbal theories that are open to myriad interpretations. The model can be run and the simulated results compared to actual behavioral results. Significant differences call for development of a more refined (complex) model. And the process continues, all the while the researcher is learning more about how people are actually controlling their lives. Powers commented about computational models as follows:

> In contrast to the method of statistical generalization, the method of modeling begins by analyzing an individual behaving system. First, the system is broken down into actual or proposed components, each of which can be described as a simple input-output relationship. Then the equations describing each component are solved as a simultaneous system to predict the individual's behavior, given the actions of any independent outside influences. The calculated behavior is compared against the actual behavior with those same influences acting. The difference between the model's behavior and the real behavior provides a basis for systematically revising the hypothetical components of the model (the known components, of course, remain the same) until its calculated behavior is in accord with observation. The method of modeling is the basis for most procedures in the physical sciences. Generalizations come afterward, not first. There is, in fact, almost no use of statistical generalization in the most successful sciences. The focus is on constructing and improving models.[24]

Tracking experiments involve building and debugging a PCT-based computer model, running simulations, and analyzing the output. This output is then compared to the output generated by human subjects under the identical conditions as used for the simulations. Depending upon the behavior being investigated, PCT tracking models can become increasingly complex to address the complexity of the underlying system being studied.

The simplest motor sensory tracking experiments involve a subject looking at a computer screen with an ability to move a mouse in order to position the cursor in line with a designated target. A simulation is run in which the computer generates a continual stream of random disturbances over time that move

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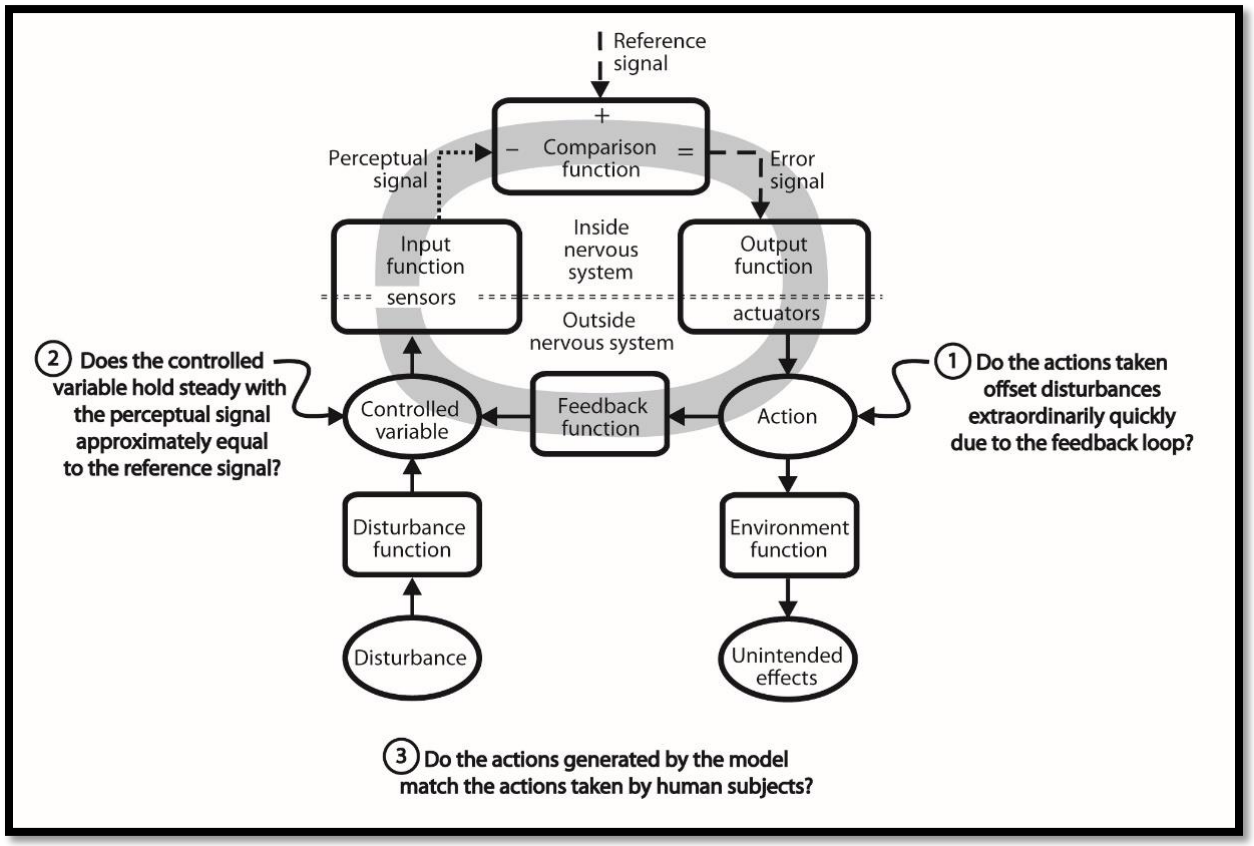
[23] Marken authored three useful books on PCT models: Richard S. Marken, 1992. *Mind Readings: Experimental Studies of Purpose.* A Control Systems Group Book; Richard S. Marken. 2002. *More Mind Readings: Methods and Models in the Study of Purpose.* St. Louis, MO: new view; and Richard S. Marken. 2014. *Doing Research on Purpose.* St. Louis, MO: new view. Also useful are two books of selected papers (relevant to modeling) of Bill Powers compiled by the Control Systems Group, Inc., Gravel Switch, Kentucky: *Living Control Systems* and *Living Control Systems II.* Finally, William T. Powers. 2008. *Living Control Systems III: The Fact of Control.* Bloomfield, NJ: Benchmark Publications.

[24] William T. Powers. 1990. "Control Theory and Statistical Generalizations." *American Behavioral Scientist* 34(1): 24-31. In this article Bill Powers presents a brief but highly revealing demonstration of how multiple regression studies can lead to wrong conclusions about economic behavior. *Every economist, actually everyone who uses multiple regression equations, would benefit from studying Powers' way of thinking so elegantly laid out in these eight pages.*

the cursor away from the designated target. This information is available to the model and, in turn, actions are generated exactly as specified by the model.

The output of the tracking simulation is plotted time series of the disturbances (movement away from the target), actions taken (movement of the cursor), and the extent of control achieved, i.e., how close over time does the cursor stay on top of the target. As highlighted in Figure 11, there are three especially important questions to answer.

Figure 11 Three important questions



A large number of tracking experiments of varying complexity have generated simulations showing that the PCT model generates a system under control.[25] The outputs show that actions do instantaneously offset disturbances and the controlled variable changes very little over time thereby maintaining the desired perception (zero error). The simulation results are impressive. But, critically important, is the answer to this question: Do the actions generated by the model match the actions taken by human subjects? Yes, they do. Consequently, these tracking experiments support the PCT view that we humans

[25] Warren Mansell and Vyv Huddy. 2018. "The Assessment and Modeling of Perceptual Control: A Transformation in Research Methodology to Address the Replication Crisis." *Review of General Psychology 22(3): 305-320.* Also see Maximilian G. Parker, Andrew B. S. Willett, Sarah F. Tyson, Andrew P. Weightman, and Warren Mansell. *Neuroscience and Behavioral Reviews* 112: 616-633.

(certainly for sensory motor tasks) function with a brain and nervous system that operates via the negative feedback loop principle. It is difficult to make a case that one can understand what is happening in these tracking experiments by ignoring negative feedback control.

As more complex behavior is studied, an iterative process ensues. A computational model is built and tested both with simulated results and actual behavior. This typically reveals a deficiency in the original model motivating the researcher to build a more complex model in a way that can better duplicate actual behavior. For example, in his last book, Bill Powers successfully built and tested a model of the functioning of a human arm and hand. He used a hierarchical system of multiple levels with multiple negative feedback control systems at each level.[26]

Let's consider the process for discovering a controlled variable. Your initial hunch that one or more controlled variables are active in the operation of a system (a robot, a human being, etc.) typically is due to a system's unexpected steadiness (lack of variation). The Test for the Controlled Variable (TCV) begins with a guess about what perceptual variable the system is sensing and controlling. This guess or hypothesis can be informed by assessing the apparent purposeful goals of the system. The next step is to apply disturbances that should have an observable effect on the variable in question if it is not under control. Consider the earlier example of my wife playing the TV in a room adjacent to my office. If my office door is opened and then I immediately close this door to offset the noise disturbance that is evidence of the discovery of a controlled variable. Creativity and perseverance are helpful for implementation of the TCV.

A research program addressed the question of the identification of a controlled variable for beavers who had constructed a dam. The hypothesis was that a controlled variable was the noise level of running water. To implement the TCV, the researchers placed a loudspeaker near the dam that played the sound of running water. To counteract the noise disturbance, the beavers piled mud on the speaker indicating that a controlled variable was discovered.

In dealing with more complex systems than a beaver dam, PCT researchers discover controlled variables by an iterative process of assuming a particular perceptual variable is controlled, building a model, and comparing the simulation results to actual behavior. Consequently, a learning process unfolds as to how the system functions and what variables are controlled.[27]

The next section addresses PCT's hierarchy of control systems that enable a person to have multiple controlled variables at different levels of the hierarchy with all of this control happening simultaneously.

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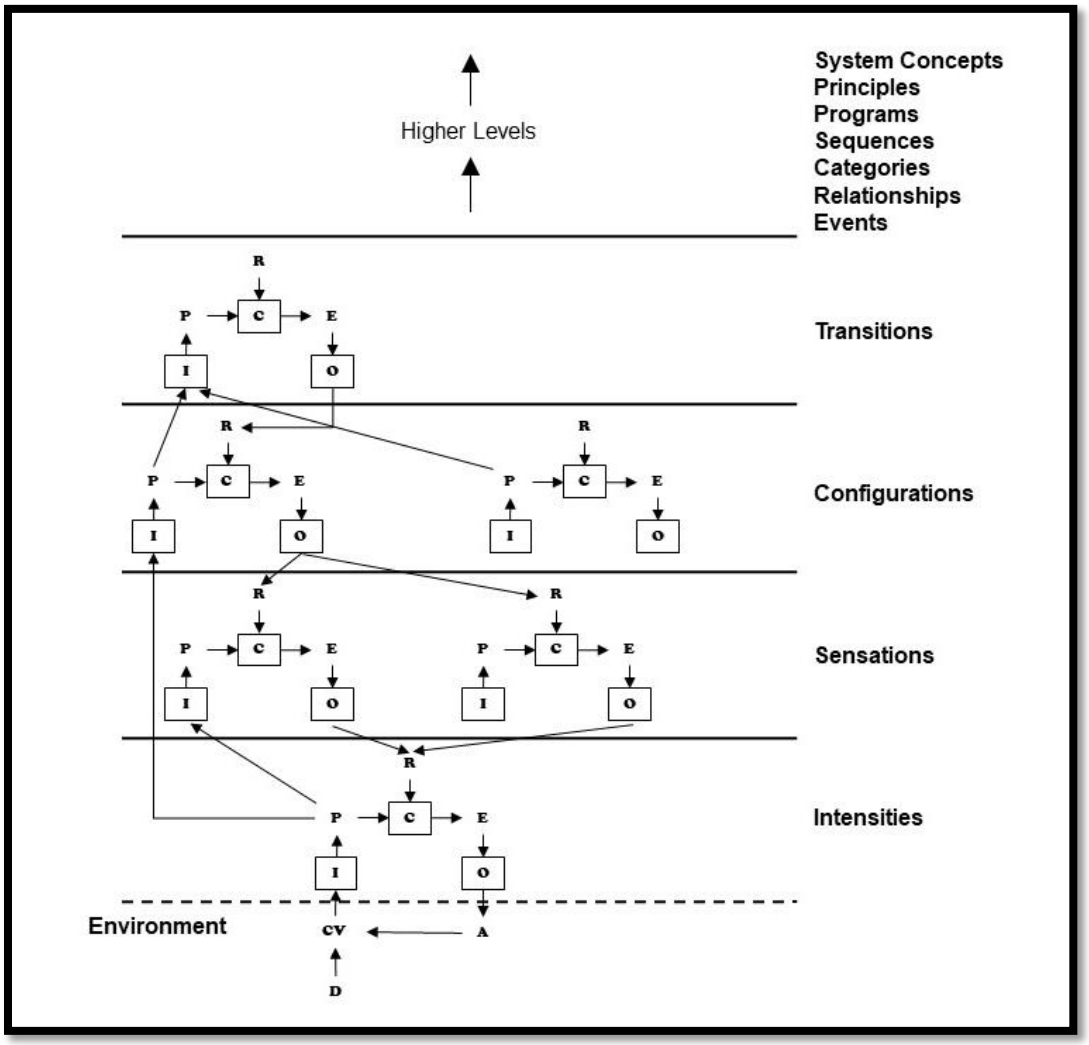
[26] William T. Powers. 2008. *Living Control Systems III: The Fact of Control.* Bloomfield, NJ: Benchmark Publications, Chapter 8.

[27] William T. Powers, Bruce Abbott, Timothy A. Carey, David M. Goldstein, Warren Mansell, Richard S. Marken, Bruce Nevin, Richard Robertson, Martin Taylor. "Perceptual Control Theory: A Model for Understanding the Mechanisms and Phenomena of Control," in Dag Forssell (ed.). 2016. *Perceptual Control Theory: An Overview of the Third Grand Theory in Psychology Introductions, Readings, and Resources.* Hayward, CA: Living Control Systems Publishing, p. 39.

PCT hierarchy of control systems

Powers proposed a nested hierarchy of control systems with eleven levels, or classes of perceptions, as enumerated in Figure 12. This figure is a hugely simplified diagram to illustrate the conceptual functioning of such a hierarchy.[28] The basic unit of analysis is a control system with a feedback loop, as previously discussed. Referring to the bottom of Figure 12, the input (I) function converts physical variables to a neural perceptual (P) signal that is compared to the reference (R) signal in the comparison (C) function. The resulting error (E) signal is converted to muscle movements in the output (O) function. The controlled variable (CV) is impacted by the disturbance (D) and an offsetting action (A).

Figure 12 PCT's hierarchy of control systems



[28] Adapted from Shelley Roy. 2008. *A People Primer: The Nature of Living Systems.* Chapel Hill, NC: New View Publications, which is a useful non-technical explanation of PCT. The other useful, non-technical overview of PCT is William T. Powers. 1998. *Making Sense of Behavior: The Meaning of Control.* New Canaan, CT: Benchmark Publications.

The above hierarchy solves a fundamental problem, i.e., in a continually changing world, we can't plan beforehand the actions needed to maintain control. The solution is variable actions that yield repeatable consequences. Being in control means that actions are quickly taken to offset disturbances in order to keep the perception of a controlled variable equal to the reference signal (intended perception—what we want to experience) sent from a higher level in the hierarchy. Note that what you *experience* (see, hear, smell, etc.) is generated by neural signals in your brain. Many internal neural signals at different perceptual levels represent the complex attributes of what we perceive in the external world.

Importantly, the PCT hierarchy differs from a command-and-control hierarchy that specifies actions to be taken. With the PCT hierarchy, higher levels do not issue commands for action; rather, they tell lower level systems what to perceive. For example, walking along the sidewalk you fail to notice the "wet cement" sign and step where you shouldn't. With a slow-moving command-and-control hierarchy that needs to both compute and communicate a new plan of action, expect to very soon be face down in cement. With PCT, the lowest level continually sends a perceptual signal to its comparator and also as an input to the next higher level, as shown in Figure 12. With your foot in wet cement, the next higher level instantaneously sends a new reference signal to the lowest level that causes a big error resulting in a much stronger action that can quickly pull your foot out of the cement. Lower level systems have much shorter neural pathways and operate considerably faster than higher level systems.

Why then so much theorizing about the brain as a supercomputer that is continually making predictions and planning actions? On the one hand, it is a good bet that these researchers have built linear cause-and-effect models and use correlations of independent and dependent variables, but not built PCT-type models. The latter involve simulation of a specific observable human behavior, comparison to actual behavior, and a critical assessment of the usefulness of one's research paradigm. On the other hand, PCT-oriented research raises fertile questions for neuroscientists and others about how our brains function and suggests possible tie-ins to closed loop causation and negative feedback loops.[29] Empirical research in psychology correlates independent and dependent variables and often seems designed to eliminate any role for feedback. Since important controlled variables are notable due to their absence of change, how can psychologists, *under the existing linear cause-and-effect paradigm*, investigate controlled variables that exhibit a lack of correlation to other environmental variables?

Returning to Figure 12, let's discuss the logic of Powers proposed eleven levels or classes of perception. As Powers noted, these eleven levels are not etched in stone. Rather, consider accepting them on a provisional basis recognizing that future research may provide reasons for modification.

Going up the levels illustrated in Figure 12 answers the question why lower levels have particular reference signals (purposes) and going down the levels answers the question how higher-level purposes

[29] Important neuroscience research on the basal ganglia provides insights about basic motor functioning of human beings. See Henry H. Yin. 2017. "The basal ganglia in action." *Neuroscientist* 23(3): 299-313. Yin employed a PCT hierarchical model. He describes the need for a PCT methodology that puts control with inputs not outputs: "The key mistake is to assume that a control system controls its outputs, the convention taught in engineering … the controlled variable is not the output but the input. Biological organisms are autonomous, which means that they possess intrinsic reference signals, whether innate or learned ... The control of output assumption reverses the organism/environment relationship. Consequently, attempts to apply control theory to neuroscience have largely failed, even though the correct equations were used. It is as if one were to use the wrong end of a key to open a lock, only to conclude that it was the wrong key."

are achieved. At the lowest level, *intensities* indicate what is happening to nerve endings and report the degree (quantity) of stimulation acting on them. *Sensations* (e.g., brightness, pressure, temperature, etc.) enables object to be distinguished from one another. Next up are *configurations* that represent particular sensations that constitute a shape that is recognized as a unit.

In moving up to a higher level, keep in mind that the control of perceptions at a particular level depend upon being able to vary lower-level perceptions. So, what higher level perceptions can be controlled via intensities, sensations, and configurations? A plausible answer is the experience of change. We experience change in the world out there and therefore *transitions* (going from a perception of cold to warm when entering a house during a frigid winter) work for the next level up.

A reasonable next level is *events* which are packages of perceptions that follow a pattern (saying hello, shaking a friend's hand, etc.). *Relationships* tie together a bark with a dog and a meow with a cat. *Categories* reflect either-or classifications that differentiate things (horse not a cow, motorcycle not a bicycle, etc.). *Sequences* represent perceptions that follow a specified order. After your income tax return is completed, then you write a check to cover what is owed, and then you mail these items to the Internal Revenue Service.

Programs connect sequences due to specific choices and if-then crossroads involved. Control of a perception of a program depends on handling lower-level perceptions to keep in sync with the logic and rational thinking reflected in the program. *Principles* are difficult to precisely define and are about ways of living one's life as, for example, an honest person, a reliable employee, and the like. *System concepts* are about big organizing ideas such as capitalism, democracy, religious beliefs, an organization's mission statement, etc. Finally, starting at the highest level, as one moves down, there are more loops that act faster and the levels become more concrete.

An especially rich vein of research to mine involves generating additional insights about the role of memory in setting reference signals and about the role of the PCT hierarchy as part of learning. Also, how might a hierarchy of control systems facilitate imagination and the generation of hypotheses for solving problems?

Interestingly, there is considerable empirical support for the emergence of a hierarchy of different levels of perception in infants at particular times. With infants, the gaining of a new perceptual level is marked by a temporary regression of capabilities and anxiety (crankiness). Reorganization (a form of learning) of their control systems takes place with trial-and-error experimentation until increased control is achieved with their new capabilities. Hetty van de Rijt and Frans Plooij—coauthors of *The Wonder Weeks*, a widely-read guidebook for parents of newborn infants—first observed the distinct regularity (as to the number of weeks since birth) of regression periods followed by leaps in cognitive development from extensive observational studies of free-living chimpanzee babies. They later learned that their observations agreed with Powers hierarchy of perceptual levels. Decades of research followed focused on human babies and their relationships with their mothers, which replicated the chimpanzee baby findings. Their subsequent PCT-oriented studies are relevant to the evolution of human cognition.[30]

[30] Mikael Heimann (ed.). 2003. *Regression periods in human infancy.* Mahwah, NJ: Erlbaum.

Powers thought that the PCT hierarchy of perceptual levels holds potential for handling conflict. Timothy Carey and others built on this idea and developed the Method of Levels (MOL) for psychotherapy.[31] Conflict occurs when two control systems at one level of the hierarchy are sending opposing reference signals to the same lower level, which explains how chronic psychological distress occurs. The greater the degree of control, the more intense the conflict. Conflicts endure due to a person continually struggling with incompatible actions. The PCT-guided solution is for the MOL therapist to engage the patient in conversations and shift awareness to the level at which the conflict originates. This can lead to an aha! moment for patients when they plainly see the root cause of their difficulties.

MOL is grounded in the solid science of PCT and brings a needed focus to psychotherapy which is populated by a wide range of practices missing a solid scientific basis. Supporting this situation are psychology textbooks and popular books that are full of arbitrary classification schemes absent a unifying theory about why we act in the ways we do.

Warren Mansell, Timothy Carey, and Sara Tai summarize:

> Control could well be a unifying phenomenon for the life sciences. It is certainly crucial when it comes to understanding and treating psychological problems … problems of living are, fundamentally, problems of control ... from the perspective of control, we might achieve greater clarity and resolution of some of the most contentious theoretical issues in psychology … [including] the debate about common versus specific factors, the 'dodo bird hypothesis' (the idea that all psychotherapy is equally effective), the categorization of problems into apparently discrete disorders, the mind/body split, the interaction between the environment and the individual's goals, and the divide between psychological and physical problems. Ultimately we might provide treatments that are more effective and more efficient because they will be based on a more accurate depiction of why we act in the ways we do.[32]

The above quote speaks volumes as to the potential for PCT to serve as a unifying theory in the social sciences. Although not a topic in this book, PCT mathematics provide an opportunity for precise language to expedite scientific progress.[33] Would not progress accelerate by shifting from an *external* observer viewpoint to the *internal* control processes that generate the observed actions in order to maintain perceptions at desired states.

PCT for business firms

The core PCT notion of the perception of a controlled variable compared to a reference state yielding an error that guides a person's actions has significant potential for management research. The thinking undergirding the Method of Levels can assist management and their HR (human resource) departments

[31] Timothy A. Cary. 2006. *The Method of Levels: How to do Psychotherapy Without Getting in the Way.* Hayward, CA: Living Control Systems Publishing. See Cary's website MethodofLevels.com.au.
[32] Warren Mansell, Timothy A. Carey, and Sara Tai. 2013. *A Transdiagnostic Approach to CBT Using Method of Levels Therapy.* London: Routledge, p. 20.
[33] The mathematics of PCT control systems are impressive as to elegance and practicality. On this topic, a particularly informative book will be published by Cambridge University Press in early 2021, *The Study of Living Control Systems*, by Richard S. Marken.

in spending less time measuring the effectiveness of their carrots and sticks initiatives and more time analyzing employees' controlled variables/hierarchical levels as this relates to reducing conflicts and increasing cooperation. The PCT explanation of human behavior could advance both research methodology and the generation of novel hypotheses in a way that spurs imagination by overcoming an automatic reliance on correlations of dependent variables with independent variables.

In reporting on their extensive research into employee motivation, Teresa Amabile and Steven Kramer note the following (PCT tie-ins are shown as bracketed and italicized words):

> Conventional management wisdom is way off track about employee psychology [*understanding human behavior*]. When we surveyed hundreds of managers around the world, ranging from CEOs to project leaders, about what motivates employees, we found startling results: 95 percent of these leaders fundamentally misunderstood the most important source of motivation. Our research inside companies revealed that the best way to motivate people, day in and day out, is by facilitating *progress*—even small wins. But the managers in our survey ranked "supporting progress" dead last.
>
> … When you do what it takes to facilitate progress in work people care about [*controlled variable*], managing them—and managing the organization—becomes much more straightforward. You don't need to parse people's psyches or tinker with their incentives, because helping them succeed at making a difference virtually guarantees good inner work life *and* strong performance.[34]

Consider the Theory of Jobs to be Done developed over a 20-year period by Clayton Christensen and his colleagues. Christensen argues that understanding customers does not drive innovation success. Rather, understanding customer jobs does. In a nutshell, here are the key elements:

> Part of the problem is that we're missing the right vocabulary to talk about innovation in ways that help us understand what actually *causes* it to succeed … This involves creating the right set of *experiences* that accompany your product or service in solving the job … We define a "job" as the *progress that a person is trying to make in a particular circumstance*.[35]

In the above quote, Christensen and his co-authors italicized certain words for emphasis. Are they not focusing on the PCT logic of controlled variables that are important to customers in achieving a goal (job to be done)? They conclude that the conventional correlation studies focused on consumer preferences are inconsequential. Such a conclusion should warm the hearts of PCT proponents.

The co-authors of the initial *Harvard Business Review* article that introduced the Jobs Theory included Christensen and Scott Cook, cofounder of Intuit and an early adopter of the Jobs Theory.[36] Cook's Intuit team developed an innovative accounting software product, QuickBooks. They focused not on

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[34] Teresa Amabile and Steven Kramer. 2011. *The Progress Principle: Using Small Wins to Ignite Joy, Engagement, and Creativity at Work.* Boston: Harvard Business Review Press, pp. 3 and 10.
[35] Clayton M. Christensen, Taddy Hall, Karen Dillon, and David S. Duncan. 2016. *Competing Against Luck: The Story of Innovation and Customer Choice.* New York: Harper Business. pp. 14, 16, and 27.
[36] Clayton Christensen, Scott Cook, and Taddy Hall. 2005. "Marketing Malpractice: The Cause and the Cure." *Harvard Business Review* December 83(12).

duplicating the functionality of their competitors' products but on what mattered most in getting the job done that customers needed done. Importantly, that put the spotlight on the controlled variable for minimizing the customer's time in learning the language and rules used in the accounting profession.

> … QuickBooks might have seemed an unlikely success. After all, the product offered *half* the functionality of more sophisticated accounting software at *twice* the price. But QuickBooks quickly became—and has remained—the global leader in online accounting software, Competitors were focused on making the best *accounting* software possible. Cook and his team focused on the job customers were trying to do.[37]

Let's take up a different topic—the not infrequent situation of a command-and-control management organization that is short-term focused to the detriment of long-term value creation, which would benefit all of the firm's stakeholders. Carrots and sticks replace an appreciation for what deeply matters to employees (their controlled variables). Managers' skill is not in mentoring employees to improve their problem-solving skills but in firefighting and workarounds as part of doing whatever it takes to meet short-term accounting targets. This carrots-and-sticks approach to managing people represents a linear causation mindset that would put a smile on the face of John B. Watson who pioneered behaviorism. In contrast, it would put a frown on the face of Peter Drucker, who, some 50 years ago, wrote about the knowledge worker: "… no one can motivate him. He has to motivate himself. No one can direct him. He has to direct himself ... He is the guardian of his own standards, of his own performance, and of his own objectives."[38]

How might PCT principles be revealed in a long-term-value-creating management organization that is diametrically opposite the short-term-command-and-control management organization? What quickly comes to mind is Lean Thinking which optimizes the flow of products and services via value streams that encompass the entire production process. Skilled lean practitioners have a worldview decidedly different from one focused on using any means necessary to hit accounting targets. Lean thinking, as practiced by preeminent firms like Toyota and Danaher, entails a knowledge-building culture that continually purges waste (including time) throughout a product's value stream. Lean employees, guided by manager mentors, learn by solving problems as part of a cognitive process that Toyota calls *kata.* It is a pattern of thinking and behaving consistent both with value creation and a win-win partnership between employees and management. Mike Rother, a leading expert on this topic offers this description:

> Toyota's improvement kata involves teaching people a standardized conscious "means" for sensing the gist of situations and responding scientifically. This is a different way for humans to have a sense of *security, comfort, and confidence.* Instead of obtaining that from an unrealistic sense of certainty about conditions, they get it from the means by which they deal with uncertainty. This channels and taps our capabilities as humans much better than our current management approach, explains a good deal of Toyota's success, and gives us a model for managing almost any human enterprise.[39]

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[37] Clayton M. Christensen, Taddy Hall, Karen Dillon, and David S. Duncan. 2016. *Competing Against Luck: The Story of Innovation and Customer Choice.* New York: Harper Business. p. 63.

[38] Peter F. Drucker. 1973. *Management: Tasks, Responsibilities, Practices.* NY: HarperBusiness p. 279.
[39] Mike Rother. 2010. *Toyota Kata: Managing People for Improvement, Adaptiveness, and Superior Results.* New York: McGraw Hill. p. 165.

(italics added)

The above italicized words "security, comfort, and confidence" are emblematic of a working experience that is highly desirable for employees—controlled variables that are critical for job satisfaction and productivity.

To sum up, management researchers (and other social science researchers) face a monumentally important choice concerning a research paradigm. If they embrace the PCT mindset, they would organize their research based on the belief that behavior is control of perception and perception deserves to be the fundamental unit of analysis.[40] If they are decidedly more comfortable with either behaviorism or cognitive psychology, they are choosing a belief that behavior is about actions in response to external stimuli.[41]

Concluding thoughts

Perceptual Control Theory has a remarkably wide range of potential applications, essentially for any discipline that involves the study of human behavior (most certainly psychology), including research on the brain and nervous system and research on technology that mimics human behavior (AI, robotic systems, and the like). Even more broadly, PCT can serve as a basis for communication about, and understanding of, the behavior of all living organisms. Innovative work is ongoing dealing with hierarchical organization of behavior for perception-based robotics.[42] Machine learning for face recognition is tying higher-level perceptions to lower-level perceptions.[43] However, search the neuroscience literature for PCT-driven research and you will likely be disappointed. But there are those who march to the beat of a different drummer than their peers, such as Henry Yin, Professor of Psychology and Neuroscience at Duke University. Yin is a rare combination of being highly skilled in both neuroscience and PCT. He summarizes the current mindset in psychology and neuroscience:

> The dominant paradigm in the study of behavior today is the *linear causation paradigm*. This paradigm, inspired by classical physics, assumes that causes precede effects, that the behavior of organisms is caused by antecedent events inside and outside the organism, and that future states such as goals and purposes cannot possibly cause behavior. *It is the basis of the general linear model in psychology and the input/output analysis in neuroscience.* But linear causation does not apply to any control system with negative feedback ... Rather than the effect of some prior cause, behavior is the

[40] For a tutorial on how to create and test computational models see Jeffrey B. Vancouver and Justin M. Weinhardt. 2012. "Modeling the Mind and the Milieu: Computational Modeling for Micro-Level Organizational Researchers." *Organizational Research Methods* 15(4): 602-623.
[41] For an insightful rebuttal to a variety of PCT criticisms, see Martin Taylor. 1999. "Editorial: Perceptual Control Theory and its application." *International Journal of Human-Computer Studies* 50(6): 433-444.
[42] See the website perceptualrobots.com that summarizes Rupert Young's research. See also the research publications of Professor Roger K. Moore at the University of Sheffield.
[43] Hinglak Lee, Roger Grosse, Rajesh Ranganath, and Andrew Y. Ng. 2009. "Convolutional Deep Belief Networks for Scalable Unsupervised Learning of Hierarchical Representations." *Proceedings of the 26th International Conference on Machine Learning.*

> observable manifestation of control in teleological systems that act on the environment to make inputs match their internal reference states.[44]
>
> (italics added)

In addition, Erling O. Jorgensen has done insightful spadework in proposing research that blends PCT and neuroscience. He notes:

> … the functional template of PCT components has a very diverse means of enactment in the nervous system. The brain is an exceedingly complicated set of structures. And yet, overlaying a set of neurophysiological maps with the engineering blueprint proposed by Perceptual Control Theory offers a promising way to explore the brain's many twists and turns.[45]

Let's focus on language. Bruce Nevin has used PCT for initiating a research program to understand how we learn and use language to benefit ourselves and others, and especially, how we control language perceptions. Interestingly, Nevin points out that the stages in which children learn language correlate with the stages of development (previously discussed) during which children operationalize the eleven perceptual levels.

Those working in organizations concerned with improving system performance use language to communicate and gain support for proposed changes to improve performance. And the operation of that changed system involves employees using language. Surely, foundational research about language and behavior represents another rich vein to be mined with potential to gain insights applicable to improving the productivity of systems that involve people. This research differs from the linear cause and effect research in the hard sciences. Nevin emphasizes this point:

> The physical sciences *must* construct abstract mathematical models because the Reality which they represent is inaccessible to direct perception. But the subject matter of PCT and of linguistics consists only of perceptions … the Test for the Controlled Variable explicitly establishes intersubjective agreement between the investigator and the subject organism … Because language is entirely a product of intersubjective agreement, the science of language has a claim on objectivity that it is more immediate than that of any other science.[46]

Kent McClelland sees PCT providing an improved research methodology to gain insights about key issues in sociology:

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[44] Henry H. Yin. 2013. "Restoring Purpose in Behavior." in Gianluca Baldassarre and Marco Mirolli (eds.). *Computational and Robotic Models of the Hierarchical Organization of Behavior.* New York: Springer. p. 319.

[45] See chapter 6 and 7 by Erling O. Jorgensen in Warren Mansell (ed.). 2020. *The Interdisciplinary Handbook of Perceptual Control Theory.* London: Academic Press. p. 191.

[46] Bruce Nevin. "Language and thought as control of perception." in Warren Mansell (ed.). 2020. *The Interdisciplinary Handbook of Perceptual Control Theory.* London: Academic Press. p. 445.

> I have turned to agent-based computational modeling because of several advantages … its inherent dynamism, its simultaneous focus on micro interactions and emergent macro patterns, its greater realism at the micro level, and its enhanced degree of scientific rigorousness ... this agent-based computational [PCT] model, which re-conceptualizes conflict as a struggle for control, goes beyond conventional theoretical approaches and offers new possibilities of scientific advancement in the sociological study of the time dynamics of conflict.[47]

As a *foundational* understanding of human behavior, PCT offers significant opportunities for more productive living in general, and in particular, for the adoption of a new paradigm to improve research and education in the social sciences.[48] For example, consider the topic of improving a person's skill in doing certain tasks, which certainly has enormous importance, ranging from patient rehabilitation to productivity gains in businesses and organizations of all kinds. The PCT view is that human action serves to control perception. Rather than instructions about observable actions, could performance be more enhanced via instructions about desired perceptions? Early research says yes.[49] Perceptual Control Theory offers a truly wide span of opportunities.

Included in this opportunity set is economics which is concerned with tradeoffs, incentives, choices, and model building. Much of empirical research in economics uses multiple regression equations that impose (linear) open-loop causation on human behavior contrary to the closed-loop causation keyed to negative feedback loops that has explained how human subjects behave in motor sensory tracking experiments. Would not economists, and their students, benefit from working with Perceptual Control Theory that explains so much about human behavior in a concise and precise language that should especially appeal to economic theorists.

A final thought. Eric Reis's recent book, *Incorruptible: Why Good Companies Go Bad and How Great Companies Stay Great,* spotlights how many firms automatically expand a bureaucratic, command-and-control hierarchy as they grow to the detriment of innovation and adaptability. Perhaps a PCT mindset could facilitate a more insightful understanding of management's (human) behavior that feeds this bureaucracy. And such an understanding could lead to change that matters and a higher level of sustained value creation.

[47] Kent McClelland.2014. "Cycles of Conflict: A Computational Modeling Alternative to Collins's Theory of Conflict Escalation." *Sociological Theory* 32(2): 100-127.

[48] Warren Mansell. 2020. "Ten vital elements of perceptual control theory, tracing the pathway from implicit influence to scientific advance." in Warren Mansell (ed.) *The Interdisciplinary Handbook of Perceptual Control Theory.* London: Academic Press, Chapter 16.

[49] Carla Brown-Ojeda and Warren Mansell. 2018. "Do Perceptual Instructions Lead to Enhanced Performance Relative to Behavioral Instructions?" *Journal of Motor Behavior* 50(3): 312-320.