Preface

During the summer of 2020, as the COVID-19 crisis was reaching a peak, *The Interdisciplinary Handbook of Perceptual Control Theory (PCT)* was published. The book was initiated by, and dedicated to, Bill Powers, the developer of PCT, who had passed away on 24 May 2013. In his chapter in the volume, he had stated: "We are now facing reality. This is going to be a revolution whether we like it or not." Powers' statement was designed to apply to the eventual transformative scientific impact of PCT, but it could just as easily have applied to the "Great Realization" of 2020. Many of us were "facing the reality" of personal vulnerability to illness, global interdependency, escalating mental health problems, pervasive inequality and racism, and an exponential climate crisis. At the same time, many of us realized the value of increased time with family and local neighborhoods, regular engagement with nature, the efficiency of remote, digital work, and the primacy of science—in the form of timely vaccine development. It seemed timely now for the development of a new volume of the handbook—one that set out the stage for PCT to contribute to many of these evolving global issues. In this volume, we aim to spell out how you—the readers, within your own fields of research and practice, across science, arts, and humanities—can help shape global developments through PCT.

The first handbook had been in development for 6 years up to 2020, and its aim was to provide a contemporary scientific update on PCT for a wider audience. Most of the authors had been involved in the science of PCT for several decades, and they provided a historical perspective on their work stretching from the origins of the theory in the 1950s and 1960s to the present day. Yet there have been many hundreds of single-minded contributors to PCT science and practice over the years who have tested and applied the theory. Each of these academics and practitioners has refined potentially useful insights as to how PCT can shape their area of work, accumulated a spectrum of experience, and have seen ahead to the kind of society that would be informed by this humanistic approach to science: a society that respects each person's individual needs and preferences; a society that identifies problems within conflicting priorities rather than in separating "good" from "bad"; a society that is curious, determined, and yet patient in its need for change; and a society that wishes to find a new perspective on itself that transcends existing plans, policies, and systems. You will find that the fundamental, working principles of PCT underpin these aspirations: *control, conflict, reorganization*, and *hierarchical organization.*

Powers' expectation of revolution describes change as inevitable. However, his own theory contradicts his statement; in PCT, inevitability is relevant only when there is no control. A wind only blows a cyclist over because the cyclist does not move the handlebars to counter the disturbance created by the wind. Revolutions happen because people make them happen; they are created. The chapters in this volume reveal the hard work and dedication that many people have demonstrated to begin to change the direction of researchers working on understanding how living things survive, and indeed thrive. The contributors of Volume II of *The Interdisciplinary Handbook of Perceptual Control Theory* have invested their labor in researching and applying PCT going forward, some of whom have utilized the theory for many decades, others for whom PCT represents a new, exciting turn in their scientific or professional career. The four of us—Warren Mansell, Eva de Hullu, Vyv Huddy, and Tom Scholte—have chosen to work together across our disciplines to support the authors, and we have strived to ensure clarity and consistency in the use of PCT throughout the book, cross-referencing across chapters and to sources in the first volume, as well as grounding the work in the wider scientific and applied literature. This volume therefore provides contemporary perspectives on a scientific paradigm that is beginning to realize its potential.

We have organized this preface to complement the preface of the first volume and set the stage for this new venture. First, we explain PCT, with particular emphasis on getting the components of the control loop defined accurately, describing reorganization and its implications, and introducing the specific levels of perception proposed by Powers. Second, having explained PCT, we situate PCT in the context of the history and philosophy of science. It defies a single categorization in the way that it cuts across the assumptions of an array of approaches, but essentially it aligns itself with *functional, phenomenological, humanistic*, and *constructivist* approaches in its stance toward the relationship between mind and the physical world. Third, we provide an overview of the chapters in this volume. The book begins with phenomenology: the fundamental perceptual levels, consciousness, and imagination. To complement this experiential beginning, the following section shows how PCT is used to model human and machine action, interaction, and cooperation. Then, its unique perspective on the science and practice of improving health is provided across the domains of cancer care, health behavior, psychotherapeutic change, serious mental health problems, and dementia. The next chapter progresses from here to the use of PCT to support well-being in schools, and more widely to the philosophy of education. The latter chapters illuminate the breadth of PCT applied to the changing society we live in—our cultural evolution, the mentality of our leaders, our living space, active participation in arts and theater. We encourage you to start the journey here, as we share with you our view of why and how this theory was first developed, and how its surface simplicity—*behavior is the control of perception*—conceals such rich and far-reaching ramifications.

Basic elements of perceptual control theory

Components of control

There are many ways to start an explanation of PCT. This is because its principles are proposed to underpin the living world.

We could begin with a simple everyday example, like the preface of the first volume: Goldilocks tried to get the temperature of her porridge "just right" by various activities—stirring it, blowing on it, or adding cold milk to cool it down to her preferred temperature or warming it up in a pan of it gets too cold. This is control.

Another beginning could be to explain that control in PCT is essentially an extension of homeostasis in biology. The *internal milieu* of every cell in the body is controlled. Variables such as temperature, salt ion concentration, oxygen and carbon dioxide concentration, and sugar levels need to be kept within bounds that allow life to persist. This control proceeds continuously and automatically with no need for learning or planning. In essence, Powers made the original proposal that certain variables that are sensed by the eyes, ears, nose, mouth, and skin are also controlled. This control also proceeds continuously and automatically much of the time, and when we see it happening, we call it "behavior."

A third way to begin to explain PCT is to describe machines that control. We often take them for granted but they have become essential for the technological advances that have led to our everyday life in the 21st century: the Watts Governor was a device that ensured steam engines generated a constant flow of energy; servo motors in aircraft wings control the angle of the flaps to ensure a safe landing; fridges, freezers, air conditioning systems, and incubators all rely on control systems. The first control device in recorded history was most likely the water clock, a device in Ancient Egypt that was closely related to the cistern in a domestic toilet. Powers (2016) describes it as the "tank that filled itself" and he illustrates its automatic nature in this quote:

> *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.*
>
> Powers (2016, p. 52)

In the above quote, it is clear that Powers was comfortable to describe the workings of a controlling machine from its first-person perspective—the control of its perception. This doesn't mean that the machine was conscious, but only that it controls a function of its inputs. For example, if the sensor in an air conditioning system is designed incorrectly, it won't control the temperature of the room effectively. Control is by default control of input.

Yet the scientific advance of PCT is not merely to illustrate the principle of control; it is to precisely describe the closed loop of functions and connections that the nervous system, body, and the environment form in order for control to happen. To clarify this explanation, we have reproduced the diagram of the fundamental unit of PCT—the control system—here (Fig. 1).

In a classic paper, Rick Marken points out that to define behavior as control is not in itself a theory (Marken, 1988). It is a natural phenomenon to be explained by a theory such as PCT. This is analogous to the study of other areas of science: the origin of new species during evolution is a phenomenon to be explained by Darwin's theory of natural selection; the study of electricity requires establishing the properties of electricity to then explain through the passage of electrons between atoms. So, Powers is, first, to be credited for establishing the phenomenon to explain that behavior is control and, second, for

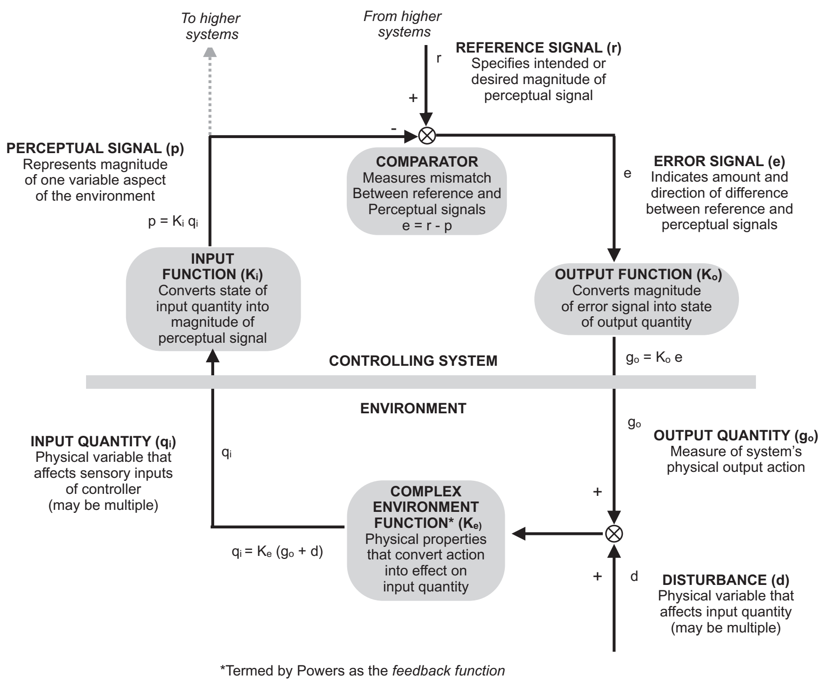

FIG. 1 A diagram of a control unit within PCT adapted from Powers' original drawing, which was redrawn by Dag Forssell (Powers et al., 2011) and modified by Phil Farrell and Warren Mansell.

establishing a detailed model of how this might work, a fundamental component of which is the closed loop shown in Fig. 1.

Fig. 1 is designed to bring together classic control engineering notation with the terms used by Powers to describe the components of the control loop. In a living system, a loop of this kind will exist for each variable aspect of the environment external to the nervous system that is being controlled. For example, a variable could be the perceived tightness of grip on the handle of a cup, or it could be the perceived distance from a spider in the room.

In most contexts, the elements of the loop function continuously within a circle and there is no beginning or end. However, human language is generated as a linear system of words organized in a sequence (see the sequence level of perception later!). So, the explanation, unlike the diagram, or the nervous system itself, needs to start somewhere. We will start at the input function.

The *input function* transforms and combines its inputs from the senses to construct the *perceptual signal* whose magnitude is an analog of the variable aspect of the environment that is being controlled—the *controlled variable*. The perceptual signal is sent to a function known as the *comparator*, which calculates the discrepancy between its magnitude and that of its *reference signal*. The reference signal is a neural specification of the desired value (goal state) of the controlled variable. The discrepancy, or *error signal*, is then transformed by the *output function* to allow a physical action within the environment. This action counteracts the effects of *disturbances*—factors in the environment that can affect the controlled variable independently of the control system itself. The actions of the system are transformed through feedback paths within the environment that are labeled *complex environmental functions* in Fig. 1, although Powers termed these the *feedback function*. These affect the *input quantity*, which refers to the elements in the environment that are sensed by the input function. This closes the loop.

It is critical to note that in a properly functioning control system, it is the reference value that has the greatest effect in the loop—bringing the perceptual signal into close alignment with its value—and, simultaneously, controlling aspects of the environment via continuous adjustments in output to act against continuous disturbances as they arise. One of the best ways to understand how the control loop works in practice is to see it working dynamically, in real time. This is possible by downloading and trying out examples of live block diagrams (https://www.iapct.org/category/demonstrations/).

There is clearly a significant amount of terminology to learn when understanding PCT. One way to make it clearer is to see real-world examples. For example, Marken (2021) produced a table to illustrate how some examples of everyday behavior may involve specific controlled variables, with specific reference values and examples of the kinds of disturbances that would need to be counteracted to maintain control by various means (Table 1). The "type" column of Table 1 refers to another element of PCT—controlled variables are organized as a *hierarchy*.

TABLE 1 **Examples of controlled variables that may underlie some everyday behaviors.**

Behavior	Variable	Reference state	Means	Disturbances	Type?
Sweetening tea	Sweetness of tea	Not too sweet	Add sugar to tea	Form of sugar (cube, granulated)	Intensity
Adjusting brightness of laptop display	Luminance level	200 Nits	Press brightness adjustment keys	Environment luminance level	Intensity
Flossing teeth	Amount of food between teeth	No food	Pull floss	Space between teeth, amount of food	Sensation
Hammering nail into plank	Nail head height above surface of plank	Flush with plank	Hit nail with hammer	Humidity, outdoor temperature, hardness	Sensation
Rolling egg into nest	Pressure on back of bill	Pressure centered	Pulling back on egg	Gravity vector	Configuration
Opening car door	Angle of door	80 degrees	Grasp, pull	Weight of door, angle of car	Configuration
Sipping tea	Position of cup	Cup at lips	Lift, tip cup	Amount of tea in cup	Relationship
Intercepting moving object	Derivative of optical angle	Zero	Movement relative to the object	Trajectory of object	Relationship
Adjusting rear-view mirror	Displacement of rear window image	Zero displacement	Grasp, twist	Tightness of hinge, height in seat	Sequence
Typing "Hello"	Sequence of letters	"Hello"	Tap keys	Resistance of keys, typos	Sequence
Seeking employment	Employment status	Employed	Read wanted ads, go to employment office	No ads, office closed	Program

This is reproduced from Table 8.1 in The Study of Living Control Systems (Marken, 2021) with the author's permission.

In fact, Fig. 1 shows that each unit sends its signals upward to input functions of higher-level units, and it receives its reference value from the downward signals from higher-level units. It is this control hierarchy that we explain next.

Levels of perception

Hierarchical control means that layers of parallel control systems work together to allow control of many different types of perception. Each input signal and each output signal are connected to control systems at higher and lower layers, as shown in Fig. 1. This is how humans are able to control complex perceptions without much effort: higher-level control systems control their perceptions through varying lower-level references, and higher-level perceptions are composed of combinations of lower-level perceptions.

The lowest level receives input from the sensory nerve endings, and each subsequent level combines those perceptual signals into perceptions of a different kind, thus creating a hierarchy in which, at every next level, many perceptions are combined into a single input function. Powers outlined a proposal of eleven levels of perceptual control. These are described in detail with examples in Chapter 1. Here, we provide a summary.

Level 1 controls the *intensity* of sensory information. Level 2 combines this sensory information into a single *sensation*. Level 3 controls *configurations* (patterns) of sensations, creating a sense of consistency in our experience. Level 4 introduces *transitions* between perceptions, and thus the experience of change. Level 5 unites perceptions of underlying levels into a single *event*. Level 6 controls how lower-level perceptions form *relationships*, creating the experience of perspective and causality. Level 7 organizes perceptions with shared properties into *categories*. Level 8 orders combinations of underlying perceptions into *sequences* with a fixed order. Level 9 controls *program* structures, such as plans that branch out in imagination. Level 10 adds an essential part of human experience by controlling *principles* that govern our plans. Level 11 is the highest level in Powers' hierarchy, controlling *system concepts* that bind all underlying perceptions together.

Powers presented his proposal of levels as a hypothesis, to be tested and reorganized if needed. The structure of hierarchical control, however, is an uncontested and essential part of understanding perceptual control, conflict, and reorganization.

Conflict occurs when two or more control systems have different reference values for the same perceptual variable. For example, a person may have a goal to be close to the edge of a balcony to see the view, but far away from the edge to prevent falling. Resolution of conflict between control systems at the same level depends on changes in the hierarchy. At least three levels are involved in conflict resolution. At the lowest level, the conflict is expressed by incompatible actions of different control systems: If you are conflicted between leaving the house and remaining inside, this would be expressed at the lowest level through muscle tension—getting ready to leave and preparing to stay at the same time. At the intermediate level, the conflict is caused by incompatible reference values of two or more control systems—both wanting to go out and exercise and wanting to stay inside and stay warm. At the highest level, the stage for this conflict is set by the references of higher-level control systems, and this is where the conflict may be resolved through reorganizing (and thus changing) these higher-level references. Wanting to exercise and stay warm are governed by the principle of keeping myself healthy and, from that level, do no longer conflict. One could use new program perceptions such as dressing well and exercising, or waiting until the sun warms up. By moving awareness to higher levels and reorganizing there, conflicts can be resolved and control can be regained. This is the mechanism through which Method of Levels (MOL) therapy operates, and MOL is covered in many chapters in this handbook. It is a way of actively listening to a person describing a problem that promotes the resolution of conflict. The listener only has two goals— to ask about the problem and to ask about *disruptions*—which are surface indicators (e.g., smiles, pauses) of perceptual experiences that are in the background, fleeting, or at the edge of awareness. Through a conversation of this kind, the speaker's awareness shifts to the source of conflict within the hierarchy, and sustains there to allow its resolution. This occurs through a process known as reorganization, described next.

Reorganization

We all have basic needs. Each of us, as individuals, are born with a genetic-phenotypic inheritance of intrinsic physiological values that must be kept within acceptable limits necessary to our continued survival. The most obvious of these are elements like blood pressure, core body temperature, hydration, etc. The careful balance of these variables is known as *homeostasis* and involves a number of processes in the body that do not require conscious awareness to function, such as shivering when body temperature is too low and sweating when it is too high. However, there are occasions when these autonomic functions are not sufficient to deal with disturbances to these essential variables. On such occasions, some new action, such as a new program, may be required; for example, "putting on a sweater" when shivering has failed to get to the target temperature. If the current actions continue to fail to sufficiently reduce intrinsic error, *reorganization* is necessary. Powers proposed that the *Reorganization System (RS)* achieves this in how it interacts with the learned perceptual hierarchy (LPH).

Conceptually speaking, the RS is *orthogonal* to the LPH, but is functionally coupled to the LPH in a critical manner. This is shown in Fig. 2. The RS is a closed-loop system in its own right. At its core is a comparator that "contains" the genetically specified intrinsic reference signals for variables that do not need to be learned by the individual during their own lifetime, but are essential for survival. Examples of these essential variables are body temperature and blood glucose levels, but they may also include unlearned sensory variables such as

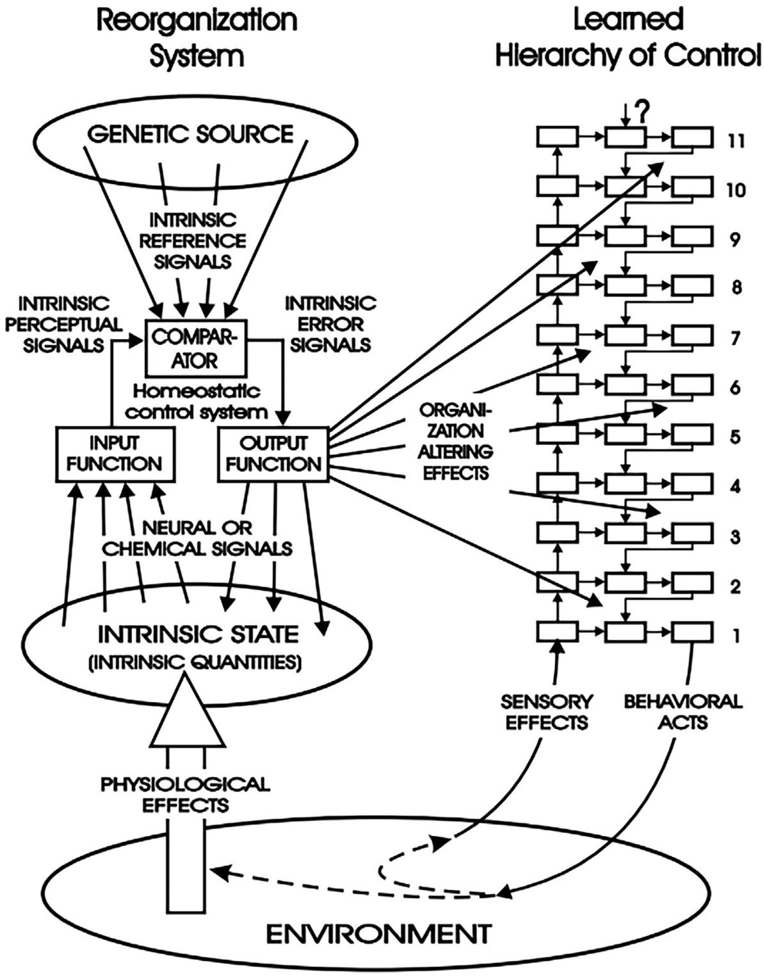

FIG. 2 The relationship between the reorganization system and the learned perceptual hierarchy, as described by Powers (1973), published in Powers (2005), and updated by Powers (see Powers, 2016), reproduced with permission from Living Control Systems Publishing.

pain, or the smell of a predator. Events and forces in the environment entail physiological effects within the body. These effects are transmitted to the RS through neural and chemical signals. If the RS comparator produces an error signal due to a discrepancy between the intrinsic reference signal for a given variable and the current state of the same variable, it will generate an output signal to the LPH, which drives the process of reorganization.

The process of reorganization has been described by Powers as follows:

[c]ontrol systems will alter their characteristics, controlling new perceptual variables in new ways.... Reorganization alters the properties of the control

> *systems involved in behavior. Such changes would alter the kinds of quantities perceived, the means of correcting error through choice of lower-order reference signals, dynamical properties of control systems, and even the state of existence of a control system. As a result, of course, visible behavior would change its character, as would experienced behavior.*
>
> Powers (2005, p. 188)

This visible behavior would, of course, make its effects felt in the environment, which would then, in addition to feeding back, via sensory perceptions, to the control systems of the LPH, feed back to the RS through altering physiological states within the body.

It is important to remember that the RS does not specify *how* the LPH should be reorganized or *what* specific features should be reorganized in what ways. It is a blind process of trial and error. William Powers and Rick Marken noticed the similarities between the process of reorganization and the movement of the *Escherichia coli* bacterium. It navigates nutrient gradients by randomly tumbling to find a new direction in which to head when it senses, through ingestion, a drop in the gradient in the surrounding medium. Computer simulation studies by Marken (1985) and Marken and Powers (1989) replicated similar "steering" constraints in humans during a computer-based target-seeking task. Participants turned in performances that were "as much as 70% as efficient as a straight-line motion to the target, in terms of average velocity in the right direction (Marken & Powers, 1989, pp. 93–4)." This indicates that a random trial-and error-process, depending solely upon a simple feedback loop, indicating the increasing or decreasing value of a single intrinsic variable, could be capable of generating efficacious reorganization in a timely manner. As Powers has explained:

> *The reorganizing system cares only about intrinsic error, which is the same regardless of what caused it. It does not care whether the behavioral organization that eliminates intrinsic error is elegant or crude, efficient or wasteful, logical or illogical, systematic or messy, prudent or foolish, realistic or superstitious. The "value system" of the reorganizing system is simple: intrinsic error is bad, and lack of intrinsic error is good. The reorganizing system is totally pragmatic: if it feels good, do it; if it feels bad, change. If change involves changing system concepts, principles, programs, relationships, events, motion, configurations, sensations, or intensities, it's all the same. Push the <u>change</u> button—it's the only one there is. If the result isn't "good," push it again.*
>
> Powers (2005, p. 196)

Nonetheless, Powers admitted that the RS is the component of PCT about which the least has been experimentally revealed and concedes that this hypothesized system might contain more sophisticated "sampling" mechanisms in terms of effective behavioral organizations:

> *I have been assuming that reorganization is essentially random. It may well be random with respect to any learned scheme, of course, but that does not mean*

> *it has to be random with respect to all criteria. There is no reason the reorganizing system could not act on the learned hierarchy in maximally efficient ways so that ineffective behaviors are quickly eliminated and effective ones quickly found.*
>
> Powers (2005, p. 198)

The process of reorganization is described, utilized, and modeled throughout the chapters in the handbook, and so it serves to push forward the research on this intriguing mechanism.

Control of perception: The unique contribution of PCT

In 1960, Bill Powers published "A General Feedback Theory of Human Behavior" across two papers in the journal *Perceptual and Motor Skills*. These papers introduced a conceptual framework of behavior, which is described as "a synthesis of many ideas, some of which have been in print for many years" (Powers, Clark, & Farland, 1960, p. 71). The articles specifically highlight how, like Newton's theory was described before him, Powers' theory sees further because it "stands on the shoulders of giants," including Norbert Wiener, Ross Ashby, Claude Shannon, Donald Hebb, and others. In the fuller account of PCT described later in *Behavior: Control of Perception*, Powers cites other renowned cybernetics and systems thinkers, such as Gordon Pask and Jerome Bruner. This raises the question: what is the key contribution of PCT beyond broader, foundational ideas, described by cybernetics and systems thinking more generally?

The preceding ideas that Powers cited in his early work contained the general themes of feedback, self-organization, and hierarchical structure. Indeed, these themes continue to be emphasized in general introductory texts on systems thinking, such as the primer by Meadows (2008). However, PCT differs from these frameworks because its starting point is an internal perspective on behavior and, from that perspective, feedback has a specific meaning. In Donella Meadow's primer, the negative feedback loop is introduced in the context of flows between resource stocks in organizations or businesses. This creates the impression that negative feedback is something *out there*. However, from a PCT perspective, negative feedback is how living systems control a perceptual variable via their actions in the world. This is the first unique premise of PCT distinct from the emphases of "first-order" cybernetics or other systems thinking ideas—living systems control their perceptions. Crucially, this premise predicts the existence of perceptual variables that can only be detected using the Test for the Controlled Variable (TCV). The TCV is described and used extensively in Section II of the handbook. While many other theories describe the importance of feedback, the variables under control are considered to be self-evident (e.g., the location of a spot on a screen in a tracking experiment). It is seldom considered that the experimenter might make the wrong assumption about this. While the possibility of this type of error has not escaped the grasp of "second-order" cybernetics (e.g., Nizami, 2015), it has remained a primarily epistemological point and has not been accompanied by the kind of robust alternative model offered by Powers. We describe second-order cybernetics next.

Emerging across the late 1960s and into the early 1970s, second-order cybernetics was defined by one of its chief founders as a shift from "the study of observed systems" (first-order cybernetics) to "the study of observing systems" (second-order cybernetics) (von Foerster, 1975, p. 2). While maintaining such fundamental cybernetic concepts as feedback and self-organization, greater emphasis, compared to that of first-order cybernetics, was now placed upon the "observer dependence" of any description of behavior, scientific, or otherwise, thus eliminating the erroneous assumption in first-order cybernetics that any organism's purpose could be dependably described by an external observer. Deeply intertwined with radical constructivism (von Glasersfeld, 1995), second-order cybernetics is similarly grounded in a biological argument against the possibility of *any* truly "objective" knowledge of the external world. In his key paper, *On Constructing a Reality* (von Foerster, 1973/2003), von Foerster leans into the "theory of undifferentiated encoding" in a manner that seems to echo Powers' hierarchical schema through which increasingly abstract perceptions are, literally, constructed from the fundamental level of *intensities*. "The response of a nerve cell does not encode the physical nature of the agents that caused its response. Encoded is only "how much" at this point on my body, but not 'what'" (p. 215). Thus, for von Foerster, "the fundamental question arises as to how does our brain conjure up the tremendous variety of this colorful world as we experience it. [...] This is the "problem of cognition," the search for an understanding of the cognitive processes" (von Foerster, 1973/2003).

Von Foerster further formulated "cognition" as a the "endlessly recursive [...] computation of descriptions of reality" with *computation* understood as "any operation (not necessarily numerical) that transforms, modifies, rearranges, orders, and so on, observed physical entities ('objects') or their representations ('symbols')." It was to this "problem of cognition" that von Foerster and his associates devoted their efforts at his Biological Computer Lab during its operations at the University of Illinois at Urbana-Champaign from 1958 to 1976 (Müller & Müller, 2007). While this work did not produce a generative model of behavior with the kind of robust precision as that developed by Powers, von Foerster did conceive of the "autonomy" of all living organisms as "synonymous with *regulation of regulation*" (von Foerster & Poerksen, 2002, p. 226). Von Foerster's close colleague, von Glasersfeld, was among those second-order cyberneticians who praised Powers' contribution to "a modified scientific scepticism, a scepticism with a positive dimension gained by adding the notion of cognitive construction" (Richards & Glaserfeld, 1979, p. 37), and recognized its significance in unequivocal terms:

> *After a half a century's, not undisputed but nevertheless powerful rule of a linear stimulus-response model of behaviour, whose realism was so naive as to be*

> *unaware of any theory of knowledge, one cannot but celebrate the propagation of a model that clearly invites epistemological interpretation.*

Such a precise generative model was not something that second-order cybernetics had managed to produce on its own.

The notion that perceptions are variables, as Powers put it in his book *Living Control Systems III*, equivalent to "meter readings," also has earlier parallels in the literature of second-order cybernetics (Powers, 2008). In their 1987 book *Tree of Knowledge*, Humberto Maturana and Francisco Varela describe an analogy to explain why organisms do not use representations of the world and suggest instead that organisms only *correlate* internal with external states (Maturana & Varela, 1987). They invite their readers to imagine that they encounter a person who has always lived in a submarine. The reader is able to communicate with the person via radio and uses this to congratulate them on navigating their way past reefs that would have endangered the submariner's journey. The submariner replies that there are no reefs, that they simply observed their measures and indicators and then guided their submarine accordingly. This analogy is useful for showing, as Powers did in his 1973 book, that perceptual variables need not correspond to anything others observe happening or believe is relevant. Perceptions are constructed from the senses for the purposes of the perceiver to control what is important to them. In PCT, this is not mere analogy; these variables are implemented in functional models and tested against empirical data. Indeed, in *Living Control Systems II*, Powers makes the point that the difference between PCT and Maturana and Varela's theory of autopoiesis is that the former can be more easily tested. Again, this illustrates that while "second-order" cybernetics has been able to correct some of the erroneous conceptual assumptions of its "first-order" predecessor, it has, unlike PCT, largely failed to move beyond philosophical postulation. The chapters in this volume provide numerous examples of how PCT has been tested in empirical studies or via its use in applied settings.

The next unique premise of PCT concerns the nature of these perceptual variables under control. As has been described above, living systems control perceptual variables at different levels in a hierarchy. Without this, they would not be able to perform the feats that enable them to survive. But the first (perceptions are controlled) and second (perceptions are constructed in a hierarchy) premises of PCT are inextricably linked—the existence of perceptual variables necessitates that these must be varied in their abstraction. The fully developed notion that more abstract variables are constructed from lower, more concrete variables, and higher levels determine the references from those below, take PCT beyond the theories that existed before it, inspired its development, and have continued alongside.

Chapter overview

In this last section of the preface, we provide an overview of the chapters in the volume, ordered into sections. The purpose of ordering the sections in this way is to first introduce the two perspectives from which Powers developed PCT: personal introspection and technical modeling. Next, we cover two critical domains in which PCT has been widely applied: health (including mental health and dementia) and education. Finally, taking a wider overview of societal applications, we bring together chapters on the self and society.

Perception, consciousness, and imagination

This book opens with three chapters that explore important aspects of our experience: different types of perception, consciousness, and imagination, through the lens of perceptual control theory. The first chapter by Eva de Hullu explains the levels of perceptual control, as outlined by Powers, painting a picture of how we control our perceptions in many different ways and how the levels work together to allow for control of increasingly complex perceptions. The model of hierarchical perceptual control offers a framework for understanding many areas of knowledge and empirical results. One such area is the understanding of human consciousness that is the center of lively debate in psychology and philosophy. Warren Mansell adds a solid PCT account of consciousness that rewards the reader with a rich perspective on why and how hierarchical control, intrinsic systems, the reorganization system, information integration, and memory work together to create and sustain the experience of consciousness. Vyv Huddy and Warren Mansell then explore the branching structure of the program level and the role of imagination as outlined by Powers (1973) in their chapter on mental simulation, showing how imagining is a way to reorganize and regain control, but also may have adverse effects when imagined solutions conflict with other controlled perceptions.

Computational and mathematical modeling

The three chapters in this section describe the implications of using PCT to specify functional models that are applied to widely varying examples. In the chapters by Max Parker and Philip Farrell, human movement and autonomous robots are considered. The degree of autonomy or volition in control systems are explored from differing perspectives, and each chapter integrates the principle of hierarchy to make sense of this. The chapters by Max Parker and Vyv Huddy begin to apply functional models of reorganization to observed data, which represents an important test of this aspect of PCT. These examples are catching performance and psychotherapy change trajectories. Huddy's chapter models, for the first time, reorganization occurring in populations of individual people and how the reorganization principle is manifest in aggregate patterns of data.

Health applications

Essentially, in placing control at the heart of life itself, Powers, and in turn Tim Carey, defined health as control, and poor health as lack of control. Jonathan Sigger continues this logic to provide a case for taking a whole new perspective on the field of health behavior change, and illustrating it with a detailed case example of how to encourage effective hand washing. Mike Rennoldson's chapter builds upon this example through considering how PCT can inform our understanding of cancer by expanding on the many ways this pervasive illness impacts upon the control of those living with the illness, their support networks, and health services. The service context takes the fore within Rob Griffiths' chapter, in which he considers the themes of control and conflict that underpin mental health services, their staff, and the consumers they serve. A primary focus is how to transform services so that they truly enable and empower people with the lived experience of mental health problems to recover. Through a scientific understanding of control within PCT, the necessary shifts can, in principle, be made. Just like the previous chapters in this section, Griffiths provides suggestions for tangible shifts in practice and service design. Going one step further in terms of implementation, the final chapter of this section takes the reader through a clinical research program that is now in place, and guided by PCT: empowered conversations for carers and people living with dementia. Phil McEvoy and Lydia Morris describe an approach that bridges the first-person accounts of living with dementia with a PCT account of how dementia challenges the capacity for control, and in turn how it may be restored. Empowered conversations may be one of the most exciting translational applications for PCT, but historically, it is within education that first demonstrated its real-world impact. This second volume of the handbook allows us to provide an overview and future vision for this work.

Schooling and education

Two chapters in this volume focus on the application of the PCT body of knowledge to education. Shelley Roy shares with us her extensive experience as an educator and school reformer in a chapter that outlines how schools could face the current societal crises (e.g., drug abuse, discrimination, prejudice, mental illness) through a move away from coercion and toward an understanding of both students and educators as control systems, who strive to reach their goals. Eetu Pikkarainen explains the complex interaction of teachers and students from a philosophical standpoint, using PCT to tackle philosophical problems such as the pedagogical paradox, human freedom, motivation, and the aims of education. Together these chapters show how PCT could help educators to get a grip on the current problems in their field, and provide ways for teachers to better understand and handle their responsibilities as educators.

The self and society

The chapters in this section explore the social mechanisms influencing the formation of specific reference values within the perceptual hierarchies of individuals. Ted Cloak, a veteran PCT researcher with over 50 years in the field, kicks things off in a spirited fashion by casting the broadly understood "folk-term," *culture*, as a mosaic of interlocking reference values which, while instantiated in the biological substrate of neuronal configurations in individual nervous systems, are posited to propagate socially through Richard Dawkins's theoretical unit of cultural information: the "meme." Carrying on in this intellectually adventurous key, Brian d'Agostino reconciles PCT with a body of theory often considered antagonistic to the field: psychoanalysis. While some PCT purists may insist that many of the elaborate psychic mechanisms posited in psychoanalytic circles are incompatible with PCT's parsimonious theory of inner conflict, as well as the strict ban on conjectural hypothesizing at the core of the Method of Levels approach to therapy, d'Agostino's chapter makes a powerful case that key psychoanalytic concepts such as the "inner feminine" and "mastery through reversal of voice" can provide valuable schemas for understanding the precise manner in which individuals psychologically adapt to particular kinds of psychically challenging circumstances through reorganization. Finally, Tom Scholte's chapter introduces a novel blend of PCT, Method of Levels, and Applied Theater as an approach to facilitating both reorganization on a personal level, and an increased understanding of the social mechanisms through which our behavior is constrained by "oppressive" reference values inculcated in us by powerful interests in our society and generating severe inner conflict. In a sense, this final chapter brings the section full circle by returning to the questions raised by Ted Cloak regarding the social propagation of system and principle variables understood as "culture," but, now, asking whether PCT can tell us something about if, and how, such "memes" can be resisted.

Sample audio of selected portions of the book available here: https://www.iapct.org/publications/books/living_in_the_loop

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