Why I Stopped Reading *Verbal Behavior* (and Continue to Study Perceptual Control Theory)

Chris Cherpas
Computer Curriculum Corporation

The program of *Verbal Behavior* (Skinner, 1957) was to specify elementary units of speech and writing, to show how these units combine and vary, continuously and simultaneously, in everyday speaking and in literary contexts, and to ultimately describe a dynamic system – the speaker – whose behavior is by no means independent of itself. But the speaker is not developed through a formal system analysis. Some of the speaker's credibility arises simply from the progressive accumulation of speech samples that are attributed to this anonymous agent: By the book's end, it is inevitable that we see the speaker as being endowed with an extensive repertoire. In effect, Skinner's literary development of the speaker amounts to the construction of a natural concept that intuitively preserves properties we observe in our own behavior – continuity, simultaneity, organization, subjectivity – and that we expect the experimental analysis of behavior to *explain*.

My own attempts to represent Skinner's (1957) qualitative system concept in a quantitative system model, within a coherent algebra of operants and strengthening operations, repeatedly failed. I could perform operant analyses with a certain amount of rigor, but my "repertoire analyses" were hardly more systematic than my sketchy images of the speaker. Like many, I turned to a selectionist framework for organizing the experimental analysis of behavior's disembodied bag of operants. A behavioral repertoire might even be modeled by a variant of genetic programming (Koza, 1992). In this effort I also failed, but the selectionist focus led me to an unexpected body of literature. In *Without Miracles: Universal Selection Theory and the Second Darwinian Revolution* (Cziko, 1995), the work of William T. Powers is introduced. Powers is the originator of perceptual control theory (PCT), beginning its development in the 1950s and continuing to do so today.

I propose here that – despite Skinner's explication of the speaker, in which *Verbal Behavior* culminates – the experimental analysis of behavior lacks the conceptual and methodological bases for explaining the properties of whole behaving systems, and that these fundamentals are present in PCT.

Correspondence may be sent to the author at Computer Curriculum Corporation, 1287 Lawrence Station Road, Sunnyvale, California 94089 (E-mail: ccherpas@cccpp.com).

Continuity

> In this way, behavior is broken down into parts to facilitate analysis. These parts are the units we count and whose frequencies play an important role in arriving at laws of behavior. They are the "acts" into which, in the vocabulary of the layman, behavior is divided. But if we are to account for its quantitative properties, the ultimately continuous nature of behavior must not be forgotten. (Skinner, 1953, p. 93)

In the domain of the speaker, frequencies do not count for much. It is *strength* that keeps the speaker in continuous motion. *Verbal Behavior* (1957) extended operants beyond instances that are counted, to include their more implicit manifestations in incipient, blended, and otherwise continuous behavior. Strength supplied the conceptual glue for binding this range of phenomena into plausibly commensurable units, while waiting on the experimental analysis of behavior to eventually work out the details.

Unfortunately, the sticky stuff steeped the experimental analysis of behavior in a quagmire – starting with the decomposition of response rate into interresponse time distributions – in which properties used to define an operant were perpetually confounded with those used to measure its strength. Although *strength* appears some 616 times in *Verbal Behavior* (Cherpas, 1993), it is not even listed in the index of *Contingencies of Reinforcement: A Theoretical Analysis* (Skinner, 1969). Strength had to be dropped, and continuity was not far behind.

In lieu of a more principled commitment to preserving continuity, the experimental analysis of behavior accepted the quasi-empirical terms, *stimulus* (S) and *response* (R), into its core ontology, and the counting of instances into its methodology, almost by default. Although the "act" of the layperson promotes behavior as a discrete endpoint in a causal chain, S-R psychology's "response" introduced even more discontinuity, because it implies a discrete antecedent as well. The experimental analysis of behavior sliced the unit into thirds, by adding a consequence. It was almost as simple as A-B-C, but accepting such cheaply purchased units would only postpone the difficult problem of accounting for continuity. Compare clicking on your computer's mouse button with moving the mouse-controlled pointer around on the screen, and consider that the experimental analysis of behavior has rarely given its rats anything but mouse buttons.

Instead of parsing behavior into instances of stimuli and responses, a science of behavior may commit, at the outset, to formulating the action of a behaving system, as well as its ongoing consequences, as continuously varying quantities. If anything is to be likened to an endpoint in a view that does not forget continuity, it is the value of a continuous variable that leaves the amount of action of a system invariant. This is the way of PCT.

Simultaneity

The most interesting parts of *Verbal Behavior* (1957) are about multiple causation, in which several variables operate simultaneously. Perhaps *concurrence* is a less metaphysically loaded term, but a search through the experimental analysis of behavior's huge literature on concurrence yields such a remote view of behavior that one cannot help but sense that we have left the life sciences and arrived in a course on business accounting. Now that the cumulative recorder has acquired museum status, students of the experimental analysis of behavior may speculate endlessly on causal interpretations of graphs that show the average rate of lever pressing (the dependent variable) as a function of the average rate of some consequences (the independent variable). Although the experimental analysis of behavior's routine comparisons of steady states, separated by what seem near lifetimes (in rat terms), are regarded as representing a conscientious, first-things-first methodology from which we may eventually understand the real-time interaction of multiple values of multiple variables, the practice provides a convenient hideout from which the conceptualization of simultaneity, like continuity, may be indefinitely postponed.

Reversing the coordinates of the behavior-consequence graph reveals the feedback function, which might raise awareness that causality in living systems need not be conceived as a one-way independent-dependent variable path leading from environment to organism, were it not for viewing the feedback loop from a virtual distance of 30,000 feet. The speaker brings simultaneity back down to Earth. Continuous, simultaneous feedback loops are essential for speech: A speaker cannot speak effectively without hearing what he or she is saying. In an important sense, *all* behavior requires at least one "listener" – the behaver – but, as Vaughan and Michael (1982) show, the "automatic" consequences in behavior are typically ignored. All the overlooked microlevel adjustments that enable rats to press levers must be sensed as consequences (automatically), while feedback loops at higher levels of temporal integration simultaneously generate their own consequences, including the occasional appearances of lab chow. If one regards isolated independent-dependent variable mappings as methodological artifacts and the *loop* as fundamental, a different science of behavior comes into view – one that reveals the experimental analysis of behavior's functional analyses to be, at best, synecdochic.

What must be resisted is the compulsion to seek a causal chain, a sequence of steps, around each cycle; such is the legacy of S-R determinism. The rat raises its paw to the lever *as* it senses the transition in a configuration of tendon stretchings. The speaker hears and feels utterances *as* they are spoken. The simultaneity of continuous action and consequence has been given some obligatory nods in the experimental analysis of behavior, but has not been regarded as fundamental enough to counteract the self-evident dictum that "the environment controls behavior." Behavior conceptualized without that assumption appears downright impractical – perhaps the esoteric object of Kantorian contemplation. But in PCT, experimentally verifiable laws can be expressed in *simultaneous equations* that hold for whole, continuous feedback loops. When the physics involved may undo simultaneity in extreme cases, PCT uses equations that converge to simpler simultaneous forms.

Organization

The unit of analysis in PCT is the *control system.* The experimental analysis of behavior adopted the term *control* to generally describe the environment's influence in behavior, but control has a specific meaning in PCT. The feedback loops alluded to above are *negative feedback control* loops. Negative feedback keeps a controlled quantity at a particular value. What we hear while speaking is usually well controlled. As disturbances in a variable environment influence such input, the control system's output changes accordingly, so that the disturbances are effectively opposed. The volume of our speech increases, for example, when what we hear is disturbed by the sounds of a passing train. PCT's experimental test for a controlled variable involves exactly this: applying disturbances that would be unopposed if control were not operating.

Control systems are the building blocks (like the experimental analysis of behavior's operants) that combine to account for the repertoire of the whole behaving organism. A hierarchy of control systems makes dimensionality and integration in that repertoire explicit and testable. Conventional hierarchies of behavior eventually "homunculize" the output of the higher order units into commands for actions at lower levels. In PCT, all control is the *control of inputs,* of consequences. Outputs know nothing of "actions." Outputs are simply *error signals* that eventually propagate down to the systems controlling perceived intensities, where variations in muscle tensions produce the only obvious, public consequences. There is no master control center to keep order in the ranks: Each level of relative temporal integration simply "sees" an eternal, continuous present.

Control systems further up the hierarchy resolve their errors through the action (not *actions*) of varying combinations of lower level systems. When a listener disagrees, we may engage an entirely different argument to make our point, although speaking more loudly may be the first resort. Failing that kind of resolution, the rising level of what may be considered here (to simplify) "net system error" is matched by an increasing rate in a random process of *reorganization;* as random modifications in the repertoire reduce such *intrinsic error,* the rate of reorganization decreases. If reorganization goes far enough, we may even reverse our most entrenched positions, for example, from the experimental analysis of behavior to the PCT view. Finally, control is never complete, so that, on the whole, the system is always operating with a mix of controlled and uncontrolled inputs.

What, then, of the apparent value-assigning functions of the experimental analysis of behavior's establishing operations (EOs) and their variants (Michael, 1982, 1993)? Although I hesitate to offer statements implying that the experimental analysis of behavior and PCT can be translated into one another, consider the following. For the experimental analysis of behavior, what is valuable is analogous to the value of a quantity that a control system's input will approach, and, when sustained, leaves the action of the system invariant. Even the smallest adjustments made by our lever-pressing rat involve eliminating differences between the values of a multitude of sensed inputs and the corresponding values toward which control converges. Now, assuming EOs and automatic consequences apply to all behavior at all levels of the hierarchy, think of the outputs, the error signals, of higher level control systems as establishing the values of the consequences produced by lower level control systems. The top level must always get its values from the reorganization process – in the developing infant, for whom the top level is still only a few layers removed from raw intensities, as well as in the mature organism, whose repertoire inevitably reaches a limit in terms of the complexity of controllable inputs for which feasible reference values could have evolved and stabilized.

A rat's hierarchically adjusted lever pressing is paralleled in the speaker's self-strengthening and secondary verbal behavior, but Skinner treats these as special, not systemic, relations. Rather than looking for organization in a taxonomy of supposedly causal environmental arrangements, PCT starts with the principle of negative feedback control and develops a theory around how an organism would be organized to achieve it in virtually all behavior. Thus, life itself is defined by control, even on the most basic, chemical level. Natural selection provides a minimal, necessary context for considering organic evolution, whereas PCT explores the role of negative feedback control, from the first molecules that were so organized as to slow their own dissolution in the substrate, onward.

Subjectivity

> The irony of it is that, while Boring must confine himself to an account of my external behavior, I am still interested in what might be called Boring-from-within. (Skinner, 1972, p. 384)

For PCT, there is an asymmetry of control, and it is not the usual one assumed by the experimental analysis of behavior in which the environment controls behavior. An organism has renewable energy resources, such that the energy expended in opposing environmental disturbances is replenished at a rate that sustains the control of inputs. In the evolutionary dawn, the earliest molecular control systems lacked the robust meta-stability of evolved organisms; they dissipated and reformed at the whim of environmental changes. Recently evolved organisms have resources for maintaining high levels of *gain* in their outputs, making control so rapid and complete across a range of disturbances that evidence of any action is practically invisible. Paradoxically, the asymmetry of control contributes to the illusion that an organism is a reactive system – it appears to be doing nothing until goaded by a sudden disturbance – but it is the physical, nonliving forces in the environments of organisms that are truly reactive.

Physics has its version of subjectivity: relativity. In PCT, the relationship between what is subjective and what is objective is, generally speaking, that between higher level and lower level control systems, respectively. Without venturing down to the lowest levels of control, the experimental analysis of behavior has perpetuated the illusion that the first data of a science of behavior consist of responses that are detectable as discrete events, as are the stimuli that "evoke" them. Once negative feedback control of input is assumed as the organizing principle, responses are viewed as events that we obviously can perceive and record, but they have no fundamental ontological status, either for us or the rat. An event is a perception controlled somewhere midway up PCT's hierarchy.

Whatever behavior is, it is not simply self-evident, as implied by the term *behaviorism*. What we see at the surface of a behaving organism can be studied scientifically as a side effect of the negative feedback control of inputs. The test for controlled variables allows us to model what control systems are operating within the organism at all hierarchical levels. A simpler approach, which can coherently scale up to account for the whole behaving system (including the speaker) may not be feasible. Two acknowledged contributors to the experimental analysis of behavior, William Baum and Hayne Reese, reviewed an article by Powers in *Science* in 1973; all are reprinted in Powers (1989). Perhaps you will take a longer, deeper look at PCT than these reviewers did. The primary source for PCT is Powers' *Behavior: The Control of Perception* (1973), but the first step is to go to the World Wide Web on your computer and point your web browser to http://www.ed.uiuc.edu/csg/. By all means, run the "demo" simulation programs to get a hands-on feel for the phenomenon of control; but then, by simply looking for it, you may see that you already have that.

REFERENCES

Cherpas, C. (1993). The concept of strength in the analysis of verbal behavior. *The Analysis of Verbal Behavior, 11*, 55-62.

Cziko, G. (1995). *Without miracles: Universal selection theory and the second Darwinian revolution*. Cambridge, MA: MIT Press.

Koza, J. (1992). *Genetic programming*. Cambridge, MA: MIT Press.

Michael, J. L. (1982). Distinguishing between discriminative and motivational functions of stimuli. *Journal of the Experimental Analysis of Behavior, 21*, 149-155.

Michael, J. L. (1993). Establishing operations. *The Behavior Analyst, 16*, 191-206.

Powers, W. T. (1973). *Behavior: The control of perception*. New York: Aldine de Gruyter.

Powers, W. T. (1989). *Living control systems: Selected papers of William T. Powers*. Gravel Switch, Ky: The Control Systems Group, Inc.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Skinner, B. F. (1957). *Verbal behavior*. New York: Appleton-Century-Crofts.

Skinner, B. F. (1969). *Contingencies of reinforcement: A theoretical analysis*. Engelwood Cliffs, NJ: Prentice Hall.

Skinner, B. F. (1972). *Cumulative record: A selection of papers*. New York: Appleton-Century-Crofts.

Vaughan, M. E., & Michael, J. L. (1982). Automatic reinforcement: An important but ignored concept. *Behaviorism, 10*, 101-112.