

PCT and Scientific Revolutions

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... The same question keeps coming up: are we going to have a revolution or aren't we?

PCT is the present state of a process that began with learning about, accepting, and starting to work out the implications of a revolutionary scientific concept, the idea of negative feedback control. The revolution started in the mind of H. S. Black on the morning of August 27th, 1927 as he was on the Lackawanna Ferry going to work at the Bell Labs, and spread rapidly over the next 20 years. When it started to leak out of the engineering world into the life sciences, however, it ran into resistance. The resistance arose because all of the life sciences with only a few minor exceptions had been developing for many decades in total ignorance of this new concept, and had created a huge network of concepts, terminology, and classifications based on other—and completely spurious—ideas of what makes behavior work. So not only did the revolution have to spread into the life sciences, it had to displace the ideas that were already there. And that aroused fierce defenses.

Arthur C. Clark gave us Clark's Theorem: the products of any highly advanced civilization will appear to us to work by magic. To this I want to add Powers' Corollary: to the inhabitants of any sufficiently retarded civilization, *everything* will appear to work by magic. Civilizations begin in ignorance and strive toward knowledge; they move from magic to science,

Magic is causation without mechanism. The mere fact that event A occurred is enough to cause event B to occur, with no intermediate processes to explain how A was transformed into B. The mere wave of a wand at Hogwarts causes someone on the other side of the quadrangle to fall flat on his back. What sci-

ence does is to provide connections from A to B in the form of smaller magics. These smaller magics are called mechanisms, and while they still involve causation without mechanism, they also provide stepping stones from A to B that are useful and in fact are the source of immense increases in understanding. Having seen these new mechanisms, we can now see how combining them differently can lead not only from A to B, from A to C, D, E, and so on.

The structure of the behavioral sciences has been mostly magical, which is to say, empirical. I recently attended a seminar on motor behavior. What we have learned in the last hundred years, apparently, is how moving one hand or two hands to a target or to a target and back again, slowly or rapidly, with the same or different distances to the target, alternating hands or repeating with one hand, with pauses between the trials or no pauses, and with spaced or continuous learning sessions, affects the accuracy of pointing. Some conjectures were offered about what the subjects were thinking by way of strategy, but nothing organized or systematic. So this was pure magic: these changes of conditions affected accuracy just because they existed, not because of any intervening processes. Afterward I said to the presenter, "This is good old-fashioned experimental psychology, isn't it?" He was quite pleased that I put it that way. He would not, I presume, have been so pleased if I had said he was studying magic. But he was. All science begins with studying magic and formulating beliefs. But after 100 years of studying, you'd think it would have gone a little way toward knowledge, wouldn't you?

Anyway, one has to admire the presenter's skill, persistence, and patience to have spent 20 years meticulously studying pointing behavior.

So the question is, are we going to have a revolution or not? I think there is only one way to do that. Scrap everything and start over. If you don't go all the way, if you aren't willing to give up everything you think you know about behavior, it will simply be too hard to make the transition. You won't be free to explore any part of the new approach any way you please; you'll always have to be careful not to upset any of your favorite apple carts. That will inhibit your thinking and generate blind spots, like continuing to believe that the way to create repeatable results is to create repeatable behaviors.

Maybe—in fact quite likely, though we shouldn't start out by thinking this way—we may discover some things about behaving organisms that the old-time psychologists also discovered, even though they had the wrong explanations for them. Even after Lavoisier put an end to 150 years of phlogiston, it remained true that if you put mice into dephlogisticated air, they will die. Only now we know that there never was any such thing as phlogiston; the oxygen had merely combined with carbon and become unbreathable. Lavoisier had the role of H. S. Black, and the result of his finding the role of oxygen in combustion was a scientific revolution that ended up replacing alchemy with chemistry. So PCT is the start of a revolution that will replace psychology and many other allied disciplines with something entirely new. As Kuhn observed, the new science will not be built on the old science; it will replace the old science.

In *Living Control Systems III*, chapter three, a “Live Block Diagram” is discussed; the program comes with the book and can run on a Windows-based PC or an Intel-based Mac with a suitable virtual-machine program in it. In this diagram you will find all the basic features of the revolutionary idea behind PCT. You will see that despite time-delays in the control loop, the loop gain is high and the control is highly accurate, and *the control system is not unstable* as so

many behavioral scientists seem to believe it must be. The time-constant of the output function, out of the box, is 30 seconds (that is, after a step-change in the error signal to a new constant value, the output will take 30 seconds to change $2/3$ of the way to its final new value, 30 more seconds to change $2/3$ of the remaining way, and so on). Despite that very sluggish response, the time constant of the overall control process is 0.3 seconds. The gain of the output function is 100: that is, the output is 100 times the magnitude of the error signal, after it comes to equilibrium. Reducing the output gain to 50—cutting it in half—reduces the output by 2%.

In other words, a negative feedback control system doesn't behave in accord with ordinary causal logic or common sense. Our common sense has been trained to fit a different model, the cause-effect model that underlies all conventional theories of behavior. If you want to be part of the PCT revolution, you have to retrain your common sense, which is exactly why you must simply give up every previous thing you learned about behavior that was based on the old common sense—that is, you have to give it all up. It is entirely wrong at its foundations.

Study the Live Block Diagram. Experiment with it any way you can think of, until it begins to make sense to you, until it starts to be part of your common sense about behavior, about control systems, about organisms. Behind it is a running model of a real control system, the same model that's used in Chapter 4 to match your own behavior in a real tracking experiment. There's nothing hypothetical about it any more; it really fits actual human behavior very closely. The more sense this block diagram makes to you, the less sense any other psychological theory will make. Do that enough and you will become part of the revolution whether you like it or not. You can't un-understand PCT once you have understood it.

Best, Bill P.