About Stimulus Response Theory and Perceptual Control Theory

Post to the Control Systems Group Network, Tue, 1 Dec 1998
From: Bill Powers
Subject: React accordingly
>> Bruce Gregory
> Rick Marken

>> OK, so "react accordingly" means "have the appropriate effect".

> Funny, I used exactly this example in just this way recently... This is the point I was trying to get at, knowing what "outputs to generate" (even if one could) is no help unless one can tell that they are reducing the error.

There is a subtle and hard-to-grasp idea here, which is especially hard to get across to most believers in conventional theories (S-R and cognitive). I have often said that we learn control systems, not acts or responses. What does this mean? It means that when we learn to control some variable, we don't learn to produce any particular action, either as a reaction to events in the world or as outputs that are planned and then executed.

To understand what we do learn, we have to see a control system as a collection of variables which are functions of other variables. For example, the output quantity is a (learned) function of the error signal. To say this does not imply any particular state of the output quantity or the error signal; it says only that whatever the value of the error signal may be, the value of the output quantity will depend lawfully upon it. The "law" is simply the form of the output function. It is that law that is learned.

The transition from an event-based model to a system (PCT) model is just like the transition from arithmetic to algebra. In arithmetic, we deal with specific numbers. We are given a problem: 2 + 3 = ?. And we answer "5." This is like stimulus-response theory, in which we are given a organism plus a stimulus, and are asked to state what response will follow: boy + girl + girl = ?, the answer being, possibly, "jealousy." Since the number of combinations of organisms and stimuli is, for all practical purposes, infinite, it would require an infinite number of such "arithmetic" propositions to cover all possible kinds of behavior.

In algebra, we start dealing with symbols that stand for a ***variable*** number—that is, for something that can be represented by any number within a range. When we say y = x + 1, we do not specify what the value of x is. It could be any number between negative infinity and positive infinity. We're just saying that whatever the value of x is, the value of y is one greater. So we're describing a ***relationship*** between two numbers, without having to say what the values of the two numbers are. This is the basic concept that we all had to learn in making the transition from arithmetic to algebra.

This is what we're doing when we say that qo = f(e): the output quantity is some function of the error signal. By specifying the form of the function f, we can describe this relationship without having to refer to any specific value of the error signal. We might say that qo = 10 * e, or if we include the time dimension, qo = 0.1*INTEGRAL(e). Note that we can't say what qo will be until we know what e will be. But the value of qo is completely determined by e, for after we have observed the value of e, and how it is changing, we can calculate the value of qo and its changes.

The equation qo = f(e) describes not a single response to a specific change in an error signal, but ***All possible responses to all possible error signals.*** It is the symbol f that stands for this universal relationship. Suppose that f stands for multiplying e by 10 to produce qo. The specific form of the function is qo = 10*e, and this remains the same for all values of e.

We can easily see that if the error signal is 1.5 units in magnitude, the output quantity will be 15 units in magnitude. But it also follows that if e is zero for five minutes, then jumps to a value of 2 and immediately goes back to zero, qo will be zero for five minutes, then jump to a value of 20 and go immediately back to zero.

The output (qo) is a momentary event because the input (e) changes so as to create a momentary event. ***But this does not mean that the output event is "caused" or "triggered" by the input event.*** The correct explanation is contained in the output equation: qo = 10*e. This relationship remains ***the same at all times*** during the changes in e. That is why a change in e is accompanied by a corresponding change in qo. Even if the organism seems to have learned to produce the output event when the input event "triggers" it, what it has really acquired is an output function such that qo = 10*e. Having acquired that ***function***, the organism will produce whatever output is implied by this equation, no matter how e changes—even if it simply remains zero or constant.

What's hard to communicate about this is that we can have a variety of outputs in response to a variety of error signals without anything changing in the system. When the output function is a simple proportionality, this relationship is not hard to see. But if the output function is at all complex, even if it's just an integration, there is no longer a one-to-one correspondence between error signal and output. Then it may seem that each different pattern of error signals causes a different "response." The fact that the same relationship between error and output exists for all apparently different responses is not so self-evident.

This same consideration holds for every relationship that makes one variable dependent on another in the control system, or in the feedback path. What is learned is a set of relationships between variables, not a set of events caused by other events. Once the physical relationships have been established, the whole control system creates specific and unchanging relationships among its variables—between reference signal and input, or between disturbances and output. These relationships arise from the way functions relate variables in the whole system. The relationships are independent of any particular changes in the variables; no matter how the reference signal and disturbance are changing (or staying the same), the organization of the system remains exactly the same.

When you learn to see behavior in terms of relationships among variables instead of causal connections between one event and another, you can see invariance where formerly you could see only specific causal connections. You can see that when someone builds a fire in the fireplace, two people may show "the same behavior", even though one of them takes off a sweater while another opens a window. Those are examples of ***the same behavior***.

Best, Bill P.