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Looking at Behavior Through Control Theory Glasses

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Behavior is always seen through the theoretical preferences of the observer. These preferences act like different prescriptions for glasses. The most popular glasses use the *causal theory* prescription, through which an organism's behavior appears to be the result of external or internal causes. This article describes glasses that use the less familiar *control theory* prescription, through which behavior looks like the organism's purposeful efforts to control its own perceptions. The consequences of looking at the same behavior through these different "glasses" are demonstrated by comparing examples of real-life behavior with the behavior of computer simulations available on the Internet. A method is described that makes it possible to determine which "glasses" provide the best view of any particular example of behavior.

Psychologists attempt to understand the mind by looking at behavior, including the behavior of the brain and nervous system. Scientific psychologists do this by looking at behavior in carefully controlled experiments. Clinical and counseling psychologists do this by looking at behavior in various kinds of interpersonal interactions (therapies). Psychologists look at behavior to obtain an objective view of the mind, one that allows *interobserver agreement* about what an organism is doing (Mitchell, 1979; Page & Iwata, 1986). For example, psychologists might not be able to agree about what is on a chess player's mind when a pawn is moved from one square to another, but they should be able to agree that the pawn was, indeed, moved. Such interobserver agreement has proven to be elusive in practice, however. The same behavior can seem quite different to different observers, leading to different conclusions about the nature of the mental processes that produced it. What looks like "moving a pawn" to one observer may look like "protecting the knight" to another.

Ambiguous Behavior

The fact that the same behavior can look different to different observers is not surprising when we realize that behavior can be no more objective than anything else we perceive. Behavior is a perception because it can be experienced only through our senses. Moreover, behavior is an ambiguous perception, like the famous "young woman/old woman" picture shown in Figure 1. In ambiguous perception, what we know to be the same physical situation can be experienced in two or more distinct ways. In the case of the "young woman/old woman" picture, the very same set of lines drawn on paper can be seen as a beautiful young woman facing away from the observer or an unattractive old woman seen in semiprofile. We are looking at the same picture—the same set of lines—in both cases. All that changes is what we perceive.

The same kind of perceptual ambiguity occurs when we are looking at behavior: We can see what we know to be the same behavior in at least two different ways. A behavioral analog of the "young woman/old woman" picture can be seen by asking a friend to keep a fingertip aligned with yours as you move your finger randomly about. There are at least two ways to see your friend's behavior in this situation. You can see your friend's finger movements as being *caused* by your finger movements, or you can see your friend's finger moving with the *purpose* of staying near your finger. One perception, the one favored by scientific psychologists, is of behavior as *caused* (Marken, 1988). The other perception, the one that is apparently favored by most laypeople, is of behavior as *purposeful* (Gelman, Durgin, & Kaufman, 1995;

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Figure 1. "Young woman/old woman" ambiguous figure.

Gergeley, Nádasdy, Gergeley, & Szilvia, 1995; Premack, 1990).

Through a Glass, Behaviorally

The way we resolve perceptual ambiguities depends, to a great extent, on what we expect to perceive (Bruner & Postman, 1949). If we expect to perceive an attractive young woman, then we will tend to see the "young woman/old woman" picture as the "young woman," at least at first glance. Similarly, if we expect to perceive a reaction to stimuli, then we will tend to see our friend's finger movements as a reaction to our own, at least at first glance.

In psychology, expectations about how behavior is perceived are embodied in the theoretical preferences of the observer. These preferences act like different prescriptions for glasses. It is as difficult to see our own theoretical preferences as it is to see the prescriptions for the glasses we are wearing, but these preferences, like the glasses, do influence the way we perceive behavior. Psychologists have used two importantly different prescriptions that have influenced what they see when they look at behavior. These can be called the *causal theory* prescription and the *control theory* prescription.

The Causal Theory Prescription

The causal theory prescription reflects a theoretical preference to see behavior as *caused* by internal (mental) or external (stimulus) events. When behavior is seen through causal theory glasses, it looks like "a show put on for the benefit of the observer" (Powers, 1978. p. 420) rather than as something the organism is doing for its own sake. The show seen through causal theory glasses consists of a pattern of actions, such as movements of the mouth and tongue, and the results of those actions, such as sharp words, that occur because they are caused by events that are inside or outside of the organism.

The causal theory prescription was first used by psychologists of the behaviorist persuasion whose theoretical preferences inclined them to believe that all behavior is caused by external (stimulus) events. So an early result of looking at behavior through causal theory glasses was an approach to understanding behavior called stimulus–response (S-R) psychology, wherein behavior was seen as a response to external stimulation. But other scientific psychologists, including cognitive scientists, now use the causal theory prescription as well (Bargh & Ferguson, 2000). The cognitive revolution produced a "bifocal" version of causal theory glasses, making it possible to see behavior as being caused by either external or internal events. But the basic prescription is still the same: Behavior is seen as the last link in a causal chain that begins in the world outside the organism (with stimuli, cues, or situations, according to behaviorists) or in the mind inside the organism (with plans, schemas, or programs, according to cognitive scientists).

The Control Theory Prescription

The control theory prescription reflects a theoretical preference to see behavior as *purposeful.* When behavior is seen through control theory glasses, it looks like the organism's efforts to produce results for its own sake, on purpose (Marken, 1992). The control theory prescription focuses on the fact that organisms vary their actions in whatever way is necessary to produce intended results and protect those results from unpredictable and often undetectable environmental disturbances, a process called *control* (Marken, 1988). Because the results produced by a control process are known to the organism only as perceptions, the behavior seen through control theory glasses appears to be the control of perception (Powers, 1973). This observation provides the fundamental basis for distinguishing the control from the causal theory view of behavior. Causal theory views internal or external events as the cause of behavioral output. Control theory views internal purposes as specifications for perceptual input.

The control theory prescription made an early appearance in the purposive psychology of Tolman (1932). Tolman saw that animals would vary their actions as necessary to produce particular results *on purpose*. For example, Tolman saw that a rat that would run to get food in a goal box would also swim to the same goal box if the maze were filled with water. The rat seemed to have the purpose of getting to the goal box and would do what was necessary to get there. Some psychologists other than Tolman, particularly those influenced by the development of cybernetics (Powers, Clark, & McFarland, 1961; Wiener, 1948), have looked at behavior through control theory glasses. But the dominant prescription in psychology has been and remains the causal theory prescription.

Philosophers of mind who talk about behavior in terms of purpose or intention (Dennett, 1989; Searle, 1986) seem to be looking at behavior through control theory glasses. But a closer look reveals that the purpose under discussion is being interpreted in terms of a causal model of behavior. The purpose described by these philosophers, whether it is called an internal program or a rational expectation, is an internal cause of output, not a specification for input. Behavior that is called "purposeful" or "intentional" is not necessarily behavior that is seen though control theory glasses. Behavior seen through control theory glasses looks like (and is described as) controlled input, not caused output.

Mother Goose

The consequences of looking at behavior through different theoretical preferences—through "glasses" with different prescriptions—can be illustrated by looking at some examples of behavior and comparing what you see with what psychologists have said they see when looking at the same behavior. One classic example of behavior that has been carefully described by psychologists is the egg-rolling behavior of the greylag goose. You can see this behavior for yourself in a short video segment that is available on the Internet.[1] A still from the video is shown in Figure 2.

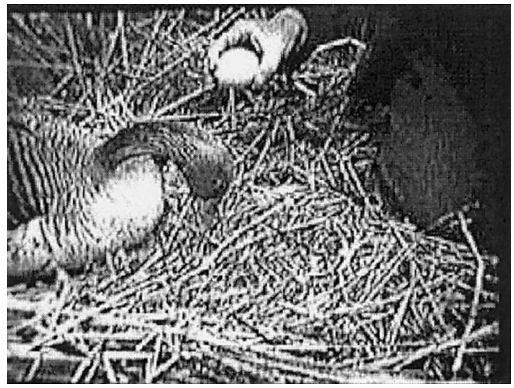

Figure 2. Greylag goose in the process of continuing egg-rolling movements after the egg is removed.

The video begins with a goose rolling an egg into her nest. This is followed by another shot of the egg-rolling behavior, but this time a researcher removes the egg just after the rolling begins, as shown in Figure 2. The Nobel Prize–winning ethologists Lorenz and Tinbergen (Lorenz, 1988) provided a classic description of this behavior. What they described seeing was a "fixed action pattern." The egg rolling seems to consist of a pattern of neck movements that, once begun, are carried out whether or not the egg is actually being retrieved. If the egg slips away or is taken away by an experimenter during the course of the action, the goose does not stop its action but completes it instead, exactly as occurs when the egg is present. Thus, it looked to Lorenz and Tinbergen as if the goose's behavior was caused by what would now be called an internal program for action: a *motor program*. Once the program starts, it continues to run off in a fixed pattern until completion.

Lorenz and Tinbergen saw the goose's behavior as a fixed action pattern because they were looking at behavior through causal theory glasses. Indeed, they were looking through the cognitive version of these glasses, because they saw the cause of the goose's behavior as being inside the goose. When you look at the Internet

[1] All of the Internet demonstrations in this article can be accessed via hyperlinks at http://www.mindreadings.com/PCTGlasses.htm. A QuickTime video of greylag goose egg-rolling behavior is available at http://www.pigeon.psy.tufts.edu/psych26/fap.htm.

video, I think you will find it easy to see the goose's behavior just as Lorenz and Tinbergen saw it. Indeed, it might be hard to imagine any other way to see this behavior. But let us take a look at the video again, this time through control theory glasses.

When you look at the goose's behavior through control theory glasses, you see the goose trying to produce a perception for herself. But what perception could the goose be trying to produce? If we try to experience the situation from the goose's perspective, we can see that one perception being produced by the goose is the feeling of pressure from the egg against the back of the bill. Indeed, all the goose knows of the egg, once it starts rolling it, is the pressure on the bill. The goose cannot see the egg at all. Rolling the egg into the nest, from the goose's perspective, means keeping the sensed pressure of the egg centered against the back of the bill. This is done by arching the neck around the egg and drawing back toward the nest, thus pushing the egg up against the back of the bill.

What happens when the egg is removed looks very different through control theory glasses than it did through causal theory glasses. Through control theory glasses, the continued movements of the neck are not the continuation of a fixed action pattern but an attempt to restore pressure against the bill from the now-nonexistent egg. The goose acts like a control system would act if its actions suddenly had no effect on the intended result of those actions. You can illustrate this for yourself by performing a simple tracking task that is available on the Internet.[2] In this task, you try to keep a cursor aligned with a target by moving the mouse appropriately. The cursor is analogous to the egg, and the target is analogous to pressure on the back of the bill. Movements of the mouse that keep the cursor on target are analogous to neck movements that keep pressure on the back of the bill.

At some point during the tracking task, the connection between mouse movements and the cursor is surreptitiously broken; actions no longer have an effect on the intended result. This is analogous to removing the egg during rolling; actions (neck movements) no longer have an effect on the intended result (pressure on the bill). What happens in the tracking task is exactly what happens in egg rolling. When the action is no longer effective it does not simply stop; rather, it continues in a way that *would* produce the intended result if the action still had an effect on that result. This is shown in the graph of the results that is plotted at the end of a tracking trial. The graph shows mouse movements continuing on after they no longer have an effect on the cursor, in a futile effort to produce the intended result: cursor on target.

Three's a Flock

The greylag goose's egg-rolling behavior looks like a "fixed action pattern" through causal theory glasses and an attempt to maintain pressure against the bill through control theory glasses. A more familiar kind of bird behavior provides another opportunity to compare the view through these two different types of glasses: the behavior of a flock of birds.

Flocks of birds are a familiar and beautiful sight. The birds fly in various patterns, including the familiar wedge, with one bird in the lead and the rest following behind. When we look at this wedge of birds through causal theory glasses, the movements of each bird, other than the one in the lead, appear to be caused by the bird in front of it. When the lead bird moves left, it seems to cause the birds behind it to move left; when it moves right, it seems to cause the birds behind to move right. A flock looks like an S-R phenomenon: Movements of the bird in front are the stimuli that cause the movements of the bird behind it.

Many computer models of flocking behavior have been built on the assumption that each bird is an S-R device, like the vehicles designed by Braitenberg (1986). Braitenberg vehicles have sensor inputs (S) connected by rules to motor outputs (R). The birds in animated computer simulations of flocking behavior are often described as though they were this kind of S-R vehicle, with the rules connecting S to R often being quite complex (Wilhelms & Skinner, 1990). These S-R models of flocking birds, sometimes called "boids" (Reynolds, 1987), are clearly based on a concept of behavior that comes from looking at flocking birds through causal theory glasses. A computer model of

[2] A demonstration of continuation of action ("fixed action pattern") when connection between action and result is removed is available at http://home.earthlink.net/~rmarken/ControlDemo/Goose.html.

flocking "boids" can be seen in action on the Internet.[3]

Through control theory glasses, flocking looks like each bird's attempt to produce a particular perceptual result for itself: keeping a constant distance between itself and the birds in front of it. This is a very different view of flocking behavior, and computer models based on this view assume that each bird in the flock is a control system rather than an S-R device. The organization of a control system is quite different from that of an S-R device. In particular, a control system does not respond to stimuli. Rather, it acts to keep some perceptual aspect of the world in a reference state, protected from disturbances.

A computer model of flocking known as the CROWD program is based on the assumption that the individuals in the flock are control systems (McPhail, Powers, & Tucker, 1992). This program can simulate a crowd (flock) of up to 255 individuals moving around on a field. The individuals will follow other individuals at a specific distance while maintaining a specific direction and avoiding collisions with each other and with stationary obstacles. Each individual in the simulation contains up to six simple control systems, each controlling perceptions such as distance to neighbors and obstacles and direction relative to a target destination.

The CROWD program can be seen in action by downloading it from the Internet and running it on a PC or PC compatible.[4] You will see that the behavior of the individuals in this control theory model of flocking is just as realistic as that of the individuals in the S-R models of the same behavior. Indeed, a close look at the S-R models shows that they are actually control systems in disguise. This is because the S-R models exist in a closed loop relationship with respect to the environment in which they act. In a closed loop, S causes R while, at the same time, R causes S. A closed loop is also called a *feedback loop*, because the effects of responses (R) are fed back as effects on the causes (S) of those very responses. The feedback in this loop is negative when responses tend to cancel out the stimulus cause of those responses. This is the case with the S-R bird models. Because they exist in a negative feedback loop, these so-called S-R models are actually negative feedback control systems (Marken, 1993). They are controlling the perception of the stimulus (S), maintaining it at some constant value.

Say Hey Willie

The difference between causal theory and control theory glasses works on the behavior of people as well as that of birds. One of the interesting things people do is play baseball. One of the great events in baseball history was Willie Mays's famous miracle catch made in the 1954 World Series. This catch is available as a realtime video on the Internet.[5] When you look at this catch through causal theory glasses, it looks like Mays's movements are caused by internal mental calculations. He seems to be mentally predicting the path of the ball, anticipating where the ball will land, and calculating the speed and direction in which he should run to get to the ball. Models of baseball catching often assume that such predictive calculations are, indeed, required for successful baseball catching (Tresilian, 1995).

When you look at the same catch through control theory glasses, things again look quite different. It looks like Mays is trying to control some perception of the current state of the ball rather than calculating the movements that will get him to where the ball will be in the future. But what perception might he be controlling? In fact, several possibilities have been proposed, but the most likely may be the one originally proposed by Chapman (1968): the optical velocity of the image of the ball on the eye. The idea is that the fielder catching a ball moves toward or away from home plate so as to keep the image of the ball rising at a constant rate relative to the background. Similarly, the fielder moves left and right so as to keep the image of the ball from moving horizontally with respect to the background.

A model of baseball catching based on the view through control theory glasses is available

[3] A simulation of "boids" flocking is available at http://www.red3d.com/cwr/boids/.

[4] The CROWD simulation program can be downloaded for PC compatibles from ftp://ftp.frontier.net/users/powers_w/crowdv2.exe.

[5] A RealTime video of Willie Mays's miracle catch in the 1954 World Series is available at http://www.mindreadings.com/mayscatch.ram.

as a Java simulation on the Internet.[6] Like Willie Mays in the film clip, the simulated fielder keeps his “eye on the ball” while it is in flight. The simulated fielder gets to the ball by controlling the optical velocity of the image of the ball relative to the background. After the catch is made, the simulation shows a graph of what the catch looks like from the fielder’s perspective. The fielder’s view while catching several different fly balls is shown in Figure 3. The graph shows the nearly straight paths of the image of the ball that are seen by the model fielder who is controlling the horizontal and vertical velocity of the image of the ball relative to the background. These visual paths correspond to the paths seen by real fielders who caught fly balls while carrying a shoulder-mounted video camera to record what they saw (McBeath, Shaffer, & Kaiser, 1995).

On the basis of data such as those depicted in Figure 3, McBeath et al. concluded that fielders catch fly balls by controlling the optical trajectory of the ball, keeping it straight (linear). Others have suggested that fielders catch fly balls by controlling the optical acceleration of the ball, keeping it equal to zero (Babler & Dannemiller, 1993). The Internet Java fielder simulation catches fly balls by controlling the optical velocity of the ball, keeping it equal to a value greater than zero (so that the image of the ball is always rising). These are three different hypotheses about the type of purpose being carried out by a fielder catching a fly ball. When we look at behavior through control theory glasses, one of the main questions to be answered is “What type of purpose is being carried out?” The control theory view of behavior suggests that the answer to this question will be given in terms of the type of perception (in this case, optical trajectory, acceleration, or velocity) that is being controlled (Marken, 2001).

Getting the Point

All of the behaviors examined so far involve an organism taking action with respect to something in the outside world. The goose takes action with respect to an egg; the bird in a flock takes action with respect to the other birds; the fielder takes action with respect to the fly ball. Because of this, it has been easy to see behavior as either a caused or a controlled result of action. But some behavior looks only like action; there are no obvious *results* produced by the action. For example, the neck movements that move the egg, the wing flapping that moves the bird, and the leg motions that move the fielder are apparently irreducible actions. It might seem that these behaviors would look the same through both causal and control theory glasses. But this is not the case. Even the actions that produce behavioral results look different through causal and control theory glasses.

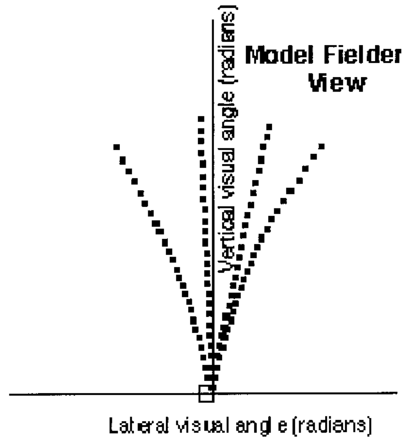

Figure 3. Model fielder’s view of the optical path of fly balls hit in several different trajectories relative to the fielder.

For example, look at your arm as you point to different places in the room. The movements of the arm look like pure actions, outputs produced by your nervous system. But this view of your arm movements is actually the way things look through causal theory glasses. The arm movement is seen as a response to your mental commands (causes). Things actually look quite different through control theory glasses. You can experience the difference for yourself by closing your eyes and noticing what you feel (perceive) as your arm moves from one place to another. You will notice that your arm movement is not just an action; it is a set of perceptions, of muscle tension and joint angle. These are called *proprioceptive perceptions*, and what you can see yourself doing through control theory glasses is manipulating (controlling) these

[6] A Java simulation of a baseball outfielder catching fly balls is available at http://home.earthlink.net/~rmarken/ControlDemo/CatchXY.html.

perceptions. Even an apparently simple movement (action) is not a response when seen through control theory glasses; it is still the control of perception. In the case of behaviors such as arm movements, however, the perceptions that are under control are completely invisible to outside observers.

A program that shows how arm movements are produced by control of proprioceptive perceptions is available on the Internet[7] for PC-compatible computers. The program, which was written by Powers (1999), is a simulation of a person reaching out with one arm to touch a target that moves in three dimensions. The person's arm has three degrees of freedom and employs realistic models of the muscles that drive the arm and the physics that convert muscle forces into arm movements. What is important about the model for present purposes is the fact that arm movements are produced by systems that control different proprioceptive perceptions, such as the angles of the force applied at the shoulder and elbow.

When you run the program, you will see a "little man" moving his arm to point at a moving target. It may look like the little man's arm movements are responses to internal commands. But this is the view through causal theory glasses. And, in this case, it is the wrong view. What the little man is actually doing is producing intended perceptions: proprioceptive perceptions of joint angles and muscle tensions that are invisible to the observer of the little man's behavior.

Balancing Act

Although it may be difficult to see arm movements as anything more than responses, some actions are so remarkable that we know there must be more to them than simply what meets the eye. A dramatic example of this comes in the form of the balancing acts done by circus acrobats. We take the most common kinds of balancing behaviors, standing and walking, completely for granted. But when the standing or walking takes place on a narrow wire a hundred feet above our heads, we notice. We see behaviors such as walking the high wire as amazing because we know there is more to it than producing walking responses. We know that the wire walker's skill is knowing how to control his or her own body. When it comes to balancing acts, most people seem to be amazed because they are looking at these acts through control theory glasses.

The problem of understanding how people are able to perform remarkable feats of balance is seen differently depending on whether one sees the problem through causal or control theory glasses. Through causal theory glasses, the problem of maintaining balance is seen as one of calculating the corrective forces needed to restore balance when it is lost. The corrective forces must be the exact inverse of the forces (dynamics) that are causing the imbalance, so this approach to balance maintenance is called *inverse dynamics*. The inverse dynamic approach to balance maintenance makes the development of simulated balance maintenance systems very difficult, because the forces that restore balance must be calculated with very high precision. Calculations that are off by only a fraction of a percentage point will have the opposite of their intended effect, increasing imbalance rather than restoring balance (Bizzi, Mussa-Onvaldi, & Giszter, 1991).

Through control theory glasses, the problem of maintaining balance is seen as one of determining the perceptions that, when controlled, result in balance being maintained. An excellent example of a balance maintenance simulation based on control theory is available on the Internet.[8] The simulation program, which runs only on PC-compatible computers, keeps an inverted pendulum balanced on a moving cart. A motor on the cart can accelerate it left and right to keep the pendulum balanced upright on the cart. A multilevel hierarchy of control systems keeps the pendulum balanced by controlling perceptions such as that of the pendulum's angular position, velocity, and acceleration. The systems control these perceptions by accelerating the cart to the left or right as necessary. An excellent description of the program is given by

[7] The "little man" movement simulation is available for PC compatibles from ftp://ftp.frontier.net/users/powers_w/armv2.exe.

[8] A control system model of a cart balancing an inverted pendulum is available for PC compatibles from ftp://ftp.frontier.net/users/powers_w/pendulum.exe.

its author, William T. Powers, in a document that is available on the Internet.[9]

Daring to Disturb the Universe

The examples of behavior described in this article make it clear that one cannot determine what an organism is doing by simply looking at its behavior. What you see when you look at behavior depends on which glasses you happen to have on at the time. The view through causal theory glasses is just as believable as the one through control theory glasses. One view is not ipso facto more believable than the other. The goose's egg rolling can be seen as a fixed action pattern or a purposeful attempt to produce pressure on the back of its bill. The flocking birds can be seen as S-R devices ("boids") or proximity controllers. The baseball fielder can be seen as a movement producer or a visual velocity controller. Arm movements can be seen as responses to mental events or controlled proprioceptive perceptions. Balancing can be seen as calculation of the inverse of dynamic equations or control of a hierarchy of perceptions. There is, however, a way to test which of these views is the more legitimate way of looking at any particular behavior. The process is called the *test for the controlled variable* (TCV), and doing it requires a bit more than just looking at behavior. One has to be willing to disturb the universe, that is, the universe of behavior (Marken, 1997).

The TCV tests the assumption that the view through control theory glasses is the correct one. It assumes that the behavior under observation is the organism's efforts to control some aspect of its own perceptual experience and test whether this behavior is, indeed, the control of perception. One starts the TCV with a hypothesis about the perception the organism is controlling. Hypotheses about possible controlled perceptions come naturally when one looks at behavior through control theory glasses: The pressure of the egg against the back of the goose's bill, the distance between birds, the velocity of the image of the ball relative to the background, sensed muscle tension, and angular velocity are all examples of perceptions that can be controlled.

What all hypothetical controlled perceptions have in common is that they are *variables*. The pressure on the back of the goose's bill, for example, is a variable because it can take on many different possible values, from very low pressure (no egg) to very high pressure (rolling the egg up an incline). Control can be viewed as the process of keeping a variable in some preselected (or reference) state, protected from disturbances. If the variable were not under control, the disturbances would cause the variable to vary right along with them. Control keeps the variable from varying along with disturbances. Control forces the controlled variable to do what the organism wants it to do: to remain constant or to vary.

It is this disturbance-resisting nature of control that is the basis of the TCV. Once you have identified a hypothetical controlled perception, you can test this hypothesis by trying to "push this variable around." That is, you act as a disturbance to the variable. If the variable is not under control, your disturbances will be completely effective; the hypothetical controlled variable will vary right along with your disturbances. If, however, the variable is under control, there will be little or no relationship between your disturbances and what the variable actually does. Indeed, if the aim of the organism is to keep the variable in some fixed state, then your disturbances will appear to have no effect on the variable at all; the organism will act to protect the variable from your disturbances, keeping the variable in the desired state. The TCV is, thus, something like the inverse of conventional behavioral test methodology. Conventional methodology is aimed at detecting an effect of one variable (the independent variable) on another (the dependent variable). The TCV, on the other hand, is aimed at detecting a lack of effect of one variable (the disturbance variable) on another (the hypothetical controlled perceptual variable).

The TCV is a method for validating (or invalidating) the view of a particular behavior through control theory glasses (Marken, 1997). If application of the TCV shows that a hypothetical controlled variable actually is under control, then the view of that behavior through control theory glasses is validated. The behavior you see does, indeed, involve the control of a

[9] Powers's description of the inverted pendulum-balancing program is available on the Internet at http://www.mindreadings.com/powerspend.pdf.

perceptual variable: The behavior has a purpose. If, however, application of the TCV shows that the hypothetical controlled variable is not under control, then the view of the behavior through control theory glasses is invalidated. The behavior you see does not involve control, at least of that particular variable: The behavior seems to have no purpose. It is impossible, of course, to prove a negative such as that a behavior has no purpose. It is always possible that the organism is controlling some other variable. But the TCV can rule out the possibility that the organism has certain types of purpose. In particular, it can rule out the possibility that the organism has the purpose of controlling the variable that was hypothesized to be under control. This purpose is ruled out if the variable is not protected from disturbance; it is ruled *in* (at least tentatively) if the variable is protected from disturbance.

Detecting the Purpose in Life

A demonstration of the use of the TCV to detect purpose is available on the Internet.[10] The demonstration is a Java program that shows three squares, each a different size, roaming randomly around the display area. One of these three squares actually has the purpose of moving in the pattern it takes; the other two squares are being pushed in these patterns by internal commands. So the behavior of one square actually has a purpose: to control a perception of its own position in two-dimensional space. The behavior of the other two squares is caused by an internal plan of action.

It is impossible to determine, simply by looking at the behavior of the three squares (their movements around the screen), which square actually has the purpose of moving around and which are being driven around by internal forces. Taking an “intentional stance” (Dennett, 1989) will not reveal which is the purposeful (intentional) square in this situation. The only way to determine which is the square with a purpose is to use the TCV. The TCV begins by looking at all squares through control theory glasses. This involves looking at all three squares as though they were controlling a perception of where they are on the screen; screen position is, therefore, the hypothetical controlled variable. This variable can be disturbed by moving the mouse, which pushes all three squares in the direction of mouse movement. One square, however, resists these pushes so as to keep its perception of its two-dimensional location on the screen under control. Thus, when you move the mouse, you should be able to determine almost immediately which square has a purpose (of controlling its own changing position on the screen) and which squares do not. The square with a purpose is the one that does not consistently move in the direction of your mouse movements (disturbances).

This demonstration illustrates some interesting characteristics of the TCV. It illustrates, for example, the importance of applying the disturbances carefully and in many different directions. If you apply the disturbance too slowly, it can be difficult to tell that one of the squares is being protected from the effects of this disturbance. The movements of the square with a purpose will not be very different from those of the other squares. Similarly, if the direction of the disturbance is applied in only one direction, it may be applied in the direction in which the purposeful square was moving anyway, so there will be little or no observable resistance. The movements of the square with a purpose will not be very different from those of the other squares.

The TCV in the Real World

Application of the TCV in the real world rarely involves actually pushing on a hypothetical controlled variable. For example, suppose that the hypothetical controlled variable is personal space; you suspect that a person is moving around so as to maintain a certain distance between himself or herself and others. This variable can be disturbed by simply walking into what you presume to be the person’s personal space. If the person backs away, protecting the space from disturbance, then you have obtained evidence that the person is controlling personal space without having directly pushed on the person.

Because language is such an important aspect of human activities, you can disturb many of the variables people control simply by talking. This

[10] A demonstration of the use of the TCV to determine which of three behaving systems is actually behaving with a purpose is available at http://home.earthlink.net/∼rmarken/ControlDemo/FindMind.html.

means that you can do the TCV verbally. For example, if you suspect that a person is controlling for "self-respect," you might occasionally insert *mildly* disrespectful comments into a discussion to see whether these disturbances are resisted. Resistance can take the form of anger or contradiction. This verbal approach to the TCV can be used to detect very sophisticated purposes. Indeed, a form of the TCV is used informally in therapeutic interviews to determine the purposes of the client. Some of these purposes may turn out to be in conflict with one another and may be the reason why the client is in therapy in the first place.

Conclusion

This article shows how different theoretical preferences act like glasses that make the same behavior appear to be either internally or externally caused output (through causal theory glasses) or purposefully produced input (through control theory glasses). The less familiar view through control theory glasses was illustrated with models available on the Internet. These models are built on the assumption that behavior is the control of perception. Once one has learned to see behavior through control theory glasses, it is possible to test the validity of this view using the TCV. The TCV can be used to determine whether any particular behavior involves the control of perception.

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