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10: ABSTRACT:

In this commentary we outline Perceptual Control Theory and suggest this as a fruitful way for Lee and Schwartz to fully embody their account of cleansing behavior. Moreover we take issue with the command control approach that Lee and Schwartz have taken seeing this as an unnecessary cognitive commitment within an embodied model of cleansing behavior.

11: MAIN TEXT:

Lee and Schwartz (LS) explain the relationship between cleansing behaviors and psychological variables using a grounded procedures approach (GPA). According to LS, the conceptual underpinning of GPA is an embodied cognition view of sensorimotor processing such that there is an increasingly distanced hierarchy of engagement from direct online activation through to partially offline semantic activation. GPA is procedural because LS link grounding, via context dependence, to a range of possible objectives all of which can change context. They focus upon a particular class of procedure, that of separation, which includes separating dirt from one's hands, leading to the elimination or attenuation of the separated entity.

Implicit within LS's account is the notion of 'command control' delivering separating behaviors as an output. The output behavior is functionally categorized as cleansing but the proximate details of the accomplishment of this task are left unexplained. To be an embodied thesis those details should be fully grounded in neural and sensorimotor mechanisms that explain the connection between the perception of something and behavior. We propose perceptual control theory (PCT) as a framework to address this gap in LS's thesis (Powers, 1973). In its simplest form PCT eschews the view of behavior as a final output, instead seeing behavior as a form of control. PCT sees perception and behaviour as a closed loop system of negative feedback: behaviour constantly adjusts against environmental disturbances to controlled variables that are specified by internal reference states. A hierarchy of increasingly abstract properties of perception specify reference states for lower level control loops.

Mansell and Marken (2015) give the example of a puff of air to an eyeball causing a blinking response. This is usually understood as a reflex – a classic input-output (I-O) system. PCT focuses upon what is being controlled: the moisture level of the eye's surface. The air introduces a disturbance to a goal-state (optimal moisture level) and the behaviour acts to maintain the perception of that state. Goal specification is internal to the system. In standard I-O paradigms goal specifications are rendered as external behavioural change. For example, in a button press task to ascertain whether a participant has noted a perceptual change on a screen, screen change is the input and the button being depressed is the behavioural difference. For PCT this is an incomplete account that omits control of the internal perception of the screen. The button press returns the screen to its 'resting state', which is the internal goal-specification: perceptual constancy has been restored.

Separation behavior is complex. Washing something away down a drain should be seen as control of an intrinsic goal of perceived cleanliness. That goal can be acquired through learning or evolutionary processes. PCT would split the perception of separation into a hierarchical arrangement of control loops because controlling cleanliness involves other purposes, each with a preferred goal, including positioning oneself in front of a basin, reaching and grasping then turning a tap to have a required pressure and temperature of water and so on. All motor actions are associated with controlled perceptions. The outcome of each action affects perception and will or will not shift perception toward a goal state to achieve homeostasis. At each level, the goal state for a particular kind of perception is compared with perceived input and any discrepancy (error signal) leads to further behavioral adjustments. It is highly likely that within a complex behavior, such as separation, there will be influence between subordinate loops.

It is discrepancy inside the system that converts into output (Powers, 1973, 2008). What we observe as behavior is a set of immediate - not sequential - effects altering the immediate environment of the system against disturbances that push sensory input away from a

preferred reference value; there is, *pace* Marken (2009, p.139), a simultaneous cause-effect loop where variations in perceptions (input) are causing variations in behavior (output) at the same time as variations in output are causing variations in input. Controlling for a higher order abstract self-perception, of the kind LS describe, requires the accomplishment of simultaneous perceptual control throughout the lower levels of the hierarchy all the way up (Powers, 1973, 2008). Thus, LS's account is not sufficiently proximate and requires an articulation of functional dependencies in the hierarchy of perceptual control.

Methodologically, LS propose finding relationships between representations in the mind of the participant and categories of separation behavior defined by the experimenter. Following Skinner's comments on methodological behaviorism we note, pace (Powers, 1973b), that simply recording stimulus-response (I-O) relationships in the laboratory will not reveal information about any internal cognitive structure. Cognitive psychologists have nonetheless adopted a form of S-R method and derived intensional hypotheses from purely extensional data (Day, 1983). Skinner's radical behaviorism and the antecedent-behavior-consequence model are not unrelated to PCT concerns and we could readily package the consequence as restoration of perceptual equilibrium, the gaining of control. In PCT, the I-O relationship does not reveal the internal properties of the system producing the output, instead, it reflects the environmental feedback function that connects output to controlled input: the quantity of output the participant's control system must produce to bring her perceptions to match an internal reference state.

More generally, PCT claims that the standard input-output approach of cognitive psychology gives the misleading impression that the input caused changes in the output, whereas in fact behavior is one part of a closed loop (Powers, 1973b; Marken, 2009). As a closed-loop explanation of behavior PCT requires a different kind of test – the test for a controlled variable (Powers, 1978). Mansell and Cary (2015) suggest the experimenter alter disturbances to a controlled variable in an environment that allows participants to perceive the consequences of their actions relevant to their goals with the important caveat that through making measurements, new disturbances are not introduced to the controlled variable. We believe this would be a useful experimental paradigm for LS to pursue, enabling them to remove their assumption of a cognitive link between input and output and to fully ground and embody their approach in perceptual process.

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