Perceptual Control Theory as a Framework for Modelling the Function and Dysfunction of Living Systems

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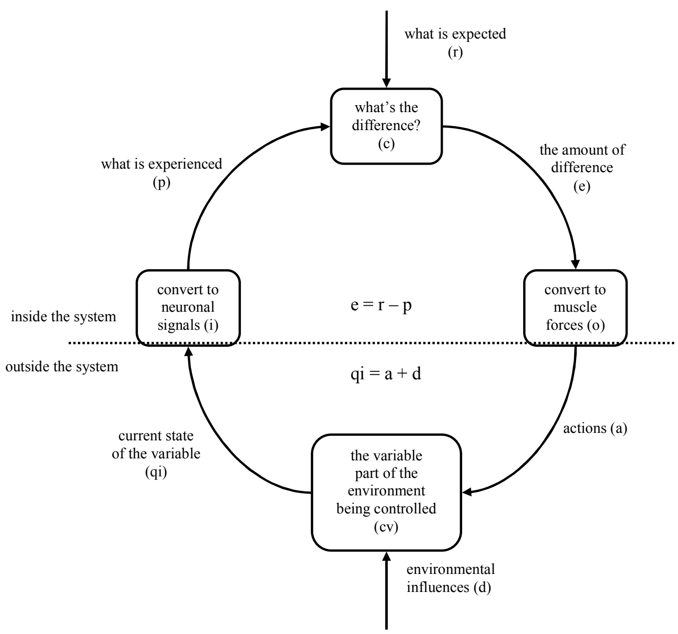
Perceptual Control Theory (PCT; Powers, Clark & McFarland, 1960; Powers, 1973, 2005) is a self-regulatory framework developed from control system engineering. The theory has been widely applied across the social and life sciences (see pctweb.org) yet it is not popularly recognised or understood within academic circles. The negative feedback loop, depicted below (Carey (2008) is integral to PCT.



The negative feedback loop functions to maintain a variable (*qi*) at, or close to, some reference value (*r*) despite the environmental disturbances (*d*) that tend to vary it. The variable is converted to neuronal signals (*i*) which are substracted from *r* to form an error (*e*) which drives the output of the system (*o*) to modify the controlled variable (*cv*) through actions (a) on that variable.

PCT proposes that human information processing is achieved through the functioning of multiple negative feedback loops and their organization with respect to one another. More specifically, the loops are organised within a hierarchical organisation. Higher level goals are achieved through setting the reference values (equivalent to goals) for lower level systems that in turn set reference values for lower order systems, and so on (see Figure 2; Runkel, 2003). In other words, a higher order goal never has a direct impact on behaviour; it merely sets the perceptual standards for lower order systems.

Within PCT, the lowest systems control the *intensity* of a perceptual signal. The systems increase in the complexity of perception with higher levels. The highest levels are concerned with maintaining *principles* (e.g. loyalty) and, in turn above, *system concepts* (e.g. the self in the world).

Any living system will have control hierarchies for many variables, and so the system as a whole needs to balance and regulate multiple lower level systems so that they each achieve their ends; in other words - so that they do not experience prolonged error. In order to manage this, the system leads to be able to modify its internal properties at the appropriate locations throughout the control hierarchies. For example, the *gain* of a system is a parameter that determines how much the error affects its output (output = error x gain). By changing the gain of different systems, they vary in the extent to which they exert control over specific variables. It is possible that at high levels in the system this may be felt by the individual as the reprioritisation of goals. Therefore, an optimization process called *reorganisation* is hypothesised to create variation in the properties of the control systems until error is reduced (Marken & Powers, 1989).

PCT considers chronic *conflict* between control systems as they key cause of psychological distress (see Mansell, 2005). Internal conflict occurs when two control systems attempt to control the same variable within different ranges. internal conflict is most likely to occur in these higher level systems where incompatible reference signals are set.

Testing PCT

There are many ways that PCT has been tested within computer models (see pctweb.org). They have essentially involved building a PCT model of a specific system and then evaluating the match between the model and the observations of how the real system works.

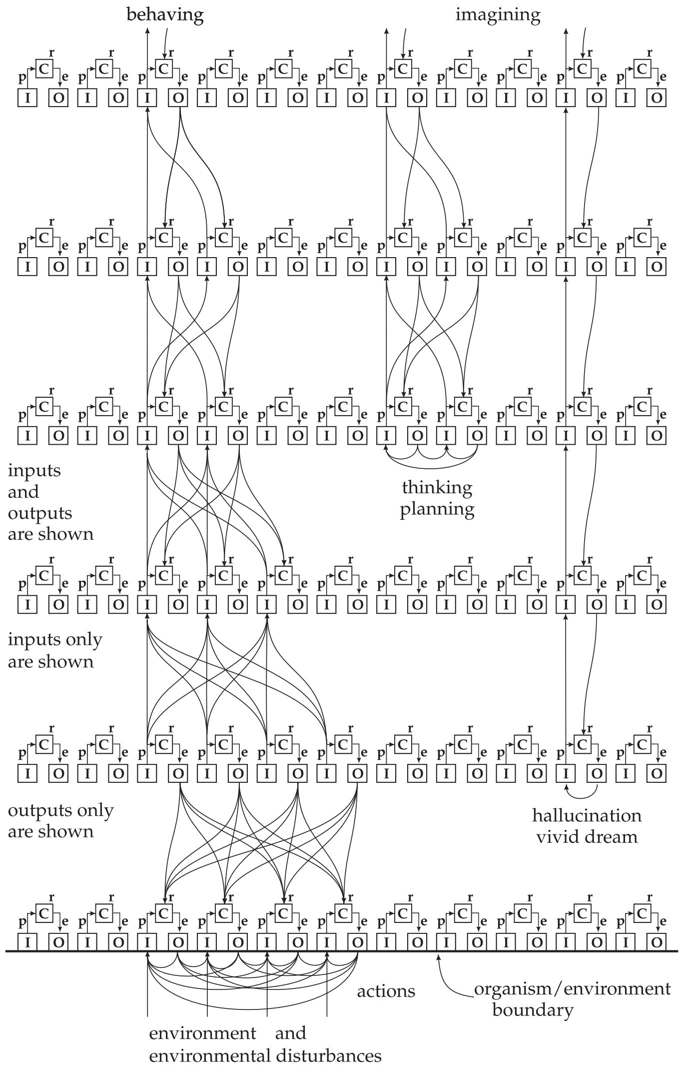
For example, Bourbon (1995) developed a PCT model of a simple tracker task that matched observed behaviour to a very high level (r > .95) over a period of five years within an individual. Marken (2001) describes a PCT model of catching fly balls in baseball that demonstrates of closer match with observed behaviour than alternative approaches. His model utilizes two parallel control systems – one that controls the vertical velocity of the image of the ball on the retina, and another that controls the lateral displacement of this image. These simulations provide a close match to data collected through mounting a portable video camera on the shoulder of a baseball fielder. In his latest book, Powers (2008) provides a wide range of different computer demonstrations of PCT.

Current Research Directions

The current research direction taken in my research group at the University of Manchester is to use PCT to model human psychological function and dysfunction, with particular relevance to psychopathology (Mansell, 2005). We are using PCT to model the jumping-to-conclusions bias (Dudley & Over, 2003) in probabilistic reasoning through the implementation of two control systems in conflict. Through differential weighting of the gains within these systems, the system can simulate every possible outcome demonstrated by individual data.

In a second project, a control system model will be used to simulate a model of bipolar disorder (Mansell, Morrison, Reid, Lowens, & Tai, 2007). The computer model will be designed to illustrate how mood swings can develop from two control systems in conflict, and that reorganization of the weighted outputs from a higher level system to these conflicted systems and a separate non-conflicted system can reduce mood swings, simulating successful recovery.

Further work in development includes working with a control systems engineer to model reorganization using MATLAB, using PCT model conflicting goals over access to psychological therapy, the development of sensimotor control within children with learning disabilities, and an online interactive therapy that promotes reorganization of higher level goals.



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