7.3 Levels of Control

One of the factors that can make a lower-level mechanism behave differently is that control mechanisms (Section 6.5) operate on it. Control mechanisms give rise to their own relation of levels. Insofar as a control mechanism operates on and changes the parts or operations of another mechanism, one can view it as at a higher level. And insofar as another control mechanism operates on it, that control mechanism is at a yet higher level. But this relation differs from the relation between mechanistic levels in two respects. The control mechanism is not a whole containing the controlled mechanism. And although the relation between control mechanisms can be hierarchical, it need not be (see Section 10.2). Whether hierarchical or not, levels of control do not give rise to reduction, as each control mechanism has its own role to play in coordinating the activity of the mechanisms it controls.

7.4 Summary

We have identified three notions of level that figure in discussions of neuroscience. Only the mechanistic conception gives rise to a notion of reduction. Some theorists advocate advancing explanations at the lowest level possible. Most proponents of mechanist explanation, however, emphasize the importance of organization at each level, and so recognize contributions of both lower and higher levels.

8 Do Neural Processes Represent Anything?

Representation is perhaps the most contested term in philosophical discussions of neuroscience. A representation stands in for and can be used by a process as a surrogate for something it represents. Humans frequently make use of representations. The phrase “nervous system” represents nervous systems and is used in many sentences in this Element. Many of the figures in this Element represent parts of the nervous system while others represent processes thought to occur in it.

On many accounts, such as the one advanced by Marr (Section 7.1), the nervous system is a computational system. A key component of a computational account is that operations are performed on representations (philosophers often refer to this as the *computational theory of mind* – see Pitt, 2020). Accounts of neural activity commonly characterize that activity in terms of what it is supposed to represent. Thus, place cells (Section 5.2) are characterized as representing places – when they spike in sequence, they indicate a sequence of locations on an animal’s route. Neurons in different regions of the visual cortex (Section 5.3) are characterized as representing edges, shapes, motion, and so on.

Neuroscientists certainly ascribe representations to neural processes. What is contentious is whether neural processes actually do represent objects and events. If so, what do they represent?

8.1 Can One Account for Neural Processes without Invoking Representations?

In Section 6.2, we introduced the dynamical systems approach to explanation that eschewed the need to appeal to mechanisms to explain neural processing. In eschewing mechanisms, this approach also rejects the idea that the brain should be viewed as a computational system that operates over representations. As an exemplar of an alternative to a computational system, van Gelder (1998) cites the governor invented by James Watt to control a steam engine so that it would maintain a constant speed regardless of what appliances were attached to it. In the governor, weights are attached by flexible spindle arms to a spindle that rotates with the flywheel of the steam engine (Figure 22(a)).[12] The arms move up or down, depending on the centrifugal force generated by the turning spindle. As a result of the linkage mechanisms connecting the spindle arms to the steam valve, the activity of the arms slows the steam flow when the flywheel is turning too fast (due to relatively strong steam flow and weak resistance) and increases it when it is turning too slowly. The governor thus uses negative feedback to control the steam engine.

To make his argument that representations are not needed to explain the Watt governor, van Gelder appeals to the mathematical characterization developed by Maxwell (1868):

$$\frac{d^2\varphi}{dt^2} = (n\omega)^2 \cos\varphi \sin\varphi - \frac{g}{l} \sin\varphi - r\frac{d\varphi}{dt} \tag{8.1}$$

in which ϕ is the angle of the arms, n is a gearing constant, ω is the speed of the engine, g is a gravity constant, l is the length of the arms, and r is the friction of the hinges. Equation 8.1 does describe the behavior of the governor and, on a dynamical systems account of explanation (Section 6.2), it provides an explanation. Importantly, there is no reference to representations.

A counterargument that one does need representations to understand Watt's governor starts by noting that the dynamical account does not answer the question of why Watt inserted the spindle arms into the governor (other than

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[12] For a video illustration of the operation of the Watt governor, see www.youtube.com/watch?v=B01LgS8S5C8.

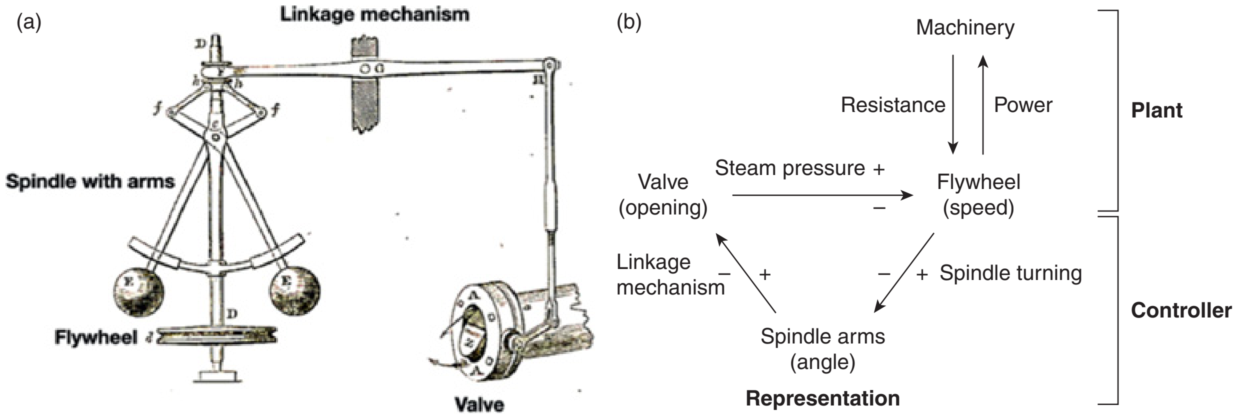

Figure 22 (a) Watt's design of the Watt governor. (b) Schematic representation showing how spindle arms represent the speed of the machinery and how this representation is used to affect the valve opening.

by saying that this allowed him to create a system that satisfies Eq. 8.1). A mechanistic explanation, by focusing on what the parts of the governor do, offers an explanation by appealing to the fact that the spindle arms stand in for the changing speed of the engine in a mechanism that can use them to adjust the speed of the engine (by acting on the valve). Precisely what they represent is not straightforward, but Nielsen (2010) showed that by solving Eq. 8.1 for ω, one can show that the speed is represented by φ, $\frac{d\varphi}{dt}$, and $\frac{d^2\varphi}{dt^2}$, that is, in terms of the angle of the spindle arms, the velocity with which it is changing, and its acceleration.

In addition, Watt's governor fits the characterization of a control mechanism. As discussed in Section 6.5, control mechanisms alter the operation of other mechanisms, in this case, by opening or closing the valve on the steam pipe, based on the measurements that they make (Figure 22(b)). Seen from the control mechanism perspective, Watt's genius was to realize that he could take advantage of centrifugal force so that the angle of the spindle arms would measure the speed of the engine. As a result of performing this measurement, the angle of the arms stands in for and so represents the speed of the engine and does so in a format that enables the governor to alter the valve setting so as to maintain the target speed. More generally, the fact that control mechanisms make measurements in order to perform their control function is what leads researchers to characterize them as employing representations – they represent what they measure. Neural mechanisms that respond to fat concentrations in the intestinal system (Section 5.1) or moving objects in one's visual field (Section 5.3) make such measurements, and so, on these accounts, can be characterized as representing these conditions.

8.2 Are Representational Ascriptions Mere Glosses by Theorists?

One might acknowledge that neuroscientists attribute representations to components of control mechanisms but insist that these are only glosses provided by theorists. Representations do not figure in the operation of the governor or the brain: the physical processes in the governor are not being used as representations by these physical systems (Haselager, de Groot, & van Rappard, 2003; Egan, 2019). The governor would work the same if disconnected from the flywheel and the steam valve as long as something turned the spindle arm. It could even be used to control some other process. One way to put this challenge is that the angle arms do not know about the flywheel or that it is acting on a steam engine, and so do not really represent it. (For a classic argument of this type directed not at brain mechanisms but artifical intelligence systems, see Searle, 1980.)

In introducing representations, we used linguistic phrases as examples. How does a word like “neuron” represent neurons? There is nothing about the word itself that determines what it represents. Waldeyer, who invented this term, might have coined a different term. Rather, its meaning depends on the conditions in which language users insert it into sentences and, especially, how they respond to it when they encounter it being used by others. This raises the question as to whether a similar account applies to neural activities characterized as constituting representations. Viewing neural activities as states in control mechanisms already suggests how a similar account can be developed: When they are generated and used in controlling other mechanisms, neural mechanisms treat them in ways similar to how language users treat linguistic phrases.

Further support for interpreting neural processes as representations is that working scientists investigate how they possess the ability to represent. When you encounter a word or phrase you do not know, you investigate when people use it and how others respond to it. Similarly, after O’Keefe characterized neurons in regions of the hippocampus as place cells, he and others set out to identify how they come to respond to particular locations and how they figure in the animal’s behavior. As discussed in Section 5.2, researchers manipulated environments to see which would produce changes in a neuron’s response. They also showed how activation of these neurons before and after rodents ran on paths occurred in anticipation and recall. At a minimum, the researchers are not just glossing an already described neural mechanism, but taking seriously the hypothesis that it functions as a map-like representation and investigating how it does so. That is, they, treat these neurons as actually representing places (Bechtel, 2016).

8.3 Do Neural Processes Accurately Represent the World?

If one accepts that neural processes do represent the world, a further question is: Do they *accurately* represent the world? Many of the approaches to ascribing content to neural processes assume that that is what they are doing. In characterizing what different visual areas do, researchers presented stimuli with a given feature and treated the neurons that responded most strongly as representing that feature. One might also wonder what would be the point of a perceptual system that did not accurately represent the world since that would seem to defeat the goal of successful interaction with the world.

Using temperature perception as an example, Akins (1996) argues that our sensory systems do not accurately represent the world. Rather, she characterizes our temperature receptors as narcissistic – they respond when the