*This is an excerpt from a report on the Perceptual Learning and Perceptual Recognition Workshop at the University of York in March of 2012, written by Kevin Connolly, Dylan Bianchi, Craig French, Lana Kuhle, and Andy MacGregor, and available at http://networksensoryresearch.utoronto.ca/Events_%26_Discussion.html*

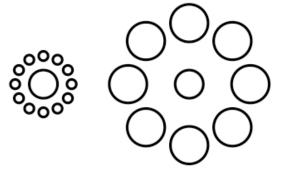**5. How Is Perceptual Learning Coordinated with Action?**

In the final presentation of the workshop, Randy Flanagan showed how the motor system displays a high degree of cognitive sophistication. During the course of executing tasks and learning new ones, the motor system employs a variety of information. Although much of the information contained within it is inaccessible to consciousness and higher cognition, the motor system contains rich bodies of information about task-relevant features of the environment and the motor system itself. This information is not innate or hardwired, but is learned through perceptual and motor engagement with a particular task or environment. The phenomena of motor learning raise at least two philosophically interesting questions: (1) what kinds of representations are involved in motor learning? and (2) Can the contents of these representations be shared among sense modalities, and if so, to what extent? On this second question, Flanagan showed some ways in which the contents are shared, while Malika Auvray, his commenter, showed some ways in which the sharing is limited.

In answering the first question, Flanagan identified four main kinds of representations that store the information utilized by the motor system: (i) probability distributions encoding statistical regularities in the environment; (ii) models used to generate predictions about the perceptual consequences of a motor command; (iii) uncertainties associated with estimated features of the environment; and (iv) evaluations of possible courses of action on the basis of decision-relevant information such as energy cost. Notably, these representations are intrinsically

probabilistic, and are manipulated according to Bayesian operations during the execution of motor skills and motor learning.

The second question is prompted by the observation that motor learning is sometimes facilitated by information contributed from a different sense modality. Experiments so far have focused on vision; two noteworthy results are as follows. First, subjects compute a Bayes-optimal prediction from noisy information from the visual and motor systems when extracting task-relevant information from the environment (Ernst and Banks, 2002). Second, subjects who had watched others moving in an unusual force field were quicker to learn to move in that force field than subjects who had not (Diedrichsen, 2007).

These results provide clear evidence that there is some sharing of information between visual and motor systems. But other well-known findings suggest that this sharing is limited. In her comments on Flanagan's talk, Malika Auvray discussed a study (Aglioti, DeSouza, and Goodale, 1995) in which subjects were shown a pair of disks embedded in a Titchener-like context (see figure below) and asked to grasp them. Despite reports to the effect that one of the disks appeared larger (an illusion), reaching behavior remained constant between disks; both disks were grasped with an accurate grip size. Apparently the visual system is duped by the illusion while the motor system is not. Results such as these have motivated the distinction in cognitive science between dorsal and ventral processing streams.

In his reply to Auvray, Flanagan pointed out that studies in which motor behavior remains insensitive to visual illusions have tended to focus on reaching. When grasping, object manipulation, and abnormal force fields are involved, Flanagan hypothesized, there is more potential for information sharing. These operations are more computationally intensive and display sensitivity to cognitive load, even where that load draws on higher cognitive processes. If Flanagan is correct in this speculation, the distinction between dorsal and ventral streams may need to be reconceived when the full range of cognitive operations involved in motor learning is taken into account. The sophistication of motor learning may suggest a closer connection between the motor system and core cognition than theorists have previously acknowledged.

**References:**

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