Shepard's mirrors or Simon's scissors?

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Abstract: Shepard promotes the important view that evolution constructs cognitive mechanisms that work with internalized aspects of the structure of their environment. But what can this internalization mean? We contrast three views: Shepard's mirrors reflecting the world, Brunswik's lens inferring the world, and Simon's scissors exploiting the world. We argue that Simon's scissors metaphor is more appropriate for higher-order cognitive mechanisms and ask how far it can also be applied to perceptual tasks.
[BARLOW; KUBOVY & EPSTEIN; SHEPARD]

What's in the black box? To understand the contents of the mind, we should consider the environment in which it acts and in which it has evolved. **SHEPARD**'s work has done much to spread this important ecological perspective, focusing on a particular vision of how the external world shapes our mental mechanisms. For SHEPARD, much of perception and cognition is done with mirrors: key aspects of the environment are internalized in the brain "by natural selection specifically to provide a veridical representation of significant objects and events in the external world" (SHEPARD, this issue, p. 582). Without entering into arguments over the need for representations of any sort (see e.g., Brooks 1991a), we can still question whether representations should be veridical, constructed to reflect the world accurately, or, instead, be useful in an adaptive sense. Clearly, not all veridical representations are useful, and not all useful representations are veridical. A less exacting view of internalization can be seen in the work of Egon Brunswik (as discussed by **BARLOW**, this issue), who proposed a "lens model" that reconstructs a representation of a distal stimulus on the basis of the uncertain proximal cues (whose availability could vary from one situation to the next) along with stored knowledge of the environmental relationships (e.g., correlations) between those perceived cues and the stimulus (Brunswik 1955). For Brunswik, the mind infers the world more than it reflects it. Herbert Simon expressed a still looser coupling between mind and world: bounded rationality, he said, is shaped by a pair of scissors whose two blades are the characteristics of the task environment and the computational capabilities of the decision maker (Simon 1990). Here, the mind must fit closely to the environment, but the two are complementary, rather than mirror images.

We expect that the mind draws on mechanisms akin to all three tools, mirrors, lenses, and scissors, from its adaptive toolbox (Gigerenzer & Todd 1999a). The question now becomes, where can each be applied? In perception, using Shepard's mirror or Brunswik's lens may often be the right way to look at things, but there are also instances where these tools are inappropriate. Consider the problem of a fielder trying to catch a ball coming down in front of her. The final destination of the ball will be complexly determined by its initial velocity, its spin, the effects of wind all along its path, and other causal factors. But rather than needing to perceive all these characteristics, reflect or model the world, and compute an interception point to aim at (with screw displacements or anything else), the fielder can use a simple heuristic: fixate on the ball and adjust her speed while running toward it so that her angle of gaze – the angle between the ball and the ground from her eye – remains constant (McLeod & Dienes 1996). By employing this simple gaze heuristic, the fielder will catch the ball while running. No veridical representations or even uncertain estimates of the many causal variables in the world are needed – just a mechanism that fits with and exploits the relevant structure of the environment, namely, the single cue of gaze angle. How widely such scissors-like heuristics can be found in perception remains to be seen, but some researchers (e.g., Ramachandran 1990) expect that perception is a "bag of tricks" rather than a box of mirrors.

Extending an ecological perspective to higher-order cognition. When we come to higher-order cognition, Simon's cutting perspective seems the most appropriate way to extend **SHEPARD**'s ecological view. Consider a simple cognitive strategy that has been proposed as a model of human choice: the Take The Best heuristic (Gigerenzer & Goldstein 1996). To choose between two options on the basis of several cues known about each option, this heuristic says to consider one cue at a time in order of their ecological validity, and to stop this cue search with the first one that distinguishes between the options. This "fast and frugal" heuristic makes decisions approximately as well as multiple regression does in many environments (Czerlinski et al. 1999), but usually considers far less information (cues) in reaching a decision. It does not incorporate enough knowledge to reasonably be said to reflect the environment, nor even to "model" it in Brunswik's sense (because it knows only cue order, not even exact validities), but it can certainly match and exploit environment structure: When cue importance is distributed in an exponentially decreasing manner (as often seems to be the case), Take The Best cannot be outperformed by multiple regression or any other linear decision rule (Martignon & Hoffrage 1999). In this situation, the two scissor blades cut most effectively. As another example, the QuickEst heuristic for estimating quantities (Hertwig et al. 1999) is similarly designed to use only those cues necessary to reach a reasonable inference. QuickEst makes accurate estimates with a minimum of information when the objects in the environment follow a J-shaped (power law) distribution, such as the sizes of cities or the number of publications per psychologist. Again this crucial aspect of environment structure is nowhere "built into" the cognitive mechanism, but by processing the most important cues in an appropriate order, QuickEst can exploit that structure to great advantage. Neither of these heuristics embodies logical rationality – they do not even consider all the available information – but both demonstrate ecological rationality, that is, how to make adaptive decisions by relying on the structure of the environment.

Why might Simon's scissors help us understand cognitive mechanisms better than **SHEPARD**'s mirror? We (and others) suspect that humans often use simple cognitive mechanisms that are built upon (and receive their inputs from) much more complex lower-level perceptual mechanisms (Gigerenzer & Todd 1999a). If these heuristics achieve their simplicity in part by minimizing the amount of information they use, then they are less likely to reflect the external world and more likely to exploit just the important, useful aspects of it, as calculated and distilled by the perceptual system (which may well base its computations on a more reflective representation).[1] While **KUBOVY & EPSTEIN** (this issue) would probably argue that neither metaphor, mirrors or scissors, helps us in specifying cognitive mechanisms, we feel that such metaphors

are vital in guiding research by providing an image of the sort of mechanisms to seek (as has been the case throughout the history of psychology – see Gigerenzer 1991). This is why it is important to point out that Simon's scissors may be a better model to have in mind than Shepard's mirror when studying a range of mental mechanisms, particularly higher-level ones.

Thus, in extending **SHEPARD**'s search for the imprint of the world on the mind from perception to higher-order cognition, we should probably look less for reflections and more for gleams. To achieve this extension, we must also discover and consider more of the "general properties that characterize the environments in which organisms with advanced visual and locomotor capabilities are likely to survive and reproduce" (SHEPARD, this issue, p. 581); these might include power laws governing scale invariance (Bak 1997), or principles of adaptively unpredictable "protean behavior" (Driver & Humphries 1988), or dynamics of signaling between agents with conflicting interests (Zahavi & Zahavi 1997), or costs of time and energy in seeking information (Todd 2001). With characteristic structures such as these before us as one half of Simon's scissors, we can look more effectively for the cognitive mechanisms that form the other, matching half.

NOTE

1. This is not to say that simplicity and frugality do not also exert selective pressure on perceptual mechanisms – **SHEPARD** appreciates the need for simplicity and speed of computation in those systems as well, for instance proposing screw displacement motions as representations because they are "geometrically simplest and hence, perhaps, the most quickly and easily computed" (Shepard, this issue, p. 585). But the amount and manner of information and processing may differ qualitatively from that in higher-order cognitive mechanisms.