Getting Our Bearings:
Advances in Understanding Spatial Reorientation

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Overview

There is widespread agreement that environmental geometry can be used in reorientation by human children, adults and non-human species. However, there is less agreement about the use of landmarks or "features". Human adults almost always use them, but feature use is less common in young children and non-human animal species. One way of explaining these facts is to suggest that there is widespread availability of a "geometric module" for reorientation by the shape of environmental enclosures, while the ability to use landmarks represents a signature achievement of human spatial cognition, related to an array of other abstract processes such as map use, spatial communication, and analogical reasoning (Lee & Spelke, 2010).

This proposal is not the only way to account for the phenomena. Several other theoretical frameworks vie to account for the hundreds of empirical findings on reorientation. One possibility is that there is an early-arising capacity to use landmarks for spatial information, with an initially low 'weight' that becomes strengthened over time (adaptive combination models, Xu, Regier, & Newcombe, 2017). Other proposals involve view-matching accounts (Stürzl, Cheung, Cheng, & Zeil, 2008) and learning theory accounts (Miller & Shettleworth, 2007).

This symposium will consist of three papers and two commentaries. The first paper will be a philosophical analysis of the arguments lying behind the various theories, and the evidence each one seeks to explain (Duval). The second and third will present new empirical evidence (Lee, Shusterman). Following these papers, two discussants will provide commentaries from the point of view of learning accounts (Miller) and adaptive combination accounts (Newcombe).

Paper 1

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This presentation will begin by summarizing the argument presented in *Cognition* (Duval, 2019) regarding **the representation selection problem** and how it offers the prospect of breaking the impasse in the debate between a geometric-module approach to spatial reorientation and a view-matching approach. The representation selection problem requires explaining how subjects can reliably select the relevant representation with which they initiate the reorientation process. The argument is that the view-matching framework does not have the resources to address this problem, while a certain type of theory within the geometric-module framework can provide a natural response to it. The article also developed a new geometric-module theory.

Duval will then go on to argue that (for reasons other than the ones discussed in 2019) we should favor geometric-module models over adaptive-combination models (like Xu, Regier & Newcombe, 2017) and associative models (like Miller & Shettleworth, 2007), especially as they pertain to animals. The argument draws mainly from work in neuroscience about place cells and head-direction cells.

Paper 2

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One of the debates surrounding reorientation findings involves the nature of the cognitive computations that underlie boundary-based spatial navigation. In particular, if there is a bias to reorient by boundaries, is it because they are represented differently from other non-boundary cues (as in the geometric module theory)? Alternatively, is it because a boundary is simply more salient due to its size, even though it is represented in exactly the same way as other visual cues (as in view-matching theories)?

In this talk Lee will argue that visual representation (although not visual view-matching) of boundaries play a crucial role in vertebrate navigation. First, she will illustrate the importance of the visual representation of the 3D environmental structure in the spatial navigation by reviewing behavior evidence from a variety of species (including humans) starting early on in development. Second, she will provide evidence from both functional neuroimaging and direct intracranial recordings of the human hippocampus that suggests that not only do we share hippocampal boundary representations with other animals, we can activate those representations with purely visual information using computer-based navigation tasks that do not require actual movement. Finally, she will propose that boundary representations in the brain's visual scene processing network provides input to and therefore ultimately guides our sense of where we are and where we are going.

Paper 3

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Experiments to date testing reorientation have typically used a rectangular space with one marked wall: a setup in which children readily use the geometric information afforded by the rectangular shape. When children succeed in this setup, it is impossible to know whether they used geometry plus an AT relation between the target and the landmark to find the target location, or whether they are truly reorienting by the marked landmark wall. Children can compute and remember locations "at" or "not at" a landmark from early ages (Bushnell et al., 1995), but they have difficulty with more complex spatial relations. Thus, the developmental trajectory traced in the rectangular reorientation setup does not answer how children come to use landmarks alone, absent geometry, for reorientation.

To address this question, Shusterman will report on a series of studies conducted in a large, square room with one marked wall. This setup eliminates informative geometry and allows us to observe children's use of landmarks alone. Results indicate no landmark-based reorientation before age 3, and a gradual, increasingly sophisticated integration of landmarks into reorientation behavior between ages 4 and 7. Young children do not use the landmarks even when they are the only cue available, a finding more consistent with a protracted conceptual process rather than a shift in the weights assigned to different cues. Drawing on these data, Shusterman will address why landmark use is challenging for children, and will lay out a theoretical account, the Spatial Symbol Hypothesis, to explain the nature of the abstract conceptual leap that children must make to use landmarks as adults do, in reorientation and other abstract spatial tasks.

Discussant 1

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One of the challenges for any account of spatial reorientation that aims to cover both the human data and the data from other species is accounting for learning. First, when non-human animals do use features (and they do), it is difficult to see how symbolic coding can account for this fact. Second, non-human animals show pronounced improvements in spatial reorientation tasks over time, tested in hundreds of trials, whereas experiments with humans, including children, involve much shorter runs of trials with no learning observed over these runs. Miller will discuss problems with various explanations of spatial reorientation when considered in the light of these data.

Discussant 2

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Adaptive combination approaches include a potential role for spatial symbols in developmental transitions, but they also consider the potential role of other factors, including environmental variations (size of the enclosure) and neural change (hippocampal development). Considering multiple factors offers flexibility in accounting for differences as well as similarities across species. However, a potential pitfall is that excessive flexibility can render an approach unfalsifiable. Newcombe will discuss how to address the philosophical and empirical questions posed in the first three papers, as well as the possibility of future studies that would make crucial predictions to adjudicate among the competing theories.

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