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Evolutionary internalized regularities

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Abstract: Roger Shepard's proposals and supporting experiments concerning evolutionary internalized regularities have been very influential in the study of vision and in other areas of psychology and cognitive science. This paper examines issues concerning the need, nature, explanatory role, and justification for postulating such internalized constraints. In particular, I seek further clarification from Shepard on how best to understand his claim that principles of kinematic geometry underlie phenomena of motion perception.

My primary focus is on the ecological validity of Shepard's kinematic constraint in the context of ordinary motion perception. First, I explore the analogy Shepard draws between internalized circadian rhythms and the supposed internalization of kinematic geometry. Next, questions are raised about how to interpret and justify applying results from his own and others' experimental studies of apparent motion to more everyday cases of motion perception in richer environments. Finally, some difficulties with Shepard's account of the evolutionary development of his kinematic constraint are considered.

Keywords: apparent motion; circadian rhythms; constraints; ecological validity; evolution; internalizated regularities; kinematic principle

Introduction

Talk of evolutionary internalized regularities in perception, although much in vogue, can be vague. One way to sharpen discussion of the topic is to focus on a particular proposal. Roger Shepard's seminal 1984 paper and decade later update (1994; reprinted in this volume) are surely worthy of such attention. Shepard skillfully probes the issues in breadth and in depth. And his ideas have had a major impact, not only in the study of vision but in other areas of psychology and cognitive science. Still, I am not sure I fully understand Shepard's claims in these papers and other elaborations (Carlton & Shepard 1990a; 1990b; McBeath & Shepard 1989). Thus, my discussion may be more fruitfully viewed as an exploration of the issues and a request for additional clarification, rather than as a criticism of Shepard's position.

I begin by briefly exploring general aspects of the nature and notion of an "internalized regularity." Next, I consider Shepard's kinematic principle, questioning the analogy Shepard draws between the internalized circadian rhythms of animals and his proposed perceptual constraint. Problems, then, are raised about the ecological validity of this constraint and the role it might play in the perception of ordinary, everyday motion. In turn, consideration of these issues would seem to pose some difficulties for Shepard's evolutionary account of the kinematic principle.

1. Constraints and internalization

To provide a framework in accord with Shepard's own ideas, I think it would be helpful to make explicit the relationship between a constraint and its possible internalization. In Shepard's sense, the claim that a constraint is internal*ized* goes beyond the claim that the constraint is presently internal or is somehow internally represented and functioning. First, the constraint must be inherited or "innate," and not the result of learning. Second, the constraint must come about by a *particular* evolutionary route. Internalized constraints result from the incorporation of features or universal regularities of the external world. If a constraint did not develop in response to a corresponding external regularity, but, for example, only tagged along on the back of another mutation or was a derived manifestation of the interaction of several independently selected evolutionary constraints, it would not, I take it, be counted as internal*ized*.

Members of the species who display the influences of an internalized principle do not themselves do the incorporating. The process of internalization takes place in prior generations as an evolutionary reflection of the environment. Shepard's focus on internalized constraints seems driven in part by the idea that such principles convey an evolutionary advantage. Establishing the specific benefits of an inherited constraint, however, is not an a priori matter. In light of issues discussed below, I am not sure what advantage Shepard's kinematic principle is supposed to confer. Nor am I very clear how and why he thinks the constraint would have come to be incorporated.

2. A paradigm case

Shepard offers an example of the circadian rhythms of certain animals as a model for his proposal about human per-

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ception. He points out that although the biological clocks of these animals appear attuned to the environment, the observed behavioral correlations are misleading. The rhythms are not under the control of external stimuli. When the animals are put in artificially altered environments their biological clocks remain largely unchanged. For Shepard the mechanism of circadian rhythms is a paradigm case of an internalized evolutionary constraint whose existence is demonstrated and manifested in its lack of dependence on the immediate environmental situation. The analogy, however, between this paradigm case and constraints on vision, requires further examination.

What is supposedly striking about the biological rhythms of these animals is their relative insensitivity to alterations in environmental conditions. The pattern of behavior continues in spite of relevant changes in the stimuli. But I am not convinced this feature of the paradigm fits all that well with the way some prominent constraints in vision theory are thought to work. Consider, for example, one of the most widely cited and accepted perceptual constraints, the rigidity principle. The visual system, it is maintained, prefers rigid interpretations over nonrigid ones. Yet, perception of objects as rigid does not run off as independently of the external stimuli as the circadian rhythms are said to do. Under normal viewing conditions, a real object that deforms its shape will generally be perceived as such. Where do things stand with regard to the force and function of Shepard's kinematic constraint?

3. The kinematic constraint and ecological validity

According to Shepard, his constraint entails that in perceiving motion "one tends to experience that unique, minimum twisting motion prescribed by kinematic geometry" (1984, p. 425). Here, I wish to examine the issue of sensitivity to environmental input raised in the previous paragraph. In particular, how are we to understand the claim that we have a *tendency* to see motion in terms of Shepard's principle of kinematic geometry?

Under normal viewing conditions, if presented with a real object moving along a path that is not the "unique, simplest rigid motion," it is most often perceived veridically. Shepard's kinematic constraint, like the rigidity constraint, then, does not cause or force perceptions that are decoupled from the actual environmental stimuli. Shepard allows as well that even in cases of apparent motion, perceptual experience may not adhere to the constraint. Thus, Shepard must square the fact that we readily see movement in violation of the kinematic principle with the claim that evolution leads us to see the world along the lines of the constraint. His solution to this problem is to claim that failures to satisfy his proffered principle occur as the result of conflicts with other constraints and stimulus conditions.

Shepard attempts to support his theory mainly by appeal to phenomena of apparent motion (and to a lesser extent imagery), not by studies of real object motion.[1] Reliance on this evidence has its difficulties:

1. In emphasizing the importance of biology, evolution, and Gibsonian theory, Shepard is anxious to champion the idea of ecological validity. Now one thing which seems clear is that the conditions and stimuli used in the apparent motion experiments are not especially typical of normal movement perception. Hence, there is the worry that results found under these limited circumstances are not ecologically valid. They may not transfer or apply to cases of real motion in more ordinary environments.[2]

2. I believe Shepard does not deal adequately with this issue, that is, with the possibility that apparent motion studies do not support substantive claims about the role kinematic geometry actually plays in normal perception. Shepard himself notes that constraints will be violated when an alternative interpretation is "forced on the observer by external conditions" (1984, p. 430). But if all it takes to *force* such perceptions on an observer are more or less ecologically standard conditions, the explanatory significance of the supposed internalized regularity is put in jeopardy.

I think Shepard slights this problem, because he wishes to stress the parallels with the circadian rhythms paradigm. Indeed, one of the major methodological lessons Shepard draws from these animal studies is that uncovering evolutionary constraints requires the use of abnormal experimental conditions. His reason is that if a constraint does embody a regularity occurring in the environment, it will remain hidden in ordinary circumstances. For it will seem as though the behavior is simply being caused by instances of that very environmental regularity. To discover constraints on circadian rhythms it was necessary to remove the animals from their ordinary environment and place them in artificially created settings.

Unfortunately, the need to appeal to relatively non-normal conditions is in tension with a commitment to ecological validity. Some of the difficulties surface when one examines Shepard's attempts to account for constraint violations in apparent motion.

4. Constraint violations

Within certain temporal and spatial limits, when a circle is flashed on the left and a square on the right, subjects report they see an object go through geometrical shape transformations while traversing the gap. They do not see it as movement of a rigid body. More complicated compressions, expansions, shape changes, along with violations of the unique kinematic path constraint are experienced in numerous other apparent motion experiments.

Shepard is well aware of such findings. His reply is that the rigidity and kinematic constraints do hold, but only under "conducive conditions" (1984, p. 430; 1994, p. 7). Notably, constraints will be violated when, as with an alternating circle and square, the demands of the principles are not consistent with or are in conflict with the stimuli. Processing limitations are said to be responsible for still other apparent motion violations of constraints. For example, Shepard argues that the time from the onset of one stimulus to the onset of the other can be insufficient to allow for the kind of motion required by the internalized principles. An appropriate rigid kinematic trajectory may be too lengthy a path to travel for it to be completed in the time available between the onsets of the two stimuli. Accordingly, the visual system resolves the conflict by "taking" a shorter path. It perceives a constraint violating shortcut path that can be traversed within the given time span. Evaluating Shepard's explanation of these apparent motion phenomena would require detailed examination, not to be undertaken here.

In any case, I do not believe Shepard's account of con-

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straint violations in apparent motion speaks adequately to concerns about the ecological validity of his kinematic principle in more richly structured environments. A claim of ecological validity would perhaps be more convincing if satisfaction and violation of the constraint were to function in ordinary motion perception as it does in apparent motion. But the case for this claim is not so obvious. Generally, a real object moving along a constraint satisfying kinematic path is not perceived as taking a constraint violating shortcut, even when the time duration would provoke a constraint violating apparent motion trajectory. Similarly, real objects moving along constraint violating non-unique paths are generally perceived as such, even when their transit times are of sufficient duration to trigger constraint satisfying paths in apparent motion.

Shepard, then, allows that in many situations the paths and deformations experienced during apparent motion violate supposedly internalized principles. He attempts to resolve this difficulty by explaining away the violations. In order to do this, he offers a set of additional conditions that must be met if apparent motion is to conform to his kinematic constraint. I do not think, however, that the function, effect, and relevance of comparable restrictions have been shown or can be assumed to hold in the perception of more everyday cases of real movement.

5. External forces

Establishing a significant role for Shepard's internalized kinematic principle to play in the perception of richly structured, everyday environments remains problematic.

1. When actual motion accords with Shepard's kinematic constraint, the influence of an internalized regularity may be minimal or nil, since as he admits, there may be enough information in the stimulus to "force" the correct perception without its aid. Alternatively, when in everyday circumstances real motion does not fit the countenanced pattern, it will usually be perceived veridically. Once again, the stimulus will be sufficient to force the correct perception. Shepard would seem to need, then, evidence indicating that his constraint continues to function in ordinary environments, environments where the external conditions appear "rich enough" on their own to determine the perception. In Shiffrar and Shepard (1991), subjects' path matching judgements of real movements are taken to support such a claim. Also, perturbation studies might be devised to show the constraint does have influence, or at least has to be "overcome," in perceiving real motions that violate the principle. Were this so, the kinematic principle might be construed along the lines of a probabilistic "soft" constraint – a constraint whose satisfaction or violation goes into determining the overall probability value the visual system assigns to possible scene interpretations.

2. In places, though, Shepard seems to downplay the need to demonstrate a significant role for the kinematic constraint in more standard conditions. As he says, "Natural selection has ensured that (under favorable viewing conditions) we generally perceive the transformations that an external object is actually undergoing in the external world, however simple or complex, rigid or nonrigid" (Shepard 1994, p. 7). So perhaps the constraint only determines "the default motions that are internally represented under the unfavorable conditions that provide no information about the motion that actually took place" (1994, p. 7). From this standpoint, worries about the ecological validity of the constraint are not very pressing, but then again the significance of the constraint in explaining ordinary perception would be further diminished.

6. Evolution

1. Failure of everyday motion to adhere to a principle of geometry or physics does not rule out the possibility that the visual system is guided or influenced by such an internal constraint. Lack of "ecological validity," nevertheless, does make more puzzling aspects of Shepard's internalization thesis. If the actual movements our ancestors experienced were not by and large instances of the unique path specified by the constraint, what would drive or account for the evolutionary incorporation of the principle? And in what sense are we to understand the constraint as reflecting a worldly regularity?

2. If the kinematic constraint is relatively weak or nonexistent in ordinary situations, an additional issue arises for Shepard's account. For such a lack of influence would suggest that the environment is typically rich enough or sufficient to *force* veridical perception independent of the constraint. This makes it more difficult to explain the biological advantage the kinematic constraint is supposed to convey. On the one hand, the constraint is not needed to perceive most everyday motion that conforms to it, the stimuli are rich enough. On the other hand, the constraint may only hinder perception of actual motions that do not fit its specifications. This last point is especially troublesome, since much of the real motion we do encounter does not traverse a path that is the unique, twisting route prescribed by kinematic geometry.

3. In various places Shepard suggests that psychological explanations that do not take an evolutionary approach are shallow, if not defective. I am not convinced this is so. Although an evolutionary perspective may be provocative and can suggest new problems and new lines of attack, models of visual processing and claims about underlying mechanisms can be formulated and tested quite independently of issues of origin. More to the point, if Shepard's kinematic constraint does play a significant role in perception, it should be of interest, even if an evolutionary internalization account of its development could not be sustained.

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NOTES

1. In Shiffrar and Shepard (1991) comparison judgments of paths of real (i.e., computer simulated) movement are offered as support. I do not think the evidence presented there much affects the issues I raise.

2. The problem is raised in Shepard (1984) and mentioned but not pursued in Carlton and Shepard (1990a) and Shepard (1994).