

Commentary on Todorovic, Schwartz, Hecht.....

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Internalized Constraints in the Representation of Spatial Layout

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Abstract

Shepard's (1994) choice of kinematic geometry to support his theory was questioned by Todorovic, Schwartz, and Hecht. His theoretical framework, however, can be applied to another domain that may be less susceptible to some of their concerns. The domain is the representation of spatial layout.

Among their insightful discussions of Shepard's (1994) theory, Todorovic, Schwartz, and Hecht raise different but interrelated concerns about Shepard's choice of kinematic geometry to support his ideas about the internalization of external regularities. These include questions about the "uniqueness" of motion in the world, the ecological validity of apparent motion, and whether the theory can be falsified. There is controversy as to whether examples from motion perception are as strong as his example of the sleep-wake cycle. Hecht calls for other domains to be specified. I propose that representation of spatial layout may be a good domain to consider in this context.

Perceiving spatial layout. The world is continuous and is packed with detail, but our view of the world is not. We cannot perceive our surrounding environment all at once. In vision, ballistic eye movements shift fixation as rapidly as 3-4 times/second. Even while fixating a specific location, high acuity is limited to the tiny foveal region (2° of visual angle) and drops dramatically outside the fovea, yielding a large low-acuity periphery. In haptic exploration (without vision), hands can touch only small regions of the surrounding world at a time. Yet, these successive inputs support a coherent mental representation of the surfaces and objects that make up natural scenes. Research on transsaccadic memory and change blindness (e.g., Irwin, 1992; O'Regan, 1992) support the idea that mental representation is more schematic and abstract than perceivers realize. I propose that in addition to maintaining layout and landmarks from prior views of the environment, mental representation includes anticipatory projections about future views. These projections are internally generated but are constrained.

Evidence for this is provided by a common representational error that occurs in memory for photographs of scenes, referred to as “boundary extension” (Intraub & Richardson, 1989). Viewers remember having seen a greater expanse of a scene than was shown in a photograph. What is important to note is that different viewers all seem make the same unidirectional error. For example, in one of their experiments, out of 133 drawings made by 37 individuals at least 95% included this unidirectional spatial extrapolation. (Examples are shown in Figure 1). In recognition tests viewers tend to rate the same view as showing too little of the scene, and will frequently select a more wide-angle view as the one they saw before (e.g. Intraub et. al., 1992). Boundary extension occurs as rapidly as 1 second following picture offset (Intraub et. al., 1996). The adaptive value of this surprising distortion is that although the mental representation is inaccurate with respect to the photograph it contains a remarkably good prediction about the scene that the camera partially recorded.

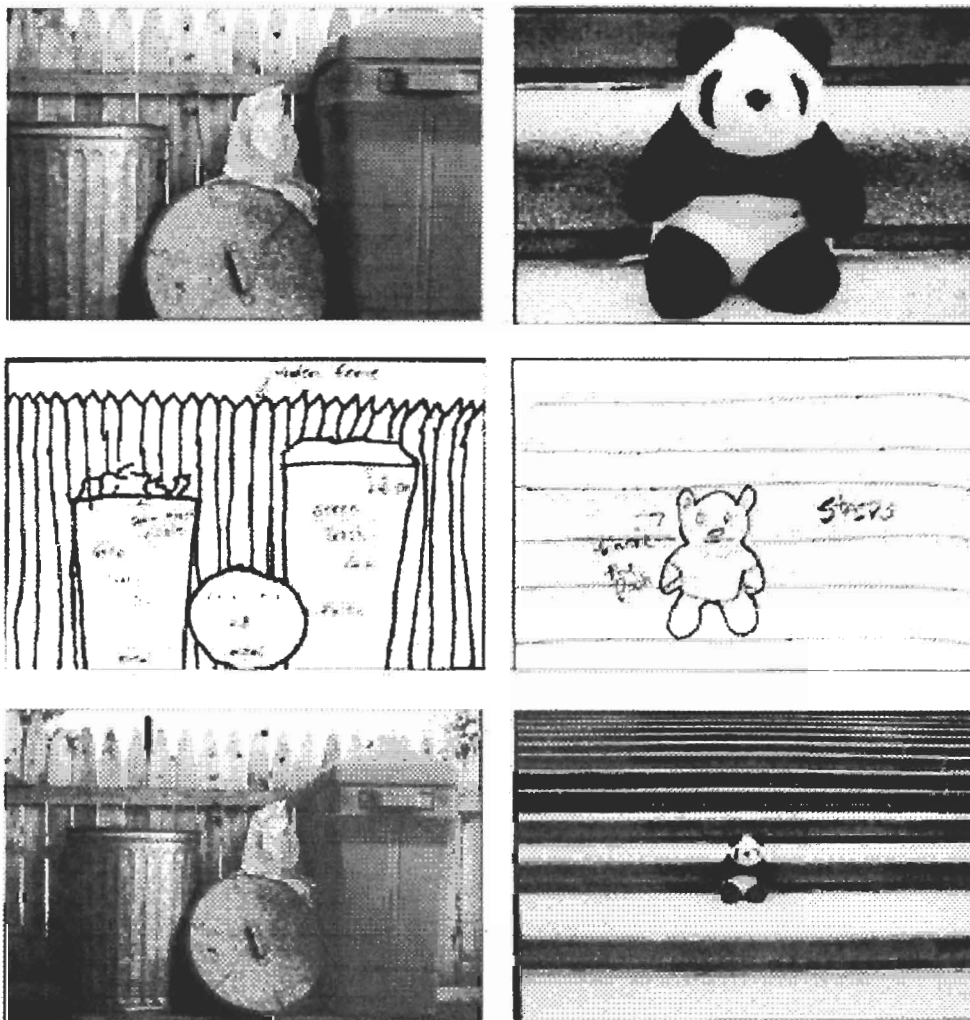


Figure 1: Top row shows stimuli, middle row shows representative subjects' drawings from memory of those stimuli, bottom row shows a more wide-angle view of the scene. Note that the remembered pictures contain information that actually did exist outside the borders of the original view. (Column 1 pictures are from Intraub and Richardson (1989), and Column 2 pictures are from Intraub et. al. (1996)

The observer’s representation is constrained to shift outward rather than inward. This may reflect the

internalization of the spatial continuity inherent in our environment. It is a universal regularity of the world that there is always more just beyond the current view. Anticipating layout would facilitate integration of successive views, and would help draw attention to unexpected features that arise when the anticipated region is actually scanned. A perceptual system with a small highly focussed sensory area that actively explores the world would function with greater economy if the border of the current view were ignored. Indeed, boundary extension does not appear to be cognitively penetrable. Even with forewarning and prior experience, viewers were unable prevent its occurrence (Intraub & Bodamer, 1993).

The “uniqueness” of spatial continuity. In his critique of the notion of “kinematic uniqueness,” Todorovic questions whether one can determine a priori which type of motion would become the one to be internalized. He describes various types of motion and asks why the perceptual system would prefer one type rather than the other. Spatial layout provides a regularity of the world that seems unequivocal. It is so fundamental that it sounds trivial; wherever one looks in the environment there is always more. Whether one is in an enclosed space or an open field, small changes in the position of the head or eyes will bring a new region into view. The continuity of spatial layout in the environment seems to provide a less debatable starting point for considering a regularity of the world that might be a good candidate for internalization.

Ecological validity. Among his concerns, Schwartz questions the ecological validity of Shepard’s focus on apparent motion. He is unconvinced that the same constraints seen in apparent motion are necessarily implemented during more normal instances of motion perception in a rich well-illuminated environment. Yet the paradigm requires the removal of information in order for the constraints to be seen. Can internalized constraints be tested without artificial circumstances? In the case of boundary extension, in one sense, looking at a photograph is like looking at the world through a window (with the borders occluding all but the exposed area). What is useful about this paradigm is that we can test the internalization hypothesis under normal viewing conditions in the 3-D world. The basic question is whether under conditions that allow for stereopsis, motion parallax, and the ability to gauge sizes and positions with respect to one’s body, would the viewer experience boundary extension?

To answer this question, viewers studied bounded regions of 6 real scenes made up of common objects on natural backgrounds. An occluding window was placed around each scene, thus exposing an area and occluding the surrounding space. The subjects directly down at the scenes, which were arranged either on tabletops or the floor. After they studied the scenes, the occluding windows were removed. Viewers returned to the same position in front of each scene and indicated how great an expanse they had seen minutes earlier. Occluding borders were placed at the designated locations and the viewers made any adjustments necessary to ensure that the exposed space was the same they remembered seeing minutes before. Subjects clearly remembered having seen a greater expanse of the scenes that they actually had -- increasing the exposed area by 45% (Intraub, under review).

Generalizing across sensory modalities. If spatial continuity is a unique regularity of the world that is an internalized aspect of representation, then we would expect to see it underlie perception of layout in any modality suited for detecting layout – i.e., vision and haptics. To determine if haptic representation would show evidence of anticipatory spatial representation, we conducted the same experiment described above with an individual who has been deaf and blind since early life, due to a genetic disorder (Leber’s Syndrome). A control group of blindfolded sighted subjects also participated. Would someone whose experience with layout is haptic show the same error experienced by sighted subjects? She also must

integrate successive inputs as her hands explore spatial layout. And the external regularity of continuity is the same irrespective of modality. What happened is that both she and the control subjects remembered having touched a greater expanse of the scene than they actually had. In this case the control group increased the area of the exposed region by 32%. The deaf/blind observer's representation of the exposed regions was remarkably similar to the control subjects. She matched or exceeded their boundary extension on all but one scene.

Can the internalization hypothesis be falsified? Hecht raises the question of whether the internalization hypothesis can be falsified (i.e., Popper's test). He argues that the resolution with which one can specify an internalized regularity will determine to what extent it can be experimentally tested. In the case of layout, we cannot specify a metric that will predict exactly how much extrapolation will occur. However, we can make predictions about patterns of responses under conditions in which the internalized regularity applies, and when it does not. In other words, we can articulate a "boundary condition" for this outward extrapolation. Drawings of objects on scene backgrounds (i.e., backgrounds that depict part of a continuous location) should give rise to boundary extension. In contrast, drawings of the same objects on blank backgrounds (object not in a depicted location) should not. If boundary extension occurred in memory for pictures in which no location was depicted, then there would be no principled argument to support the contention that boundary extension reflects an internalized constraint about the world.

Intraub, Gottesman and Bills (1998) conducted a series of experiments to test this contrast. Boundary extension occurred in memory for pictures with the surfaces depicted in the background, but not for those with blank backgrounds. In the latter condition a unidirectional distortion was not obtained, instead size averaging occurred (larger objects were remembered as smaller and smaller objects were remembered as larger). In other experiments in the series, we tested Shepard's (1984) proposal that imagination should draw upon the same internalized constraints as does perception. We found a striking effect of imagination instructions in this task. Subjects viewed the same drawings of objects on blank backgrounds; one half imagined natural backgrounds behind the objects while they viewed them, the other half imagined the objects' colors while they viewed them. Imagining scene background resulted in boundary extension, whereas imagining object colors resulted in size averaging. Mental representation of the same objects was affected in a predictable manner depending on whether or not the subject imagined layout.

In conclusion, perception of spatial layout appears to be a plausible domain for testing ideas about internalized constraints. It provides a complementary approach to the problem. Instead of depriving the viewer of information so that we can reveal the underlying constraint, we examine the constraint through evaluation of a normally occurring "error."

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