Cognitive Development 43 (2017) 159–169

Contents lists available at ScienceDirect

Cognitive Development

journal homepage: www.elsevier.com/locate/cogdev

Are all geometric cues created equal? Children's use of distance and length for reorientation

Sami R. Yousif[a], Stella F. Lourenco[b,*]

[a] Yale University, Department of Psychology, 2 Hillhouse Ave, New Haven, CT 06520, United States
[b] Emory University, Department of Psychology, 36 Eagle Row, Atlanta, GA 30322, United States

ARTICLE INFO

Keywords:
Navigation
Reorientation
Geometry
Modularity
Gestalt
Shape

ABSTRACT

To navigate the world, human adults rely on various types of geometric cues. Yet there is debate over which cues young children use to guide reorientation. Some researchers have argued that particular geometric cues, such as distance, are privileged with respect to navigation, at least early in human ontogeny. On this view, children rely exclusively on distance to regain their orientation. Other geometric cues, such as length, are used for object recognition or two-dimensional form analysis, not reorientation. Here we show that children are capable of using multiple Euclidean cues to reorient, but their ability to use these cues can be masked by global shape information. We argue that children are flexible in their use of geometric cues for reorientation, using both distance and length cues. The role of global shape in facilitating or impeding reorientation is discussed.

1. Introduction

For all mobile organisms, survival is dependent on the ability to navigate the surrounding environment successfully. Because organisms can become disoriented, even in relatively familiar environments, successful navigation may rest on recovering one's orientation. Researchers who study navigation in human and nonhuman animals have long debated the mechanisms that underlie spatial reorientation. At stake in this debate are questions about the extent to which the cognitive mechanisms are shared across species and which environmental cues support reorientation (Cheng, 2008; Cheng & Newcombe, 2005; Gallistel, 1990; Spelke, Lee, & Izard, 2010; Twyman & Newcombe, 2010; Vasilyeva & Lourenco, 2012). The current study was designed to shed light on the latter question by testing what types of geometric properties human children rely on to guide reorientation.

In a seminal study, Cheng (1986) found that rats relied on the geometry of a rectangular chamber to localize a target after a period of brief disorientation. In this study, rats (who were tested individually) were first shown that food was buried in one of the corners of a rectangular chamber. Rats were then removed from the chamber and subsequently returned to a novel position within it. Rats' behaviors revealed that they relied exclusively on the chamber's geometry to search for the food following disorientation (see also, Margules & Gallistel, 1988). When non-geometric features such as distinctive odors or visual patterns at each of the corners were available, they ignored these features, using only the chamber's geometry during their search for the food. This research led to the claim that spatial reorientation in rats was supported by a cognitive module that processes the geometry of surface layouts exclusively, and it is a claim that has since been extended to other animal species and even human children (Hermer & Spelke, 1994; for reviews, see: Cheng, 2008; Cheng & Newcombe, 2005; Twyman & Newcombe, 2010).

Other research, however, has found that human children can, and do, utilize non-geometric features to reorient, providing

* Corresponding author.
E-mail address: stella.lourenco@emory.edu (S.F. Lourenco).

http://dx.doi.org/10.1016/j.cogdev.2017.04.001
Received 7 May 2016; Received in revised form 28 March 2017; Accepted 3 April 2017
Available online 18 April 2017
0885-2014/

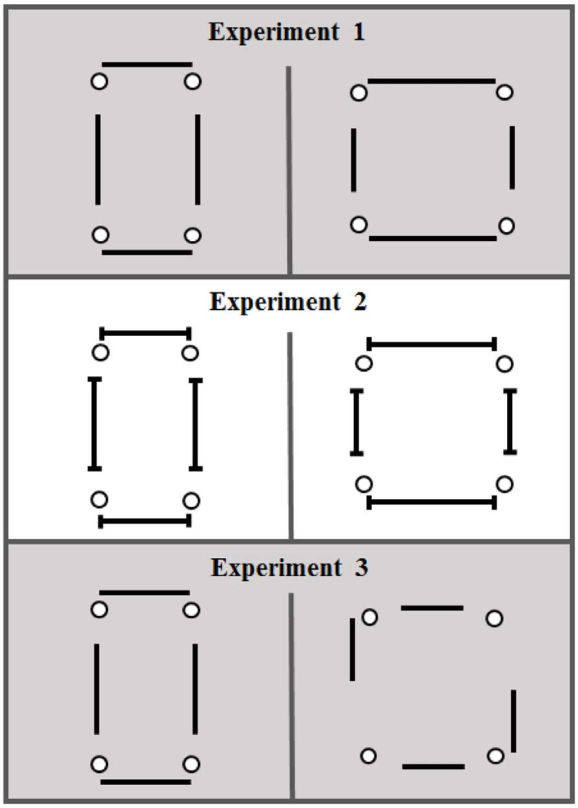

Fig. 1. An illustration of the fragmented spaces used in each condition of the three experiments in the current study (Experiment 1 was a replication of Lee, Sovrano et al. (2012). In Experiments 1 and 2, the distance condition (left panel) was comprised of equal-length walls at different distances whereas the length condition (right panel) was comprised of walls at equal distances but of different lengths. In both experiments, the relevant distances in the distance condition were between the parallel walls, crossing through the centroid of the space. In Experiment 3, a rectangular distance condition (left panel), the same as that in previous experiments, was compared to a square distance condition (right panel), in which the relevant distances were between the edges of the walls and the imputed shape was a square. Circles represent the containers placed at each of the potential hiding locations. The lengths of the walls and the distances between them are to scale. However, the containers and appendages have been enlarged to make them more visible in the figure.

evidence against a reorientation system than relies exclusively on geometry. For instance, although wall color (e.g., a blue-colored wall in a rectangular room) is not used in small spaces (e.g., 4 by 6 feet), it is used reliably in larger spaces (e.g., 8 by 12 feet; Learmonth, Nadel, & Newcombe, 2002; Learmonth, Newcombe, Sheridan, & Jones, 2008; Twyman, Friedman, & Spetch, 2007). There are also conditions in which cues unrelated to the spatial layout, such as dot size (i.e., small versus large dots on separate walls of a square space) and luminance (i.e., lighter versus darker gray walls in a square space), are utilized successfully by young children in disorientation tasks (Huttenlocher & Lourenco, 2007; Lourenco, Addy, & Huttenlocher, 2009; Nardini, Atkinson, & Burgess, 2008). More recently, it was even found that wall colors in a kite-shaped space facilitated children's use of the space's geometry following removal of the non-geometric features (Lourenco & Cabrera, 2015).

Although accumulating evidence suggests sensitivity to non-geometric features by human children, an open question is how geometry is represented in the mind and brain given its use across a variety of contexts (Twyman & Newcombe, 2010). In particular, recent research has focused on what properties of geometry children encode and rely upon to guide reorientation. A recent proposal is that reorientation is limited to the processing of a subset of geometric properties (e.g., Spelke et al., 2010). According to Spelke et al. (2010), certain properties of Euclidean geometry, such as distance, are used for reorientation, whereas others, such as length and angle, are used for object recognition and two-dimensional (2D) form analysis. In support of this proposal, Lee, Sovrano, and Spelke (2012) tested children within fragmented spaces of freestanding walls. The fragmented spaces in this research were designed to isolate specific geometric properties such as distance and length (see Fig. 1). In one condition, children were disoriented in a fragmented space composed of equal-length walls positioned at different distances in the shape of a rectangle. In another condition, the fragmented space consisted of pairs of different-length walls positioned at equal distances in the shape of a square. Lee, Sovrano et al. (2012) reported that although children were able to reorient successfully in the former case, as indicated by their searches to the geometrically appropriate locations, they were unable to do so in the latter case. This finding was taken as evidence for preferential processing of distance information in the system guiding reorientation, and it has since been extended to other animal species (i.e., zebra fish; Lee, Vallortigara, Flore, Spelke, & Sovrano, 2013). It has even been claimed that the preference for distance is so prevalent that children may rely on illusory distance information (i.e., illusory depth created by dots of varying sizes on walls in a square space) to reorient (Lee, Winkler-Rhoades, & Spelke, 2012; Spelke et al., 2010).