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Speed and accuracy of reorientation from a bird's eye view: Does the type of spatial information matter?

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ABSTRACT

This set of studies examines accuracy and reaction times of human adults in a reorientation task when the spatial information available is manipulated. All experiments used within subjects designs in which participants saw figures containing different types of useful spatial information (Experiment 1: a landmark, a geometric cue, a landmark and a geometric cue, and no useful cue) or pairs of different cues (Experiment 2a: two landmarks, two geometric cues, and a landmark and a geometric cue together; Experiment 2b: two configurations of two landmarks, two geometric cues, and a landmark and a geometric cue together) on a computer screen and were asked to find a location on a rotated version of the figure following a short delay. In Experiment 1, participants were less accurate in the landmark condition and the conditions that included geometric elements were faster. In Experiments 2a and 2b, the conditions that included geometry were faster than the landmark only condition that had no geometry. The results are discussed in terms of theoretical accounts of the processing of featural and geometric sources of information.

The ability to reorient in the world is crucial to survival. In the course of everyday navigation organisms need a way to reestablish orientation once it is lost (coming out of a subway tunnel or simply losing track of which direction you are facing). In studies of reorientation, participants must perform an action that requires location knowledge (most often by finding a hidden object) following a manipulation to disrupt the participant's orientation in space. Reorientation can be accomplished by using information that is available in the environment. All species tested (including rats, fish, chicks, monkeys, humans, and others) have been shown to be capable of using the geometric features of the environment to reorient (for review, see Cheng, Huttenlocher, & Newcombe, 2013; Cheng & Newcombe, 2005). However, it is not uncommon for more than one location to fit the same geometric description. For example, in a rectangle, pairs of diagonally opposite corners are congruent. In these cases non-geometric or featural information, can be used to disambiguate the geometrically congruent corners and find the target. For example, if one of the walls in a rectangular room is a distinctive color, the congruent corners are visually distinctive even though geometrically the same.

Reorientation ability has been an area of fierce debate about the nature of spatial cognition. There are a number of competing views vying to offer a complete view of reorientation and thus contribute to an understanding of spatial navigation. The first of the perspectives discussed here comes out of the finding that rats use geometric information exclusively, which led to the proposition of a geometric module (Cheng, 1986; Gallistel, 1990). More recently the argument about the existence of a geometric module has mostly been within the developmental literature (Hermer & Spelke, 1994, 1996; Lee, Shusterman,

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& Spelke, 2006; Lee & Spelke, 2010). This view claims that reorientation ability is part of a geometric module in the strong sense; that is, the geometric features of an environment are used first for reorientation, following which features can be used in an associative manner to localize the target in a search task (Fodor, 1983; Lee et al., 2006; Lee & Spelke, 2010). The newest instantiation of the theory contains the two step process, which can account for the finding that even toddlers use features, and has implications for the way information can be combined in tasks that require reorientation. In this view, reorientation is achieved using geometry in step one, followed by an associative process where features are used to disambiguate any geometric congruities (Lee & Spelke, 2010).

The opposing theoretical view is one that instead claims reorientation is achieved through the adaptive combination of available cues (Newcombe & Huttenlocher, 2006). In the adaptive combination model, multiple sources of information are combined into a single representation. How those pieces of information are combined and which ones are preferred varies with the maturity of the organism and the situation. “Information that is high in salience, reliability, familiarity, and certainty and low in variability, is given priority over other sources of information” (Twyman & Newcombe, 2009, p. 1344).

Initial research using a reorientation paradigm with rats found an exclusive reliance on geometric information (Cheng, 1986), and this conclusion has been widely cited. Recent research, however, has found successful reorientation using a combination of geometric and non-geometric (featural) information in a large number of non-human animal species (e.g. Gouteux, Thenus-Blanc, & Vauclair, 2001; Kelly, Spetch, & Heth, 1998; Sovrano, Bisazza, & Vallortigara, 2002, 2003; Vallortigara, Zanforlin, & Pasti, 1990; for review, see Cheng et al., 2013; Cheng & Newcombe, 2005).

Research with human children has yielded a mixed picture. Initial experiments found results that mirrored those obtained with rats (Hermer & Spelke, 1996). Children saw a toy hidden in a small rectangular space, were disoriented and were then encouraged to search for the toy. Their searches were concentrated in the two corners that were geometrically appropriate, but with no preference for the correct corner even when distinctive featural information was available. Further research showed that use of features appeared between the ages of 5 and 6 years (Hermer-Vazquez, Moffet, & Munkholm, 2001; Learmonth, Newcombe, & Nadel, 2002; Learmonth, Newcombe, Sheridon, & Jones, 2008).

Subsequent research, however, called this view into question. Children as young as 18 months can use features to reorient (Learmonth, Newcombe, & Huttenlocher, 2001). Young children used a landmark to guide their search and thus were successful in their search. The contrast between the Hermer and Spelke (1996) and Learmonth et al. (2001) results was subsequently shown to be due to the size of the enclosure (Learmonth et al., 2002).

The reorientation research with adults has found that they consistently use landmarks to reorient (Hermer-Vazquez, Spelke, & Katsnelson, 1999; Ratliff & Newcombe, 2008). Much of the research has used adults as a comparison group, but the adult preference for landmarks is pronounced. Research also shows that spatial as well as linguistic interference tasks disrupt the ability of adults to use features (Jacobs, Thomas, Laurance, & Nadel, 1998; Ratliff & Newcombe, 2008). In addition, Ratliff and Newcombe found that interference effects are obtained only in incidental learning conditions, showing that adults can utilize both geometric and featural information for reorientation in cases where they know ahead of time that reorientation will be required. Using a computer display instead of actions in a real space, Sturz and colleagues (Sturz, 2014; Sturz, Forlaines, & Bodily, 2012; Sturz, Kilday, & Bodily, 2013) have taken a further look at adult humans' use of geometric information. In these virtual spaces, the effective use of geometry was examined, and findings focused on the importance of the field of view (FOV). Participants' ability to use the geometric information effectively was related to how much of the geometry was available within the FOV.

In the experiments reported here, the question is not what the adults prefer, but what their response speed can tell us about which sources of information are processed faster. The use of a virtual space allows for exacting measurement of response time, and a within-subjects design allows a look at differences in response speed in different conditions across a single group of participants. In this study, participants had a 100% FOV available to give them the maximum amount of geometric information.

Experiment 1

The current experiment is related to the Ratliff and Newcombe (2008) study in that it looks at adult use of geometric and featural information in a reorientation paradigm. This experiment looks at reaction times and accurate location choice in a computer generated task when the available information for reorientation is manipulated. Using a within subjects design, adults were presented with schematics of a space under four different conditions, one in which the only available information was landmark based (L), one where the only information was geometric (G), one where both landmark and geometric (LG) information were available, and a final condition in which there was no way to reorient (N). Differences in reaction time to the different configurations offered a window into how adults use and combine these sources of information.

Method

Participants

Participants were 78 university students who participated for extra credit in one of their classes. Of the 78 participants in the final sample, 57 were female. The average age was 20.4 (17–29). Seventeen additional participants were excluded for