Navigational strategy may be more a matter of environment and experience than gender

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ABSTRACT

In the study of wayfinding there is considerable controversy about what factors determine when and how strategies are selected. Allocentric strategies rely on the presence of distal, relational stimuli whereas egocentric strategies rely on the presence of proximal or simple guidance stimuli. Strategy use has often been explained by studies of internal factors like gender but little weight has been given to the study of how strategies are selected. The present study examined the effects of recent experience on strategy selection in three specially designed versions of a virtual Morris water maze (vMWM). Thirty-seven participants were trained either in an allocentrically biased "Place" maze or an egocentrically biased "Cue" maze, and then tested in a "Dual-strategy" maze, in which both allocentric and egocentric strategies were equally efficient. All participants trained with the Cue maze selected an egocentric strategy whereas two thirds of participants trained in the Place maze chose an allocentric strategy. A verbal probe revealed that allocentric strategists were more aware of features in the virtual environment than were egocentric strategists. No evidence of gender differences in strategy selection or navigation performance was found.

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Wayfinding is the means by which people navigate from one place to another in familiar and unfamiliar large-scale space, and as such, is a critical ability for everyday life. However, the cognitive mechanisms underlying navigation are not completely understood. Although a number of different categorizations of navigational strategy have been proposed (O'Keefe & Nadel, 1978; Sutherland & Dyck, 1984; Trullier, Wiener, Berthoz, & Meyer, 1997), perhaps the most accepted is the dichotomy into egocentric and allocentric strategies (Klatzky, Loomis, Beall, Chance, & Golledge, 1998; Kolb, Sutherland, & Whishaw, 1983). Egocentric strategies rely on perceptions of the environment from the perspective of the navigator and may be either response-based (e.g., navigation by a series of left/right turns) or cue-based (navigation to a landmark or sequence of them) or a combination of the two (Trullier et al., 1997). In contrast, allocentric strategies rely on a cognitive map, an internal representation of the environment that is independent of the navigator's current perspective (Nadel & Hardt, 2004; O'Keefe & Nadel, 1978). Converging evidence from behavioral and brain imaging studies suggests that each strategy is mediated by a different cognitive-neural system (for review see, Burgess, 2008).

A third navigational strategy has been proposed which, depending on definition and circumstances, overlaps with egocentric and allocentric strategies. This type of navigation has been called path integration, inertial navigation, dead reckoning and ideothetic navigation (for review, see Etienne & Jeffery, 2004). When studied in an open featureless environment where

direct paths can be taken between any two points, especially when the navigator is deprived of sight or visual cues, navigation can be accomplished by the navigator keeping track of internal cues. These cues are generated by the navigator's own (egocentric) responses (movements and actions) in order to compute distances and directions traveled. This information can be used to compute the most direct route back to the origin; under these circumstances this form of navigation would be considered egocentric. However, in more common circumstances where there are paths and obstacles which limit travel, and environmental features which define locations and choice points for routes, such inertial navigation might well act as an additional source of information to help select egocentric responses to environmental stimuli or to locate the navigator within a cognitive map of the environment. In their extensive review of research on the role of self-generated movements (i.e., path integration or ideothetic navigation), by insects, birds, rodents and humans, Cheng, Shettleworth, Huttenlocher, and Reiser (2007) conclude that this system serves largely as a reference and back-up to resolve ambiguity among navigational cues and plays no significant role when navigational stimuli are clear and unambiguous. Accordingly, the present study addressed only the dichotomy between egocentric and allocentric navigation.

The study of egocentric and allocentric strategy use is a relatively new field and much of the research seems to be based on the assumption that strategy use is determined mainly by innate factors such as stimulus salience (e.g., Wolbers & Hegarty, 2010), gender (e.g., Chai & Jacobs, 2010; Saucier et al., 2002) or age (e.g., Moffat & Resnick, 2002). Far fewer investigations have considered that strategy use may also be affected by external factors such as the availability of useful stimuli or the opportunity for experience with these stimuli (Wolbers & Hegarty, 2010). This is partly because many navigation tasks are designed in such a way that only one strategy type is likely to be elicited. For example, studies may exclusively investigate either route learning (e.g., Nemmi et al., 2011) or place learning (e.g., Woolley et al., 2010). Indeed, the most common type of navigation study appears to employ place-based tasks to study internal factors (e.g., gender, aging) that might influence the ability to form a cognitive map (and use allocentric strategies) (e.g., Kallai, Makani, Karodi, & Jacobs, 2005; Moffat & Resnick, 2002; Woolley et al., 2010). To date, attention has been paid mostly to the identification of strategies and to their use rather than to the availability and selection of these strategies. Thus there is a need to investigate the factors affecting strategy choice.

Although several studies have demonstrated that strategy choice and use is determined by gender (for review see, Lawton, 2010), others suggest that several factors may contribute. In virtual environments that offer the opportunity to navigate using either an egocentric or an allocentric strategy, male and female participants spontaneously selected one or the other in relatively equal proportions (Iaria, Petrides, Dagher, Pike, & Bohbot, 2003; Schmitzer-Torbert, 2007; Van Gerven, Schneider, Wuitchik, & Skelton, 2012). Furthermore, in some studies, participants were able to switch strategies (Etchamendy & Bohbot, 2007; Iaria et al., 2003; Igloi, Zaoui, Berthoz, & Rondi-Reig, 2009) suggesting that many (and perhaps most) people have both egocentric and allocentric strategies at their disposal. Together these studies raise the important issue of what factors might influence the choice of one strategy over another.

The factor most commonly assumed to control which strategy is used at a given time is familiarity with the environment or route (e.g., Golledge, 1999; Maguire et al., 1998). Familiarity is crucial to strategy selection because the ability to select a given strategy may depend on both the availability of useful environmental information and the degree of prior exposure to this type information (Burgess, 2006). In other words, for a strategy to be selected, relevant stimuli have to be present and the person has to be sufficiently experienced (or familiar) with these stimuli (or similar ones). For example, Jacobs and Schenk (2003) proposed that if the navigating animal has not gained experience with particular types of stimuli then the system that utilizes those stimuli will not be activated. However, the effects of experience presumably extend beyond just a familiarity with the visual features of the environment. That is, experience consists also of reinforced behavior and successful navigation resulting from the use of a particular navigational strategy. Therefore, experience should have an effect on strategy selection.

Although there has been considerable research on the effects of experience per se on subsequent navigational learning, most of this work has been conducted in the context of testing the cognitive map theory versus the associative learning theory and many of the studies have compared simple cues to configurations of cues (see Chamizo, Aznar-Casanova, & Artigas, 2003; Cheng et al., 2007). Cheng et al. (2007) cite one study showing that in rats in a Morris water maze (MWM), training with a proximal cue that stays the same between trials and between training and testing can lead to overshadowing of room cues (Roberts & Pearce, 1999). Although they never test the reverse, these authors do cite two rat studies showing that (a) distal extra-maze cues can overshadow intramaze cues proximal to the goal, only if the proximal cues are made unreliable (Redhead, Roberts, Good, & Pearce, 1997) and (b) in a radial maze, extra-maze visual cues can overshadow or block intra-maze tactile cues (Diez-Chamizo, Sterio, & Mackintosh, 1985). Although there have also been human studies investigating the possibility of overshadowing and blocking of distal cues by proximal cues (Bodily, Eastman, & Sturz, 2011; Ratliff & Newcombe, 2008), these studies have examined only orientation (i.e., pointing to a goal from a fixed location) and not navigation (which involves movement and multiple decisions). The difference may seem trivial until one remembers the importance of relative spatial locations (of environmental features to each other) to allocentric navigation (O'Keefe & Nadel, 1978) and how, in many cases, this is not apparent from a fixed location at the start of navigation. Furthermore, using eye-tracking, we have recently found that the environmental cues used during orientation are not necessarily the ones used later during navigation (Yim & Skelton, 2013). This finding is consistent with that of a study (Hamilton, Rosenfelt, & Whishaw, 2004) showing that rats in a MWM with a visible platform orient using allocentric cues but use egocentric cues to navigate to the platform.

Miller and Shettleworth (2007) review several studies showing that in humans, the geometry of an enclosed room (e.g., locations relative to the long axis of a rectangular room) might or might not block or overshadow proximal cues depending