Humans Rely on Egocentric Representations for Accurate Spatial Navigation

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Humans and many animals rely on internal representations of their environment to guide their navigation (Gallistel, 1990; O'Keefe & Nadel, 1978; Tolman, 1948). It has been debated whether the internal representation is egocentric, containing information about self-to-object relationships, or allocentric, containing observer-free information about object-to-object relationships (Bisiach & Luzzatti, 1978; Easton & Sholl, 1995; McNaughton, Knierim & Wilson, 1995). Because the allocentric relationships among multiple locations can be derived from an egocentric representation, and the egocentric distances and directions of each target can also be calculated from an allocentric representation of several targets plus knowledge of the distance and orientation of the observer relative to one or some of the targets, it is hard to distinguish the two theses under normal circumstances.

We investigated the consequences of disorientation on the accuracy of spatial knowledge of multiple object locations in human adults. If humans rely on allocentric representations of object locations and places (a cognitive map) coupled with a process for updating self position and orientation relative to these locations, then disorientation should cause an inaccurate assessment of the self position or orientation, but the knowledge of the allocentric relationships among targets should remain intact. On the other hand, if the internal representation guiding accurate navigation contains information about the egocentric distances and directions of target locations, and is updated as the observer moves and turns, then the disruption of the updating system will generate errors in the representation itself.

In our first experiment, 20 Cornell students learned six target locations around a square chamber situated in a lab, and then were required to point to the targets with eyes closed and blindfolded, either while remaining oriented or after they had been disoriented by one-minute self rotation. Subjects made significantly more errors in their assessment of the spatial relationships among the six targets when they were disoriented than when they were oriented, suggesting that the representation is altered after disorientation. In our second experiment, we used a translucent blindfold and introduced a directional light so that subjects experienced the same physical stimulation but remained oriented throughout the experiment. These subjects showed no decrease in the accuracy of their assessment of target relationships after the rotation, indicating that the decreased accuracy after disorientation was not due to the physical stimulation of the vestibular system. The last experiment followed exactly the same procedure as the Exp. 2 except that the directional light was removed during the self rotation and reintroduced immediately after the rotation stopped, such that subjects became disoriented but could use the light as a reorientation cue. Subjects effectively regained their sense of orientation, but their knowledge of the spatial relationship among the targets was as inaccurate as the disoriented subjects in Exp. 1. This finding suggests that the error in their representation after disorientation is not due to inaccuracy of the pointing responses after self rotation, or to an altered sense of self position and orientation but rather to a genuine impairment in the representation of target relationships.

The finding that spatial representations of the immediate environment are influenced by one's sense of orientation casts doubt on the view that spatial memory and navigation depend on an allocentric cognitive map. Instead, humans may navigate by representing the egocentric distances and directions of objects and places and by continuously updating these representations as they move and turn.

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