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# Isolating observer-based reference directions in human spatial memory: Head, body, and the self-to-array axis ☆

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**Abstract**

Several lines of research have suggested the importance of egocentric reference systems for determining how the spatial properties of one's environment are mentally organized. Yet relatively little is known about the bases for egocentric reference systems in human spatial memory. In three experiments, we examine the relative importance of observer-based reference directions in human memory by controlling the orientation of head and body during acquisition. Experiment 1 suggests that spatial memory is organized by a head-aligned reference direction; however, Experiment 2 shows that a body-aligned reference direction can be more influential than a head-aligned direction when the axis defined by the relative positions of the observer and the learned environment (the "self-to-array" axis) is properly controlled. A third experiment shows that the self-to-array axis is distinct from – and can dominate – retina, head, and body-based egocentric reference systems.


*Keywords:* Spatial memory; Reference frames; Reference system; Egocentric representations

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## 1. Introduction

Perceiving and mentally representing the locations of objects and places in one's environment is a fundamental prerequisite to most of human behavior. Because locations can be specified only in and through a reference system (or reference frame), the scientific investigation of the reference systems used in perception and memory has become an increasingly important area of contemporary research in spatial cognition (Behrmann, 2000; Carlson-Radvansky & Irwin, 1993; Hinton & Parsons, 1981; Levinson, 1996; Pani & Dupree, 1994; Rock, 1973; Shelton & McNamara, 2001b). One aspect of cognitive reference systems that has received a great deal of research attention is the *reference direction* that is used to code spatial information. (Another aspect, the origin of the reference system, has received considerably less research attention.) When applied to the memorial coding of spatial information, a reference direction can be thought of as conceptual "north" (Shelton & McNamara, 2001b), a privileged or preferred direction that is used to organize and define angular relationships. Broadly speaking, reference directions can be defined with respect to: (a) environmental features such as salient landmarks or the North Pole, yielding an *environmental* reference direction (McNamara, Rump, & Werner, 2003; Werner & Schmidt, 1999) (b) the inherent structure of a stimulus or stimulus array, yielding an *intrinsic* reference direction (Mou & McNamara, 2002), or (c) the orientation of part of an observer's body, yielding an *egocentric* reference direction (Shelton & McNamara, 1997).

One critical issue in the field of spatial cognition is to determine which reference direction is typically used in a given situation. In the last decade, several lines of investigation have converged to suggest the importance of egocentric reference directions as a particularly influential means of mentally organizing the spatial properties of one's environment. For example, investigators have shown that when asked to imagine a familiar environment, patients with unilateral sensory neglect fail to report objects that would appear on the neglected side of their bodies' midline (Bisiach & Luzzatti, 1978), suggesting an egocentric coding of these scenes (Easton & Sholl, 1995; Werner & Schmidt, 1999). Work in normal populations has shown that pointing to targets from an imagined viewpoint is typically influenced by the targets' location in body-centered coordinates (Sholl, 1987; Franklin & Tversky, 1990). Similarly, patterns of errors in pointing to targets after disorientation suggest that navigation in one's immediate environment is largely governed by transient egocentric mental representations of space, instead of enduring allocentric representations (Waller & Hodgson, 2006; Wang, 1999; Wang & Spelke, 2000, 2002).

Some of the most compelling evidence for the importance of egocentric reference directions in memory for spatial layouts has come from the work of McNamara and his colleagues who have shown repeatedly that people are relatively accurate at imagining or recognizing orientations within a layout of objects when those orientations were experienced during learning. Likewise, people are relatively error-prone when imagining or recognizing orientations that were not experi-