

# Mental representation of space: Insights from an oblique distribution of hallucinations

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Received 18 April 2006; received in revised form 10 October 2006; accepted 13 October 2006

Available online 17 November 2006

## Abstract

Three-dimensional spatial distributions of hypnagogic and hypnopompic hallucinations associated with sleep paralysis were used to investigate the internal representation of space. Left–right asymmetries in human preferences and abilities are well established. Parallel effects are also observed as lower-upper asymmetries. These parallels could reflect common underlying mechanisms or additive effects of independently evolved horizontal and vertical asymmetries. This study adds to the growing literature on multidimensional spatial biases in a context free from the influence of task-related factors. We present evidence of an oblique bias in the projection of both sensory and motor hallucinations toward lower-left and especially upper-right external space exceeding that accounted for by an additive model of separate horizontal and vertical biases. These observations are consistent with theories regarding a systematic functional relation of hemispheric with ventral and dorsal cerebral organization.

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**Keywords:** Representational space; Horizontal/hemispheric asymmetries; Vertical/ dorsal-ventral asymmetries; Sensory hallucinations; Vestibular-motor hallucinations; Sleep paralysis

## 1. Introduction

The current study investigates relations among spatial biases along the three cardinal axes, as revealed by the three-dimensional distribution of hallucinations associated with sleep paralysis (SP). Hallucinations represent an interesting perspective on both perception and representation. Hallucinations are defined as perception without an adequate external source and having a vivid sense of reality (e.g., American Psychiatric Association, 1994; Bentall, 1990). Thus, hallucinations are experienced as perception, but must draw upon internal representations, broadly conceived. Before describing the present study, we briefly review literatures pertaining to spatial biases in perception, representation, and hallucinations, as well as the theoretical mechanisms of SP hallucinations.

### 1.1. Multidimensional spatial biases in perception and attention

Asymmetries in perception, attention, and movement along the horizontal, vertical, and radial dimensions (cardinal axes) of space have often been interpreted in terms of hemispheric and dorsal-ventral brain organization (Barrett, Crosson, Crucian, & Heilman, 2000; Christman & Niebauer, 1997; Drain & Reuter-Lorenz, 1996; Hagenbeek & Van Strien, 2002; Previc, 1990, 1998; Springer & Deutsch, 1998). Common examples include overt limb preferences, differences in local/global processing, high/low spatial frequency analysis, performance on line-bisection tasks, and susceptibility to spatial neglect (Christman & Niebauer, 1997; Lee, Harris, Atkinson, Nithi, & Fowler, 2002; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004; Peyrin, Chauvin, Chokron, & Marendaz, 2003; Previc, 1990, 1998; Rapsak, Cimino, & Heilman, 1988; Shelton, Bowers, & Heilman, 1990; Springer & Deutsch, 1998). Understanding such biases can provide insight into evolutionary and neurodevelopmental trends, as well as possible aetiological mechanisms for pathology (Bracha, Cabrera, Karson, & Bigelow,

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1985; Dennis et al., 2005; Drain & Reuter-Lorenz, 1996; Lee et al., 2002; Nicholls et al., 2004; Previc, 1990, 1998, 2006; Rapcsak et al., 1988). That is, two global ontological and phylogenetic trends in cortical organization and cytoarchitecture implicate the progression of hemispheric specialization on the one hand (Bradshaw & Rogers, 1993; Corballis, 1991; Hiscock & Kinsbourne, 1995; Rogers, 2000; Springer & Deutsch, 1998) and dissociation between dorsal (archicortical) and ventral (paleocortical) brain regions/paths on the other (Christensen & Bilder, 2000; Sanides, 1969). Observations of normal functional anisotropies and the effects of focal brain damage have been important for the development of theoretical accounts linking these anatomical trends with behavioural (dys)function. For example, schizophrenia has been framed as an evolutionary by-product or neurodevelopmental disorder associated with preferential dysfunction of both the left hemisphere (e.g., Crow, 1997) and dorsal cortical regions (e.g., Christensen & Bilder, 2000).

Mixed findings have been obtained regarding additivity of horizontal and vertical asymmetries and whether the two sets of biases reflect independent or shared neurocognitive mechanisms remains controversial (Barrett et al., 2000; Chen, Yao, & Liu, 2004; Christman & Niebauer, 1997; Dennis et al., 2005; Drain & Reuter-Lorenz, 1996; Hagenbeek & Van Strien, 2002; McCourt & Garlinghouse, 2000; McCourt & Olafson, 1997; Nicholls et al., 2004). These prior studies have been based largely on stimulus-driven effects for which specifics of the experimental context, including the stimuli, response protocols, and participants' strategies can influence results (Bradshaw, Nettleton, Nathan, & Wilson, 1985; Dennis et al., 2005; Drain & Reuter-Lorenz, 1996; Hagenbeek & Van Strien, 2002; McCourt & Garlinghouse, 2000; McCourt & Olafson, 1997). Furthermore, participants are typically tested one dimension at a time. For example, using line-bisection tasks, horizontal orientations are typically used to determine left–right biases (lateralization) and vertical stimuli for up–down (elevation) biases, although a few investigators do use oblique orientations to assess interactions with lines tilted at  $\pm 45^\circ$  (e.g., Nicholls et al., 2004).

Assessment has also been largely limited to peripersonal space (i.e., one's immediate surrounding; See Previc, 1990, 1998), a limitation inherent to pen-and-paper and computerized tasks. Similarly, motor biases are often measured by performance or preference in the use of stimuli (e.g., pegboard tasks, hand preference for brushing one's teeth). Several measures of whole-body movement are also used to assess turning behaviour, but, on the whole, results appear inconsistent and/or unreliable (Mohr & Lievesley, *in press*). Importantly, anisotropies have also been observed in the radial direction between peripersonal and more distal extrapersonal space (Mesulam, 1999; Shelton et al., 1990; Weiss, Marshall, Zilles, & Fink, 2003), which in turn may affect horizontal and vertical biases (McCourt & Garlinghouse, 2000; Previc, 1990, 1998, 2006). In addition, for oblique orientations, it is possible that equal but independent biases combine to produce an additive effect (e.g., rightward and upward biases leading to an enhanced bias towards the top right of lines angled at  $45^\circ$  clockwise of vertical).

## 1.2. Representational and perceptual space

Literatures pertaining to perceptual-motor asymmetries do not necessarily extend to mental representation. Just as perceptual neglect has been pivotal towards understanding the neural bases of the former (Heilman, Watson, & Valenstein, 1993; Mesulam, 1999), comparative study of representational neglect has provided key insight into the latter. That is, in addition to inattention towards part of external space, neglect may also manifest in internal or mnemonic representations of space (Bisiach, Luzzatti, & Perani, 1979; Heilman et al., 1993). Patients may present with both forms of neglect, which are often similarly lateralized (Heilman et al., 1993; Mesulam, 1999). However, neurological cases have also shown these forms of neglect to be dissociable and implicate different cognitive mechanisms (Beschin, Basso, & Della Sala, 2000; Logie, Della Sala, Beschin, & Denis, 2005).

Among healthy individuals, Nobre et al. (2004) observed similar performance in orienting attention to locations within external and internal representations as well as largely overlapping neural activation consistent with Mesulam's (1999) core attentional system. Differences between conditions have also been observed, however; for example, a number of prefrontal regions were selectively activated during internal orienting, consistent with the working-memory demands of the task. This group also recently observed a common network for orienting based on transient perceptual cues and episodic memory for scenes, with the latter resulting in faster reaction times, an advantage that correlated with memory-specific activation of the hippocampus (Summerfield, Lepsien, Gitelman, Mesulam, & Nobre, 2006). These studies suggest that similar biases might be expected for representational and perceptual tasks to the extent that these rely on common attention-related mechanisms, but that unique features of representational tasks will be more associated with endogenous mnemonic processes.

Systematic investigation of normal biases in representational space has received much less attention than its perceptual counterpart. Consistent with the perceptual domain (Jewell & McCourt, 2000), there is evidence for right pseudoneglect on some representational tasks (Nalcaci, Cicek, Kalaycioglu, & Yavuzer, 1997; Nalcaci, Kalaycioglu, Cicek, & Budanur, 2000; Rousseaux et al., 2001; Sandor, Bachtold, Henn, & Brugger, 2000). As suggested by a reviewer, however, lack of clear lateral representational biases may be, at least in part, due to the operation of a non-cardinal or interactive bias. Further characterization of the common and unique features of spatial biases in representational processing will confer improved understanding of the normal cognitive and neural mechanisms involved and those affected by neglect syndromes. In this context, the current study investigates whether interactions among spatial biases observed in perceptual-motor tasks extend to endogenously driven experiences relying on representational space.

## 1.3. Spatial biases among hallucinations

In contrast to the perceptual, motor, and representational tasks discussed above, hallucinations are internally generated

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