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Research report

Evidence for elevated cortical hyperexcitability and its association with out-of-body experiences in the non-clinical population: New findings from a pattern-glare task

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ABSTRACT

Individuals with no history of neurological or psychiatric illness can report hallucinatory Out-of-Body Experiences (OBEs) and display elevated scores on measures of temporal-lobe dysfunction (Braithwaite et al., 2011). However, all previous investigations of such biases in non-clinical populations are based on indirect questionnaire measures. Here we present the first empirical investigation that a non-clinical OBE group is subject to pattern-glare, possibly as a result of cortical hyperexcitability (Wilkins et al., 1984). Fifty-nine students at the University of Birmingham viewed a series of square-wave gratings with spatial frequencies of approximately .7, 3 and 11 cycles-per-degree, both black/white and of contrasting colours. The illusions and discomfort reported when viewing gratings with mid-range spatial frequency have been hypothesized to reflect cortical hyperexcitability (Wilkins, 1995; Huang et al., 2003). Participants also completed the Cardiff Anomalous Perception Scale (CAPS: Bell et al., 2006) which included experiential measures of disruptions in 'Temporal-lobe Experience'. Participants who reported OBEs also reported significantly more visual illusions/distortions and significantly greater discomfort as a result of viewing the mid-frequency gratings. There were no such differences with respect to gratings with relatively lower or higher spatial frequency. The OBE group also produced significantly elevated scores on the CAPS measures of Temporal-lobe Experience, relative to controls. Collectively, the results are consistent with there being a neural 'vulnerability' in the cortices of individuals pre-disposed to some hallucinations, even in the non-clinical population.

1. Introduction

The processing of 'self-consciousness' involves many coordinated mechanisms including; (i) egocentric processing from one's own perspective (ii) a sense that we are the agents of our own thoughts and actions (iii) a sense of body ownership and body image; and (iv) that we are distinct from our environment (see Berlucchi and Aglioti, 2010; Lenggenhager et al., 2009;

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Longo et al., 2008; Lopez et al., 2008; Peelen and Downing, 2007). All these processes support a continuous and stable notion of 'self' in space and feelings of embodiment across time (i.e., that we are the same person over time). Indeed, appropriate action and behaviour is dependent on such stable body-based processing and multi-level representations of the 'self' leading to a coherent sense of relationship to one's body (embodiment).

Recent evidence suggests that the complex neurocognitive processes underlying stable self-awareness and embodiment are not error-proof and can breakdown, leading to striking distortions in body-image and body-based hallucinations. One such hallucination is the Out-of-Body Experience (OBE). The OBE can be defined as an experience where the individual *"perceives his/her environment from a perspective outside of their physical body"* (Blackmore, 1982). These experiences are striking and vivid and can be described as being endowed with all the attributes of veridical three-dimensional sensory perception – factors that might be responsible for the 'paranormal' or 'spiritual' interpretations these experiences often receive (Blackmore, 1982; Cook and Irwin, 1983; Eastman, 1962; Irwin, 1985; Palmer, 1978).

There has been an increasing interest over recent years in studying such hallucinations of self-reduplication and their underlying neural substrates, to provide a more comprehensive understanding not just of the hallucinations themselves, but also the processes mediating stable 'in-the-body' experiences as well (Arzy et al., 2006; Braithwaite, 1998; Braithwaite et al., 2011; Braithwaite and Dent, 2011; Blanke et al., 2005, 2002; Blanke and Metzinger, 2009; Brugger, 2002; Brugger et al., 1997; Bunning and Blanke, 2005). Indeed, one recent suggestion from clinical neurology has been that the many varieties of self-reduplication experiences [i.e., sensed-presence experiences, autoscopic hallucinations (the perception of oneself as an external object), heautoscopy (duality of consciousness)] and the OBE, may represent phenomenological manifestations that differ along a continuum of disintegration of the egocentric self in space (Brugger, 2002; Brugger et al., 1997; see Braithwaite and Dent, 2011; for a discussion).

The dominant view is that OBEs result from a disintegration of multi-sensory integrative processes that reside primarily in the temporal-parietal junction (TPJ) region and are typically involved in supporting a stable and coherent sense of 'self' in space (Arzy et al., 2006; Blanke and Arzy, 2005; Blanke et al., 2002, 2004, 2005; Brugger, 2002). By this account, the OBE represents a perverse self-model that occurs due to abnormal patterns of brain activation that impact on the successful integration of stable visual, spatial, tactile, vestibular, and proprioceptive information.

Supportive evidence for the role of the TPJ comes from an MRI/lesion analysis of neurological patients who experience OBEs, where in the majority of cases the involvement of the TPJ was identified (Blanke et al., 2004: see the review by Blanke and Arzy, 2005; Blanke and Mohr, 2005). In addition, electrical stimulation of the TPJ region of the epileptic brain can artificially induce OBEs and associated feelings of dissociation (Blanke et al., 2002; see also Tong, 2003; for a discussion). Collectively, the findings from neurological studies suggest that patient OBEs have their basis, at least in part, in paroxysmal abnormalities located in the TPJ.

However, as fascinating as these studies are, one limitation is that none of them have investigated these factors in relation to non-clinical OBE samples – and as such, it remains an open question as to the applicability of findings from neurological samples to the non-clinical population. It is still unclear what anomalies and/or biases in processing non-clinical individuals who report spontaneous OBEs may display relative to control samples. As a consequence of this omission our understanding of these hallucinations, and the underlying predispositions to experience them, remains incomplete.

1.1. *Assessing cortical hyperexcitability*

There are a growing number of findings that support the notion that some patient groups who also report aura experiences may have more excitable brains – and that this can be measured inter-ictally between transient paroxysmal events (i.e., as a general background state and vulnerability). The implication from these studies is that both predisposition to aura and the presence of hyperexcitation are strongly associated. For example, (i) visual evoked potentials are generally of greater amplitude and fail to habituate in migrainers with aura, relative to controls; and (ii) trans-cranial magnetic stimulation (TMS) of the visual cortex has shown that the threshold at which phosphenes are induced is significantly reduced in migraine patients with aura (Aurora and Welch, 2000; Aurora and Wilkinson, 2007; Aurora et al., 1999, 1998; Aggugia et al., 1999; Gawel et al., 1983; Young et al., 2004; though see Afra et al., 1998). Collectively, such findings have been taken as evidence that the visual cortex is hyperexcitable, inter-ictally, in migrainers and those who report aura.

In addition, perceptual tasks have a long history of being applied to assess cortical hyperexcitability in patient groups. For example, Palmer et al. (2000) have shown that migrainers with aura demonstrate a reduced effect of meta-contrast masking relative to both migrainers without aura, and controls. In addition, patients with photosensitive epilepsy and migraine with aura also demonstrate increased levels of visual discomfort and associated visual distortions/illusions as a result of viewing striped patterns of a particular spatial frequency (SF) – a phenomenon known as pattern-glare (see Wilkins, 1995; Wilkins et al., 1984). Therefore, the idea of a relationship between increased levels of neuropsychological activity and resultant sensory anomalies/hallucination is neither controversial nor without empirical support.

Other tasks have revealed that certain patterns, specifically gratings with a SF close to three cycles per degree (cpd), are uncomfortable to look at and have been known to induce seizures in patients with photosensitive epilepsy (Wilkins et al., 1980). Striped patterns with these properties are epileptogenic and are regarded as aversive by a large minority of the population, particularly those 10% with migraine. The patterns are not only aversive to look at but can induce a variety of visual distortions and illusions. These include the appearance of phantom colours, and distortions of shape and of motion which may implicate the role of higher association cortex in mediating these effects (i.e., regions responsible for the processing of colour and motion; V4/V5). In addition, direct evidence from brain-imaging studies (fMRI) of the brains of migrainers has shown an abnormally large visual cortical activation in response to the striped patterns (fMRI: Huang et al., 2003) – consistent with the pattern-glare task