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;

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

indexing cortical hyperexcitation in such populations. Interestingly, the degree of pattern-glare reported (discomfort and associated visual phenomena) correlated with the degree of cortical hyperexcitability and the hyper-activation occurred mainly in pre-striate areas only in response to epileptogenic patterns. Such pattern-induced cortical hyper-activation is thought to reflect an underlying hyperexcitability of the visual and sensory association cortex (see also Huang et al., 2011; for additional evidence from brain-imaging methods).

The suggestion that pattern-glare effects may index cortical hyperexcitability in pre-striate and more anterior visual cortex is intriguing in the context of hallucinations like the OBE that may also be triggered by irritable processes impacting on multi-sensory integration. Although the notion of a 'disruption' in TPJ processing has been a common and strongly argued theme for the occurrence of OBEs (Blanke et al., 2002, 2004, 2005) it is not entirely clear how it may come about in the absence of a known psychopathology. All recent published examples are based on observations from neurological patients who, for whatever reason, are known to display particular abnormalities in neural function.

The present study sought to provide an investigation of whether non-clinical individuals also prone to OBEs displayed a general increase in baseline cortical excitability that may itself be a contributing factor leading to such 'disruptions' in neural processing. As the studies discussed above demonstrate, hyperexcitability (as a general inter-ictal state) and transient paroxysmal abnormalities can co-occur, and both are linked to aura and hallucinatory episodes. Based on these observations, we predicted that OBEs with a strong visual component to them might be more prevalent in a brain that displays other signs of hyperexcitability. Therefore, we predicted that even an attenuated increase in hyperexcitability may still be measurable by established behavioural tasks which have previously been used in patient populations where the organic basis of the hyperexcitability is more obvious and directly linked to the clinical symptoms.

2. Overview of the present study

To our knowledge this is the first empirical investigation of cortical hyperexcitability in a non-clinical group of hallucinating individuals (those who reported OBEs) — that extends beyond questionnaire measures alone. To do this we devised a modified computer-based version of the pattern-glare test to assess the degree of pattern-glare as an inferred associate of underlying cortical hyperexcitability (cf. Wilkins, 1995; Wilkins et al., 1984). The pattern-glare task is attractive for current purposes as; (i) there is a literature exploring effects of pattern-glare with neuronally vulnerable populations (with recent investigations also adopting brain-imaging methodology: see Huang et al., 2003, 2011); (ii) it provides the participant with no reference, in and of itself, to its underlying aims (something which is difficult to avoid with many questionnaire measures in the present context); and (iii) it provides two independent measures (discomfort/associated visual phenomena) of glare and cortical irritability — both of which should show a general relationship to each other.

The task also provides a measure of hemispheric laterality of the visual distortions which is interesting for OBE studies because it has been reported that, approximately 80% of neurological OBEs were related to brain damage in the right-hemisphere (see Blanke and Arzy, 2005; Blanke and Mohr, 2005; Bunning and Blanke, 2005 for reviews). Currently there are no published findings on any laterality effects in a non-clinical population of individuals reporting OBEs.

This pattern-glare task was complemented by the employment of the Cardiff Anomalous Perception Scale (CAPS: Bell et al., 2008, 2006) as a measure of individual propensity to experience anomalous perceptions. The CAPS is a 32-item, psychometrically verified measure of an individual's predisposition to experience perceptual anomalies and has been used successfully with OBE populations previously (Braithwaite et al., 2011). In contrast to our previous study, and to increase reliability and power in the present analysis, here we adopted the use of an 11-item 'Temporal-lobe Experience' factor (highly associated items identified via a principal components analysis: Bell et al., 2006) as an additional indicator of neural instability in the temporal-lobe specifically. This 'Temporal-lobe factor' contains a number of items that are commonly reported in pre-seizure aura-type experiences by patients with temporal-lobe epilepsy (either spontaneously or via direct electrical stimulation; Gloor, 1986; Gloor et al., 1982; Halgren et al., 1978; Penfield, 1955; Penfield and Perot, 1963), and in attenuated form by the normal population (Makarec and Persinger, 1987, 1990; Persinger and Makarec, 1986, 1993; Persinger, 2001). An increased propensity to report these specific anomalous perceptions is taken as an indicator of the possible presence of paroxysmal-type discharges underlying temporal-lobe dysfunction.

In addition to the CAPS we devised a new pre-screen for the OBE group. This pre-screen was based on a combination of previous attempts to explore a more refined taxonomy of OBEs (Braithwaite and Dent, 2011; Easton et al., 2009) and further previous research from our own laboratory on OBEs (Braithwaite et al., 2011). There may be multiple routes to induce an OBE and phenomenological differences may reflect crucial differences in as yet unknown processes. Any participants who reported their experiences as being induced as the result of recreational drug use, alcohol, anaesthesia, or as a direct result of prescription medication were excluded from the present study.

3. Method

3.1. Participants

Fifty-nine participants took part in the present study. Of these, 95% were female and 58 (98%) reported that they were right handed. None reported any personal medical history of seizure, epilepsy or were diagnosed as having migraine. All participants were undergraduate or postgraduate students (MSc/PhD) from the School of Psychology at the University of Birmingham, UK. Participants ranged in age from 18 to 36 years, with an average age of 20.1 years (OBE group mean age 20.1 years, nonOBE group mean age = 20.6 years). All received course credit or a small financial payment for taking part in the study.
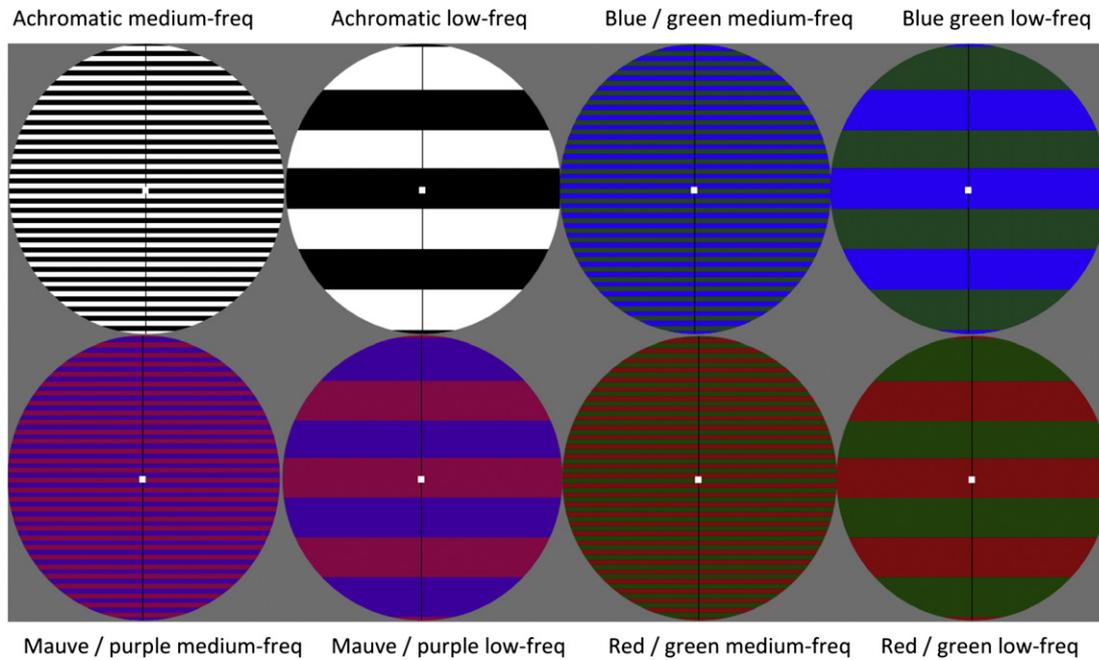
Fig. 1 — **Achromatic and chromatic pattern-glare stimuli combinations, for both medium and baseline low SF stimuli employed in the present experiment (note** — **high-frequency baseline stimuli were also employed but the gratings were too fine to faithfully represent here. See text for a full description of the task and procedure).**

3.2. Pattern-glare task

For the present experiment we devised a modified and computerized version of the Pattern-glare test (Wilkins, 1995; Wilkins et al., 1984). The task differed from previous investigations in that (i) it was computerized so that the stimuli were presented and responses gathered via a standard digital method and (ii) we employed both achromatic and chromatic (various colour combinations) pattern-glare stimuli. This allowed us to generate a variety of trial types and assess the consistency of performance across a block of trials allowing for a more covert measure of cortical excitability in non-clinical populations. It also allowed us to avoid habituation effects occurring from the repeated presentation of a single set of stimuli. For our present purposes, we were not directly concerned with the potency of the individual colours — more the effect of the crucial medium-frequency discs per-se (irrespective of colour) between individuals who reported OBEs and those who did not.

The experiment was set up in E-prime v2.0. There were three separate classes of pattern-glare stimuli (gratings) that differed in terms of their SF and their colour. The three separate SFs were (i) a low SF baseline disc (approx. .7 cpd); (ii) a high SF baseline disc (approx. 11 cpd) and the critical medium SF disc (approx. 3 cpd). All discs were presented separately and centrally on a 17-inch LCD screen, and extended an area of

Table 1 — **An overview of the computerized pattern-glare task employed in the present study. All questions were repeated and asked for all stimuli.**

Questions	Responses	Additional information
How comfortable?	$-5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5$	Select one response and click to continue
Did you experience the following phenomena when looking at the stripes?	Pain/discomfort	Select as many as necessary/relevant and then click to continue
	Shadowy shapes amongst the lines	
	Shimmering of the lines	
	Flickering	
	Red	
	Green	
	Yellow	
	Blur	
	Bending of any lines	
	Nausea/dizziness	
	Unease	
Are the effects greater in the	left visual field (LVF)	Click one response and click to continue
	right visual field (RVF)	
	Roughly equal in both visual fields	
	No effect	

Table 2 – OBE pre-screen questions and response categories.

OBE pre-screen questions	Responses
Have you ever had an experience where you have perceived/experienced the world from a vantage point outside of the physical body?	Yes/No/Don't know
How frequently do the experiences occur?	Scale of 1–5; 1 = once, 5 = very frequently
Did you see a representation of your physical body or not and if so, from what position?	(Part I) Yes/No/Don't know (Part II) free response
What position was your physical body in at the time of the experience(s)?	Free response
Did you visually see the world from a perspective outside of your physical body?	Yes/No/Don't know
Did you feel detached from the body?	Yes/No/Don't know
Did you feel in control of your experience(s)?	Yes/No/Don't know
How long do you estimate the experience(s) lasted?	Scale of 1–5; 1 = ≤1 min, 5 = ≥30 min

110 mm wide by 115 mm high (13 × 13 degrees of visual angle). Viewing distance was approximately 60 cm. Each separate SF occurred in either achromatic (black/white) or three separate chromatic combinations. The coloured gratings were red/green (with RGB values of 165, 0, 0 and 0, 80, 0, respectively) mauve/purple (174, 0, 84 and 84, 0, 174), green/blue (0, 83, 45 and 0, 0, 245) and because the bars were composed of no more than two types of lit pixels (Red Green or Blue) with values chosen to provide similar luminance, the gratings had chromaticities that lay at the extremes of the colour gamut of the display. They were designed to stimulate principally the L-M channel, the S-LM channel and both channels jointly. Examples of the stimuli employed in the current task are given in Fig. 1. For reliability, each individual exemplar disc was presented twice – thus making a total block of 24 trials (two trials per exemplar, and eight trials per SF). Every trial followed exactly the same presentation procedure.

A trial began with the presentation of one of the pattern-glare discs (chosen randomly). Participants were instructed to concentrate on a small fixation dot in the middle of the disc for a few seconds before proceeding with their responses. Accompanying the disc, was an initial question on how 'comfortable' the pattern was to look at (on a full scale of −5 = for very uncomfortable, 0 = neither comfortable nor uncomfortable, and +5 = for very comfortable). Participants rated the stimuli by moving the mouse cursor over the appropriate number and clicking on a button to proceed to the next question. The next question asked about associated visual phenomena that may be present when they view the pattern and provided a number of options (see Table 1). Participants could click on as many options as they required before clicking on the option to continue to the next question. Finally participants were asked whether or not any visual illusory effects occurred in one visual field (left visual field: LVF / right visual field: RVF), both visual fields equally, or neither visual field (see Table 1).

Further to this procedure, an additional measure was put in place in case the visual patterns were too uncomfortable to look at during the rating process. Here, pressing the space-bar would remove the disc from view (but not the questions or response options). A further pressing of the space-bar would make it re-appear and so on. As an additional measure of visual discomfort the numbers of space-bar presses were also recorded for each and every pattern-glare stimulus. The procedure outlined in Table 1 was repeated for all 24 pattern-glare stimuli. The experiment took approximately 30 min to complete.

3.3. Questionnaire measures

3.3.1. CAPS
Participants respond initially to each question with a yes/no response (scored 1/0 respectively). The maximum overall potential CAPS score for any participant was 32.[1] Overall scores and those for specific 11-item 'Temporal-lobe Experience' factor were analyzed for differences between the groups.

3.3.2. OBE pre-screen
In conjunction with the CAPS measure, participants were assigned to the OBE group on the basis of their answers to an OBE pre-screen questionnaire measure. In line with our previous studies, we employed a question based on Blackmore's (1982) definition for what counts as an OBE, *"Have you ever had an experience where you have perceived/experienced the world from a vantage point outside of the physical body?"* – and this formed the first question of the pre-screen. In addition to this question participants were given further qualifying information that (i) such an experience can feel totally real at the time of the experience with all the phenomenological qualities of veridical perception and (ii) that such experiences can be fleeting and transient or more sustained. An answer of 'yes' was concordant with participants being classified as subject to OBEs and then a series of follow-up questions (detailed below) concerning the phenomenological aspects and differences in the experiences were also asked.

The questions contained within the pre-screen are summarized in Table 2.

4. Results

Of the 59 participants who took part in this study, 13 (22%) claimed to have experienced at least one OBE at some point in their life. Results from the OBE pre-screen showed that of the OBE group, 11 (84%) claimed to have experienced multiple (more than one) vivid OBEs and continued to do so (15% reported two experiences and 7% reported only one). In all cases,

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[1] In the original CAPS measure, when a 'yes' response was given, there were three additional subscales that needed to be answered (how distracting, how distressing and how frequent such experiences were scored on a Likert scale of 1–5). However, this component of the questionnaire is irrelevant to the present study. For clarity and conciseness, we have omitted these results here. Such findings from OBE samples have been reported elsewhere (Braithwaite et al., 2011).
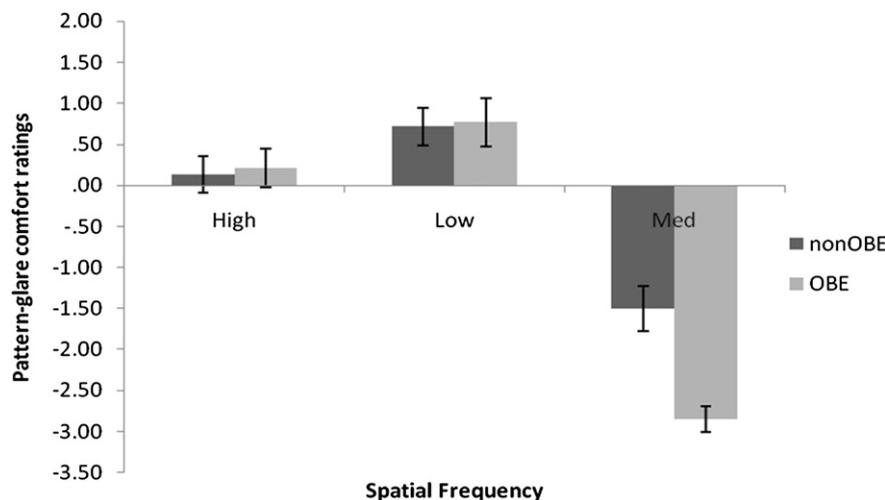
Fig. 2 − Pattern-glare comfort ratings for achromatic stimuli showing baseline (High/Low) and the medium (Med) frequency stimuli for both the OBE and nonOBE groups (negative scores indicate increased irritability/hyperexcitability). Error bars = 1 standard error (SE).

(100%) OBEs were reported to have strong visual components to them and in all cases these experiences were reported with strong feelings of detachment. There were no reported instances OBEs consisting of purely 'felt' shifts in perspective devoid of a visual component (i.e., vestibular/proprioceptive components alone). Of the OBE group, 7 (53%) reported seeing their own body/body-part, or some form of body representation of the physical self during the OBE. The majority (61%) of the reported OBEs consisted of an elevated perspective during the OBE. In terms of self-perceived duration of the experience, 2 (15%) were reported as being less than 1 min long, with 8 (61%) being reported as being 1−5 min long and 3 (23%) being reported as being 15 min to hours long. The vast majority of experiences (77%) occurred while the individual was in the lying position. There was a tendency for OBEs to last between 1−5 min (61%) with only 15% reporting they lasted less than 1 min or more than 1-h. Only one person (7%) from the OBE groups reported being in control of the experience. These findings show that the current OBE sample is largely representative of OBE samples reported previously (Braithwaite et al., 2011; Easton et al., 2009).

4.1. Pattern-glare results

Neither the OBE group or the nonOBE group found the discs so uncomfortable that they needed to press the space-bar to remove the stimuli from sight during the ratings process. As a consequence, there were no responses to explore in this regard. Because the literature on pattern-glare relates only to achromatic patterns, initial analysis separated out comfort ratings for achromatic and chromatic stimuli in relation to both the OBE and nonOBE groups.

4.2. Pattern-glare: achromatic stimuli

4.2.1. Baseline stimuli comparisons
For the whole sample, and for achromatic stimuli, low-frequency baseline stimuli tended to be rated as more

comfortable (mean = .74) than the high-frequency baseline discs (mean = .17). This was further explored for the baseline stimuli via a 2 (Group: OBE vs nonOBE group) × 2 (SF: low vs high) mixed ANOVA. There was a main effect of SF, $F(1, 57) = 4.99$, $p < .05$. High-frequency baseline stimuli were rated as more uncomfortable than low-frequency baseline stimuli. There was no main effect of Group, and the Group × SF interaction was also not significant (all Fs < .01 all Ps > .80). Although there was an overall difference between ratings for baseline low-frequency stimuli and baseline high-frequency stimuli, there were no additional differences between the groups.

4.2.2. Baseline versus medium-frequency comparisons
Because there was no reliable interaction between the groups for baseline stimuli; we collapsed the data for both low and high-frequency discs into one unitary 'baseline' category and then compared these responses to those for the critical medium-frequency stimuli. This revealed a significant main effect of SF, $F(1, 57) = 111.46$, $p < .001$. The main effect of Group was not significant, $F(1, 57) = 2.77$, $p = .101$. Most critically, and in contrast to that seen for baseline stimuli, the Group × SF interaction was also significant, $F(1, 57) = 8.04$, $p < .007$. This interaction component was further explored by carrying out a between-subjects t-test on comfort ratings for both the OBE and nonOBE group for the medium-frequency stimuli alone, and this was significant, [$t(56.8) = 4.24$, $p < .001$ (two-tailed)].[2] Although both groups rated the medium-frequency stimuli as being more uncomfortable, relative to the baseline stimuli, the OBE group provided significantly more negative ratings than the nonOBE group for achromatic stimuli (see Fig. 2).

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[2] Note, the Levene's test for equality of variances was significant − suggesting some heterogeneity in variability. As a consequence, corrected values and corrected degrees of freedom are reported.

4.3. Pattern-glare: chromatic stimuli

4.3.1. Baseline stimuli comparisons
In line with the pattern seen for achromatic stimuli, low-frequency chromatic baseline stimuli tended to be rated as more comfortable overall (mean = .82) than the high-frequency chromatic baseline stimuli (mean = .36). For chromatic stimuli we explored each different colour and baseline frequency in a 2 (Group: OBE *vs* nonOBE) × 2 (SF: low *vs* high) × 3 (disc type: red/green; blue/green and mauve/purple) mixed ANOVA. This revealed a significant main effect of SF, $F(1, 57) = 4.50$, $p < .05$. The main effect of Colour just failed to reach significance $F(2, 114) = 3.05$, $p = .051$ — though it is suggestive that the effects may be different across the three
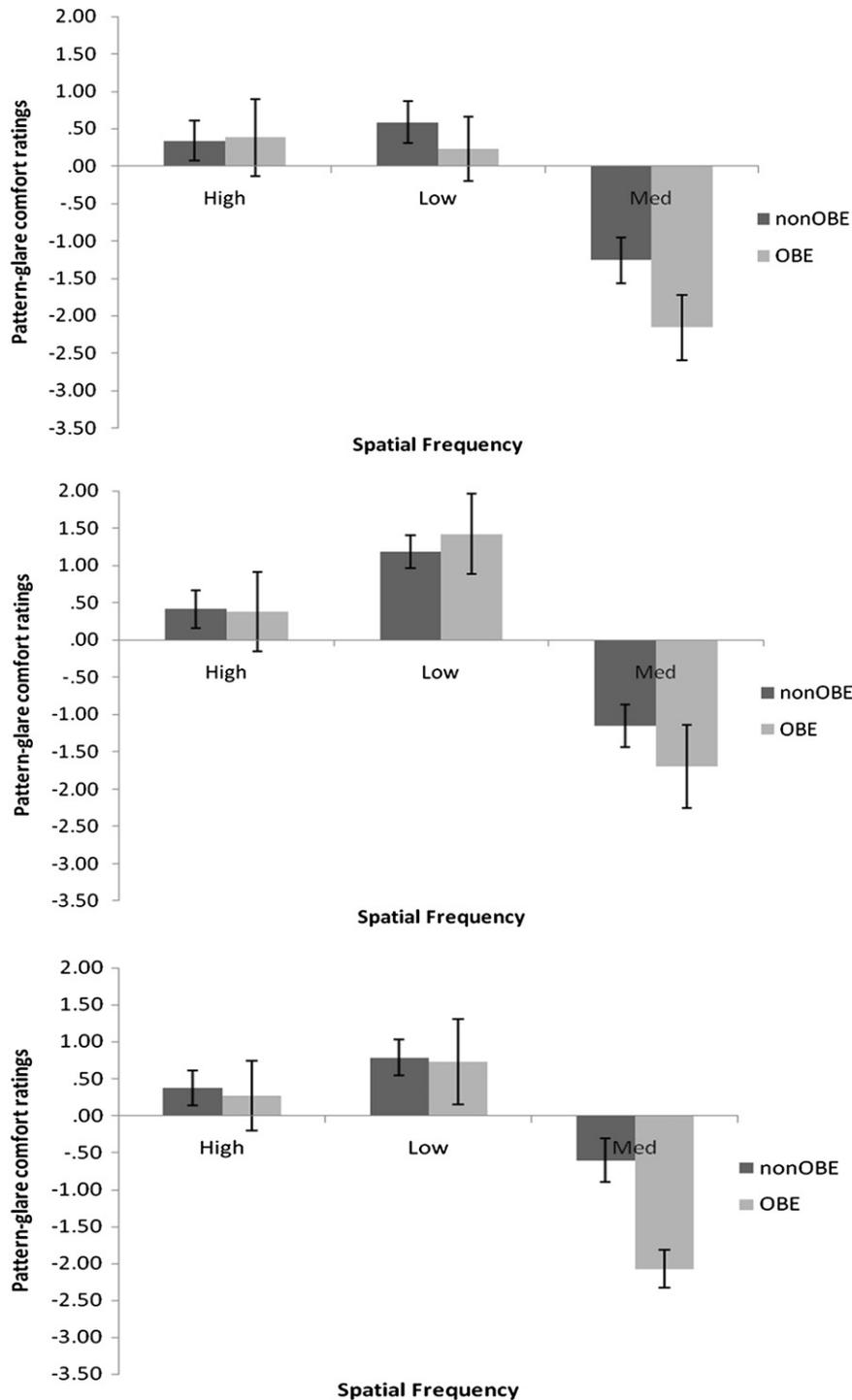

Fig. 3 — Pattern-glare comfort ratings for chromatic stimuli showing baseline (High/Low) and the medium (Med) frequency stimuli for both the OBE and nonOBE groups. Top panel (blue/green); mid panel (mauve/purple); bottom panel (red/green). Error bars = 1 standard error (SE).

different chromatic combinations. The main effect of Group, the Group × SF and the Group × Colour interactions all failed to be significant (all Fs < .5, all Ps > .780). The SF × Colour interaction was marginally significant, $F(2, 114) = 3.16, p < .05$, which suggests that the marginal effects of colour reported above may be mediated further by SF.[3] However, most crucially the 3-way Group × SF × Colour interaction was not significant for the baseline stimuli, $F(2, 114) = .50, p = .605$. Although certain colours may have been more uncomfortable at specific frequencies − this did not interact with whether participants were in the OBE group or not − both groups provided similar ratings for the baseline stimuli.

4.3.2. Baseline versus medium-frequency comparisons

Following our procedure for the achromatic stimuli, we collapsed across both baseline SFs to create one baseline category. In addition, the findings from the baseline analysis justified collapsing across Colour, as a factor, for the medium-frequency stimuli as well. These components were compared via a 2 (Group: OBE vs nonOBE) × 2 (SF: Baseline vs Medium frequency) mixed ANOVA. This revealed a significant main effect of SF, $F(1, 57) = 138.22 = p < .001$. The main effect of Group was not significant, $F(1, 57) = 1.53, p = .221$. Most critically, the Group × SF interaction was significant, $F(1, 57) = 6.69, p < .02$.

This interaction component was further explored by carrying out a between-subjects t-test on comfort ratings for both the OBE and nonOBE group for the medium-frequency stimuli alone, which was borderline significant, $[t(57) = 2.01, p < .05$ (two-tailed)]. These findings for chromatic stimuli generally mirror those seen for achromatic stimuli. In both cases, the OBE group provided significantly more negative ratings for medium-frequency stimuli than the nonOBE group (see Fig. 3).

4.4. Pattern-glare: associated visual distortions / illusions

Due to the lack of group differences and interactions, and to increase sensitivity in the analysis, we pooled data across all stimuli (achromatic and chromatic) to explore associated visual illusions and distortions reported as a function of viewing the pattern-glare stimuli. Associated visual phenomena reported during the viewing of the stimuli are illustrated in Fig. 4. A 2 (Group: OBE vs nonOBE) × Condition (Baseline vs Medium Frequency) mixed ANOVA was applied to the data. This revealed a significant main effect of SF, $F(1, 57) = 115,86, p < .001$. There were reliably more visual phenomena reported during the viewing of critical medium-frequency stimuli relative to viewing baseline stimuli. There was also a main effect of Group, $F(1, 57) = 10.45, p < .01$, with the OBE group reporting significantly more visual phenomena than the nonOBE group. Importantly, there was a significant

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[3] A look at Fig. 2 suggests that the baseline ratings for low-frequency blue/green stimuli were lower than the same frequency stimuli in mauve/purple and red/green. However, one-way ANOVAs applied to these data failed to reveal significant effects. In addition, and more importantly, there were no interactions with group and these factors.
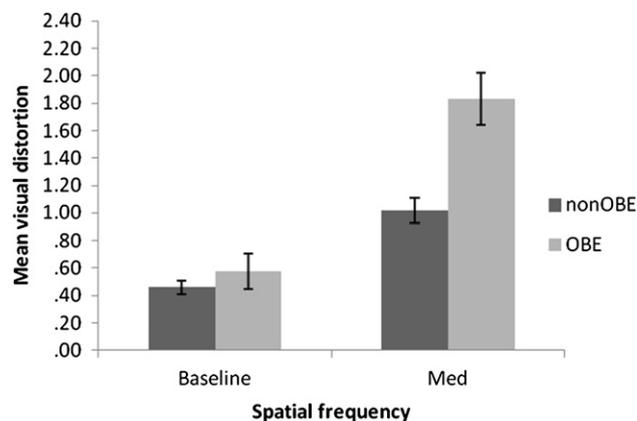

Fig. 4 − Mean visual distortion/illusion scores for the nonOBE and OBE groups plotted for both the baseline SFs and the medium (Med) SF.

interaction between Condition × Group, $F(1, 57) = 16.42, p < .001$. Elevated scores for the OBE group occurred only for the medium-frequency stimuli and not the baseline stimuli. This was confirmed by exploring the interaction component further with a between-subjects t-test carried on the levels of associated visual distortions and illusions for medium-frequency stimuli only for both the OBE group and the nonOBE control group. This was significant, $[t(57) = 3.93, p < .001$ (two-tailed)].

In terms of the visual field in which visual phenomena were reported to occur, the vast majority (94%) provided an 'equal in both visual fields' response. Only 6% differed and they reported 'no effect'. As a consequence, visual field effects were not analyzed further. To summarize the results from the pattern-glare test, the OBE group rated medium-frequency patterns as significantly more uncomfortable relative to the nonOBE group. In addition, the OBE group also reported significantly more associated visual phenomena relative to that for the nonOBE group − but only for the crucial medium-frequency stimuli. There were no between-groups differences or 3-way interactions for any of the baseline stimuli.

4.4.1. Results: CAPS

The overall averaged total CAPS score for the combined sample was 8.05. The highest CAPS score reported from the nonOBE group was 18 (out of a possible highest obtainable score of 32) with scores ranging from 0 to 18. The highest CAPS score from the OBE group was 27 with scores ranging from 7 to 27. Following our previous procedure (Braithwaite et al., 2011), and due to the scores being severely non-normally distributed, the CAPS data were analyzed using non-parametric Mann−Whitney tests. The OBE group scored significantly higher (mean = 14.62, SD = 5.38) relative to the nonOBE group (mean = 6.20, SD = 4.51) in terms of their overall CAPS scores − this difference was significant (Mann−Whitney $U = 64.500, Z = 4.312, p < .001$). The OBE group provided significantly elevated CAPS scores − consistent with them reporting more perceptual anomalies relative to the nonOBE group. Only one participant (2.9%) from the nonOBE group scored higher than the mean value for the OBE group.

Items from the questionnaire that had been identified as a 'Temporal-lobe factor' were selected and both groups
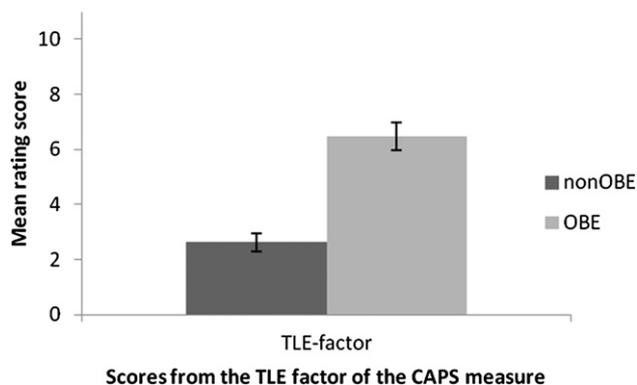
Fig. 5 – Mean scores from the Temporal-lobe Experience factor (11-items) of the CAPS measure plotted for both the nonOBE control and OBE group (error bars = 1 SE).

directly compared in relation to their scores on this specific factor. The OBE group produced significantly elevated scores, relative to the nonOBE group, on this measure of 'Temporal-lobe Experience' (Mann–Whitney $U = 58.000$, $Z = 4.443$, $p < .001$). This is consistent with the OBE group displaying an increased degree of instability in temporal-lobe processing relative to the nonOBE group (see Fig. 5).

5.   General discussion

Twenty-two percent of the present sample of non-clinical individuals reported at least one OBE during their lifetime. Eighty-five percent of the OBE group reported multiple experiences which supports previous claims that individuals are more likely later to have repeated experiences (i.e., singular spontaneous OBEs are quite rare: see Alvarado, 2000). The overall prevalence of reported OBEs is consistent with previous studies which have examined the occurrence of OBEs in university student populations (Braithwaite et al., 2011; Easton et al., 2009; McCreery and Claridge, 2002, 1995; Murray and Fox, 2005; see also Blackmore, 1982; Irwin, 1985). Importantly, none of our OBE group reported any medical history of a seizure, or of being diagnosed with epilepsy or migraine (with or without aura).

In all cases, (100%) OBEs were reported with a strong visual component to them where individuals reported specifically 'seeing' the world from an external vantage point as well as more generally 'experiencing' the world from another vantage point. Similarly, in all cases the OBE group reported strong feelings of detachment associated with these experiences. Consistent with our previous investigations (Braithwaite et al., 2011), only 53% of the OBE group reported seeing an actual physical representation of their own body/body-part, during the OBE. Therefore, recent attempts to redefine the OBE as an experience where one sees a representation of themselves from an external vantage point is misleading (cf. Blanke et al., 2005; Ehrsson, 2007). A representation of the physical self does not appear to be a necessary pre-requisite for an experience to qualify as an OBE –

with nearly half our OBE sample not reporting such phenomenology. This result is noteworthy and does question why other studies have developed and fostered newer definitions with additional components (i.e., seeing a representation of the physical self) as being crucial to the definition of the OBE. While such instances of self-reduplication certainly do occur, both our present study here and our previous investigations (Braithwaite et al., 2011) clearly show that this is not necessarily the case (at least as far as non-clinical/non-pathological instances of the OBE are concerned). Whether these differences in phenomenological content are little more than an epiphenomenon or reveal important, though as yet obscure differences in the underlying mechanisms sub-serving the OBE, remains to be seen. Nevertheless, such instances place important constraints on future attempts to redefine the OBE beyond that of its core experiential components.

The majority of OBEs (61%) involved an elevated perspective. The predominance of the elevated perspective has been commented on before where it has been argued that such 'birds-eye' views of the self are common in autobiographical memories and such representations may well be recruited into experiences where the internal representation of the self has become somewhat ambiguous and can be re-established by drawing upon information stored in autobiographical memory systems (Blackmore, 1996, 1993).

For pattern-glare performance, there were no reliable higher-level interactions for baseline stimuli between groups – consistent with the notion that such effects were matched and no meaningful differences existed between the groups when rating the baseline stimuli. Crucially, individuals who reported hallucinatory OBEs did provide significantly more negative ratings of visual discomfort than the controls, selectively for the medium-frequency stimuli. In addition, this result was mirrored by the significantly elevated scores for associated visual distortions/illusions reported by the OBE group as a result of viewing the medium-frequency pattern-glare stimuli. These findings occurred for both achromatic and (to a slightly lesser degree) chromatic stimuli. These findings are evidence that hallucinatory OBE groups can display increased levels of pattern-glare phenomena which in turn, are suggestive of an underlying cortical hyperexcitability.

The selectivity of the association with respect to SF argues against a basic response-bias explanation of the current results. If the OBE group were merely generically biased to produce a certain form of response – then this would have been evident in the pattern-glare findings for the baseline stimuli. Clearly, this did not happen. While response biases may well be present in hallucinating groups, and such biases can be psychologically important in themselves, they are not a sufficient explanation for the full pattern of findings reported here (see also Braithwaite et al., 2011; for a further discussion on response biases).

Interestingly, there were no real differences of laterality reported by the OBE group for the visual illusions they experienced while viewing the pattern-glare stimuli. These findings are not in line with the hemispheric biases reported with neurological patients – where OBEs were predominately associated with pathologies of the right-hemisphere (see the reviews by Blanke and Arzy, 2005; Blanke and Mohr, 2005;

Bunning and Blanke, 2005). The reasons for the failure to find such effects of lateralization are not immediately clear but may relate to the bilateral involvement of the pre-striate cortex rather than the TPJ in the pattern-glare test (Huang et al., 2011).

In addition to the effects seen for pattern-glare, we predicted that the OBE group should show elevated scores, relative to controls, on the measure of Temporal-lobe Experience from the CAPS questionnaire. This prediction was confirmed. These particular findings are consistent with recent accounts proposing that the OBE may occur due to a temporary dysfunction in multi-sensory integration processes that may reside primarily in the temporo-parietal region (Blanke et al., 2002, 2004; Blanke and Metzinger, 2009; Blanke and Thut, 2007; De Ridder et al., 2007). The present findings are also consistent with accounts which have shown elevated signs of temporal-lobe disturbance in relation to general paranormal/mystical experience – though here we relate it specifically to the OBE in the non-clinical population.

Although some of the literature on OBE-type hallucinations has given attention specifically to the TPJ region (i.e., Blanke et al., 2002, 2004, 2005), other literature pertains to more diffuse medial temporal-lobe processes (Neppe, 1983; Makarec and Persinger, 1987, 1990; Persinger, 2001; Persinger and Makarec, 1986, 1993) in these and related experiences. Whether these regions enjoy a functional interdependence in mediating similar experiences, or form part of a wider network of embodiment and conscious experience of 'the self' remains to be fully delineated in the context of OBE-type hallucinations and kindred hallucinations of self-reduplication.

Our current findings provide separate and independent evidence of (i) increased visual discomfort for medium-frequency stimuli from the OBE group; (ii) an increased prevalence of visual illusions/distortions associated with viewing such stimuli, and (iii) increased scores on measures of Temporal-lobe Experience, supporting the view that individuals who report OBEs display increased signs of cortical hyperexcitability relative to control groups who are not prone to such experiences. This is striking when one notes that such findings are clearly present without clear clinical neurological conditions or a psychopathology. These findings also have implications for studies which have typically employed only questionnaire responses to assess biases in a supposed continuum of temporal-lobe instability in the non-clinical population (cf. Neppe, 1983; Makarec and Persinger, 1987; Persinger and Makarec, 1993; Persinger and Koren, 2001; see Persinger, 2001). The present findings also confirm the possibility of exploring hyperexcitability in a population where other invasive methods, such as employing depth electroencephalographic electrodes, are simply not possible and they demonstrate the need for more direct measures of cortical hyperexcitability in hallucination-prone groups. Following the work of Huang and colleagues (Huang et al., 2003, 2011) who investigated fMRI BOLD responses to pattern-glare in migrainers, it can be anticipated that non-clinical hallucinating OBE groups and non-hallucinating groups may well differ in the amplitude of the fMRI BOLD response (at least for individuals reporting OBEs with a strong visual component to them). Such possibilities are currently being explored.

5.1. Cortical hyper-excitability/irritability in the non-clinical population

To our knowledge this is the first study to assess, in non-clinical but hallucination-prone individuals, the perceptual phenomena that have elsewhere been associated with cortical hyperexcitability. These results from non-clinical individuals are thematically similar to previous studies investigating predisposition to aura in temporal-lobe epilepsy, in migraine, and the relationship between temporal-lobe disturbance and general anomalous experiences (Blanke et al., 2002, 2004, 2005; Blanke and Thut, 2007; Braithwaite et al., 2011; Easton et al., 2009; Mohr and Blanke, 2005; Makarec and Persinger, 1987, 1990; Neppe, 1983; Persinger and Makarec, 1993). As a consequence, they dovetail neatly with the notion of a continuum view of neural instability and anomalous experience.

Previous studies have shown a link between paroxysmal discharges in the epileptic brain and OBE-type aura experiences (Blanke et al., 2005, 2002) and the present study implies that such neural events may also take place (albeit in attenuated form) in the non-epileptic brain. As a consequence, the implication is that these findings from epileptic patients can now be extended, at least in principal, to accommodate individuals grouped on the basis of non-clinical predisposition to specific anomalous perceptions and hallucinations (i.e., the OBE). It remains to be seen whether the current findings can be extended beyond OBE samples and are also relevant either to other forms of hallucinations of the self (i.e., sensed-presence/felt-presence experiences), or indeed, hallucination proneness per-se. Although it is tempting to predict that the results may generalize to concepts like schizotypy and the 'healthy schizotype' we suggest there may also be important limitations that are worth considering.

For example, in the present study there were no individuals who merely 'felt' (i.e., not visual OBEs) as if they occupied another location in space. While OBEs most likely reflect a multi-sensory process, it is not clear if a task which measures a visual-based irritability would also be sensitive enough to reveal differences in people experiencing non-visual forms of the OBE. In addition, the vast majority of our OBE group here reported more than one OBE and appeared to have these experiences with some degree of frequency. Furthermore, as recently argued by Braithwaite and Dent (2011), although the term OBE is convenient, it is likely to encompass the union of many sub-divisions of the experience that may require quite separate explanations. Whether all sub-divisions of hallucinations of self-reduplication, or even the OBE would display results consistent with the present findings remains to be seen. Nevertheless, one tentative prediction from the present findings is that hallucinations which have a strong visual component to them, may well be associated with increased signs of cortical hyperexcitability as assessed by visual pattern-glare procedures.

5.2. How does increased pattern-glare relate to OBE hallucinations?

One important question is how a general notion of pattern-glare phenomenon (and the implied underlying hyperexcitability) relates to the more specific phenomena of

hallucinations of the self like the OBE. Our results suggest that, at the very least, the pattern-glare task reveals a trend for increased irritability/hyperexcitability in the cortex of some individuals prone to certain forms of hallucination that have a strong visual component to them. As such biases in irritability appeared to be present at the time of testing, when no hallucinatory experiences were being reported, then it seems reasonable to assume that such processes are not part of the paroxysmal ictal-state per-se (or a non-clinical isomorphic factor) and may represent more of a general neuronal vulnerability in some hallucinatory-prone individuals.

However, the notion of hyperexcitability is a rather general one, and the OBE is a rather specific form of hallucination. Having now demonstrated, via improved methodologies, that such hyperexcitability is associated at least with some variants of the OBE, it is important to try to bridge the explanatory gap between such general and specific concepts. Although it is difficult to make any specific claims about the location and nature of any cortical hyperexcitability from the present findings (and we make no such specific claims here) it is certainly worthwhile to speculate on the theoretical possibilities.

One possibility is that hyperexcitability may provide the background vulnerability for inducing such experiences (i.e., be responsible for the underlying disruption or breakdown in the typically stable model of embodiment). By this account, temporally occurring paroxysmal-like anomalies may be more prevalent in hyperexcitable brains and may well be responsible for the initial disruption in incoming sensory signals − leading to a breakdown in stable egocentric multisensory integration. The resulting outcome of the multisensory integration processes is dependent on, and only as good as, the information the system receives. If anomalies are already present within the incoming information then this will impact on the resultant interpretation of those signals.

For example, hyperexcitability in sensory and association cortex could have an influence here via impacting on the appropriate timing of the multiple sources of incoming information required for a constant and coherent integration of the self. Therefore, although a resultant breakdown may occur within integrative processes in regions like the temporal-parietal junction (TPJ) and beyond, the foci of the hyperexcitability may not be so geographically specific and need not necessarily reside in those regions. As a consequence, neural irritability may permeate through a number of brain regions associated with sensory perception − but may not be directly associated with higher-level integrative processes themselves. An implication of this account is that the higher-level integrative processes may still be operational and may actually be trying to integrate incoming signals that have already been compromised. This account is consistent with the absence of any lateralization of the visual distortions to the left visual field.

Another possibility is that any neural anomalies underlying cortical hyperexcitability may well be primary located and restricted within the brain regions responsible for multisensory integration itself (TPJ and beyond; Blanke et al., 2002,

2005), as opposed to earlier sensory systems. By this account, the neural processes responsible for cortical hyperexcitation are housed within the components responsible for the higher-level integrative processes underlying stable perception of the self in space. In addition, the incoming sensory signals may have good integrity. Evidence from OBEs of neurological origin is generally consistent with this latter 'integration' view (Blanke et al., 2002, 2005). The above conceptions are, of course, not mutually exclusive and may co-occur.

On a more general note, the presence of increased excitability may also be responsible for endowing such hallucinatory experiences with all the three-dimensional visuo-perceptual qualities of veridical perception due to the increased firing in sensory cortex during such hallucinations. This may help to explain the realistic qualities of the experience and why many individuals report the experiences as being extremely vivid, and perceptually real. Such experiences may well be underpinned by a level of increased neural excitation greater than that typically sub-serving stable veridical perception.

6. Conclusion

We present new evidence that the cortex of some non-clinical hallucinators (i.e., those prone to OBEs) can display associated signs of cortical hyperexcitability. We devised a computer-based version of a pattern-glare task to assess predisposition to visual distortions/illusions and levels of visual discomfort. We found that the propensity to experience visual illusions co-occurred with visual discomfort and with increased scores on an independent measure of temporal-lobe instability. All these factors reliably distinguished the OBE group from a control nonOBE group and all are consistent with the notion of increased cortical hyperexcitability in the OBE hallucinating group. Collectively, these results considerably extend both the findings from neurological patient studies and more indirect questionnaire studies, and suggest a neural 'vulnerability' in the cortices of individuals pre-disposed to visual OBE-type hallucinations even in the non-clinical population.

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