

## Signs of increased cortical hyperexcitability selectively associated with spontaneous anomalous bodily experiences in a nonclinical population

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*Introduction.* The current study examined the presence of cortical hyperexcitability, in nonclinical hallucinators, reporting different forms of anomalous bodily experiences (ABEs). Groups reporting visual out-of-body experiences and non-visual sensed-presence experiences were examined. It was hypothesised that only those hallucinators whose experiences contained visual elements would show increased signs of visual cortical hyperexcitability.

*Methods.* One hundred and eighty-two participants completed the “Pattern-glare task” (involving the viewing of striped gratings with spatial frequencies irritable to visual cortex)—a task known to reflect degrees of cortical hyperexcitability associated with hallucinatory/aura experiences in neurological samples. Participants also completed questionnaire measures of anomalous “temporal-lobe experience” and predisposition to anomalous visual experiences.

*Results.* Those reporting increased levels of anomalous bodily experiences provided significantly elevated scores on measures of temporal-lobe experience. Only the visual OBE group reported significantly elevated levels of cortical hyperexcitability as assessed by the pattern-glare task.

*Conclusions.* Collectively, the results are consistent with there being an increased degree of background cortical hyperexcitability in the cortices of individuals

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predisposed to some ABE-type hallucinations, even in the nonclinical population. The present study also establishes the clinical utility of the pattern-glare task for examining signs of aberrant visual connectivity in relation to visual hallucinations.

**Keywords:** Anomalous body experiences; Cortical hyperexcitability; Embodiment; Hallucinations.

## INTRODUCTION

There has been a long relationship in the literature between the concepts of excessive neurophysiological activity, cortical hyperexcitability and sensory hallucination/aura (De Boismont, 1853; Klüver, 1966; Manford & Andermann, 1998; Siegel, 1977; Siegel & West, 1975). Indeed, hallucinations have been associated with most situations that can lead to significantly increased neurophysiological activity including (but not restricted to); (1) drug studies, (2) sensory deprivation, (3) electrical and magnetic stimulation of the brain, (4) psychopathology/psychoses, (5) illness/delirium/fever, (6) migraine, and (7) certain forms of epilepsy (Bear, 1979; Devinsky & Lai, 2008; Gloor, 1986; Gloor, Olivier, Quesney, Andermann, & Horowitz, 1982; Halgren, Walter, Cherlow, & Crandall, 1978; Manford & Andermann, 1998; Penfield, 1955; Penfield & Perot, 1963; Sacks, 1995; Siegel, 1977; Siegel & West, 1975). Collectively, these studies demonstrate that the location and proliferation of neural excitation can significantly impact on the phenomenological contents of conscious experience.

Interestingly, similar findings (albeit attenuated in magnitude) have been reported in the nonclinical population. Increased signs of instability and dysfunction in temporal-lobe processing, in the nonepileptic population, have also been shown to be associated with propensity to report paranormal and spiritual experiences—thus possibly extending the concept of cortical hyperexcitability to nonclinical samples (Makarec & Persinger, 1987, 1990; Neppe, 1983; Persinger, 2001; Persinger & Koren, 2001; Persinger & Makarec, 1986, 1993). The implication from these studies is that *aura-like* hallucinatory experiences in the nonepileptic brain reflect transient *paroxysmal-like* discharges in neural systems. Although a plausible premise, it is also important to note that if such attenuated discharges do exist in the nonepileptic brain, their existence is not extensively evidenced beyond indirect questionnaire measures of associated anomalous perceptions.

The current study explores the presence of cortical hyperexcitability as a predisposing factor to anomalous perceptions in certain nonclinical hallucinators—namely those who report anomalous bodily experiences (ABEs). More specifically, we investigate measures of visually induced excitability in two groups of hallucinators: (1) those who report visual

out-of-body experiences (OBEs); and (2) those who report nonvisual sensed-presence experiences (SPEs), compared to controls on a more direct behavioural task.

### Cortical hyperexcitability and the pattern-glare task

Striped patterns (i.e., gratings) with a spatial frequency close to three cycles-per-degree (cpd) of visual angle are well known to produce visual discomfort in susceptible observers (Conlon, Lovegrove, Barker, & Chekaluk, 2001; Marcus & Soso, 1989; Wilkins, 1995; Wilkins & Evans, 2001; Wilkins et al., 1984). The patterns are not only irritable to sensory cortex and aversive to view, but can also induce phantom visual distortions, illusions, and somatic sensations. This form of visual discomfort and the associated visual phenomena that can accompany it have been termed “pattern glare” (Evans & Drasdo, 1991; Wilkins, 1995; Wilkins & Nimmo-Smith, 1984; Wilkins et al., 1984). Wilkins and colleagues (Wilkins, 1995; Wilkins et al., 1984) have suggested that pattern glare itself is due, in part, to excessively strong neural responses and thus reflects an elevated degree of underlying cortical hyperexcitability.

The idea that increased levels of pattern glare reflect an elevated degree of underlying hyperexcitability at the cortical level and enjoy a close relationship with instances of aura has been gaining considerable currency. For example, pattern glare has been associated with neurological conditions where increases and imbalances in neurophysiological activity are known to occur, including: migraine and the presence of migraine aura (Evans, Patel, & Wilkins, 2002; Nulty, Wilkins, & Williams, 1987; Wilkins, Patel, Adjamian, & Evans, 2002; see Harle & Evans, 2004, for a review), photosensitive epilepsy (Wilkins et al., 1984, 1999), stroke (Beasley & Davis, 2012), and spontaneous hallucinations in nonclinical populations (Braithwaite, Brogna, Bagshaw, & Wilkins, in press; see Evans & Stevenson, 2008, and Wilkins, 1995, for reviews). Direct evidence for a hyperexcitable cortex in migraine with aura has been provided by Huang et al. (Huang, Cooper, Satana, Kaufman, & Cao, 2003; Huang et al., 2011), who demonstrated elevated fMRI/BOLD levels in the visual cortex of migraineurs, with aura, but only in response to irritable visual stimulation. In addition, Coutts, Cooper, Elwell, and Wilkins (2012) tested 20 migraine patients (15 with aura) and showed that the time course of cortical response (using near-infrared spectroscopy) was reduced for migraineurs relative to controls, but only for mid-frequency stimuli—consistent with a more reactive (possibly excitable) visual cortex in these patient groups. Furthermore, the degree of pattern glare experienced by observers has been shown to correlate with levels of neural activity in the visual and association cortex (Wilkins, Tang, Irabor, Baningham, & Coutts, 2008), and, in patients with

photosensitive epilepsy, paroxysmal activity in the visual cortex has been shown to be related to the spatial frequency of the stimuli (approx. 3 cpd), which was a more potent evoking stimulus relative to other exemplars like checkerboards (see also Wilkins, 1995; Wilkins et al., 1984). Therefore, increases in the background excitability of the cortex appear to be associated with transient (possible paroxysmal) disruptions in neural activity which can result in hallucinatory experiences and aura.

Although it might be intuitively seductive to think that effects from basic stimuli like gratings mainly reflect low-level and possibly early subcortical processes, the following observations go against this view as a complete explanation: (1) Effects of pattern glare are magnified under binocular (relative to monocular) viewing conditions—consistent with contributions coming from integrated cortical processes (Wilkins et al., 1984); and (2) brain-imaging data showing increased BOLD activation in association cortex and regions extending beyond primary visual cortex alone in response to the presentation of irritable stimuli (Huang et al., 2011).

Many of these findings were gleaned through variants of what has become known as the “pattern-glare” task. This task involves the presentation of three types of grating stimuli: (1) a low spatial-frequency stimulus (typically around 0.3–0.7 cpd), (2) the critical medium-frequency stimulus (typically around 3 cpd), and (3) a high spatial-frequency stimulus (typically around 11 cpd). Observers provide two independent measures of pattern glare, a rating of visual comfort/discomfort and the number of associated visual phenomena induced from viewing a given grating. Both high and low frequency gratings are considered baseline stimuli and are not associated with high levels of pattern glare, either in the form of visual comfort ratings or associated visual phenomena. Effects of pattern glare are principally evidenced by stronger negative ratings of visual comfort in response to the presentation of the critical medium-frequency grating, and an endorsement of more associated visual phenomena (visual distortions/illusions/halos), relative to the presentation of the baseline stimuli.

Recent research from our laboratory has shown that pattern-glare effects can be associated with complex hallucinatory experiences like the out-of-body experience (OBE)—at least for those instances that involve a strong visual component to the hallucination (Braithwaite et al., in press). These and related anomalous bodily experiences are thought to highlight the importance of a breakdown or disruption in multisensory integration processes—leading to a disintegration of the embodied “self” (Arzy, Thut, Mohr, Michel, & Blanke, 2006; Blanke & Arzy, 2005; Blanke, Landis, Spinelli, & Seeck, 2004; Blanke & Metzinger, 2008; Blanke & Mohr, 2005; Blanke et al., 2005; Blanke & Thut, 2007; Braithwaite et al., 2011, in press; Braithwaite & Dent, 2011; Brugger, 2002; Brugger, Regard, & Landis, 1997; Bunning & Blanke, 2005; De Ridder, Van Laere, Dupont, Menovsky, & Van de

Heyning, 2007). However, the vast majority of previous research concerning the idea of “neural disruption” has been directed towards patient groups with neurological conditions and deficits resulting in periodic anomalous imbalances in neurophysiological activity and paroxysmal neural firing (see Blanke & Mohr, 2005; Blanke, Ortigue, Landis, & Seeck, 2002; Brugger, 2002; Brugger et al., 1997; De Ridder et al., 2007). There have been few investigations of these factors in nonclinical samples who also report ABEs.

There are a number of ways in which cortical hyperexcitability may be related to high-level multisensory hallucinations like the OBE. For example, such excitability could impact on the timing of incoming visual information to higher level integrative processes. The coherent sense of embodiment rests on a coordinated set of inputs from various sensory regions of the brain. If certain information is not available for integration at the correct time, or it is available but degraded in some way, then the integrative processes will seek to combine whatever compromised information is available—possibly resulting in a form of illusory conjunction or combination of the sensory information that is intact. In this sense, hyperexcitability and associated transient neural disruptions may induce a form of “dysconnection” (cf. Friston, 1998, 1999; Stephan, Friston, & Frith, 2009) between brain regions and between crucial visual and other sensory information.

The concept of a dysconnection between the senses, or hierarchical representations within a network, leading to positive symptoms in schizophrenia has been gathering some momentum over recent studies—with an emphasis being placed on its impact on temporal integration—which could, in principle, be extended to accommodate bodily distortions (Friston, 1998, 1999; Fuster, 1995, 2001; Pettersson-Yeo, Allen, Benetti, McGuire, & Mechelli, 2011; Stephan, Baldeweg, & Friston, 2006; Stephan et al., 2009). Note—the “dysconnection” account does not necessarily imply “fewer” connections within neural systems, more the presence of aberrant connectivity that impacts on the functional coordination of distributed information.

One suggestion is that increases in the background level of cortical hyperexcitability could be associated with hallucinatory episodes, where elevated hyperexcitability makes transient neural disruptions more prevalent. Both appear to be associated with anomalous experiences and aura. These findings appear to hold for both neurological and nonclinical groups and provide an exciting vehicle for the more objective assessment of underlying mechanisms subserving anomalous perceptions.

## OVERVIEW OF THE PRESENT STUDY

The present study sought to examine cortical hyperexcitability and its association with specific forms of nonclinical ABEs. In contrast to our

previous investigation, here we examined pattern glare in two groups with different types of anomalous bodily experience, that varied in terms of the copresence and magnitude of visual components associated with their hallucinations (as well as nonhallucinating controls). Therefore, here there was a group characterised by no or low degrees of visual hallucination that acted as a further control group for the high visual hallucination group.

Previous demonstrations of pattern-glare effects in those who report anomalous bodily experiences like visual OBEs, might be questioned in that such associations could be due to secondary (i.e., even nonvisual) factors such as increased anxiety or suggestibility—all of which might be increased in hallucinating groups. By this account, increased signs of pattern glare in healthy individuals who report hallucinations, might not actually be measuring elevated levels of cortical hyperexcitability. Instead they may reflect components that are more a consequence (secondary) of the generic presence of hallucinations.

To address this possibility here two groups of nonclinical hallucinators which varied in terms of the degree and intensity of anomalous visual experiences associated with their ABEs were examined. As with our previous investigation, those reporting visual OBEs were recruited. In addition, here we also sampled those who report sensed-presence experiences (SPEs). At their core, these SPEs are not, in and of themselves, visual in nature. They reflect an overwhelming “feeling” of a close-by sentient being that has intentions towards the experient (Cheyne, 2001; Cheyne & Girard, 2004; Girard & Cheyne, 2004; Girard, Martius, & Cheyne, 2007; Persinger, 2001; Persinger, Bureau, Pedery, & Richards, 1994). They are also sometimes referred to as “felt presences” or merely, an “experience of presence”—to highlight the lack of direct visual-sensory information (Cheyne, 2001; Cheyne & Girard, 2004, 2007). Cheyne and Girard (2007) make the salient point that, although both the SPE and OBE may exist under the umbrella category of “anomalous bodily experiences”, there are clear differences between hallucinations where one may visually perceive a *self* (as can happen in the OBE), and those where one feels the [unseen] presence of *another* (SPE). Therefore, although both types of experiences represent ABEs that are clearly multisensory in nature, they reflect different biases underlying the distinct phenomenology.

It is important to clarify that it is not being assumed here that SPEs are completely devoid of visual elements—as this is simply not the case. Visual elements can accompany or precipitate the main experience or indeed furnish the SPE itself—particularly when they are associated with instances of sleep paralysis and hypnogogia/hypnopompia (Cheyne, 2001; Cheyne, Rueffer, & Newby-Clark, 1999). However, visual hallucinations and distortions are much rarer than other sensory contributions (e.g., auditory hallucinations) in the SPE, and when they do occur they tend to be far less vivid (Cheyne,

2001). As a consequence, our assumptions here are ones of bias, where the SPE group are seen as having fewer sensory-visual components associated with them, relative to visual-OBEs.

In contrast, although the OBE can be a “felt” experience, it can typically contain strong visual elements as well such as the shift in visual perspective and moving through a three-dimensional world. In addition, in some contexts the OBE can be precipitated by, and associated with, other visual distortions/hallucinations such as scintillating phosphenes, elementary visual phenomena, and kaleidoscopic imagery (i.e., in near-death situations; Blackmore, 1993). Furthermore, as the current study is focusing on visual OBEs, then, by definition, the experiences having visual disturbances, distortions, and hallucinatory aspects are crucial. Therefore, the assumption here is that both groups represent different forms of ABE, where one appears to contain fewer contributions from hallucinatory visual phenomena than the other. This relative bias may reflect differences in underlying neural vulnerabilities in visual sensory brain regions, where the intuitive prediction is that anomalous experiences containing more salient visual anomalies will be more closely associated with signs of hyperexcitability in visual areas of the brain.

To explore the presence and degree of cortical hyperexcitability in these groups we used the modified computer-based version of the pattern-glare test devised and detailed in our previous study (Braithwaite et al., in press; discussed more fully in the Method section). The pattern-glare task was complemented by a revised version of the Cardiff Anomalous Perception Scale (CAPS; Bell, Halligan, & Ellis, 2006), which provided a measure of individual predisposition to anomalous perceptions across a range of sensory modalities. The original CAPS is a 32-item, psychometrically verified measure and has been used previously to successfully delineate OBE groups from controls (Braithwaite et al., 2011, in press).<sup>1</sup> The CAPS does not contain a question on OBEs (though it does on SPEs), and the addition of this question is the difference between this revision and the original. Specific questions from the CAPS measure were used to provide a metric for increased perceptual anomalies from both temporal-lobe disturbance and disturbances underlying visual processing.

It was predicted that if hallucinatory ABEs (either SPEs or OBEs) are dependent to some degree on underlying neural dysfunctions, then such experiences would be more prevalent in a brain that displays signs of being

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<sup>1</sup> In line with our previous work, prescreen questionnaires asking about various phenomenological aspects of both OBE and SPE were also administered (including questions on the visual nature of the OBE). The purpose of these was to ensure we gleaned important information about the veracity of the experiences and the participants correctly classified their own experiences. These measures have been detailed elsewhere (Braithwaite et al., in press).

hyperexcitable. This should hold true for both neurological samples and, albeit in attenuated form, for nonclinical groups predisposed to anomalous experiences as well. In terms of the current study, for the SPE group, this may come in the form of elevated scores on questionnaire measures of temporal-lobe experiences (relative to controls), as contributions from disruptions in temporal-lobe processing have been associated with the SPEs in both neurological and nonclinical groups (Brugger, 2002; Brugger, Regard, & Landis, 1996, 1997; Landtblom, 2006; Persinger, 2001). Measures of visual anomalies and indexes of visual pattern glare might not dovetail as effectively with the specific vulnerabilities underlying SPE hallucinations (relative to the visual OBE group).

Second, if pattern-glare effects do reflect an increased neural response in visual association cortex, then arguably such effects should be more prevalent in those reporting ABEs that are expressed with strong visual components to them (in the present case, visual OBEs). This would be evidenced in the present study by both the independent questionnaire measures of predisposition to anomalous experience (temporal-lobe experience and visual experiences) and elevated signs on both measures of pattern glare.

Third, if pattern-glare effects for these samples are not reliably related to visually mediated cortical excitability, but are due more to secondary effects like suggestibility and increased anxiety, then the effects seen for both hallucinatory groups should be (1) elevated relative to control groups, and (2) perhaps matched to each other in terms of severity, as it seems reasonable to assume that these secondary effects might impact roughly equally across difference types of anomalous experience. Such factors would be evidenced by high scores on all questionnaire measures and by increased signs of pattern glare for both hallucinatory groups.

## METHOD

### Participants

One hundred and eighty-two participants took part in the present study. Of these, 176 (96.7%) were female and 168 (92.3%) reported that they were right handed. Prescreening criteria (made explicit during the advertisement of the experiment) excluded anyone with a medical history of seizure, epilepsy, or had been diagnosed with migraine, with or without aura. Participants were asked if they were taking any form of medication at the time of testing and all declared that they were not. 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 40 years, with an average age of 21.2 years. All received course credit or a small

financial payment for taking part in the study. It was an a priori condition that participants who reported their experiences resulting from recreational drug use, alcohol, anaesthesia, or as a direct result of prescription medication would be excluded from the present study.

### Pattern-glare task

The present experiment employed the same computerised pattern-glare task as devised for previous investigations (Braithwaite et al., in press). The experiment was programmed in E-prime version 2.0 and was run in a dimly lit laboratory. There were three separate classes of pattern-glare stimuli (horizontally striped gratings) that differed in terms of their spatial frequency (SF) and their colour. The three separate spatial frequencies were (1) a low spatial frequency baseline grating (approx. 0.7 cpd), (2) a high spatial frequency baseline grating (approx. 11 cpd), and (3) the critical medium spatial frequency grating (approx. 3 cpd). All gratings were presented separately and centrally on a 17-inch LCD screen, and extended over an area of 110 mm wide  $\times$  115 mm high (13.175  $\times$  13.768 degrees of visual angle). Viewing distance was not fixed but was approximately 60 cm. Each separate spatial frequency occurred in either achromatic (black/white) or three separate chromatic combinations (red/green, mauve/purple, green/blue). Previous research has suggested that effects of pattern glare can be stronger for achromatic stimuli and these were the main focus here. The chromatic stimuli were only used as filler stimuli to break up the presentation of the achromatic gratings and to prevent habituation to the repeated presentation of achromatic gratings. Each individual disc was presented twice—thus making a total block of 24 trials (two trials per grating, including filler stimuli, totalling eight trials per spatial frequency). Every trial followed exactly the same presentation procedure.

A trial began with the presentation of one of the pattern-glare gratings (chosen randomly). Participants were instructed to concentrate on a small fixation dot in the middle of the disc for approximately 5 s before proceeding with their responses. Accompanying the disc was an initial question (presented on the computer screen) on how visually “comfortable” the pattern was to look at (on a full scale of  $-5$  = “extremely uncomfortable”,  $0$  = “neither comfortable nor uncomfortable”, and  $+5$  = “extremely 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. This was followed by another question asking about any associated visual phenomena that may have occurred during the viewing of the pattern. A number of options were provided (i.e., shimmering, flickering, blur, shadows, bending of lines, nausea, pain, coloured halos, etc.; see Braithwaite

et al., in press) and participants could click on as many options as they required before clicking on the option to continue to the next question.<sup>2</sup> Finally, participants were asked whether or not any visual illusory effects occurred in one visual field (LVF/RVF), both visual fields equally, or neither visual field.

Participants were instructed that if the stimuli were too uncomfortable to look at then pressing the spacebar would remove the disc from view (but not the questions or response options). A further pressing of the spacebar would make it reappear and so on. As an additional measure of visual discomfort the number of spacebar presses was also recorded for each and every pattern-glare stimulus.

### Questionnaire measures

*Revised-Cardiff Anomalous Perception Scale (CAPSr).* The CAPS is a 32-item measure of predisposition to perceptual anomalies (Bell et al., 2006). The revised version employed here (CAPSr) is based on that from previous investigations where a single question on out-of-body experiences is added: “Have you ever had an experience where you have perceived the world from a vantage point outside of the physical body?” (see Braithwaite et al., 2011, in press). In the original CAPS measure, a subscale of 11 items were shown to be highly correlated with each other, reflecting a “Temporal-Lobe Experience Factor” (TLE factor) (Questions 1, 2, 4, 6, 10, 12, 16, 24, 26, 27, 32; Bell et al., 2006; see also Bell, Halligan, Pugh, & Freeman, 2011, for a general replication). Crucially, these items have been shown to be reliably associated specifically with OBEs (Braithwaite et al., 2011, in press). This subscale was originally constructed from experiences commonly reported in pre-seizure aura states reported by patients with complex partial seizures (either spontaneously or via direct electrical stimulation; Gloor, 1986; Gloor et al., 1982; Halgren et al., 1978; Penfield, 1955; Penfield & Perot, 1963), and in attenuated form by the normal population (Makarec & Persinger, 1987, 1990; Persinger, 2001; Persinger & Makarec, 1986, 1993). Collectively, this literature supports the notion that these experiences are associated with underlying, possibly paroxysmal, neural activity leading to varying degrees of temporal-lobe dysfunction and in some circumstances ABEs.

In addition to the TLE factor, here we also identified all questions on the full CAPS measure that asked about anomalous visual experiences—in order to construct a “Visual Experiences Scale” (VES; Questions 4, 19, 22,

<sup>2</sup> In total there were 11 options presented. Three of these were related to illusory colours or halos (red, green, yellow), which in the analysis were pooled into one “colour distortion” category and thus counted as one category (or option).

23, 26, 31) and provide a metric of predisposition to anomalous visual experiences specifically (perhaps reflecting an underlying neural vulnerability in visual processing). Two of these questions (Questions 4 and 26) were also part of the original TLE factor discussed earlier (Bell et al., 2006). These two questions were removed from both scales and discarded from the current study—thus reducing potential contamination across the factors of interest here (TLE and VES). This resulted in a nine-item TLE measure (from the original 11 items) and a four-item Visual Experiences Scale (VES).

Participants responded initially to each question with a yes/no response (scored 1/0 respectively). In addition, participants also provided a frequency score for how often such experiences occurred (on a 5-point Likert scale: 1 = “hardly ever”, 5 = “all the time”). Both these scores here were pooled to reflect an overall indication of both the occurrence of these experiences and the frequency of them in one overall metric. Both factors are consistent with signs of anomalous experience and an underlying neural disturbance.

Importantly, although both the OBE and TLE questions were used to delineate the hallucinatory groups, they were removed from the analysis of the questionnaire measures (to avoid circularity in the measures). Finally, as part of a prescreening procedure (before completing the CAPS<sub>r</sub> or pattern-glare task), we sought to ensure that participants who reported OBEs did not also report SPEs (or vice versa). This was done by administering some preliminary prescreening questionnaires which asked for additional information about various accompanying phenomenological characteristics of these experiences (see Braithwaite et al., in press, and Footnote 1). If participants reported both experiences, this counted as exclusion criteria and they did not take part in the main experiment. The efficacy of the prescreening was supported by the observation that questions on both OBEs and SPEs also featured on the CAPS<sub>r</sub> measure, and both questions did not receive combined positive endorsement by those participants who successfully passed through the prescreening.

## RESULTS

Of the 182 participants who took part in this study, 123 (68%) did not claim any ABEs (either SPEs or OBEs as defined and highlighted here) and thus made up our control group. Fifty-nine participants (32%) reported some form of ABE. Forty-one (22%) reported at least one SPE, and 18 (10%) reported a visual OBE at some point in their life. The entire OBE group reported that their experiences had a strong visual component to them. Although other sensations were also present and contributing to the realism of the experience (i.e., vestibular distortions/floating sensations)—in all cases

these always cooccurred with visual aspects of the experience (i.e., unreal perspectives, seeing a body-double, elementary visual phenomena, etc.).

### TLE and VES scores

The overall median TLE-score for the whole sample ( $N = 182$ ) was 6.00 (range = 0–19). The overall median VES-score for the whole sample was 2.00 (range = 0–12). The descriptive statistics for the OBE hallucination group, the SPE hallucination group, and the nonhallucinatory control group on measures of temporal-lobe experience are given in Table 1.

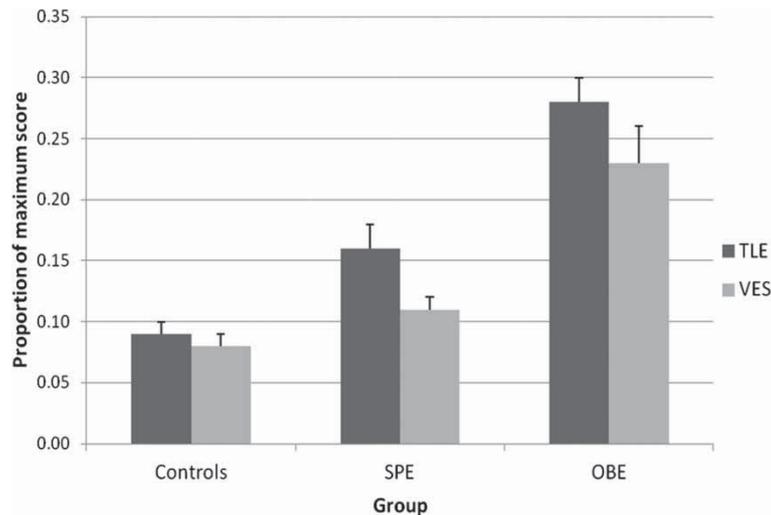
Only 21% of the control group scored higher on measures of TLE than the median of the SPE group, with this dropping to 2% relative to the median of the OBE group. Around 12% of the SPE group scored higher than the median for the OBE group on this same measure. For the VES measure, approximately 38% of the controls scored higher than the SPE group, with this dropping to 2% relative to the OBE group. Only 17% of the SPE group scored higher than the median for the OBE group.

All data for both the TLE and VES scales were converted into a proportion of possible maximum values from their respective subscale. These scores are given in Figure 1 for each group. The formal analysis was carried out on these corrected-proportion scores. A Shapiro-Wilks test was carried out on the TLE data from the whole sample and revealed a nonnormal distribution,  $W = 0.92(df = 182)$ ,  $p < .001$ . Therefore, the TLE scores were analysed using a nonparametric between-subjects ANOVA-equivalent Kruskal-Wallis test, which revealed a significant effect across the three groups,  $\chi^2(2) = 47.93$ ,  $p < .001$ .

This was broken down further by carrying out Mann-Whitney tests ( $p$ -values corrected via the Bonferroni method). The SPE group provided significant higher TLE scores relative to the control group,  $U = 1470.00$ ,  $z = 4.02$ ,  $p < .001$ . This was also the case for the OBE group relative to the control group (with some suggestion of an increased effect for this comparison),  $U = 117.50$ ,  $z = 6.15$ ,  $p < .001$ . Finally, the difference between the OBE group and the SPE group was also reliable, with the OBE group

TABLE 1  
Descriptive statistics from the TLE and VES scales for the control group and both SPE and OBE hallucinatory groups from the present study

Group	Median TLE score	Range	Median VES score	Range	Sample size ( $N$ )
Controls	4	(0–17)	2	(0–7)	123
SPE group	8	(0–19)	2	(0–12)	41
OBE group	14.5	(7–19)	6	(1–12)	18



**Figure 1.** Data from both the TLE and VES scores plotted as a function of possible maximum scores from the different subscales across the three groups. Error bars = 1 standard error.

providing the most elevated score of temporal-lobe experience,  $U=152.50$ ,  $z=3.57$ ,  $p < .001$ .

To summarise, both hallucinatory groups provided increased TLE scores relative to the control group, with the OBE group producing significantly elevated TLE scores, relative even to the SPE group. This is consistent with both of the hallucination-prone groups reporting an increased number of experiences, thought to reflect an underlying dysfunction in temporal-lobe processing, but this being particularly the case for those reporting OBE-type experiences.

The same procedure outlined earlier was applied to the VES scores. A Shapiro-Wilks test also confirmed that these data were not normally distributed,  $W=0.85(df=182)$ ,  $p < .001$ . A Kruskal-Wallis test was applied to the VES scores and revealed a significant main effect of group,  $\chi^2(2) = 16.38$ ,  $p < .001$ . Mann-Whitney tests revealed that the difference between the control group and the SPE group, was not reliable,  $U=2355.50$ ,  $z=0.65$ ,  $p = .51$ . In contrast, there was a significant difference between the control group and the OBE group,  $U=464.50$ ,  $z=4.08$ ,  $p < .001$ . The difference between the OBE group and the SPE group was also reliable, with the OBE group providing the most elevated scores on the Visual Experience Scale,  $U=189.00$ ,  $z=3.02$ ,  $p < .005$ . To summarise, only the OBE group provided significantly increased VES scores relative to the control group.

Finally, the differences between scores for both the TLE and VES scales, within the groups were also explored with a Wilcoxon test. Only the SPE

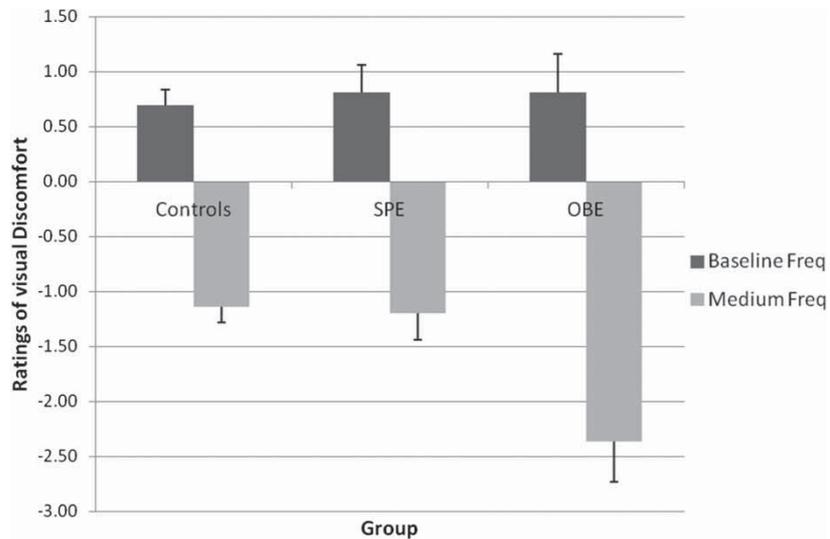
group produced a reliable difference, with TLE scores being significantly increased relative to the VES scores for this group,  $z = 2.67$ ,  $n\text{-ties} = 35$ ,  $p < .009$ , two-tailed. There were no reliable differences between the scores for both scales for the control group,  $z = 0.840$ ,  $n\text{-ties} = 99$ ,  $p = .40$ , two-tailed. Although the mean difference between these measures appears comparable between the OBE group and the SPE group (see Figure 1), higher variability for the OBE group led to this effect being unreliable,  $z = 1.31$ ,  $n\text{-ties} = 17$ ,  $p = .19$ , two-tailed.

### Achromatic pattern glare

*Visual discomfort.* No participant found the stimuli so uncomfortable that they needed to press the spacebar to remove it from the computer screen during the experiment (as a consequence, there were no spacebar responses to analyse in this regard). To explore patterns within the baseline stimuli, both the high-frequency and the low-frequency baseline stimuli were entered into a 3 (group: controls/SPE/OBE)  $\times$  2 (stimulus type: high vs. low frequency) mixed-subjects ANOVA. This revealed only a main effect of stimulus type,  $F(1, 179) = 42.33$ ,  $p < .001$ , where low-frequency stimuli were rated as less visually aversive relative to the high-frequency stimuli. However, there was no interaction between group and stimulus type,  $F(2, 179) = 1.40$ ,  $p = .24$ , and no main effect of group,  $F(2, 179) = 0.11$ ,  $p = .90$ . As a consequence, the data from both baseline stimuli sets were collapsed to make one unitary “baseline” category for further comparisons with the medium-frequency stimuli.

The data from the medium-frequency gratings were compared to those from the pooled baseline outlined above in a 3 (group: controls/SPE/OBE)  $\times$  2 (stimulus type: baseline vs. medium frequency) mixed-subjects ANOVA. This revealed a significant main effect of stimulus type,  $F(1, 179) = 219.86$ ,  $p < .001$ , and a significant Group  $\times$  Stimulus type interaction,  $F(2, 179) = 4.61$ ,  $p < .02$ . The main effect of group was not significant,  $F(2, 179) = 1.52$ ,  $p = .22$ . All groups reported significantly more negative scores of visual comfort for the medium-frequency stimuli, relative to the baseline stimuli (see Figure 2).

The interaction component was broken down further by a one-way ANOVA on the data from the medium-frequency stimuli only across the three groups and then by a series of between-subject  $t$ -tests (all further comparison  $p$ -values corrected via the Bonferroni procedure). The one-way ANOVA was significant,  $F(2, 179) = 4.75$ ,  $p < .02$ . There was no reliable difference between the control group and the SPE group,  $t(162) = 0.205$ ,  $p = .84$ . However, there was a reliable difference between the control group and the OBE group,  $t(139) = 3.11$ ,  $p < .01$ , and both the SPE and OBE



**Figure 2.** Ratings of visual discomfort for both baseline and medium-frequency stimuli across all three groups. Controls and hallucinators: SPE = sensed-presence experiences; OBE = out-of-body experiences. Error bars = 1 standard error.

hallucinatory groups,  $t(57) = 2.56$ ,  $p < .03$ . The interaction component can thus be explained by an increased visual discomfort, for medium-frequency stimuli, from the OBE hallucinatory group relative to the other groups (see Figure 2).

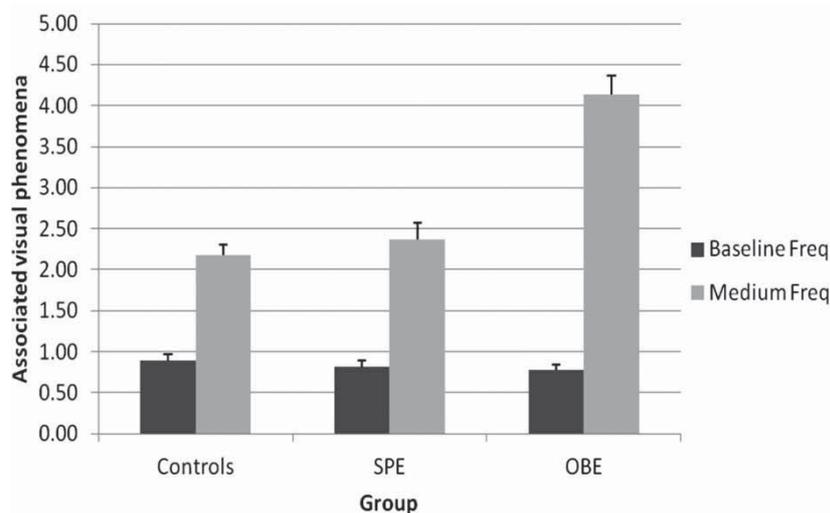
Finally, a Pearson's correlation analysis between reported TLE scores and the visual discomfort ratings for medium-frequency stimuli, for the entire sample, was carried out. This revealed a small but significant negative correlation,  $r = -.35$ ,  $N = 182$ ,  $p < .001$ , two tailed, where higher TLE scores were reliably negatively correlated with increased negative ratings of visual discomfort. This was repeated for the VES scores, which also revealed a small yet significant negative correlation,  $r = -.25$ ,  $N = 182$ ,  $p < .002$ , two-tailed, where negative ratings on measures of visual comfort were associated with increased scores for anomalous visual experiences.

*Associated visual phenomena/visual distortions.* Similar to that for visual comfort ratings, data for the mean number of reported associated visual phenomena and distortions from viewing the medium-frequency gratings were compared to those from the pooled baseline outlined above in a 3 (group: controls/SPE/OBE)  $\times$  2 (stimulus type: baseline vs. medium) mixed-subjects ANOVA. This revealed a significant main effect of stimulus type,  $F(1, 179) = 238.93$ ,  $p < .001$ , and a significant Group  $\times$  Stimulus type interaction,  $F(2, 179) = 18.65$ ,  $p < .001$ . The main effect of group was also

significant,  $F(2, 179) = 11.91, p < .001$  (see Figure 3). The main effects and interaction component were broken down in the same manner as that described earlier. There was no significant difference for the associated visual phenomena reported for the baseline stimuli, across the three groups,  $F(2, 179) = 0.68, p = .51$ . In contrast, for medium-frequency stimuli there was a significant difference in the number of associated visual phenomena reported,  $F(2, 179) = 16.60, p < .001$ .

Between-subject  $t$ -tests revealed no reliable difference between the control group and the SPE group,  $t(162) = 0.748, p = .44$ . However, there was a reliable difference between the control group and the OBE group,  $t(139) = 5.72, p < .001$ , and between both the SPE and OBE hallucinatory groups,  $t(57) = 5.15, p < .001$  (Figure 3). To summarise, there were reliably more associated visual phenomena reported during the viewing of the critical medium-frequency stimuli, relative to the baseline stimuli, but only for the OBE hallucinatory group.

As with visual comfort scores, a Pearson's correlation analysis between reported TLE scores and the number of associated visual phenomena/distortions, for medium-frequency stimuli for the entire sample, was carried out. This revealed a significant positive correlation,  $r = .61, N = 182, p < .001$ , two tailed, where higher TLE scores were reliably correlated with increased levels of associated visual phenomena from viewing the medium-frequency striped stimuli. Associated visual phenomena were also explored



**Figure 3.** Mean number of associated visual phenomena reported across all three groups. Controls and hallucinators: SPE/OBE from viewing both baseline and medium frequency gratings. Error bars = 1 standard error.

in relation to VES scores, which revealed a significant correlation between these factors,  $r = .36$ ,  $N = 182$ ,  $p < .001$ . In terms of effects of visual field, all participants reported that effects were either equal in both visual fields, or “no effect” if they rated no discomfort and no visual distortions. As a consequence, effects of visual field were not analysed further.

Overall, the pattern-glare test revealed important differences across both controls and the separate hallucination-prone groups. These differences occurred independently for both dimensions of visual comfort and associated visual phenomena, with some evidence suggesting stronger responses from the latter component. Both the OBE group and SPE group scored higher on measures of TLE, relative to controls, consistent with the notion that such experiences are associated with some form of temporal-lobe disturbance. The OBE group also displayed increased signs of pattern glare relative to the SPE (low-visual) group and controls. These effects were restricted only to the crucial medium-frequency stimuli and such differences were not present for the baseline stimuli

## GENERAL DISCUSSION

The present study examined the degree of cortical hyperexcitability selectively associated with anomalous bodily experiences. Two groups prone to reporting different forms of ABEs were compared (with controls). Individuals prone to SPEs acted as a further form of control group, for those who reported OBEs with associated visual components, but one still prone to hallucinations.

Both ABE groups scored significantly higher on measures of temporal-lobe experience relative to the nonhallucination control group. This is consistent with both groups reporting significantly elevated levels of anomalous experiences that may reflect underlying neurophysiological anomalies in temporal-lobe processing. This finding is also consistent with previous investigations and shows that the groups in the present study were largely representative (Braithwaite et al., 2011, in press; Cheyne, 2001; Persinger, 1993; Persinger et al., 1994). Interestingly, the OBE group scored reliably higher on this measure than the SPE group which may imply an increased rate and range of associated perceptual anomalies for this group.

In contrast to the findings seen for the TLE measure, significantly elevated scores for anomalous visual experiences were only observed for the visual OBE group. The SPE group were not reliably distinguishable from controls on the measure of anomalous visual experience. This result lends broader support for the suggestion that SPEs are associated with fewer visual hallucinations, which were also less frequent here, relative to other hallucinatory groups (Cheyne, 2001; Cheyne & Girard, 2009). It also

provides support for our own assumption that the SPE group might represent a selection of hallucinators with a lessened emphasis on visual contributions to their hallucinatory phenomenology and thus less likely to show signs of neural vulnerabilities in visual sensory cortex. Therefore, it is not just that the SPE has fewer visual hallucinations associated with it, but those reporting SPEs tend to report fewer and less frequent visual hallucinations more generally extending beyond the SPE itself.

Collectively, the findings from both questionnaire measures provide evidence that our hallucinatory groups here (1) provided significantly elevated scores on some measures of anomalous perception thus providing some validation for the groupings, and (2) that the differences between the hallucinatory groups on the VES map, onto the phenomenological differences between the contents (i.e., lower/higher visual elements) of the ABE.

Importantly the independent findings from both the questionnaire measures of anomalous perception and the pattern-glare task go against the notion that such effects are due solely to secondary (nonsensory/visual) factors such as suggestion and anxiety. For example, such an argument cannot explain why the SPE group scored higher on only one measure of anomalous perceptions (the TLE measure) relative to controls. Factors like suggestion would arguably induce a generic response bias that would have an impact on all measures. Such generic effects may or may not be equivalent between the groups, but a reliable difference between hallucination groups and controls, for both measures, would be a necessary condition for the argument. Clearly this did not happen.

In addition, notions of increased suggestion in the ABE groups fail to account for the full pattern of responses from the pattern-glare task. Although all groups found the high-frequency baseline grating less comfortable to view than the low-frequency grating, there were no interactions between group and stimuli. All groups provided roughly matched ratings for baseline stimuli. One might have expected increased scores of pattern glare even for the baseline stimuli for the ABE groups, relative to controls, if reliable effects of bias such as those mediated by suggestion were present.

Furthermore, notions of generic biases cannot explain why the effects of pattern glare, a visual task, were significantly stronger for medium-frequency gratings for the OBE group, relative to the SPE group. In other words, measures of visual irritability were significantly elevated for the visual hallucination group and were not as evident in the group which reported significantly fewer visual anomalies as part of their hallucinatory phenomenology. This was the case for both measures of pattern glare (comfort and the number of associated visual phenomena). As a consequence, we argue that the most parsimonious interpretation of the present findings is that these pattern-glare effects do indeed reflect the presence of increased neural vulnerabilities in visual-sensory cortical processing.

One limitation of the present study is that the sample only contains a few males and has a mildly limited age range (22 years). Both factors should certainly be acknowledged when extrapolating these findings to the general population. Although such factors may qualify the present data, they are not overly problematic. For example, although pattern-glare effects are associated with migraine, and migraine can be more common in females than males, Evans and Stevenson (2008) failed to find any statistical differences between genders even when both groups were matched for age, suggesting that gender differences were not crucial for the occurrence or prevalence of pattern glare. In the same study, only mild/borderline effects of age were reported, although further research is needed to fully explore the effects of pattern glare across wider age ranges. Furthermore, the present findings are in line with a wealth of previous studies, recruiting a wide demographic, showing that visual discomfort, associated visual distortions, and hence, signs of underlying hyperexcitability, are more prevalent for the medium frequency gratings and are themselves associated with visual hallucination (Braithwaite et al., in press; Conlon et al., 2001; Coutts et al., 2012; Huang et al., 2003, 2011; Wilkins, 1995; Wilkins & Evans, 2001; Wilkins et al., 1984, 1999, 2008; see Evans & Stevenson, 2008, for a review).

### **The relationship between cortical hyperexcitability and anomalous bodily experiences**

At first glance effects of pattern glare may appear somewhat divorced from the complex and compelling hallucinations that make up many manifestations of ABEs. However, as noted in the Introduction, cortical hyperexcitability may be related to multisensory hallucinations like ABEs in a number of ways. An elevated level of background excitability might mean that localised sensory systems would also be more excitable and arguably closer to seizure thresholds. This notion is evidenced by the cooccurrence of increased excitability, the presence of paroxysmal EEG activity, and resultant aura in neurological groups (Evans & Drasdo, 1991; Evans et al., 2002; Huang et al., 2003, 2011; Wilkins, 1995; Wilkins & Nimmo-Smith, 1984; Wilkins et al., 1984, 2008). A host of external stressors may interact with these neural vulnerabilities making neural systems unstable. Under certain conditions (i.e., visual stress, fatigue, sensory reduction, confusion) these stressors may impact on background levels of cortical hyperexcitability to such a degree that spontaneous paroxysmal activity becomes more likely. The contents of the resultant hallucinatory aura may reflect the location of the paroxysmal activity (i.e., aberrant firing in visual cortex may result in elementary or even complex visual phenomena), or it may reflect the functional impacts such disruption can induce in other brain regions.

ABEs are multisensory in nature, and much of the research on these experiences has focused on there being a breakdown in the specific integrative processes themselves (Arzy et al., 2006; Blanke & Arzy, 2005; Blanke et al., 2004, 2005; Blanke & Metzinger, 2008; Blanke & Mohr, 2005; Blanke & Thut, 2007; Brugger, 2002; Brugger et al., 1997; Bunning & Blanke, 2005). The realism and striking nature of these experiences clearly reflect more than just visual contributions to the experiences. However, few studies have examined the integrity of the separate incoming sensory information requiring integration or explored what underlies this notion of “disruption” in processing or how it occurs in nonclinical hallucinators.

Evans and Stevenson (2008) argue that visual gratings are particularly potent at aggravating localised neural assemblies by inducing concentrated excitation which might overwhelm shared inhibitory resources within focal assemblies. As a consequence, potent gratings like those employed in the pattern-glare test may overstimulate the visual cortex and lead to a breakdown in cortical inhibition. One potential consequence from this is that, as inhibition breaks down, becoming less focused and more diffuse, typically stable visual contributions to any internal model of the “self” or reality would become compromised. If perceptual/sensory driven models break down and can no longer support a stable model of the “self”, then contributions from internal models (i.e., imagery, memory, spatial processing) may take over.

Furthermore, if pattern-glare effects reflect sensory preintegration processes, then hyperexcitability could impact on the timing of incoming visual information to higher level integrative processes. The coherent sense of embodiment would be compromised if crucial sensory information was either not available for integration at the correct time, or was available but severely degraded in some way. By this account hyperexcitability and its associated transient neural disruptions could be viewed as inducing temporary forms of “dysconnection” (reflecting aberrant connectivity) between different levels of hierarchical representations—a concept gaining currency in research on temporal integration and the positive symptoms of schizophrenia (Friston, 1998, 1999; Pettersson-Yeo et al., 2011; Stephan et al., 2006, 2009).<sup>3</sup> Further support for these ideas can be taken from studies showing that pattern-glare effects reveal a more neurally responsive (earlier-acting) cortex in some patient groups—suggestive of a difference in the temporal properties of hyperexcitable cortices (Coutts et al., 2012). Therefore, although neural vulnerabilities underlying pattern glare may lie outside

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<sup>3</sup> Although typically cast as resulting from hypothesised *structural* lesions, the concept of dysconnection pertains more to the possibility of aberrant connection, which may imply increased and/or decreased connectivity. In addition, functional notions of dysconnection can also be entertained, where dysconnection/desynchronisation between neural systems can impact on the typically stable throughput of neural signalling.

of multisensory integration processes, they have important implications for such processes. According to this view, the foci of hyperexcitability do not need to be geographically specific and do not necessarily need to reside in integrative centres of the brain (Braithwaite et al., in press).

A different account extends the effects of pattern glare (and underlying cortical hyperexcitability) beyond the sensory and into higher level integrative processes. By this account localised temporal anomalies in neural activity are tied more directly to integrative processes themselves—a position evidenced to some degree by neurological studies (Blanke et al., 2002; De Ridder et al., 2007; see Blanke & Arzy, 2005; Mohr & Blanke, 2005). Although these accounts are not necessarily mutually exclusive, the selective effects of pattern glare here, existing primarily for visual hallucination groups, might place some constraints on this view at least as far as visual contributions are concerned.

Irrespective of exactly how, where, and when cortical hyperexcitability exerts its influence on conscious experience, the present evidence provides further support that it does, and that such effects cannot be explained satisfactorily by generic secondary response bias factors for hallucinatory groups. The data presented here are in line with the broader consensus from neurological samples that pattern-glare tasks measure cortical hyperexcitability (Coutts et al., 2012; Evans & Drasdo, 1991; Evans et al., 2002; Huang et al., 2003, 2011; Wilkins, 1995; Wilkins & Nimmo-Smith, 1984; Wilkins et al., 1984, 2008). However, here we extend these concepts, albeit in attenuated form, to nonclinical complex hallucinations.

## CONCLUSION

The present study provides evidence that increases in the background level of cortical hyperexcitability can be associated with anomalous experiences in the nonclinical population. This association exists even for higher level multisensory hallucinations (like some ABEs)—providing the experiences have strong visual components to them. Viewed in concert with our previous findings, the present data further demonstrate that increased effects of pattern glare do reflect elevated levels of cortical hyperexcitability associated with predisposition to anomalous experiences in certain nonclinical populations. The present findings also have important wider clinical implications. Although pattern-glare tasks have been explored with neurological samples, this has predominantly focused on patients with migraine and epilepsy (and associated aura). The observation that (1) relative effects of pattern glare can exist in the absence of both migraine and epilepsy, and (2) that they can be associated with the copresence of anomalous perceptions provides significant theoretical momentum to explore such factors in wider clinical cases. In

addition, the pattern-glare task is attractive as it contains no reference, in and of itself, to hallucinations that could influence suggestible observers and it provides a number of independent measures of cortical hyperexcitability (i.e., visual comfort, associated visual phenomena). These factors mean that such tasks have the capacity to significantly extend previous clinical investigations beyond subjective questionnaire methods alone. Although it is unlikely that elevated effects of pattern glare will be present or associated with all forms of visual hallucination, establishing the rate and range of such effects, within hallucinating samples will be illuminating for future theory. These tantalising possibilities are currently being explored.

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