Predisposition to Out-of-Body Experience (OBE) is Associated with Aberrations in Multisensory Integration: Psychophysiological Support from a "Rubber-hand Illusion" Study.

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Abstract

It has been argued that disorders in body-ownership and aberrant experiences in self-consciousness are due to biases in multisensory integration. Here we examine whether such biases are also associated with spontaneous Out-of-Body Experiences (OBEs) in a non-clinical population. One-hundred and eighty participants took part in a rubber-hand illusion (RHI) experiment with synchronous and asynchronous visual and tactile stimulation. A realistic threat was delivered to the rubber-hand after a fixed period of stimulation. Self-report exit questionnaires measured the subjective strength of the illusion and psychophysiological measures (skin conductance responses / finger temperature) provided an objective index of fear / anxiety towards the threat. Control participants reported a stronger RHI, and revealed larger threat-related skin conductance responses during synchronous compared with asynchronous brushing. For participants predisposed to OBEs, the magnitude of the skin conductance was not influenced by brushing synchrony - fear responses were just as strong in the asynchronous condition as they were in the synchronous condition. There were also no reliable effects of finger-temperature for either group. Collectively, these findings are taken as support for the presence of particular biases in multisensory integration (perhaps via predictive coding mechanisms) in which imprecise top-down tuning occurs resulting in aberrant experiences in self-consciousness even in non-clinical hallucinators.

Keywords: Out-of-body experience; Multisensory integration; Hallucination; Rubber hand illusion; Predictive coding.

Statement of Public Significance

Stable experience of our bodies is dependent on the coherent integration of multiple sources of sensory information. However, the mechanisms underlying this seemingly effortless process can breakdown resulting in hallucinatory anomalous bodily experiences. One such experience is the Out-of-Body experience (OBE) where the observer reports experiencing the world from a vantage point outside of the physical self. Using a body illusion task (the Rubber-Hand illusion), this study provides novel experimental evidence that the brain processes mediating typically stable and coherent self-consciousness are biased in those predisposed to hallucinatory Out-of-Body Experiences. Collectively the present findings show, for the first time, these inherent biases may well underlie a predisposition to anomalous and hallucinatory experiences even in non-clinical groups. Implications for contemporary theories of multisensory integration and self-consciousness are discussed.

Introduction

Coherent self-consciousness is dependent on a multitude of neurocognitive mechanisms and processes including: the experience of body-ownership (the experience of one's body being one's own: Ehrsson, 2012; Gallagher, 2005), the experience of embodiment (the perception of using and having a body, and that one's sense of self is localised within one's bodily boundaries), being a physical, feeling, and acting *self*, and the concept of *presence* (the conscious experience of being present in the here and now: Arzy, Thut, Mohr, Michel & Blanke, 2006; Blanke & Metzinger, 2009; Blanke, 2012; Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004; Metzinger, 2004; Sanchez-Vives and Slater, 2005; Seth, 2009; 2013; 2014; Seth & Friston, 2016; Seth Suzuki, & Critchley, 2012). These factors can vary in their intensity across experiences with important consequences for self-consciousness.

The dominant current view is that self-consciousness results from successful multisensory integration (e.g., between visual, tactile, somatosensory, and vestibular modalities) that occurs constantly within the brain. Indeed, these processes are typically stable, durable and reliable, providing a unified experience of the 'self' across time. However, a growing body of research is revealing that breakdowns in multisensory integration can occur and result in striking disorders of body-ownership (Apps & Tsakiris, 2014; Blanke & Arzy, 2005; Blanke, Ortigue, Landis, & Seeck, 2002; Blanke, Landis, Spinelli & Seeck, 2004; Blanke, Slater & Serino, 2015; Braithwaite, Broglia & Watson, 2014; Brugger, 2002; Seth, 2009; 2013; Seth et al., 2012). These instances show that rather than being fixed and permanent, multisensory integration is flexible and fallible - which can lead to aberrant experiences of embodiment, body-ownership and self-consciousness. Examining the neurocognitive mechanisms that cause such breakdowns can help us to build theoretical models, not just for how such disorders occur, but also for how stable embodiment emerges from the flux of neural processing, thus informing scientific ideas on fundamental aspects of human self-consciousness.

One form of aberrant body experience is the Out-of-Body Experience (OBE). OBEs can be defined as an experience in which observers perceive the world from a vantage point outside of their physical body (Blackmore, 1982; Braithwaite & Dent, 2011; Braithwaite, Samson, Apperly, Broglia & Hulleman, 2011; Cook & Irwin, 1983; Irwin, 1985). In terms of phenomenology, OBEs can be reported as being incredibly vivid and 3-dimensional with the perceptual qualities of veridical perception. Although such experiences can happen in association with psychopathology and neurological conditions (i.e., schizophrenia, epilepsy, migraine: Blackmore, 1986; Comfort, 1982; Critchley, 1950; Gabbard, Twemlow & Jones, 1982; Lippman, 1952; 1953; Sacks, 1995; Siegel, 1977), they can also occur in the apparent complete absence of them (in non-clinical groups: Blackmore, 1982; Braithwaite & Dent, 2011; Braithwaite et. al., 2011; 2014, Braithwaite, Mevorach, & Takahashi, 2015; Easton, Blanke, & Mohr, 2009; Irwin, 1981; Murray & Fox, 2005; Twemlow, Gabbard & Jones, 1982). For non-clinical groups, hallucinatory OBEs have been associated with specific biases in exocentric perspective-taking, body-transformation processes and increased cortical hyperexcitability demonstrated via behavioural and brain-stimulation methods (Blackmore, 1987; Braithwaite, Broglia, Bagshaw, & Wilkins, 2013a; Braithwaite, et al, 2011a; 2013b; 2013c; 2015; Cook & Irwin, 1983).

There are a number of overarching frameworks for understanding aberrant perceptions currently enjoying considerable attention. These include (but are not restricted to); multisensory disintegration, dysconnection, predictive coding, and aberrant saliency accounts. Aberrant experiences like the OBE have been linked to a disruption or breakdown in multisensory integration processes which typically sub-serve a coherent unified sense of an embodied self (Blanke et al., 2002, 2004; Blanke & Arzy 2005; Blanke and Metzinger, 2009;

Stein & Stanford, 2008). Consequently, the OBE is seen to represent a somewhat distorted model of selfhood that occurs due to abnormal patterns of brain activation impacting on the integration of multisensory information. It follows that damage or disruption in key networks responsible for the online and dynamic integration of multisensory inputs can result in aberrations of self-consciousness (Blanke et al., 2002; 2004; Blanke & Arzy, 2005). Examples of such anomalous body experiences include; (1) autoscopic hallucinations; (2) heautoscopic hallucinations; (3) sensed-presence experiences; and in terms of the present study; (4) the OBE.

Although a useful and influential view, the generic notion of a ‘breakdown’ in multisensory integration is somewhat ambiguous. It is not clear what is necessary or sufficient for such breakdowns to occur or how exactly this breakdown manifests spontaneously, even more so in non-clinical hallucinators. Dysconnection accounts propose that aberrant connectivity, either between the senses, or within different levels of hierarchically organized representations, impact on the timing of multisensory integration and stable self-consciousness – resulting in disorders of conscious experience (Friston, 1998, 1999; Fuster, 1995; Pettersson-Yeo, Allen, Benetti, McGuire, & Mechelli, 2011; Stephan Baldeweg, & Friston, 2006; Stephan, Friston, & Frith, 2009)[1]. Applied specifically to aberrant body experiences like the OBE, such dysconnection might occur between visual, tactile, vestibular, and somatosensory processing, impacting on the effective integration of the incoming information and thus the experience of selfhood and embodiment.

Salience accounts propose that observers place unwarranted priority (attentional and / or emotional) on irrelevant information leading to both aberrant self-perceptions and the formation of delusional beliefs (Kapur, 2003). These processes can be related to the idea of

[1] Note the concept of 'dysconnection' refers to aberrant connectivity - which includes over or under connectivity within and between brain regions with consequences for the efficacy of functional processing.

hyperreflexivity, where patients with schizophrenia have been shown to place an aberrant emphasis on internal bodily signals which in turn magnifies the impact of such signals in general body awareness with implications for experience and belief (Sass & Parnas, 2003; Sass, Pienkos, Nelson, & Medford, 2013). Under these circumstances, body signals dominate the contents of consciousness and receive reciprocal boosts as a result of attentional processing being directed towards them which, in turn, culminates in a self-perpetuating cycle of hyperreflexivity.

Expanding on ideas of sensory processing, predictive coding accounts have also been extended to explain the existence of body-ownership, agency, the sense of presence, and disorders within these concepts (Clark, 2013; Corlett, Frith & Fletcher, 2009; Corlett, Honey, & Fletcher, 2007; Corlett, Taylor, Wang, Fletcher & Krystal, 2010; Friston, 2005; 2010; Schultz & Dickinson, 2000; see also Apps & Tsakiris, 2014). Predictive coding accounts argue that perceptual systems need to reconcile new sensory evidence against pre-existing expectations (referred to as *priors*) that drive predictions about the self and its surroundings. According to these accounts, the brain is seen as constantly trying to minimise the mismatch or *prediction error* between incoming sensory signals and the emerging internal models generated to explain them. Stable self-consciousness results from the successful “explaining away” of the emerging *prediction error* occurring between these sources in the system at that time so that bottom-up sensory data and top-down predictive models dovetail as neatly as possible. The lower the degree of sensory discrepancy between these factors, the more stable the experience of selfhood becomes.

Seth and colleagues have proposed an 'interoceptive inference' version of predictive coding in which emotion or, more accurately, 'interoception' is at the centre of this predictive process (Seth, 2009; 2013; 2014; Seth et al., 2012; Seth & Friston, 2016; Critchley et al., 2004; see also Barrett & Simmons,2015; Bechara & Naqvi, 2004; Herbert, Herbert &

Pollatos, 2011; Tsakiris, Tajadura-Jiménez & Costantini, 2011). Interoception refers to an awareness of internal physiological and visceral body signals and the generation of subjective feeling states (emotion). Exteroception relates to the perception of incoming signals from the outside world / environment. The interoceptive inference account argues that body-ownership and presence are moulded by predictive multisensory integration of self-referent signals arising from both interoceptive and exteroceptive sources. By this account, subjective feeling states (emotions) are the consequence of predictions about the interoceptive state of the body. Applied to disorders of presence and embodiment, aberrant experiences arise due to pathologically imprecise interoceptive predictive signals.

Note that, the different theoretical accounts discussed above may not strongly conflict in their attempts to provide theoretical frameworks for understanding embodiment, presence, and disorders of the self. For example, a breakdown in multisensory integration is, in some ways, a description of the product / outcome of underlying aberrant processes. Those aberrant processes themselves could be conceptualised via dysconnection impacting on the timing of integration, aberrant salience processes, or a predictive coding model. For example, dysconnection theories posit that brain regions can be hyper or hypo connected within themselves and between regions within functional architectures. This pattern of aberrant connectivity has clear implications for the efficacy of functional processes. That is, dysconnection could impact on the generation, maintenance and modification of multisensory contingencies (i.e., the generation of priors and their effectiveness in reducing prediction-error) that are central to the interoceptive / predictive coding account as well as impact on the integrity and timing of the incoming (exteroceptive) information. A similar argument can be made for aberrant saliency accounts, perhaps even more so when one considers these ideas in view of recent interoceptive inference accounts of predictive coding in which a role for emotion is central.

Experimental induction of anomalous body experiences: The Rubber-hand illusion (RHI)

The Rubber-hand illusion (RHI) depends on the integration of multisensory inputs into a hierarchical representation of the embodied self and provides a useful experimental method for exploring body-ownership (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005; Longo, Schuur, Kammers, Tsakiris & Haggard, 2008). In the RHI observers watch a prosthetic rubber-hand being stroked, in synchrony with the ‘felt’ stroking of their own unseen physical hand. After a short while, observers typically report a feeling of 'ownership' of the rubber-hand as if it was part of their physical body. The illusion is typically attenuated when the visual and tactile stimulation are presented asynchronously. Importantly, the illusion provides a method for manipulating and altering the processes of body-ownership, embodiment, and the online representation of the body (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005; Tsakiris, Carpenter, James, & Fotopoulou, 2010; Longo, et al., 2008; Tsakiris, Prabhu, & Haggard, 2006).

The presence and strength of the illusion has been measured in a variety of ways including subjectively via exit questionnaires, and more objectively, via skin conductance responses (SCRs) measuring fear / emotional arousal responses to a threat-stimulus presented to the rubber-hand, proprioceptive drift (where the perceived location of the real hand migrates to the location of the rubber hand), drops in skin temperature and brain-imaging (e.g., Armel & Ramachandran, 2003; Botvinick & Cohen, 1998; Costantini & Haggard, 2007; Ehrsson, 2007; 2009; Ehrsson, Spence & Passingham, 2004; Ehrsson, Wiech, Weiskopf, Dolan & Passingham, 2007; Guterstam, Petkova, & Ehrsson, 2011; Longo et al., 2008; Moseley et al., 2008; Ocklenburg, Rüther, Peterburs, Pinnow, & Güntürkün, 2011; Tsakiris & Haggard, 2005; Tsakiris, et al., 2006; Tsakiris, Hesse, Boy, Haggard & Fink, 2007).

The illusion has been used to examine anomalous body experiences in both patient groups and non-clinical hallucinators (Braithwaite et al., 2014; Peled, Ritsner, Hirschmann, Geva, & Modai, 2000; Thakkar, Nichols, McIntosh, & Park, 2011). For example, in a previous study we found that those predisposed to anomalous body experiences, also took longer to report the presence of the illusion (relative to a control group), and displayed distinct profiles in autonomic responses suggesting atypical biases in multisensory integration (Braithwaite et al., 2014).

Collectively these studies show that the RHI can be used to explore intersensory contingencies and their role in body-ownership. In addition, they provide initial evidence for the presence of biases in multisensory integration and that such biases are associated with aberrations in self-consciousness. However, despite this, there is a paucity of research exploring the RHI and the over-arching theoretical frameworks outlined above in those predisposed to sub-clinical levels of aberrant perceptions / hallucinations of self-consciousness. This is an important omission because current accounts only posit such biases as part of psychopathology / neurological conditions, and fail to account for the presence of sub-clinical hallucinations. In addition, if such biases in multisensory integration are present in sub-clinical populations, this would significantly expand the applicability of the theoretical accounts so far proposed.

Despite a growing popularity in research on multisensory integration and anomalous experiences in self-consciousness, few studies have actually investigated these factors in non-clinical groups specifically screened for predisposition to such experiences. Typically, studies use a low number of participants to represent the whole sample (circa N=15 to 20), that take part in a given experiment and the emerging conclusion is often that such findings have *'implications'* for anomalous body experience (experiences which were never actually screened for, explored or delineated within the sample in the first place, see Braithwaite et al., 2014, for a similar discussion). There are additional reasons why failing to explore individual differences by screening and testing participants in this way might be problematic. Evidence is now emerging that dissociative experience can be fractionated along central experiential dimensions, which reflect a diverse underlying neurocognition, and that such experiences are indeed present in the general population. Therefore, experimental samples might unintentionally include hallucinators who reflect very different neurocognitive biases to control participants. Furthermore, the participants within such a group might well exhibit a diverse range of neurocognition themselves.

For example, depersonalization-type experiences may well be dissociative but the experience of self remains within the physical body (Braithwaite et al., 2013c; Dewe, Watson & Braithwaite, 2016; Kessler & Braithwaite, 2016; Sierra & David, 2011; Sierra, 2009). In contrast, in the OBE, there is a shift in experiential perspective where the self is liberated from its physical shackles, and the differences between these forms of dissociative experience do appear to be associated with diverse neurocognitive biases (Braithwaite et al., 2013c; Kessler & Braithwaite, 2016). As a consequence, interpreting such general ‘implications’ from studies that do not attempt to differentiate between these factors becomes difficult, with these recent developments placing some restrictions on the scope of subsequent conclusions. A consequence of this is that we are not aware of any previous published study that has coupled RHI methods to specific investigations of OBEs in sub-clinical groups[2].

Overview of the present study

The present study examined whether biases in multisensory integration and emotional processing were present and associated with spontaneous Out-of-Body Experiences (OBEs) in

[2] Thakkar et al. (2011) do identify a single OBE participant in their study – but no formal statistical comparison is made and the participant is reported anecdotally. Braithwaite et al. (2014) investigated a large sample of those predisposed to general anomalous body experiences which included but was not restricted to OBEs.

a non-clinical population. This was achieved by inducing anomalous experiences of limb ownership (using the RHI), and by exploring autonomic emotional responses to perceived body threats in those predisposed to spontaneous OBEs and control groups. Subjective (exit questionnaire responses) and previously established objective psychophysiological responses (SCRs and finger temperature) were used as indices of the presence and strength of the illusion.

In line with other work, we expected that there would be an association between the strength of emotional response to threats under conditions of an experimentally induced body-illusion and the predisposition to report spontaneous OBEs and anomalous hallucinatory experiences. If the OBE is associated with aberrant emotional processing then one prediction is that emotional fear responses (SCRs) elicited during the RHI may be distinct from the typical pattern reported for control groups. This would be revealing with respect to the latent intersensory biases underlying the illusion, underlying stable embodiment and spontaneous aberrant body experiences like the OBE.

For example, if OBEs reflect a similar form of dissociative experience as those reported by patients with Depersonalization disorder (DPD), then one would predict an overall suppression of emotional reactivity (for both synchronous and asynchronous RHI brushing conditions), as has been shown for Depersonalization groups when viewing aversive stimuli (Phillips et al, 2001; Sierra et al., 2002, Sierra, 2009; Sierra & David, 2011; see Dewe et al, 2016; for evidence with sub-clinical groups using a novel real body-threat paradigm). It has been argued that this emotional suppression is responsible for the experience of one's own body not feeling real and bodily sensations feeling flattened, dull and lifeless.

In contrast, the OBE group might show increased fear responses either overall (for both synchronous and asynchronous conditions) or for only one of the brushing conditions, relative to the control group. The former finding may implicate a general aberrant emotional response - consistent with aberrant saliency accounts of anomalous experiences but also extended here to include aberrant emotional processing tied to body experience specifically (cf. Kapur, 2003). The latter finding might also be more consistent with an interoceptive inference account in that the OBE group may make less precise predictions and over-attribute any close visuo-tactile contingencies as coming from themselves even when this is not the case. Such findings would provide clear evidence for the presence of such biases and advance our understanding of the processes underlying these experiences.

Two objective psychophysiological measures were recorded; skin conductance responses (SCRs) and finger temperature[3]. Drops in finger temperature have been associated with fear responses and have been demonstrated under RHI conditions for the hand under-going the illusion (Moseley et al., 2008; Kammers, Rose, & Haggard, 2011: though see also Hohwy & Paton, 2010; Paton, Hohwy, & Enticott, 2012; for failures to replicate). Both SCRs and finger temperature provided independent measures of psychophysiological processing relating to anxiety, fear and emotion.

The present study went significantly beyond previous work in a number of important ways. First, we directly examined intersensory biases between a non-clinical group reporting spontaneous OBEs (as an instance of aberrant self-consciousness) relative to a large control group. We explored how predisposition to the OBE related to emotional processing by examining whether such individuals showed an enhanced or suppressed emotional response - suggesting important differences in body-ownership / embodiment for these individuals.

Second, by exploring these effects in non-clinical hallucinating groups, we expand significantly the applicability of some of the latest theories relating to psychopathology into wider populations. If such biases are present and measurable, in-between hallucinatory

[3] Note – due to controversies and ambiguity over the validity of proprioceptive drift (PD), and that drift can occur without even the induction of the illusion, we prefer to use SCRs as an objective measure of embodiment induced via a threat stimulus (see Rhode et al., 2011; Holle et al., 2011; Crucianelli et al., 2013; for examples of problems with PD measures).

episodes, this would suggest the presence of aberrant multisensory integration processes as a general background trait even in sub-clinical populations and in the absence of potent drugs.

In the present study, a large number of participants completed a host of questionnaires designed to quantify predisposition to anomalous dissociative experiences. They also completed a screening questionnaire for elucidating the presence of OBEs (see Appendix B). These measures were coupled with two independent psychophysiological responses known to provide an index of emotional / fear responses (SCRs and finger temperature). The psychophysiological measures were taken under two RHI conditions in which participants experienced the illusion (synchronous brushing) and a non-illusion control (asynchronous brushing).

Method

Participants

One hundred and eighty participants were recruited from (1) the School of Psychology at the University of Birmingham UK, (2) the general public via a short television feature that appeared on the local news asking for interested participants to come forward and (3) the Department of Psychology, Lancaster University, UK. Of the 180 tested, 164 were female (91%), and 171 (95%) were right-handed. Participants ranged in age from 18–65 years ($\bar{X}$ = 22 years, SD = 8.83). Using an Out-of-Body Experience pre-screen questionnaire (see Braithwaite et al., 2013a; 2011), 31 participants (17%) were classified as 'OBEers' (87% female, $\bar{X}$ age = 32 years, SD = 16.41, range 18-65 years), with a remaining 149 making up the control group (92% female, $\bar{X}$ age = 20 years, SD = 3.66, range 18 - 49 years). At the time of recruitment, all participants were screened for any excessive fear / aversion / phobia to needles or blood.

Questionnaire Measures

Cardiff Anomalous Perception Scale (CAPS)

The Cardiff Anomalous Perception Scale (Bell, Halligan, & Ellis, 2006) consists of 32-items measuring predisposition to anomalous experiences across several modalities. Similarly to previous investigations of the CAPS with OBE samples, an additional question on whether participants had experienced an OBE was included to help identify OBEers. This question was used to delineate the OBE group but was not included in the numerical analysis for that group (the 'yes' scores were removed from the analysis for the OBE group so that they did not artificially inflate CAPS scores relative to controls). Participants were asked to respond '*Yes*' or '*No*' for each item (scored 1/0 respectively). These Yes / No responses represented the basic endorsement of such experiences. For every '*Yes*' response, there was an additional 5-point scale on how frequently the experience occurred and on how intense the experience was (both on a 5-point Likert scale),

Temporal Lobe Experience Factor (TLE):

Eleven items from the original CAPS measure have been identified as being highly correlated with each other, reflecting a 'Temporal-Lobe Experience Factor', (items Q1, Q2, Q4, Q6, Q10, Q12, Q16, Q24, Q26, Q27 and Q32; Bell et al., 2006). Previous research has shown that those predisposed to OBEs score higher than controls on these specific items (Braithwaite et al., 2011; 2013a; 2015). The scoring of these items is the same as that described above for the CAPS and both the presence and frequency of these experiences were measured. Note, this means that our analysis is based separately on the remaining 21 CAPS items and the 11 TLE items.

Cambridge Depersonalization Scale (CDS)

The Cambridge Depersonalization Scale (Sierra & Berrios, 2000; Sierra & David, 2011) is a 29-item measure of dissociative experiences typically associated with Depersonalization (DP) and Derealization (DR). Although OBE groups have been shown to score highly on some of the factors from the CDS measure, the OBE is a very different dissociative experience to DP/DR. Depersonalization pertains to feelings of disconnection and detachment from oneself, one's body, and one's thoughts. In contrast, Derealization is associated with feelings of disconnection and detachment from one's surroundings. Participants provide a frequency score on a 5-point Likert scale, ranging from 0 (*Never*), to 4 (*All the time)* and provide a duration rating using a 6-point Likert scale, 1 (*Seconds*) to 6 (*Over a week)*. Final scores for each item are then pooled across Frequency and Duration ratings, giving a potential range of scores between 0-290. A clinical cut-off score of 70 has been established and produces a sensitivity of 75%, with high internal consistency (Cronbach alpha = 0.89) and half-split reliability (0.92). Sierra, Baker, Medford and David (2005) established a 4-factor structure for the CDS (accounting for 73.3% of the variance). These factors were; (a) Anomalous Bodily Experiences (ABE); (b) Emotional Numbing (EN), (c) Anomalous Subjective Recall (ASR), and (d) Alienation from Surroundings (AFS; pertaining to experiences of derealization). This four-factor solution is used to explore responses across the present sample.

Out-of-Body Experience (OBE) Pre-screen Questionnaire

If participants answered 'yes' to the basic OBE question that we added to the CAPS measure, then they also completed a short OBE pre-screen. The pre-screen contained 24-items that measured phenomenological aspects of OBEs, such as experiencing an external perspective, the frequency of such experiences, their vividness, whether the experiences were visual or not, the degree of connection felt by the observer to their physical body and the out-of-body perspective etc. (see Braithwaite et al., 2011; 2013a; 2013b; for similar versions of the screen and Appendix B). The pre-screen was designed primarily to ensure those who claimed to have had an OBE were categorizing their experience with accepted definitions of the experience which cannot be achieved by a basic single question[4].

Rubber-hand illusion Exit Questionnaire (RHI Exit Q)

The Rubber-hand illusion exit questionnaire was a hybrid exit questionnaire, based mainly on previous literature (Botvinick & Cohen, 1998; Mussap & Salton, 2006; Longo et al. 2008). It consisted of 15-items, each with a response scale ranging from -5 *(Definitely Not)* to +5 *(Definitely Yes*). Positive values indicated increased subjective endorsement of the illusion. The RHI exit questionnaire consisted of 7 items designed to measure the actual embodiment experienced (i.e., the convincingness of the illusion / ownership of the rubber-hand), and 8 control items (designed to explore the degree of suggestibility and response bias within the sample: see Appendix A).

Electrodermal Activity (EDA) – Skin Conductance Responses (SCR)

All psychophysiological measures were acquired via a Biopac MP36R data-acquisition unit fitted with a 24-bit A/D converter (Biopac systems Inc, Goleta, CA). The unit was connected to a HP pro Elitebook 8740w laptop (8GB RAM / 450GB memory) with an Intel® core™ i7 based processor (CPU, a 2GHz NVIDIA quadro 5000M graphics card, and 64-Bit Windows 7OS). The data-acquisition rate was 2000 samples per second with the gain set to x1000. Signals were recorded via Ag-AgCL pre-gelled (Biopac isotonic gel: 101) 1cm disposable

4 Based on unpublished findings from our laboratory, we estimate that between 20% - 30% of individuals incorrectly characterise their anomalous body perceptions as an OBE, thus establishing the importance of a screening measure.

electrodes (EL507) connected to EDA sensor leads (SS57L). The electrodes were attached to the non-cleaned distal phalanges of the index and middle fingers of the dominant hand.

All signal data were first subjected to visual analysis before any formal analysis. Artefacts, if present, were removed by applying a baseline smoothing algorithm by down-sampling the signal in steps of 200 samples / sec. Data were analysed using Biopac's AcqKnowledge v4.1 software, running custom programmed Find-Cycles routines on the signal (Braithwaite, Watson, Jones, & Rowe, 2013d). SCRs were quantified as deflections crossing a threshold of 0.01µs (microsiemens) from the background signal, and defined as a delta function between the onset of the SCR (defined by the threshold) and the maximum peak amplitude reached in that SCR (see example signal in Figure 1). SCRs less than 10% of the maximum peak were discarded from the analysis.

All SCR data (deltas) were initially normalised via the Log (SCR+1) correction to make them suitable for parametric analysis (Dawson, Schell, & Filion, 2007; Boucsein et al., 2012). Normalized SCRs were then standardised to correct for individual differences via a z-score transformation ($z = (X - \mu) / \sigma$) following the recommendations of Ben-Shakhar, (1985; 1987). To do this, SCRs from both conditions (synchronous / asynchronous) were merged, with all SCRs pooled to calculate a representative mean and standard deviation, per participant[5]. This ensured that any differences in threat-SCR amplitudes were comparable across different participants.

Finger / Body Temperature

Body temperature was measured by a second channel configured on the MP36R unit, sampled at 7.8Hz, via a finger digit sensor (SS18LA) attached to the distal phalange of the index finger of the non-dominant hand that was hidden from view. Hand / finger-temperature

[5] Note, there were no significant differences in the amplitudes of the non-specific SCRs between the groups (both *F*s <1). Only the main effect of brushing condition was reliable (F (1, 153) = 9.87, *p* = .002). Therefore, pooling the signals is validated.

measurements are considered sensitive and reliable indexes of an individual's overall body temperature and thermal comfort (Wang, Zhang, Arens, & Huizenga, 2007).

Procedure

All sensors (for SCRs and body temperature) were attached 15 mins before the start of the experiment to ensure good quality contact was made, and that the readings from the temperature sensor had stabilized before recording began. For the initial section of the experiment the questionnaires relating to aberrant and anomalous experiences (CAPS and CDS) were administered to all participants, and the OBE questionnaire was included when applicable. Once completed, the RHI procedure was administered. Participants sat in front of a wooden frame fixed to a table. They were instructed to maintain fixation on the rubber-hand throughout the RHI procedure; which comprised of an initial 60-second baseline period, followed by 150-seconds of brushing, the threat-procedure, and lastly a 60-second post-threat baseline period. All participants received synchronous (visual and tactile stimuli occurred together) and asynchronous (visual and tactile stimuli occurred individually) brushing at a frequency of approximately 1Hz. The order of brushing conditions was counterbalanced across participants. Following each condition, participants were given the RHI Exit Questionnaire (see Appendix A).

During the task, participants simultaneously observed a realistic androgynous rubber-hand (a movie prop) being brushed and felt brushing stimulation on their real hand, which was hidden from view. Participants were instructed to place their non-dominant hand through a curtain and on to a lower panel, ensuring their real (brushed) hand was obscured from view. A rubber-hand was placed onto an upper level platform, 8cm above the participant's own hidden hand, at approximately 20° inclination from the participant. The hand was positioned in an anatomically congruent position to that of their real hand / arm; a factor known to be important for eliciting strong illusions (Tsakiris & Haggard 2005). To increase the believability of the illusion, participants were asked to wear the plain white blouse / shirt provided, which covered their upper body. The rubber-hand was secured into the sleeve, so that only the rubber-hand / forearm were visible, and gave the impression of protruding from clothing being worn by the participant. Participants were informed that after a fixed time period of brushing, a realistic threat would be delivered to the rubber-hand. This verbal instruction was given to reduce any surprise / startle response, and to measure true autonomic arousal related to a 'perceived threat' (cf. Armel & Ramachandran, 2003). The threat came in the form of a simulated 'blood giving’ procedure. To ensure an accurate representation of an injection procedure, a highly realistic syringe (custom made film prop) fitted with a 2.5-inch retractable needle approached the rubber-hand, and was seemingly ‘inserted’ into the skin. Once inserted, the plunger was slowly pulled back and the syringe began to fill with approximately 3cm of simulated blood (see Figure 1). Participants were instructed to maintain fixation on the needle / rubber-hand during the whole process. This procedure was repeated for both the synchronous and asynchronous brushing conditions (counterbalanced across participants).

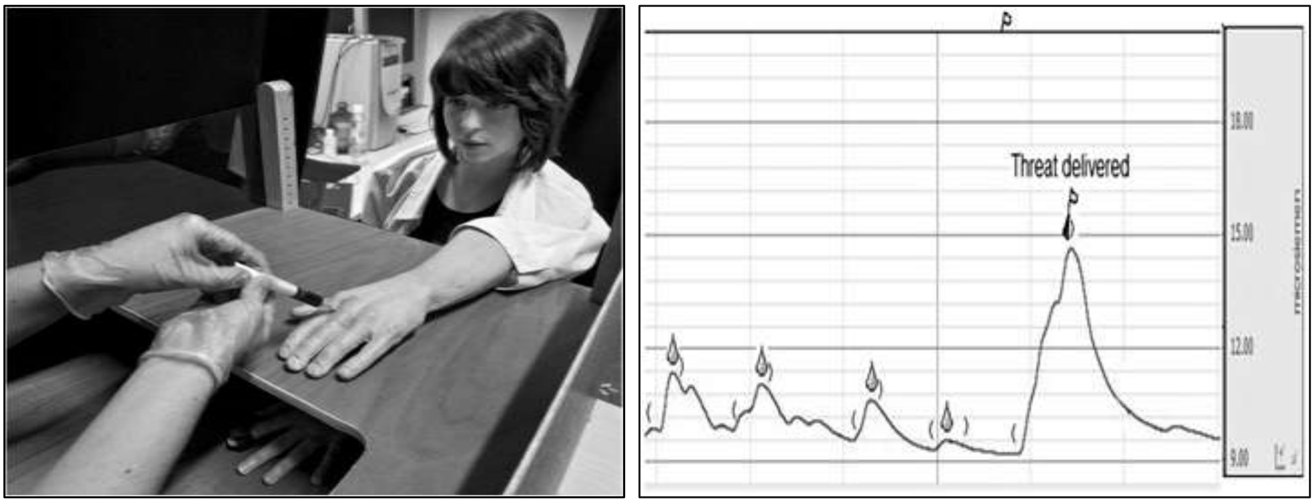

Figure 1. Example of the experimental set up used in the current study. After the brushing period, a realistic syringe with a retractable needle was plunged into the rubber-hand. Then the plunger was pulled back and the syringe seemingly filled with blood - simulating a realistic blood-giving procedure (left). In parallel with this, SCRs were measured as an objective index of fear / emotion (right). The threat-related SCR is denoted on the signal (threat delivered, right figure) amongst the other background SCRs (known as Non Specific-SCRs: NS-SCRs). Finger temperature was also measured (not shown here).

Results

A total of 180 participants were tested, and based on established criteria for identifying non-responders in terms of flat EDA profiles, (Boucsein, 2012; Dawson et al., 2007), 25 participants (14%) were removed from the analysis due to being hypo-responsive[6]. In general, these participants produced fewer than 2 NS-SCRs during the entire RHI procedure (across the merged signals). The analysis was conducted on the remaining 155 participants (92% female), of which 25 were defined as the OBE group (88% female) and 130 as the control group (93% female). Where appropriate (as indicated via Shapiro-Wilks tests), non-

[6]Around 10% of healthy control populations and approximately 25% of psychopathic populations are typically non-responders (for discussion see Dawson et al. 2007).

parametric Mann-Whitney *U* tests were applied to non-normally distributed data, *p*-values were corrected for multiple comparisons using Bonferroni correction. For the parametric comparisons the unequal sample sizes had no implications for homogeneity of variance between the groups (the ratio difference in standard deviation between the groups never exceeded 1.21 and the Levene's tests failed to be reliable - suggesting similar variance). Effect size is denoted as r for non-parametric (Mann Whitney U) tests and partial eta squared (η_P^2) and Cohen's *d* are used for ANOVAs and t-tests (see Cohen 1988; 1992).

Cardiff Anomalous Perception Scale (CAPS)

First, the responses for items on the CAPS were analysed (without the 11 TLE items). The OBE group produced significantly elevated scores on these items, relative to the control group, U (25, 130) = 988.50, $p < .005$, $r = .25$ (Figure 2). Further, the OBE group also experienced these perceptions significantly more frequently than the control group, as indicated by the frequency of experiences rating scale, U (25, 130) = 1,017.50, $p < .005$, $r = .24$; Figure 2.

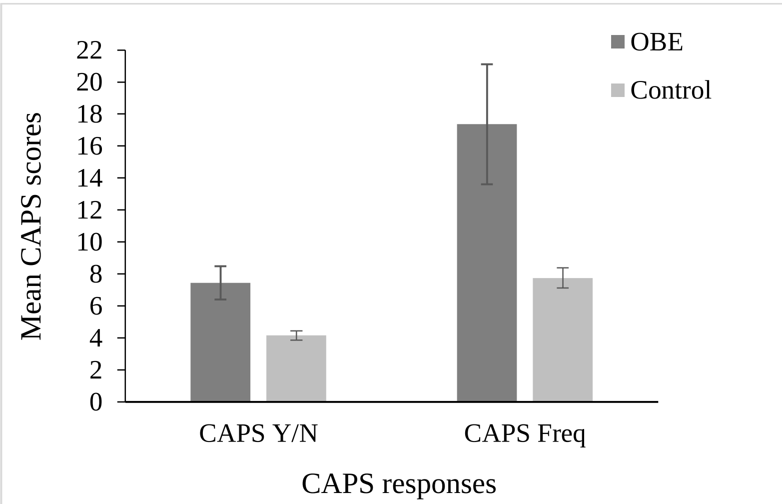

Figure 2. Average CAPS Yes / No scores (scored 1/0 for each question) on the left and average CAPS Frequency scores (scored 1 - 5) on the right for the OBE and control groups (error bars indicate ±1 SE).

TLE Factor

The Yes/No responses for the 11-item TLE factor were analysed. The OBE group had significantly higher TLE scores than the control group, *U* (25, 130) 917.00, $p < .001$, $r = .28$. Furthermore, the OBE group also reported a greater frequency of such experiences *U* (25, 130) 934.00, $p < .001$, $r = .27$ (Figure 3). These results suggest that the OBE group experienced more anomalous perceptions and more frequently, relative to the control group.

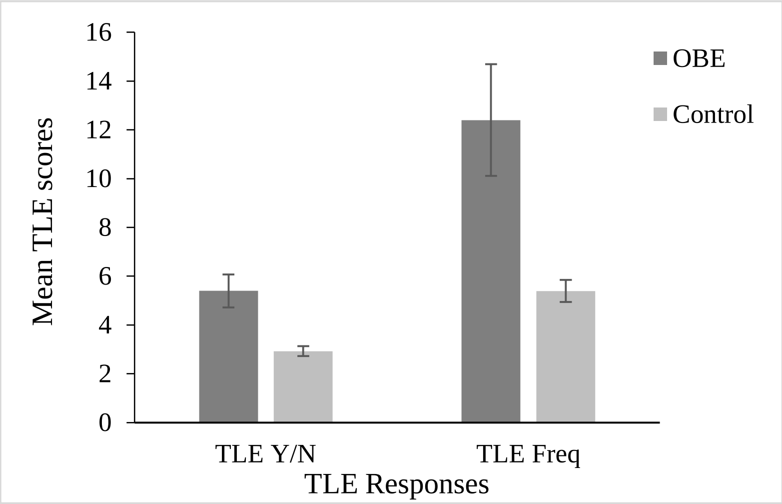

Figure 3. Average TLE Yes / No scores (scored 1/0 per question) on the left and average TLE Frequency scores (scored 1-5 per question) on the right for the OBE and control groups (error bars indicate 1 ±SE).

Cambridge Depersonalization Scale (CDS)

The OBE group had higher total CDS scores than the controls (OBE $\bar{X}$ = 45.56, controls $\bar{X}$ = 25.15; *U* (25, 130) = 770.00, $p < .001$, $r = .33$). Moreover, 16% of the OBE group obtained a score of 70 or above (compared to 2% of the control group). Next, the four factors identified from the CDS were explored individually to identify specific biases in anomalous experience. When corrected for multiple comparisons, Mann-Whitney U tests revealed that the OBE and control groups differed significantly on only two of the CDS factors; these were

ABE (Anomalous Body Experiences), *U* (25, 130) = 498.00, $p < .001$, $r = .45$; and AFS (Alienation from Surroundings), *U* (25, 130) = 842.50, $p < .001$, $r = .31$. The two remaining factors did not differ significantly, EN (Emotional Numbing), *U* (25, 130) = 1,250.00, $p = .06$, $r = .15$ and ASR (Anomalous Sensory Recall), *U* (25, 130) = 1,414.00, $p = .304$, $r = .08$ (although the EN factor was borderline; see Figure 4). Importantly, these results go against the notion that the OBE group responses were being overly influenced by a generic response bias / power of suggestion. If this were true, all four factors should have been reliably increased for the OBE group. Clearly this was not the case.

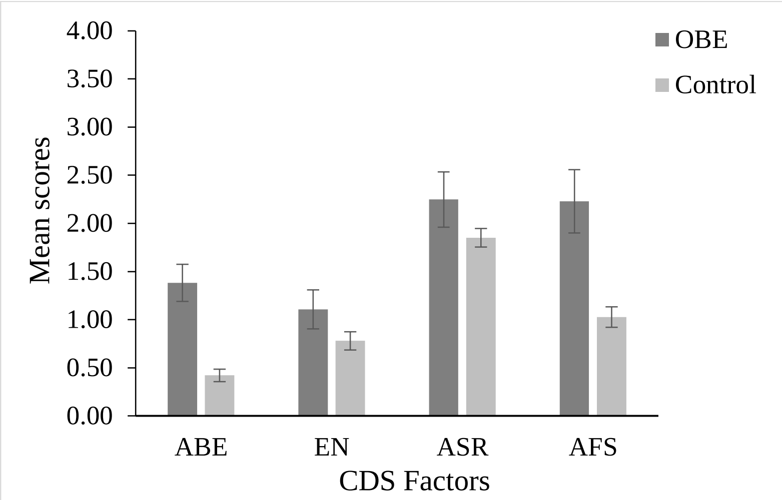

Figure 4. Average scores of each CDS Factor, for the OBE and control groups (error bars indicate ±1 SE; data corrected for unequal items on each factor).

In summary, the findings reveal that the OBE group reported significantly elevated degrees of anomalous perceptions relative to the control group on two independent questionnaire measures. These data provide additional evidence, other than just the self-declaration of being an OBEer, that the OBE group were statistically distinct from the control group in terms of predisposition to broader aberrant perceptions. Importantly, non-reliable findings in two CDS factors, demonstrated that the OBE group were not simply more suggestible or prone to response bias compared to the control group.

RHI Exit Questionnaire - control questions

The ratings for the control questions were pooled for each participant. Although negative in both cases, across the entire sample, control items were endorsed more strongly in the synchronous compared with the asynchronous brushing condition, and this difference was reliable, (Sync $\bar{X}$ = -1.21, Async $\bar{X}$ = -1.98; t (154) = 6.47, $p < .001$, d = 0.52). The control item differences were explored via a 2 (Group: OBE vs. control) × 2 (Brushing condition: synchronous vs. asynchronous) mixed ANOVA which revealed a significant main effect of Brushing, F (1, 153) = 9.05, $p < .005$, $\eta_P^2 = .056$, but no main effect of Group, F (1, 153) = .71, $p = .402$, $\eta_P^2 = .005$. There was also a significant Brushing × Group interaction, F (1, 153) = 7.43, $p < .01$, $\eta_P^2 = .046$. At first glance, the interaction may be taken as evidence for a difference in suggestibility for the OBE (hallucination) group. However, an examination of Figure 5 suggests this might not be the best way to interpret this finding. Control item ratings were the same for the OBE group in both synchronous and asynchronous conditions, and both of these corresponded to the control group ratings in the synchronous condition. In other words, none of the ratings from the OBE group were endorsed more positively than those from the synchronous condition for the control group. Instead, the interaction appears to be driven by the control group’s stronger tendency to reject the items under the asynchronous condition only.

Additional exploration using paired t-tests revealed that the control group reported significantly greater negativity in the asynchronous compared to synchronous brushing condition, t (129) = 7.20, $p < .001$, d = 0.63, whereas the OBE group showed no difference, t (24) = .15, $p = .884$, d = 0.03. In addition, independent t-tests revealed that the OBE and control group did not differ significantly in their endorsement of control items for the synchronous condition, t (153) = -.42, p = .675, d = 0.09. The difference between the groups for the asynchronous condition approached significance, t (153) = 1.88, p = .062, d = 0.41.

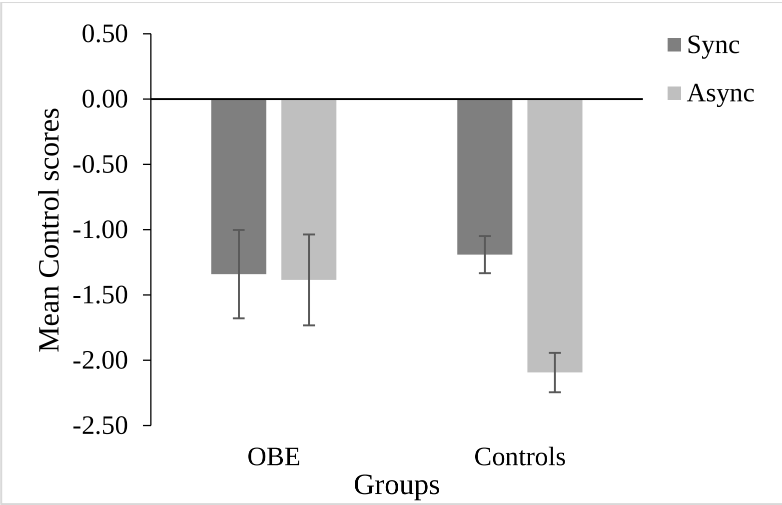

Figure 5. Mean control ratings for the OBE and control groups in synchronous and asynchronous brushing conditions (error bars indicate ±1 SE).

RHI Exit Questionnaire - Embodiment questions

The ratings for the individual embodiment / illusion questions were pooled into one score. Endorsement of the Embodiment items provides a measure of the subjective strength of the illusion. Across the whole sample, the strength of endorsement for the embodiment items was significantly stronger with synchronous than with asynchronous brushing, (Sync $\overline{X}$ = 2.72, Async $\overline{X}$ = .14: t (154) = 14.73, p < .001, d = 1.18). This is the basic RHI effect.

A 2 (Group: OBE vs. control) × 2 (Brushing condition: synchronous vs. asynchronous) mixed ANOVA revealed a significant main effect of Brushing condition, F (1, 153) = 90.21, p < .001, η_P^2 = .37, a significant main effect of Group, F (1, 153) = 6.54, p < .02, η_P^2 = .04 and a significant Brushing × Group interaction, F (1, 153) = 4.70, p < .05, η_P^2 = .03 (Figure 6). Paired t-tests confirmed that the typical RHI effect (synchronous >

asynchronous) was found in both the OBE group, t (24) = 4.61, p < .001, d = 0.92, and the control group, t (129) = 14.20, p < .001, d = 1.25. Independent t-tests revealed that for the asynchronous condition, the strength of RHI endorsement was greater for the OBE group than for the control group, t (153) = 2.79, p = .01, d = 0.64, but there was no significant group difference for the synchronous condition, t (153) = 1.51, p = .133, d = 0.33.

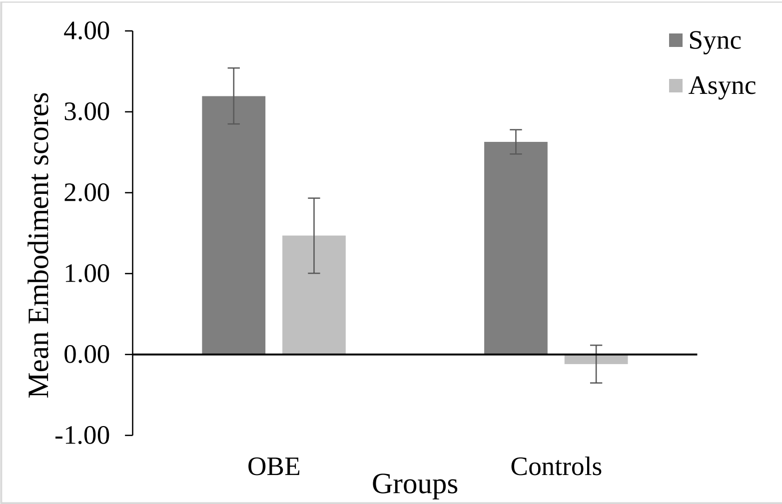

Figure 6. Mean Embodiment ratings for the OBE and control groups in synchronous and asynchronous brushing conditions (error bars indicate ±1 SE).

Findings from the Embodiment items on the RHI Exit Questionnaire suggest a distinction between synchronous and asynchronous brushing for the OBE group compared with the control group. Specifically, the OBE group reported significantly higher illusions of embodiment (relative to the control group), but only in the asynchronous condition.

Skin Conductance Responses (SCRs)

Collapsed across the whole sample, threat-SCRs were significantly larger in the synchronous brushing condition than in the asynchronous brushing condition (Sync $\overline{X}$ = 1.69, Async $\overline{X}$ = 0.93: t (154) = 6.98, p < .001, d = 0.56). The threat-related SCRs were analysed using a 2

(Group: OBE vs. control) × 2 (Brushing condition: synchronous vs. asynchronous) mixed ANOVA. This revealed significant main effects of Brushing, F (1, 153) = 11.91, p < .001, η_P^2 = .07, and Group, F (1, 153) = 6.49, p < .02, η_P^2 = .04, and a significant Brushing × Group interaction, F (1, 153) = 6.94, p = .01, η_P^2 = .04 (see Figure 7). Follow-up t-tests showed that for the control group, a typical RHI effect was observed; there were significantly larger threat-SCRs in the synchronous compared with the asynchronous brushing condition, t (129) = 7.60, p < .001, d = 0.67. However, in contrast to this, the OBE group displayed no such reliable differences, t (24) = .44, p = .665, d = 0.09. Two independent t-tests, revealed that the groups did not differ reliably in the strength of their SCRs during the synchronous condition, t (153) = .59, p = .557, d = 0.12, but the OBE group displayed significantly larger threat-SCRs in the asynchronous condition compared with controls, t (153) = 3.39, p < .001, d = 0.75 (see Figure 7).

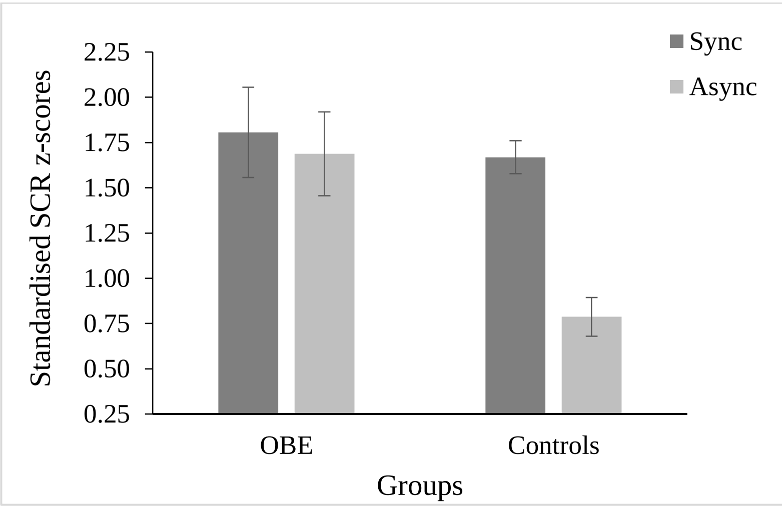

Figure 7. Standardised threat-related SCRs (z-scores) for the OBE and control groups for both synchronous and asynchronous brushing conditions. The higher the score, the larger the emotional response towards the syringe / blood giving procedure (error bars indicate ±1 SE).

Body Temperature

The body-temperature signal (degrees Celsius, °C) was divided into three epochs: (1) the baseline period before brushing began (60-seconds); (2) the brushing period itself (150-seconds) and (3) the post-threat period (60-seconds). The mean temperature was then calculated for each of the three epochs separately for the synchronous and asynchronous brushing conditions.

These data were explored via a Group (OBE vs control) × Brushing condition (synchronous vs asynchronous) x Time period (1 vs 2 vs 3) mixed ANOVA which revealed no significant main effects or interactions (all *Fs* < 2.6; all *P*s > .111; Figure 8).

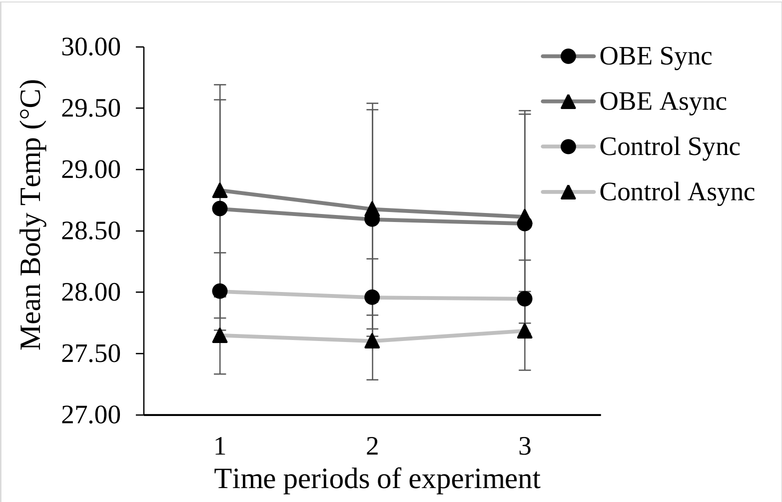

Figure 8. Mean body temperature for the OBE and control groups during synchronous and asynchronous brushing conditions as a function of trial epoch (error bars indicate ±1 SE).

General Discussion

The present study examined the role of intersensory biases in the mediation of an experimentally induced body illusion, in those predisposed to spontaneous OBEs. Subjective and objective measures of the strength of emotional / fear responses to perceived body threats were quantified under both synchronous (illusion) and asynchronous (baseline) stimulation conditions. Several new findings were revealed.

In terms of subjective measures, the illusion was rated as being stronger under synchronous brushing conditions, relative to asynchronous brushing conditions - replicating the basic RHI effect across the sample (Armel & Ramachandran, 2003; Botvinick & Cohen, 1998). In addition, and surprisingly, those prone to spontaneous OBEs rated the illusion as being significantly stronger relative to the control group, but only for the asynchronous condition. There was no reliable difference in the subjective strength of the illusion for the synchronous brushing condition between the two groups. The selective effects of perceived embodiment also go against a generic response bias account for the results of the OBE group.

Overall, standardised threat SCRs were much stronger in the synchronous condition, relative to the asynchronous condition (Armel & Ramachandran, 2003; Ehrsson et al., 2007; Guterstam et al., 2011). This is consistent with the notion that observers were, on the whole, showing greater fear responses to threats where the visual and tactile stimulation were coupled, and leading to the interpretation that the rubber-hand was part of the physical body.

What was striking about the SCR findings was the observation that there were no reliable threat differences between the brushing conditions for the OBE group. Threats delivered under the asynchronous brushing condition produced fear responses that were just as strong as those under the synchronous condition, but only for those predisposed to aberrant body experiences (OBEs). The threat was perceived just as strongly even though the visuo-tactile contingencies were uncoupled in the asynchronous condition.

In addition, not only did the OBE group display no reliable difference between the brushing conditions, but the threat SCRs were significantly stronger than the control group's SCRs in the asynchronous condition. These findings are consistent with the questionnaire data; the OBE group demonstrated increased endorsement in the asynchronous condition in terms of their threat-related SCRs and felt embodiment of the rubber-hand compared to the control group.

Finger-temperature measurements were inconclusive. There was no evidence for reliable drops in finger-temperature for the RHI illusion protocol or as a fear / anxiety response towards the threat. These null findings add to other research also failing to replicate effects for finger temperature measurements as an indicator of the RHI (Hohwy & Paton, 2010; Marasco, Kim, Colgate, Peshkin & Kuiken, 2011; Paton et al., 2012; Rohde, Wold, Karnath & Ernst, 2013). Of note, the lack of an effect here cannot simply be explained by our brushing conditions being too short in duration because previous studies have reported effects of temperature at comparable and indeed shorter durations (Hohwy & Paton, 2010; Kammers et al., 2011; Thakkar et al., 2011). As a consequence, the role of finger-temperature as a reliable indicator of body ownership in the RHI remains contentious and we do not speculate further on these specific findings.

For both the subjective strength of the illusion and the SCR data, the crucial differences between the groups were clearly present for the asynchronous brushing condition and absent for the synchronous condition. Why might this be the case? One possibility is that in the synchronous condition performance might have been at ceiling for both groups. That is, the visuo-tactile cues might have been so strong and convincing for both groups, that it masked any possible delineating factors between the groups - at least in the absence of any psychopathology or psycho-active agents. These findings are also in line with our previous study in which there were no reliable differences between those predisposed to more general anomalous body experiences and controls, on subjective ratings of the strength of the illusion (Braithwaite et al., 2014).

Overarching theoretical accounts: Some speculations.

Our findings show, for the first time, the presence of intersensory biases in those predisposed to OBEs. As well as being associated with self-reports of spontaneous occurrence of bodily hallucinations, these biases were also revealed under the experimental conditions of the RHI. The observation that the fear response was equivalent under both synchronous and asynchronous conditions was striking, even more so when it is noted that this bias was observed for non-clinical groups.

The lack of a difference in fear responses for the OBE group suggests the presence of habitual biases in the processing and integration of multisensory information in those predisposed to OBEs. Sensitivity to the temporal congruency of incoming sensory information is a fundamental principle of all multisensory integration accounts (Blanke & Metzinger, 2009; Stein & Stanford, 2008) and thus, any deviation from optimal integration will have implications for coherent embodiment and self-consciousness.

One view could be that the OBE group displayed less precision in the coding of visuo-tactile integration. This in itself could reflect a difference in their sensitivity to visual tactile asynchronies and / or the timing of integration itself – a prediction made and accounted for within both dysconnection and multisensory accounts (Braithwaite et al., 2014; Costantini et al., 2016).

However, Kapur's (2003) notion of aberrant salience does not explain why the hallucination group here did not report stronger illusions or produce stronger fear SCRs for the synchronous condition (relative to control groups). Although the overall pattern of responses (no difference between synchronous and asynchronous) might be described as aberrant, or at least non-typical, the OBE group did not produce significantly stronger SCRs for the synchronous brushing condition – suggesting that the overall level of response was well within the standard range of responses.

Predictive coding accounts of multisensory integration would argue that top-down priors are being overly aggressive or liberal in their explaining away of prediction errors to a degree beyond that required to maintain an accurate distinction of *me / my body* (interoception) relative to *my surroundings / environment* (exteroception). Ultimately, in this context predictive coding processes are asking, *"what is the probability that these signals are coming from me?"* and they are over-including things that are *me* when in fact they are not (Seth, 2009; 2013; 2014; Seth & Friston, 2016; Seth et al., 2012; Critchley et al., 2004; see also Barrett & Simmons,2015; Bechara & Naqvi, 2004; Herbert et al., 2011). The consequence of this process is an aberrant feeling of embodiment for the rubber-hand (as evidenced by exit questionnaire responses) and aberrant emotional responses (as evidenced by SCRs) under conditions even when the visuo-tactile contingencies are not tightly coupled. Ultimately this is somewhat akin to a Type I error, in that the system decides there is a significant *me* signal when in fact it should not.

Interestingly, there is wider support for the ideas being discussed here. For example, Morgan et al., (2011) showed that the strength of the RHI is augmented by ketamine, a substance known to replicate the symptoms of psychosis and produce an altered sense of self. Crucially, the effects of the illusion were enhanced in the ketamine condition (relative to a placebo condition), and this occurred even under asynchronous brushing conditions (see also; Corlett et al., 2007; 2009, for an expanded discussion in relation to predictive coding). These findings share some similarity to those of the present study in that either an administered drug (Morgan et al., 2011) or already present biases in multisensory integration (predisposition to OBEs) can lead to an increased tendency to accept ownership of an illusory limb. This occurs even when there is contradiction between sensory information (the asynchronous condition). However, the present findings are even more striking in that the difference typically observed between the brushing conditions was completely abolished for the autonomic SCR measures here, and that this occurred in sub-clinical hallucinators.

As noted in the Introduction, dysconnection accounts are not necessarily in conflict with multisensory integration or predictive coding accounts as all may co-exist with one being more of a cause (dysconnection) and the other more of a consequence (e.g., a breakdown in multisensory integration, timing, and a resultant sensory bias). We acknowledge that the overarching theoretical ideas explored here are speculative. The current study provides no direct measure or manipulation of interoceptive sensitivity as a predictor of the RHI illusion thus the specific issue of whether higher or lower sensitivity is meaningfully related to the illusion or OBEs remains unclear. Nonetheless, our study provides the first objective evidence that those predisposed to hallucinatory OBEs show habitual biases in multisensory integration as revealed by specific response patterns to the RHI. This could be due to imprecise or failures of predictions, dysconnection in multisensory networks, aberrant biases in the timing of integrative processes, or a combination of the above. Therefore, exactly how such biases manifest themselves is now an important matter for future research.

Diverse aberrant experiences

Our findings support the view that aberrant perceptions experienced as part of the OBE are distinct from those reported in DPD (Braithwaite et al., 2013c; Gabbard et al., 1982; Kessler & Braithwaite, 2016). Such observations may have important implications for the development of predictive coding accounts proposed for aberrations in self-consciousness. Previous research has shown that patients with DPD show a suppressed emotional response to aversive stimuli - which may go some way to explaining the specific types of anomalous experiences reported (Sierra, 2009; Sierra & David, 2011).

In contrast, the OBE is often described as being extremely vivid, 3-dimensional, and convincing - aspects that no doubt contribute to the often 'paranormal / spiritual' interpretations of such instances (Blackmore, 1982; Cook & Irwin, 1983; Irwin, 1985). If both forms of distorted self-consciousness / presence arise due to imprecision in top-down priors, then the notion of imprecision may occur in a number of ways or at different levels within a hierarchically organised processing system. The challenge then becomes how to formulate the predictive coding account to explain both forms of aberrant experience which while both dissociative, relate to a diverse phenomenology.

The present findings provide evidence for an increased emotional / fear response in one of the conditions which is not consistent with the general findings of suppressed emotional reactivity from DPD groups. In the asynchronous condition, the OBE group reported phenomenologically stronger illusions, and stronger SCRs in reaction to the threat (relative to the control group) - suggestive of stronger integration thus resulting in an increased emotional reaction to the threat.

If a predictive coding account is to be fostered for these types of experiences, we suggest that these findings extend the notion of imprecision in priors in important ways. For example, in terms of DPD, as discussed in recent theoretical accounts by Seth and colleagues (Seth, 2009; 2013; 2014; Seth & Friston, 2016; Seth et al., 2012), imprecise predictions (priors) may lead to a failure to correctly integrate veridical interoceptive body signals with exteroceptive information - leading to the false probabilistic interpretation that signals are *not me* when indeed they are (under-embodiment). Such imprecision is argued to cause attenuation in the sense of presence. This process thus leads to the feeling of dissociation and disconnection from the bodily self in that the body no longer feels *real* to these patients due to a remaining and aberrant degree of prediction error. Put simply, imprecision results in a weakened saliency of the egocentric sense of a feeling of *self*.

In contrast, for dissociative experiences like the OBE, imprecision may work in a different way or reflect prediction error at a different level of hierarchically organised networks important for presence and embodiment. Here, imprecise priors may lead to an over-embodiment when the false probabilistic interpretation is that *'it is me'* when in fact, it is not. By this account, accurate representations of the bodily-self typically supported by feedback from integrative processes, may become unreliable and weakened (as with DPD), whilst at the same time the observer connects more strongly to external / exocentric representations of the self or surroundings and thus feel *out of body*. A weakened or attenuated connection to sensory signals which maintain a stable and coherent sense of bodily self in space, at a given time, may unite the OBE and DPD, but in the case of the former, additional processes appear to mediate the experience of connection to an exocentric point in space. It is as yet unclear what these additional processes might be, but accounts of shared-body representations being important for action and emotion, and disorders of body-ownership have been proposed within Bayesian / predictive coding frameworks (Ishida, Suzuki, & Grandi, 2015). In addition, exocentric representations / perspective-taking mechanisms are also an important part of spatial cognition and have shown associations with the occurrence of OBEs as well as having been argued to be important on theoretical grounds (Braithwaite & Dent, 2011; Braithwaite et al., 2013c, Kessler & Braithwaite, 2016).

It is interesting to note that many contextual situations known to be conducive to the induction of an OBE, which include the use of floatation tanks, meditative techniques requiring the body remain still for prolonged periods of time, sensory deprivation, or instances of sleep paralysis, all imply situations where feedback from body signals (i.e., proprioceptive / vestibular / somatosensory) become ambiguous, unreliable and less predictable. Indeed, on a more general and anecdotal note, we have interviewed observers who reported OBEs occurring during ski jumps and parachuting - where the acceleration experienced was far more severe than that expected. Again, such instances may represent situations that make the incoming exteroceptive signals unable to be accounted for by predictive priors and hence unable to support a veridical and stable sense of self.

One potential puzzle is that given the OBE group scored high on measures of Depersonalization / Derealization (the CDS questionnaire), why didn't they show the same pattern as patients with DPD reported in the wider literature (i.e., a suppressed emotional response, not an enhanced one)? One possibility is that although the OBE group did score high on the CDS, this was only on two sub-scales of the measure - which suggests a more selective bias for those predisposed to OBEs. In addition, it may well be that some of the anomalous-body experiences associated with DPD may also occur co-morbidly with the OBE - though the presence of OBEs suggests additional processes might also be present. Evidence for this assertion is that although high CDS scores can co-occur with predisposition to OBEs, having the OBE selectively enhances performance at an exocentric perspective-taking task (Braithwaite et al., 2013c; see Kessler & Braithwaite, 2016; for a more extensive discussion).

A further possibility refers to the CDS measure itself which may lack precision in delineating the subtle differences between anomalous experiences in DPD and the OBE, and so elevated scores on the CDS may reflect ambiguity in the items on the measure with respect to the subtle differences between these dissociative experiences. The true nature of phenomenological differences between anomalous experiences of self and presence in DPD and the OBE, reliably captured by a validated measure, awaits clarification.

Future Research

Previous studies have shown that perturbations of the RHI protocol can influence the illusion. For example, altering the plausible orientation of the rubber-hand with respect to the body, altering skin tone, realism, and distance of the rubber hand to the observers body all reduce the strength of the illusion (Ehrsson et al., 2004; Guterstam et al., 2011; Haans, Ijsselsteijn & de Kort, 2008; Tsakiris & Haggard, 2005). However, on the basis of our asynchronous condition findings it is possible that OBE groups would show much smaller (or even no) reduction in responses to such perturbations. Therefore, one avenue of future research would be to examine the rate and range of circumstances under which the illusion survives for those predisposed to the OBE relative to a reduction in responses measured / reported by control groups. On a different note, Longo et al., (2008) noted sub-divisions of embodiment, arguing for a separation between the concepts of ownership, agency and location. Accordingly, it would be worth examining how these separable factors might map onto predisposition to the OBE and other related aberrant experiences in self-consciousness (i.e., depersonalization experiences, autoscopy, heautoscopy and anomalous body experiences in psychosis / schizophrenia and schizotypy) to gain a more fine grained and selective understanding of the nature of the biases in multisensory integration underlying disorders in self-consciousness, embodiment and presence. Finally, we suggest that future investigations of the RHI should screen all participants for predisposition to anomalous bodily experiences – even if such predisposition is not the main focus of the study. Not doing so leaves open the possibility that such samples include individuals prone to DPD or OBE type experiences as well as true controls with little or no predisposition at all. Based on the findings from the current study and the growing wider literature, such imprecision will have implications for the nature of the conclusions that can be drawn.

Conclusion

In the current study we have demonstrated that biases in multisensory integration are associated with a predisposition to aberrant experiences of the bodily self, even for sub-clinical hallucinators. One possibility is that those prone to OBEs make less precise predictions and over-attribute visuo-tactile contingencies as coming from themselves, leading to distinct dissociative experiences in self-consciousness (as revealed by the data in asynchronous brushing conditions). Our study goes significantly beyond previous work by demonstrating that biases, previously thought to be present only in psychopathology and psychosis, may also be present (albeit in attenuated form) in sub-clinical populations, are measurable in between hallucinatory episodes, (suggesting such aberrant multisensory integration may be a general background trait), and that biases for the OBE appear to be related to a specific form of imprecision. Finally, the observation that some hallucinators experience a strong RHI even in asynchronous conditions has important implications for all studies of the RHI as such individuals may well influence the findings of studies that have not screened for relevant participant characteristics.

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Appendix A: Rubber Hand Illusion Exit Questionnaire

Question	Measurement Item
1. It seemed as if I were feeling the touch of the paintbrush in the location where I saw the rubber hand touched.	Embodiment
2. It seemed as though the touch I felt was caused by the paintbrush touching the rubber hand.	Embodiment
3. I felt as if the rubber hand was my own.	Embodiment
4. It felt as if my (real) hand were drifting towards the rubber hand.	Control
5. It seemed as if I may have more than one hand or arm.	Control
6. It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand.	Control
7. It felt as if my hand was becoming ‘rubbery’	Control
8. It appeared (visually) as if the rubber hand were drifting towards my (real) hand	Control
9. The rubber hand began to resemble my own (real) hand, in terms of shape/size/skin tone or some other visual feature.	Embodiment
10. It felt as if the rubber hand was connected in some way to my body.	Embodiment
11. I had the feeling that if I had tried to move my hand, the rubber hand would have moved.	Embodiment
12. I felt as if my hand (being stroked with the paintbrush) was bigger than my other hand (which wasn’t being stroked).	Control
13. My (real) hand being stroked felt as if it changed in temperature i.e. became hotter or colder (please circle which)	Control
14. I couldn't feel my real hand being stroked with the paintbrush.	Control
15. How believable was the illusion?	Embodiment

Appendix B: Out-of-Body Experience Screening Questionnaire

An out-of-body experience (OBE) can be defined as *"an experience in which a person seems to perceive the world from a location outside of their physical body"*. The following questions concern the details of the OBE you believe you have experienced. We would appreciate it if you could be as honest as possible when giving your answers. All answers are completely confidential.

Initials:_______________ Age:__________ Gender:_________
Handedness:___________

1. Have you ever experienced the world from a vantage point outside of the physical body (an OBE)?

Definitely Not Definitely Yes

1 2 3 4 5 6 7

2. To what extent do you feel 'connected to / aware of' your physical body during your OBE(s)?

Definitely Not Definitely Yes

1 2 3 4 5 6 7

3. To what extent do you feel 'connected to / aware of' being located at an external (from physical self) point of view during your OBE(s)?

Definitely Not Definitely Yes

1 2 3 4 5 6 7

4. If you have experienced an OBE, has this happened more than once?

No (only once) **Yes** (more than once)

5. How frequently would you say you have experienced OBE(s)?

Don't know Very infrequently Very frequently
0 1 2 3 4 5 6 7

6. How vivid would you describe your experience(s)

Don't know	Extremely non-vivid						Extremely vivid
0	1	2	3	4	5	6	7

7. Were you relaxed and at ease at the time of your experience(s)?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

8. Was there a visual component to the experience – where you visually perceived the world from a different vantage point outside of your physical self?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

9. If your OBE(s) involved a visual component, did you see a representation of your physical body during the experience(s)?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

10. Are your OBE(s) best characterised as a strong feeling or sensation of being in a different location to the physical self with no visual component to the experience?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

11. Did you feel completely detached from your physical body during the OBE(s)?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

12. In what position was your physical body during the OBE(s)? *(circle all that apply)*

Laying down (supine) Sitting down Standing up Don’t know Not applicable

Other (please give details) __________

13. Relative to your physical body, in what position in external space did you perceive the world from? *(circle all that apply)*

Directly above　Above & in front　Above & to the side　Above & behind
Directly Below　Below & in front　Below & to the side　Below & behind
Directly to the side　Don't know　Not applicable

Other (please give details) __________

14. Were you in control of your detached self during the experience(s) so that you could 'will' yourself to move around?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

15. Approximately how long did the experience(s) last?

Don't know　Please give approximate details (in secs / mins) _________________

16. Do any of these sensations accompany your OBE(s) *(circle as many / few as apply)*

Floating　Dissociation　Tingling sensations　Ringing in the ears　Fear
Bliss　Confusion　Clarity　Falling　Intense emotional feelings　Dizziness
Nausea　Numbness　Duality of consciousness　Apprehension　Shifts in body temperature　Paralysis　Heightened senses　Suppressed / foggy senses

Other (please give details) _______________________________________

17. As an experience, was your OBE(s) convincing at the time it was occurring?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

18. Is the context(s) typically associated with your OBE(s) best described as traumatic or highly stressful?

Don't know	Definitely not						Definitely yes
0	1	2	3	4	5	6	7

Different for different instances? Yes / No

Details___________________________________

19. How long ago was your most recent experience?

Don't know Years________: Months:__________ Weeks:______ Days:________

20. Do you suffer from Migraine?

Yes (typically with aura) Yes (typically without aura)

No Aura but no migraine

21. Do you suffer from any form of epilepsy or any form of seizure?

Yes (with aura) Yes (without aura) No

Any further Details (e.g., temporal lobe / complex partial seizures):____________________

22. Have you ever had the feeling of unfamiliarity (however fleeting or sustained) for persons that are well known and familiar to you?

No **Yes**

(If **Yes** please rate the approximate frequency of occurrence below)

Don't know	Happens hardly at all					Happens all the time
0	1	2	3	4	5	6	7

23. Do you suffer from any form or neurological condition / disorder?

Yes / No (Further information)_____________

24. Were you taking any medication / substances at the time of the experience(s)

Yes / No (Further information)______________

Any further comments?.....