Deliberate and spontaneous sensations of disembodiment: capacity or flaw?

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Abstract

Introduction: Hallucinations that involve shifts in the subjectively experienced location of the self, have been termed "out-of-body experiences" (OBEs). Early psychiatric accounts cast OBEs as a specific instance of depersonalization and derealisation disorder DPD-DR. However, during feelings of alienation and lack of body realism in DPD-DR the self is experienced within the physical body. Deliberate forms of "disembodiment" enable humans to imagine another's visuo-spatial perspective (VPT), thus, if a strong relationship between deliberate and spontaneous forms of disembodiment could be revealed, then uncontrolled OBEs could be "the other side of the coin" of a uniquely human capacity.

Methods: We present a narrative review of behavioural and neuroimaging work emphasising methodological and theoretical aspects of OBE and VPT research and a potential relationship.

Results: Results regarding a direct behavioural relationship between VPT and OBE are mixed and we discuss reasons by pointing out the importance of using realistic tasks and recruiting genuine OBEers instead of general DPD-DR patients. Furthermore, we review neuroimaging evidence showing overlapping neural substrates between VPT and OBE, providing a strong argument for a relationship between the two processes.

Conclusions: We conclude that OBE should be regarded as a necessary implication of VPT ability in humans, or even as a necessary and potentially sufficient condition for the evolution of VPT.

Keywords: Out-of-body experiences; perspective taking; (dis-)embodiment; temporo-parietal junction; HOBT task

Introduction

Hallucinations which appear to involve shifts in the subjectively experienced location of the self, so-called "out-of-body experiences" (OBE), have fascinated scientists and philosophers for decades if not centuries (Metzinger, 2009) and are experienced by ~10% of the typical population across all cultures. During an OBE subjects typically experience the spontaneous and uncontrollable sensation that their self is leaving the location of their physical body and adopting another position in space that can be rotated, vis-à-vis, above the body, etc (e.g. Blackmore, 1982; Cook & Irwin, 1983; Eastman, 1962; Irwin, 1985). During the phenomenon called "heautoscopy" subjects even experience themselves as being located in two places at once, usually/often in a vis-à-vis configuration (e.g. O. Blanke & Mohr, 2005). Metzinger (2004) described OBEs as a threefold deviance from the normal self: In terms of unity of the self, location of the self, and experienced visuo-spatial perspective. The question we will address here is whether these deviances should be regarded primarily as a processing flaw or rather as a necessary implication of a uniquely human capacity.

The current and dominant view is that the OBE occurs due to a temporary disruption in multisensory integration processes, where typically stable egocentric processing has become impaired to such an extent that it can no longer represent a coherent sense of embodied 'self' (see O. Blanke & Metzinger, 2009; O. Blanke et al., 2005, for reviews). Early accounts of OBE came from psychiatry, where it was cast as a specific instance of depersonalization disorder DPD-DR (Noyes & Kletti, 1976, 1977), which would clearly define OBEs as a flaw of typical neuro-cognitive functioning. However, this view has recently been challenged due to quite striking differences in experienced vividness of OBEs compared to the rather dulled sensations accompanying DPD-DR, yet most crucially, due to the described perspective and location

shifts in OBE, which does not appear to be a defining characteristic of DPD-DR (e.g. Blackmore, 1982; Gabbard & Twemlow, 1984; Mauricio Sierra, 2009).

The subjective experience of spontaneously perceiving oneself outside ones' own body has triggered scientific interest in the OBE phenomenon itself, yet, also in its relationship to controlled forms of disembodiment (O. Blanke et al., 2005; Braithwaite & Dent, 2011). Humans are able to mentally simulate leaving the physical location of their body and imagine the self as being in a different (exocentric) location. A very practical application of this ability in social interaction appears to be the ability to imagine another's visuo-spatial perspective or, metaphorically speaking, to put oneself into the other's shoes. If a strong relationship between deliberate and spontaneous forms of disembodiment could be assumed, then uncontrolled OBEs could reflect a crucial human capacity that is accompanied by spontaneous manifestations in some individuals.

In the current position paper we will therefore explore the possibility that what is usually conceived of as a flaw of the system, i.e. spontaneous, uncontrollable OBE hallucinations, might just be "the other side of the coin" of a capacity unique and indispensable to humans. Before reaching such a conclusion, however, one would have to convincingly argue for a direct relationship between OBE and perspective taking in the first place. While it seems plausible that people experiencing spontaneous OBEs might also be more effective at deliberately imagining themselves in a different location than their physical body, only few studies have been conducted that directly compared perspective taking efficiency between people who experience OBEs ("OBEers") and people who don't ("non-OBEers") and these studies have mainly reported inconclusive findings so far (but see Braithwaite et al., 2013; Braithwaite, Samson, Apperly, Broglia, & Hulleman, 2011; Easton, Blanke, & Mohr, 2009). In the current

position paper we set out to revisit the relevant literature, explore possible explanations for inconsistent findings, and reach novel conclusions that could inform future research.

Why perspective taking should be related to OBEs

At first glance one obvious reason for inconsistent findings regarding a relationship between visuo-patial perspective taking (VPT) and OBE could be that the two are simply unrelated. However, in this Section we provide arguments for a likely connection between visuo-spatial perspective taking (VPT) and OBE that is largely based around the recently accumulating evidence that VPT is indeed a form of deliberate disembodiment. If VPT can be tied to internal representations of the body and their deliberate manipulation, then a connection to OBE and the subjective experience of spontaneous disembodiment seems likely and an in-depth search for how to unravel this relationship, and why current findings might be inconsistent, could therefore prove to be an important endeavour.

Typical perspective taking tasks in the literature require participants to make spatial (or visual) judgments from an imagined (virtual) or another person's point of view in space (see A. F. d. C. Hamilton, Kessler, & Creem-Regehr, 2014 for linking spatial and social cognition). This may involve indicating the direction of a target from the imagined perspective or viewpoint by means of pointing (Kozhevnikov & Hegarty, 2001; Kozhevnikov, Motes, Rasch, & Blajenkova, 2006; Wraga, Creem, & Proffitt, 1999), key presses for left vs. right directions (Kessler, Cao, O'Shea, & Wang, 2014; Kessler & Rutherford, 2010; Kessler & Thomson, 2010; Michelon & Zacks, 2006) verbal left vs. right localisations (Kessler & Rutherford, 2010), or indicating how an object appears from another('s) perspective (e.g. do they see a '6' or a '9'; Surtees, Apperly, & Samson, 2013). It has commonly been proposed that VPT could involve a form of self-rotation (e.g. Michelon & Zacks, 2006; Zacks & Michelon, 2005; Zacks, Vettel,

& Michelon, 2003), yet, it remained unclear how the "self" should be conceived of in this context. In computational linguistics, for instance, VPT was regarded as a purely abstract/mathematical rotation/transformation of a frame of reference (FOR) with an origin ("origo") and three axes (two horizontal axes: left/right & in front/behind: and the vertical axis: above/below) for dimensioning space (Levelt, 1996; Moratz & Tenbrink, 2006; Retz-Schmidt, 1988, for a general overview). Recent research, however, revealed that the transformed self is not merely an abstract FOR but should be conceived of as an "embodied self", in the sense that body- and posture-related representations are engaged during VPT (Kessler et al., 2014; Kessler & Rutherford, 2010; Kessler & Thomson, 2010; Kessler & Wang, 2012; Surtees et al., 2013).

Embodiment

Several previous observations had indicated that VPT could indeed be related to internal body representations. For instance, Kohzevnikov and Hegarthy (2001) reported that participants began physically turning their bodies towards the target perspective at angular disparities higher than 100°. This rather anecdotal evidence was further supported by the observation that other species like apes and ravens (Brauer, Call, & Tomasello, 2007; Bugnyar, Stöwe, & Heinrich, 2004; Call & Tomasello, 2008; Emery & Clayton, 2009) physically move around obstacles to be able to see what an experimenter or a conspecific might be able to see (especially when a promise of food was implied). This led Kessler & Thomson (2010) to hypothesise that VPT may have evolved or developed from a physical body rotation/translation into another('s) viewpoint; in other words, a real body movement could have become a mentally simulated one.

Kessler and Thomson's (2010) prediction was that VPT should be affected by manipulations of body posture and related internal representations of the body, i.e. the so-called "body schema", which has been defined by Coslett and colleagues (e.g. Coslett, Buxbaum, & Schwoebel, 2008; Medina, Jax, & Coslett, 2009) as a continuously updated, dynamic representation of body part locations based on proprioceptive and efference-copy information. Specifically, Kessler & Thomson (2010) predicted that a posture manipulation should impact on VPT in a direction-sensitive way: If the participant's body was already turned towards the target viewpoint, i.e. in the direction of the mental self-rotation (SR), then response times should be faster than when the body was turned in the opposite direction. This was exactly what was found (Kessler & Thomson, 2010) and the authors concluded that substantial parts of the body schema were involved in mental self-rotation during VPT, suggesting that the transformed self was not an abstract FOR but an embodied self. Somewhat paradoxically, this embodied process of mental self-rotation logically leads to a partially disembodied self that could be a deliberate counterpart to the OBE phenomenon described as heautoscopy (the self being perceived in two places at the same time, in the physical location of the body and in a second, out-of-body location and perspective).

The initial findings by Kessler & Thomson (2010) were subsequently replicated several times (Kessler et al., 2014; Kessler & Rutherford, 2010; Kessler & Wang, 2012; Wang, Callaghan, Gooding-Williams, McAllister, & Kessler, 2016), followed by replications and extensions from other labs. For instance, showing embodied SR being engaged when visual (in addition to spatial left/right) judgements were made from another's perspective (e.g. do they see a '6' or a '9'; Surtees et al., 2013). Other recent research has further corroborated the general notion that perspective taking is linked to internal representations of the body and its action and posture repertoire (Falconer & Mast, 2012; Tcaci Popescu & Wexler, 2012; Tversky & Hard,

2009; van Elk & Blanke, 2014): For instance, by using a physically turning chair and showing that direction congruence speeded up response times for VPT (van Elk & Blanke, 2014), or by using caloric stimulation of the vestibular organ, inducing a subjectively experienced rotation that speeded up left/right judgements when "felt" rotation was congruent with target orientation (Falconer & Mast, 2012; but see Lenggenhager, Lopez, & Blanke, 2008). In view of these recent behavioural findings it is reasonable to conclude that VPT is indeed a form of deliberate mental disembodiment, suggesting a possible link to spontaneous disembodiment during OBE.

In addition, Braithwaite et al. (2014) have recently presented evidence that those predisposed to anomalous / aberrant experiences of the self, took longer to attain the subjective impression of a body-illusion (the rubber-hand illusion, RHI), relative to a control group, and showed signs of increased autonomic arousal before the illusion was declared. Both objective measures are consistent with the notion that predisposition to aberrations in embodiment do indeed reflect latent biases in multi-sensory integration - even in sub-clinical groups. More recently, Braithwaite, Watson and Dewe (submitted) have shown that an OBE specific group showed just as strong a threat / fear response (skin conductance responses) under baseline asynchronous brushing conditions of the RHI as they did under synchronous illusion conditions. In essence this implies that the OBE group were displaying an 'over-embodiment' even when visuo-temporal contingencies were not tightly coupled. These researchers argued that the OBE group failed to suppress the level of sensory discrepancy (prediction-error) between bottom-up and top-down sources of information leading to strong embodiment under conditions when it should not occur. In contrast to the findings for an OBE group, Dewe, Watson and Braithwaite (in press) provide evidence that those predisposed to depersonalization-type experiences show a flattened emotional response to a novel task where the observers own real hand is subjected to a threatening stimulus – suggesting they do not embody as strongly even for their own body.

These new findings further support the contention that the OBE and DPD-type dissociative experiences are not the same and appear to have their basis in diverse multisensory biases.

Furthermore, Cascio et al. (2012) reported initially reduced susceptibility to- and then delayed build-up of the RHI in autistic children, which could be conceived of as a reduced susceptibility to OBEs. Autistic children have also been reported to have reduced (or developmentally delayed) social and VPT abilities in particular (A. F. D. Hamilton, Brindley, & Frith, 2009). Our previous research has further linked autistic traits in the typical population with reduced embodied processing during VPT (Kessler & Wang, 2012) and with overall reduced VPT speed (Brunye et al., 2012). Based on these considerations one may tentatively conclude that it could be a lack of multisensory integration including the body schema (Cascio et al., 2012) that might be the reason for reduced RHI in autism as a reflection of a less manipulable/flexible body schema, which in turn impacts on embodied aspects of social cognition and empathy (Kessler & Wang, 2012). Such a link between social skills and embodied processing (see also Myachykov, Scheepers, Fischer, & Kessler, 2014) is further corroborated by our previous observations that females, who on average have higher social skills than males and a reduced prevalence for autism (e.g. Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), are the more embodied and/or more effective perspective takers (Kessler et al., 2014; Kessler & Wang, 2012). Importantly, OBEs appear to be more common among females (e.g. Murray & Fox, 2005) corroborating a link with social skills. Overall these considerations further strengthen the notion of a relationship between implicit body-related processing reflected by OBE and RHI and the embodied aspects of deliberate VPT and social skills.

In the light of the findings discussed in this Section, a link between deliberate embodied transformations during VPT and spontaneous disembodiment during OBE appears plausible

and likely. In order to further strengthen the case for such a relationship we will examine the overlap in neural substrates for VPT and OBE in the following Section.

Neural correlates

Previous research in social cognitive neuroscience has implicated the temporo-parietal junction (TPJ) as a crucial area within a network generally engaged when inferring others' experiences and mental states (Arzy, Thut, Mohr, Michel, & Blanke, 2006; O. Blanke et al., 2005; Bögels, Barr, Garrod, & Kessler, 2014; Van Overwalle & Baetens, 2009; Zacks & Michelon, 2005) and particularly during high-level visuospatial perspective taking (Arzy et al., 2006; O. Blanke et al., 2005; Bögels et al., 2014). A variety of notions have been proposed for the role of TPJ involvement, e.g. suggesting a role in spatially transforming frames of reference or in simultaneous co-representation of several frames of reference (Schurz, Aichhorn, Martin, & Perner, 2013). However, based on lesion studies (G. Berlucchi & Aglioti, 1997; Giovanni Berlucchi & Aglioti, 2010; O. Blanke et al., 2005; Buxbaum, Giovannetti, & Libon, 2000; Tsakiris, Costantini, & Haggard, 2008; Wolpert, Goodbody, & Husain, 1998), areas in the parietal cortex including the TPJ have been associated with the body schema (e.g. Coslett et al., 2008; Medina et al., 2009). Thus, TPJ could be involved in body schema processing as well as in perspective taking, making it a likely candidate for an overlapping neural substrate between VPT and OBE, especially in the light of the embodied mental self-rotation results discussed in the previous Section.

However, it is also important to point out that recently the TPJ has been meaningfully segregated into several sub-parts. Recent structural and functional investigations suggest subdivisions of TPJ along an anterior-posterior and a ventral-dorsal dimension (Igelström, Webb, & Graziano, 2015; Mars et al., 2012). Converging results seem to indicate that a

posterior section of TPJ (pTPJ) is particularly linked to social processing (Carter & Huettel, 2013; Igelström et al., 2015; Mars et al., 2012) suggesting that this section in particular could be involved in VPT. Showing an overlap in pTPJ between VPT and OBE would be particularly strong evidence for overlapping neural substrates.

To address the issue directly (see Fig. 1), Wang et al (2016) employed magnetoencephalography (MEG) for measuring neural activity during the task developed by Kessler and colleagues (Kessler & Rutherford, 2010, specifically). This allowed the authors to investigate the neural correlates of embodied mental self-rotation; in other words, the neural correlate of deliberate disembodiment (Fig. 1). Indeed, the (right) pTPJ was identified as the crucial hub in a network that transformed the embodied self into another's viewpoint (Wang et al., 2016). Importantly, this role was confirmed by means of a TMS interference experiment that targeted the right pTPJ (Fig. 1). TMS pulses selectively abolished the embodied processing aspects (posture congruence effect), while non-TMS control trials exhibited typical posture congruence effects (Wang et al., 2016).

Another important piece of the puzzle is provided by Blanke and colleagues (2005) who compared the cortical source of OBEs in a patient suffering from epilepsy with the neural correlates of a simple perspective taking task (the so-called "out-of-body transformation" task, OBT) and also identified the posterior part of TPJ as the overlapping neural substrate. The OBT task presents observers with a schematic figure which is either facing the observer or facing away from the observer. Participants are instructed to try to adopt the perspective of the figure and decide on what hand (left / right) the figure is wearing a distinctive glove and bracelet. Hence the task is thought to engage perspective-taking processes when the mannequin is facing

the observer (the OBT condition), but not when observer and mannequin are aligned (baseline condition).

Specifically, Blanke et al (2005) tested a patient, who suffered from spontaneous OBE as part of her epilepsy with the OBT task while recording neural activity intracortically from the TPJ and a control site (the parahippocampal gyrus). Only recordings from the TPJ but not the control site revealed modulation by the OBT condition compared to the baseline condition and the recording site in TPJ was identified as part of the epileptogenic generator that produced the OBEs. In a further experiment the authors targeted the (right) TPJ with TMS in a sample of typical control participants and observed delayed OBT responses compared to the baseline condition, to a control site, and to a control task (mental object rotation).

Overall, TPJ and pTPJ in particular does not seem to be confined to deliberate embodiment of another(’s) viewpoint (Wang et al. 2016) but also seems to be associated with spontaneous OBE (O. Blanke et al., 2005; Braithwaite & Dent, 2010; Braithwaite, Samson, Apperly, Broglia, & Hulleman, 2010), suggesting a common correlate between OBE and perspective taking (OBT and full-blown VPT tasks) in pTPJ.

Figure 1 about here

Processes and sub-processes in TPJ related to disembodied selves

In addition to further arguing the case for a direct relationship between VPT and OBEs, the evidence described in the previous Section (O. Blanke et al., 2005; Wang et al., 2016) also allows reconciling diverging views of the role of pTPJ in perspective taking and OBE by suggesting it as the locus of convergence between implicit body representation, i.e. the body

schema (e.g. Coslett et al., 2008; Medina et al., 2009), and deliberate processes that use simulated manipulations of these representations to imagine the embodied self in another(’s) viewpoint. Wang et al (2016) proposed that pTPJ might also control the conflict that arises between a simulated self where parts of the body schema have been mentally rotated outside the current location of the body, while parts of the self and the body schema remain tied to the body’s current physical location (see also May, 2004). Note that without the latter, mental self-rotation would always result in a full-blown OBE (instead of a heautoscopy-like state). Thus, we propose that VPT and OBE could be similar yet not necessarily identical in their subjective experience of the self.

Our reasoning further implies that humans represent others primarily by generating an alternative representation of their self in the other’s circumstances (e.g. their body posture, viewpoint, perspective, socio-emotional context, etc.; e.g. Pezzulo, Iodice, Ferraina, and Kessler (2013). Accordingly, pTPJ might play a crucial role in simulating projected selves and controlling conflict with the self that remains in the physical location of the body (Wang et al., 2016).

This shift away from representing “the other” (e.g. Santiesteban, Banissy, Catmur, & Bird, 2012) towards alternative embodied selves (Wang et al., 2016) is corroborated by the role of TPJ in OBE (e.g.O. Blanke et al., 2005), where an alternative embodied self seems to be generated spontaneously, while no other is present. Furthermore, previous research by Kessler and colleagues also used an empty chair as the target viewpoint, i.e., instead of “the other”, where participants had to imagine themselves being seated, while making left/right judgments towards target objects (Kessler & Thomson, 2010, Expt. 2). Importantly, the basic mechanism of embodied mental self-rotation was also engaged in this version without avatar, as suggested

by typical effects of posture congruence and angular disparity (Kessler et al., 2014; Kessler & Rutherford, 2010; Kessler & Thomson, 2010; Kessler & Wang, 2012; Surtees et al., 2013). This further corroborates the notion of a body-schema-related conflict in TPJ between a projected self (via simulated body-schema rotation) and the self that remains physically embodied (May, 2004 proposes a similar notion, but see Kessler & Thomson, 2010, for discussion). Sometimes during OBE individuals report that they perceive their self as being embodied in two locations at the same time (so-called heautoscopy; O. Blanke & Mohr, 2005). This indicates that the proposed split of the self is subjectively possible and while it is being perceived as odd, when it is triggered uncontrollably, it may serve the crucial purpose of perspective taking, when it is engaged deliberately.

In this context it is important to distinguish between sub-processes or processing stages of a full-blown OBE, since some stages could also be present in other forms of hallucinatory / dissociative disorders - but only when all are present at once, a genuine OBE is experienced. We can assume that in order to 'get out of body' two basic processes must occur. One is a reduced saliency or stability of the typically dominant egocentric sense of self. Whether this is achieved through an active attentionally demanding processes of 'suppression' quite similar to VPT or rather through a more spontaneous 'weakening' is still unclear, yet, OBEs are typically experienced as spontaneous episodes. Secondly, a transformational and representational system, that allows for the simulation of an alternative embodied self with a different perspective (Wang et al., 2016) would need to be engaged, which could be quite similar to deliberate VPT processing. The net consequence of the co-occurrence of these two stages (self-perspective inhibition and ‘other’ perspective excitation) would be sufficient to support an OBE - where one's perceived location appears to be relocated in exocentric / environmental co-ordinates. Our current view of pTPJ functioning proposes that the 1st stage and the initiation of

the 2nd stage would depend on pTPJ, while the transformation process itself could recruit wider motor-related areas subserving the involved body schema manipulation (see Wang et al., 2016, for confirmatory findings and discussion).

There is some utility to this generic framework of processing stages. For example, simply having a reduced, diluted and weakened egocentric sense of self would not be sufficient for an OBE, but might contribute considerably to other forms of dissociative disorders in self-consciousness such as depersonalization / derealization or anxiety disorders. A mild weakening (egocentric) and activation (exocentric) may contribute to 'duality' in consciousness - occupying two points in space at the same time (heautoscopy). However, when these processes are further exaggerated they may become sufficient for a complete shift in experienced perspective (an OBE).

While behavioural evidence from VPT studies and neuroimaging results both suggest that a relationship should exist between VPT and OBE, the evidence obtained from studies that aimed at directly relating the two in terms of performance remains mixed. The following Section revisits this evidence and proposes an explanation for the mixed results that could inform future research.

Revisiting mixed findings on the link between OBE and VPT

We have reviewed behavioural and neuroimaging studies suggesting that the brain processes involved in the deliberate mental transformation of one's own body may be the same as those implicated in perspective taking (for review see Kessler & Wang, 2012; Kessler & Thomson, 2010; Kessler & Rutherford, 2010; van Elk & Blanke, 2013; Popescu & Wexler, 2012) and it was suggested that this provides a logical link to OBE. This is echoed by the relevant literature

on OBE (Arzy et al., 2006; Blackmore, 1982; Olaf Blanke & Arzy, 2005; O. Blanke et al., 2005; Braithwaite et al., 2011; Brugger, 2002; Cook & Irwin, 1983; Easton et al., 2009; Mohr, Blanke, & Brugger, 2006; Overney, Arzy, & Blanke, 2009), yet, only a handful of these studies actually explored performance on a perspective taking task in direct relation to samples reporting OBEs - and these have produced mixed results (Braithwaite et al., 2011; Easton et al., 2009).

One possible reason for the mixed results could be that most of these studies used performance on the OBT task (see previous Section; Fig. 2, far right) to explore perspective-taking in relation to OBE. Interestingly, impairments and not benefits, in the OBT conditions have been shown for participants who scored positively on a measure of perceptual aberrations related to schizotypy (Mohr et al., 2006) and more recently for those specifically reporting OBEs (Braithwaite et al., 2011; though see also Easton et al., 2009).

A major criticism of the OBT task is that using only two angular disparities of 0° and 180° does not constitute an ideal perspective taking task (Braithwaite & Dent, 2011). It is impossible to observe a monotonic increase in response times across several angular disparities that would be typical of perspective taking processes. Using only 180° angular disparity further facilitates the use of alternative, non-embodied strategies for solving the left/right task. That is, participants might employ a mental computation along the lines of "my left is their right", which would not involve embodied mental self-rotation at all. Kessler and Wang (2012) indeed reported such individual strategies at highest angular disparities (160° in this case), where response times were suddenly faster compared to smaller disparities (120°). Such a "dog-leg" pattern where RTs suddenly drop off at angular disparities around 180° allow identification of a strategy change, however, if only 180° is employed as the sole disparity, this becomes

impossible (Gardner, Brazier, Edmonds, & Gronholm, 2013; Gardner & Potts, 2011). Relatedly, the left/right judgements at 180° in the OBT task induce stimulus response incongruences that further affect processing (May & Wendt, 2013).

Another criticism of the OBT task is directly related to OBEs and highlights the lack of realism as a potential source for contra-intuitive or mixed findings (Braithwaite et al., 2013). Besides criticising the rather schematic mannequins that potentially discourage embodiment of their orientation (e.g. Kessler and colleagues always used realistic avatars and stimuli) it was also suggested that the front and back facing mannequins did not capture the perspectives that are typically experienced during OBEs, which are often reported to involve "looking down" at the physical body (Braithwaite et al., 2013). Based on this reasoning Braithwaite et al (2013) devised a novel Human-Out-of-Body-Transformation (HOBT) task (see Fig. 2, left) that used photographic images of a human body viewed at a slight angle either from above or below, thus, introducing conditions that were more comparable to those during an OBE (i.e. the "above" viewpoints).

Besides criticising the standard OBT task, Braithwaite and colleagues also emphasised the importance of considering a homogenous sample of OBEers. Early accounts for OBE came from psychiatry, where it was cast as a specific instance of depersonalization (Noyes & Kletti, 1977). Depersonalization disorder (DPD) is a syndrome which reflects a severe disruption in self-awareness that can include dissociative experiences (Mauricio Sierra & David, 2011). Patients classically describe feelings of remoteness, estrangement from the self, feeling like a robot or automaton, and a flattening of emotional affect (Mauricio Sierra, 2009; Mauricio Sierra & David, 2011). However, the assumed relationship between OBEs and DPD-DR has been questioned more recently. There are phenomenological and contextual differences (e.g.

vividness of OBEs vs. general dullness in DPD-DR) that have led to the view that OBEs and the anomalous bodily experiences reported in DPD-DR are not the same and may reflect quite different neurocognitive underpinnings (Blackmore, 1982; Gabbard & Twemlow, 1984; Gabbard, Twemlow, & Jones, 1982; Mauricio Sierra, 2009). There is further some confusion over the terminology used when describing the anomalous experiences reported by DPD-DR patients (Mauricio Sierra, Baker, Medford, & David, 2005; M Sierra & Berrios, 1997). What patients appear to be describing is that they feel their bodies are unreal and do not belong to them. There is a 'disconnection' but not a 'relocation'. So a closer examination of these accounts shows that the perceiving 'self' is still typically described as being located inside the physical self – so there is no external 'disembodiment' or shift in experiential perspective.

Thus, it appears to be extremely important to precisely determine whether the participants or individuals included in the OBE sample for a perspective taking experiment truly experience vivid OBEs including exocentric shifts of their self and perspective in contrast to rather general feelings of alienation and estrangement towards their bodies - yet importantly, without a subjective shift in the location/perspective of the self. Such a mix of genuine OBEers and patients suffering from DPD-DP may have affected previous sampling and the results in consequence. The importance of this distinction is highlighted by Braithwaite et al's (2013) findings, showing accelerated perspective taking in the newly developed HOBT task, yet only when reported hallucinations involved genuine OBEs, i.e., the self was perceived in a different location/perspective than the physical body. Therefore, only those whose hallucinations involved a perceived shift in perspective displayed processing benefits for a task that involved embodying another's viewpoint. These findings led the authors to propose a fractionation of the more typical unitary notions of 'dissociation' and that one important aspect across various neurological conditions, illnesses, etc, is whether the dissociation experienced includes

exocentric disembodiment or a reduced saliency in the egocentric sense of self (see also Dewe et al., this issue). The implication here is that being dissociated and being out-of-body are not necessarily functionally equivalent.

There are important implications here for many studies in the literature claiming that their findings are 'important' for understanding the OBE, while not actually testing or pre-screening for either OBEs or DPD-type experiences. An important development in this area, for future studies, is to explore individual differences and predisposition or resilience to diverse dissociative experiences in order to understand more fully the implications of their findings. These distinctions also have wider implications for clinical studies and other patient groups. For example, patients with schizophrenia do report a range of anomalous body experiences such as a loss of body boundaries (fusion phenomena) and passivity experiences (attenuation in agency). However, the OBE has been shown to be no more frequent in patients with schizophrenia than healthy controls (Blackmore, 1986)– and as such the OBE does not appear to be related to any additional co-morbid and underlying neural abnormalities associated with these conditions and disorders. Furthermore, the OBE is perhaps best thought of as a hallucination of embodiment and not necessarily a delusion of agency (i.e., passivity). For the many anomalous body experiences that patient groups describe, it is often the case that there is no shift in experiential perspective and hence these types of experiences, though dissociative, appear unrelated to VPT and the OBE. This crucial distinction in the phenomenological aspects of the hallucination may well have considerable utility in exploring embodiment and VPT across a range of neurological and clinical disorders.

In conclusion, a significant positive relationship between OBEers and perspective taking performance emerges if an appropriate task is used and if suitable participants are selected:

Under optimal conditions a tendency towards spontaneous disembodiment can indeed lead to faster perspective taking.

Figure 2 about here

Conclusions: Flaw or Capacity?

Humans are likely to be the only species to have mastered the skill of mentally simulating alternative realities. This includes alternative selves in different locations and perspectives than the current physical body location. In the previous Sections we have reviewed findings showing that this simulation process is based on the action and posture repertoire of the body and involves a process of deliberate manipulation of the internal body schema, most likely via the TPJ area of the brain, resulting in virtual disembodiment, where the self is perceived in another location and perspective than the physical body. As argued, this deliberate disembodiment bears a striking resemblance to the subjectively experienced disembodiment during spontaneous OBEs, further corroborated by an overlapping neural substrate in TPJ. Finally, a critical review of previous mixed findings regarding the relationship between OBE and VPT revealed that in suitable conditions genuine OBEers can indeed be the more effective perspective takers.

In sum, these findings allow for two conjectures to be proposed that differ in the degree of speculation involved. Firstly, in light of the accumulating evidence we propose that genuine OBEs should not be regarded as a flaw in the system of certain individuals but as "the other side of the coin" of full-blown perspective taking, a capacity quite unique and indispensable to

humans (for a distinction from perspective "tracking" see Wang et al. 2016; Flavell, Everett, Croft, & Flavell, 1981). While the evidence for a positive relationship between VPT and OBE is growing, better designed studies will be necessary to enhance our understanding of the relationship. Future studies should employ perspective taking tasks that are better suited than the standard OBT task for tapping into genuine exocentric perspective transformations, i.e., that engage the body schema in simulation mode. The newly developed HOBT task constitutes one such alternative (Braithwaite et al., 2013), while the paradigm developed by Kessler and colleagues allows to directly and independently test for body schema involvement (posture effect) and offers more angular disparities, which could further help eliminating alternative strategies (e.g. "my left is their right" around 180° disparity). The body posture effect together with a larger number of angular disparities would be beneficial for testing VPT in relation to OBEers, since the slopes across more than two angular disparities enable robust estimates of self-rotation speed allowing identification of fast genuine perspective takers (conforming to Kessler et al., 2014; Kessler & Wang, 2012).

These considerations argue for a positive relationship between OBE and VPT, which seems to imply that OBEs are a small price to pay for the overall ability of the species to simulate other('s) visuo-spatial perspectives. One could therefore describe OBEs at the species level as a subjectively disturbing yet necessary condition for full-blown VPT processing.

However, on a more speculative note, one could argue that OBEs are not only a necessary but a sufficient condition for the evolution of VPT. It is possible that the emergence of OBEs was the evolutionary reflection of an increasingly frail relationship between the sense of self, the body, and reality as a whole. While this may result in mental health issues in some individual cases, generally due to a "looser" grip on reality, yet, potentially also due to the frightening

nature of OBEs, it would at the same time maximise the flexibility of a species' neurocognitive system and its malleability via executive control. If the sense of self was rigidly grounded and attached to the physical body (as may well be the case in other species) then it would be much harder to "playfully" overcome this bond for simulating alternative selves and realities in the mind. It is therefore a speculative yet not improbable conjecture to propose that OBEs may have evolutionarily preceded mental simulations of alternative selves and realities, i.e. high-level perspective taking (Flavell et al., 1981). It could be that the default embodied cognitive system of our species had to reach a certain level of frailty, i.e., malleability via executive control (alongside enhanced control capacity), thus producing uncontrollable spontaneous episodes of disembodied dissociation, before the potential for mental simulation was realised and recognised by our species and subsequently transmitted culturally (e.g. Kessler et al., 2014).

Although the second conjecture is highly speculative, it may still inform and guide future research. For instance, it would motivate research into how exactly children may develop the capacity for perspective taking around the age of 4-5 years (Gzesh & Surber, 1985; A. F. D. Hamilton et al., 2009; Piaget & Inhelder, 1948). A relationship with executive functioning, for instance, has been reported (Nilsen & Graham, 2009; Qureshi, Apperly, & Samson, 2010), but could other significant predictors of performance and developmental trajectory be more basic, e.g., in form of a more malleable body schema? For instance, one could follow Braithwaite et al's (2014) pioneering work using the rubber-hand illusion to establish if the strength and vividness of this body schema illusion relates to VPT ability at a young age (in conjunction with executive functioning).

Even if our second conjecture may be dismissed as too speculative, the conclusion we suggest for the research field to consider is that genuine OBEs should not be regarded as a flaw of the system as such but as a reflection of the flexibility in terms of mental simulation ability that our species has acquired. A stronger clinical dissociation of OBEs from general DPD-DR should be a consequence of this reasoning, alongside improved future experiments that employ more suitably selected individuals as well as more appropriate tasks that are able to reveal the benefits of neurocognitive systems that are susceptible to OBEs.

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Figure Captions

Figure 1. Wang et al (2016) paradigm and findings. 1) Shows an example stimulus (originally used by Kessler & Rutherford, 2010) with an avatar (target perspective) located at 160 angular disparity (clockwise) and with a red target to the left of the occluder from the avatar's perspective. Below the stimulus the two possible body postures of the participant are shown (body turned clockwise or anticlockwise, while the head remained gazing straight ahead at the monitor). With respect to the stimulus the posture could either be congruent (body turned towards the avatar in the same direction as the assumed mental self-rotation) or incongruent (body turned away from the avatar in the opposite direction of the assumed mental self-rotation). 2) Wang et al identified the right posterior temporor-parietal junction (pTPJ) as showing the maximum overlap between embodied processing (posture congruence effect) and rotation demands (angular disparity effect). 3) In a subsequent experiment the authors targeted the pTPJ with dual pulse transcranial magnetic stimulation (dpTMS), which disrupted the posture congruence effect.

Figure 2. Stimuli in the Human-Out-of-Body-Transformation (HOBT) task (left) and the standard OBT task (far right). All example stimuli shown require a "left" response. Note that in addition to realistic photographic images of a human body, the HOBT task also varies the viewpoint of the body (from above, above and rotated, from below, below and rotated), approaching viewpoint changes (i.e., the 'above' viewpoints) often reported during OBEs.

Figure 1.

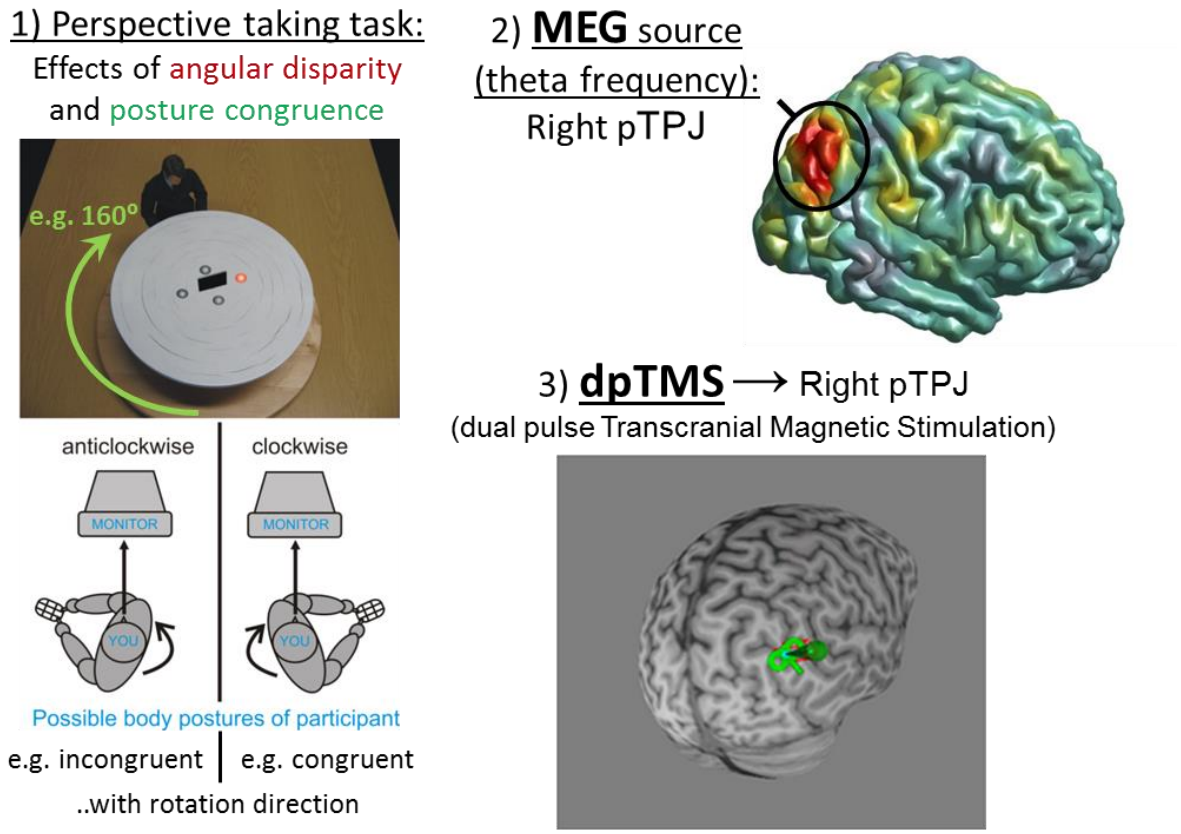
1) Perspective taking task:
Effects of angular disparity
and posture congruence
e.g. 160°
anticlockwise
clockwise
MONITOR
MONITOR
YOU
YOU
Possible body postures of participant
e.g. incongruent
e.g. congruent
..with rotation direction
2) MEG source
(theta frequency):
Right pTPJ
3) dpTMS ⟶ Right pTPJ
(dual pulse Transcranial Magnetic Stimulation)

Figure 2.