Understanding the out-of-body experience from a neuroscientific perspective

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Chapter 5

UNDERSTANDING THE OUT-OF-BODY EXPERIENCE FROM A NEUROSCIENTIFIC PERSPECTIVE

Jane E. Aspell and Olaf Blanke

ABSTRACT

The self is a multifaceted entity. Studies of the self as it relates to the body (the ‘bodily self’) have revealed three crucial aspects of bodily self-consciousness: (1) ownership (2) self-location and (3) visuo-spatial perspective. The normal bodily self includes the representation of an owned body (1), and the self is experienced as being localized within this owned body (embodied), at a definite location in space (2). Moreover, in healthy humans, the external world is experienced *from* this location, i.e. consciousness has an inherent visuo-spatial perspective (3) whose origin normally coincides with self-location. Scientists have only very recently begun to investigate the links between these different aspects and their underlying neural bases (Arzy, Seeck, Ortigue, Spinelli, & Blanke, 2006a; Aspell, Lenggenhager, & Blanke, 2009; Ehrsson, 2007; Ehrsson & Petkova, 2008; Lenggenhager, Mouthon, & Blanke, 2009; Lenggenhager, Tadi, Metzinger, & Blanke, 2007). Here we argue that the scientific understanding of the bodily self can be informed by the study of OBEs because these aspects of the self are experienced as spatially distinct from the physical body during these experiences (Blanke, Landis, Spinelli, & Seeck, 2004). How is it possible that these features of the bodily self can ‘come apart’ in an OBE? The study of what causes them to dissociate in an OBE and the examination of how these aspects of the bodily self relate to behavior and neural processing in healthy subjects will provide important insights into how these aspects of self are related: phenomenally, behaviorally and neurally.

INTRODUCTION

If you ever had the experience of lying in bed, about to fall asleep, when suddenly you had the distinct impression of floating up near the ceiling and looking back down at your body on the bed, then it is likely that you had an out-of-body experience (OBE). Here is a description of an OBE by Sylvan Muldoon, one of the first authors to describe his own OBEs (and those of others) in great detail: *"I was floating in the very air, rigidly horizontal, a few feet above the bed […] I was moving toward the ceiling, horizontal and powerless […] I managed to turn around and there […] was another 'me' lying quietly upon the bed"* (Muldoon & Carrington, 1929) (Fig.1).

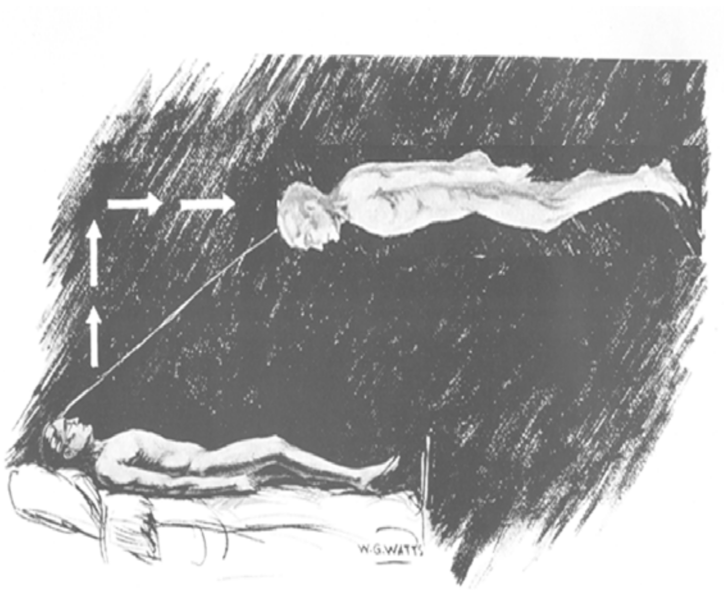


Figure 1. Depiction of the phenomenology of the OBE with elevated self-location (the light upper body), visuo-spatial perspective, and autoscopy (the body shown on the bed). [Modified version of a figure from (Muldoon & Carrington, 1929)]

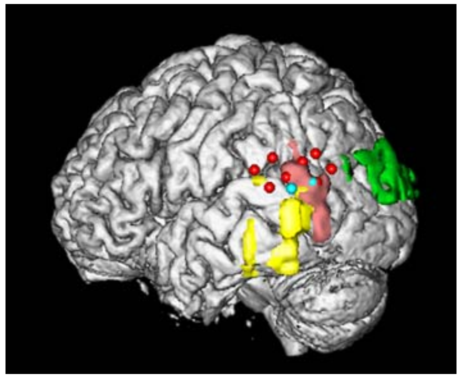
OBEs are bizarre departures from normal human experience but they are much more than a mere curiosity for science and the humanities: an OBE is effectively a breakdown of the bodily self, thus the study of this phenomenon is likely to lead to insights into the bodily foundations of self-consciousness. OBEs can be characterized by three phenomenological elements: the impression (1) that the self is localized outside one's body (disembodiment or extracorporeal self-location), (2) of seeing the world from an extracorporeal and elevated perspective, and (3) of seeing one's own body from this perspective (Blanke et al., 2004; Irwin, 1985). OBEs are striking phenomena because they challenge our everyday experience of the spatial unity of self and body,: the experience of a "real me" that 'resides' in my body and is the subject or "I" of experience and thought (Blackmore, 1982).

OBEs have been reported since time immemorial and have been estimated to occur in about 5% of the general population (Blackmore, 1982; Irwin, 1985). OBEs also occur in various medical conditions (Blanke et al., 2004), and several precipitating factors have been determined including certain types of neurological and psychiatric disease. In healthy subjects they may also occur during hypnagogic and hypnopompic hallucinations (Cheyne & Girard, 2009; Terhune, 2009). They can also occur in cases of awareness during general anesthesia, sensory deprivation, marijuana use, rapid body position changes (as during falls or car accidents) and extreme fear (Bünning & Blanke, 2005). To date, only a few neurological and neuroscientific investigations have been carried out on OBEs, probably because, in general, they occur spontaneously, are of short duration, and happen only once or twice in a lifetime

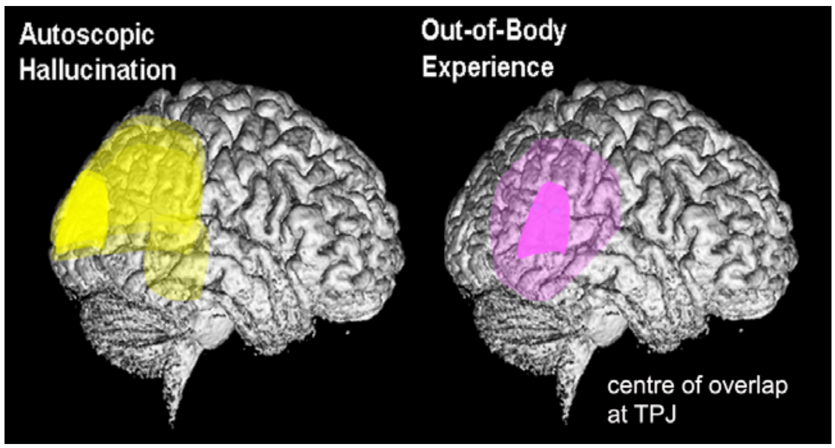
(Irwin, 1985). Investigations of neurological patients with OBEs have several advantages as OBEs in patients may occur repeatedly, sometimes in quick succession, and in rare instances can be induced by electrical stimulation of the brain (Blanke, Ortigue, Landis, & Seeck, 2002; De Ridder, Van Laere, Dupont, Menovsky, & Van de Heyning, 2007; Penfield, 1955). An individual undergoing an OBE usually experiences a dissociation between his self-location and his visuo-spatial perspective with respect to the felt and/or seen location of his own body – in other words, he perceives his own body (and the world) from a spatial location that does not coincide with the felt and seen position of his body (Blanke et al., 2004; Blanke & Mohr, 2005; Brugger, Regard, & Landis, 1997). In OBEs the origin of the visuo-spatial perspective is co-localized with self-location (as it is for healthy subjects), but the body is experienced at a different location. What causes this dissociation of unity between self and body? In this chapter we will present a description of the neurology and neuroscience of OBEs and we will argue that studying OBEs and their involved brain mechanisms provide unique opportunities for gaining a scientific understanding of the bodily self. We will also present recent findings from studies with healthy subjects which have sought to simulate, via controlled experimental manipulations, some of the aspects of the out-of-body experience, in order to understand the role of multisensory integration in OBEs and more generally, in bodily self-representation.

THE OUT-OF-BODY EXPERIENCE: ETIOLOGY AND ANATOMY

Out-of-body experiences have been reported to occur in various generalized and focal diseases of the central nervous system. OBEs associated with focal damage typically occur in cases of epilepsy, traumatic brain injury, vascular brain damage and migraine (Devinsky, Feldmann, Burrowes, & Bromfield, 1989; Kölmel, 1985; Lippman, 1953; Todd & Dewhurst, 1955). Generalized neurological etiologies include generalized epilepsy, cerebral infections (e.g. meningitis and encephalitis) and intoxication (Blanke et al., 2004; Brugger et al., 1997; Dening & Berrios, 1994; Devinsky et al., 1989; Hécaen & Ajuriaguerra, 1952; Lhermitte, 1939). OBEs of focal origin mainly implicate posterior regions of the brain and some authors have suggested a primary involvement of either the temporal or parietal lobe (Blanke et al., 2004; Devinsky et al., 1989; Hécaen & Ajuriaguerra, 1952; Todd & Dewhurst, 1955). There is no consensus on whether the left or right hemisphere is more involved in OBEs: some authors found no hemispheric predominance (Dening & Berrios, 1994; Devinsky et al., 1989; Hécaen & Ajuriaguerra, 1952) but others have suggested that the right hemisphere is more implicated (Brugger et al., 1997; Grüsser & Landis, 1991)**.** More recently, Blanke and colleagues (Blanke et al., 2004) argued for a crucial role for the cortex at the temporo-parietal junction (TPJ; Fig.2) of the right hemisphere. The crucial role of the right TPJ has been suggested because lesion overlap in several patients with OBEs centered on this region (Blanke et al., 2004; Blanke & Mohr, 2005), electrical stimulation of this region can give rise to OBE-like experiences (Blanke et al., 2002; De Ridder et al., 2007; Penfield & Erickson, 1941), and because the TPJ is activated during mental imagery of disembodied self-location (Arzy, Thut, Mohr, Michel, & Blanke, 2006b).



A.



B.

Figure 2(A). Mean lesion overlap analysis of five patients from (Blanke et al., 2004). Each color represents a different patient Mean overlap analysis is centered on the TPJ. [Modified version of a figure from (Blanke et al., 2004)] (B) - Mean lesion locations in patients with autoscopic hallucinations and out-of-body experiences. Lesion locations of eight patients with autoscopic hallucination (Blanke & Castillo, 2007) are represented by the light yellow color with the region of maximum overlap - in a dark yellow color – centering on temporo-occpital and parieto-occipital cortex. In contrast, the centre of lesion overlap for a group of patients with OBEs (Blanke & Mohr, 2005) is at the temporo-parietal junction (dark pink color). [Modified version of a figure from (Blanke & Castillo, 2007)]

Other work suggests that damage to certain subcortical structures such as the brainstem and the spinal cord may also be associated with OBEs. OBEs frequently occur during dreams (Green, 1968; Muldoon & Carrington, 1929) and it has been hypothesized that the generalized paralysis that occurs during REM-sleep dreams might be a precipitating factor of such OBEs (Bünning & Blanke, 2005). In keeping with this, other studies found that subjects with near death experiences that include OBEs commonly have sleep paralysis (Nelson, Mattingly, Lee, & Schmitt, 2006; Nelson, Mattingly, & Schmitt, 2007; see also Dieguez & Blanke, 2008). It has also been speculated that bodily mechanisms related to abnormal motor and somatosensory signals may lead to OBEs during general anesthesia (Bünning & Blanke, 2005). In general anesthesia, somatosensory and motor signals from the body are disturbed due to the application of muscle relaxants while the patient is in a state of partial awareness. The resulting conflicting condition (partial awareness combined with abnormal somatosensory and motor signals) has been proposed as one of the main patho-mechanisms for awareness during general anesthesia (Blacher, 1975; Moerman, Bonke, & Oosting, 1993; Sandin, Enlund, Samuelsson, & Lennmarken, 2000; Spitellie, Holmes, & Domino, 2002) and might also account for OBEs in these circumstances (Bünning & Blanke, 2005). Thus, disturbed somatosensory and sensorimotor signals from large parts of the body in (1) tetraplegia with severe somatosensory loss, (2) general anesthesia (Moerman et al., 1993), and (3) during sleep paralysis (Nelson et al., 2006) seem to disturb the integration of multisensory body-related information in personal space due to interference with brainstem, spinal cord and peripheral nervous system signaling information from the somatosensory and motor systems. As REM intrusions or sleep paralysis have been linked to damage or interference with brainstem mechanisms, the recent observation of an OBE following a spinal cord lesion (Overney, Arzy, & Blanke, 2009) implicates cervical spinal cord mechanisms. OBEs during general anesthesia and in patients suffering from Guillan-Barré syndrome (Cochen et al., 2005) even point to the implication of the peripheral nervous system.

MULTISENSORY DIS-INTEGRATION IN OBES

The anatomical, phenomenological and behavioral data collected from patients has led to the hypothesis that the abnormal perceptions in OBEs are due to selective deficits in integrating multisensory body-related information into a single coherent neural representation of one’s body and its position in extra-personal space (Blanke et al., 2004; Blanke & Mohr, 2005). This theory extended previous propositions made for the related phenomena of phantom limb sensations (Brugger, 2002; Brugger et al., 1997) and synesthesia (Irwin, 1985). Furthermore, the OBE deficits have been attributed to abnormal processing at the TPJ, as mentioned earlier, TPJ lesions are found in patients with OBEs (Blanke et al., 2004; Blanke & Mohr, 2005) and neuroimaging studies (Arzy et al., 2006b; Blanke et al., 2005; Vallar et al., 1999) have shown that this region plays an important role in multisensory integration, embodiment and in generating an egocentric perspective in healthy subjects (see also Bremmer, Schlack, Duhamel, Graf, & Fink, 2001; Calvert, Campbell, & Brammer, 2000; and Leube et al., 2003).

More precisely, Blanke and colleagues (Blanke et al., 2004; Blanke & Mohr, 2005) have proposed that OBEs occur when there is (1) a disintegration in own-body (personal) space because of incongruent tactile, proprioceptive and visual inputs alongside (2) a disintegration between personal and extrapersonal space due to incongruent vestibular and visual inputs. They further suggested that the phenomenological variation between different types of autoscopic phenomena - the group of illusions that affect the experience of the entire body and include OBEs, heautoscopy and autoscopic hallucination - can be explained by different levels of vestibular disturbance. Vestibular dysfunction is greatest in OBEs, which are strongly associated with feelings of floating and elevation (usually absent in autoscopic hallucinations (Blanke et al., 2004)). During autoscopic hallucinations patients see their body in extrapersonal space, but there is no disembodiment and no self-attribution (ownership) of the illusory extracorporeal body (Blanke et al., 2004; Brugger et al., 1997). The pronounced vestibular disturbance in OBEs fits with the greater implication of the TPJ in this disorder (Blanke & Mohr, 2005; Lopez, Halje, & Blanke, 2008), as the core region of vestibular cortex is located in the TPJ (Brandt & Dieterich, 1999; Fasold et al., 2002; Lobel, Kleine, Bihan, Leroy-Willig, & Berthoz, 1998).

EMPIRICAL STUDIES OF THE BODILY SELF IN HEALTHY SUBJECTS

How can the relations between the different aspects of the bodily self that are dissociated in OBEs be investigated in healthy subjects in the research laboratory? Two groups (Ehrsson, 2007; Lenggenhager et al., 2007) separately developed novel techniques to dissociate (1) the location of the physical body, (2) the location of the self (self-location), (3) the location of the origin of the visuo-spatial perspective, and (4) self-identification. Both groups utilized congruent and incongruent visual-tactile stimulation to alter these four aspects of bodily self-consciousness, thereby extending a protocol similar to that used in a related corporeal illusion - the rubber hand illusion (RHI; Botvinick & Cohen, 1998) - to the full body (see Fig. 3). The general idea in these full body studies is to mislead subjects about where they experience their body and/or self to be, and/or with what location and which body they self-identify with. To achieve this, a visual (real-time video) image of their body was presented via a head-mounted-display (HMD) that was linked to a video camera that filmed their back from behind (Fig. 3). They were thus able to see themselves from an 'outside' or third-person perspective, as though they were viewing their own body from the visuo-spatial perspective of the camera. In one study (Lenggenhager et al., 2007), subjects viewed the video image of themselves (the 'virtual body') while they were stroked on their back with a stick. This stroking was felt and also seen, and the seen stroking was either synchronous with the felt stroking (i.e. the touch was seen on the same part on the body as where it was simultaneously felt) or was asynchronous with it (when a video delay was added). The stroking manipulation thus generated either congruent (synchronous) or incongruent (asynchronous) visuo-tactile stimulation, and this has been shown to affect the perception of hand ownership and hand location in the RHI (Botvinick & Cohen, 1998). It was found that (1) the illusion of self-identification with the virtual body (i.e. global ownership, the feeling that 'the virtual body is my body') and (2) the referral of touch ('feeling the touch of the stick where I saw it touching my virtual body') were stronger when subjects were stroked synchronously than when they were stroked asynchronously (Lenggenhager et al., 2007). Self-location was also measured by passively displacing the body of the blindfolded subjects after the stroking period and then asking them to walk back to the original position. Note that, as predicted, self-location was experienced at a position that was closer to the virtual body, as if subjects were located "in front" of the position where they had been standing during the experiment. This ensemble of measures has been termed the full body illusion (FBI).

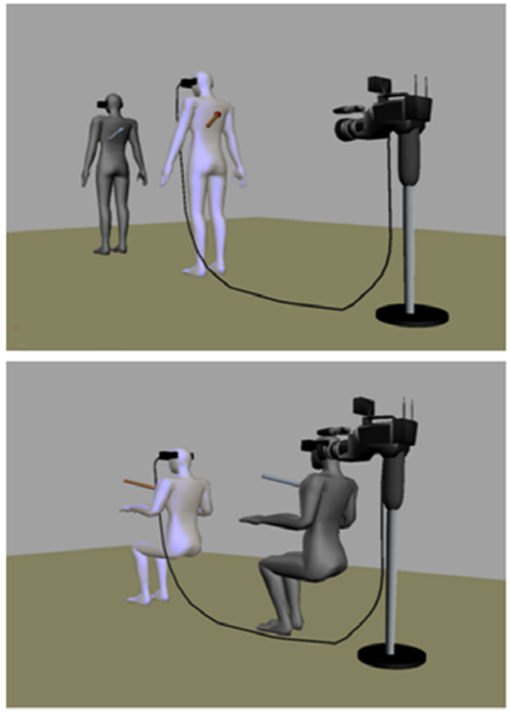


Figure 3. Experimental set-up in synchronous (back) stroking condition in (Lenggenhager et al., 2007) [top panel] and in synchronous (chest) stroking condition in (Ehrsson, 2007) [bottom panel]. In both panels the physical body of the subject is light-colored and the dark-colored body indicates the hypothesized location of the perceived body (bodily self). [Modified version of a figure from (Lenggenhager et al., 2009)]

In a related study (Ehrsson, 2007) subjects were stroked on their chest (Fig. 3). They were seated while they viewed themselves (via an HMD) from behind, and they could see a stick moving (synchronous or asynchronous with the touch) just below the camera's lens. In this case, subjects (1) felt that the stick they saw was touching their real chest, (2) self-identified with the camera's location and felt that looking at the virtual body was like viewing the body of someone else. Self-location was not quantified in this study by using the drift measure as in (Lenggenhager et al., 2007); instead, a threatening stimulus was presented to the apparent location of the origin of the visuo-spatial perspective (just below the camera). The skin conductance response to a swinging hammer (approaching the camera) was found to be higher during synchronous stroking than during asynchronous, providing implicit physiological evidence that subjects identified and localized themselves to the position of the camera.

There were several differences in bodily experiences in these two similar set-ups, and it is worth considering what may account for these. Meyer (Meyer, 2008) proposed (in a response to these studies) that in both set-ups the brain may use at least four different sources of information to generate the conscious experience of self-location and self-identification: (1) where the body is seen (2) where the world is seen from (the origin of the visuo-spatial perspective) (3) where the touch is seen to occur and (4) where the touch is felt to occur. (Although Meyer separates (1) and (3) it is not clear that these can be classified as different cues/sources of information). These four 'cues' do not correspond in the experimental set-ups (but of course in everyday life, they usually do). Meyer argued that the most important of these cues (for the conscious experience of self-location) might be where the touch is *seen* to occur (i.e. where the stroking stick is seen). He concluded this because, firstly, in neither set-up did self-location (measured by drift (Lenggenhager et al., 2007) and/or questionnaire scores (Ehrsson, 2007) exactly coincide with the location where the touch was felt (i.e. where the physical body was located). Secondly, the seen location of the virtual body biased self-location in one study (Lenggenhager et al., 2007) but not in the other (Ehrsson, 2007), and thirdly, the location of the visuo-spatial perspective corresponded to self-location in Ehrsson (2007) but not in Lenggenhager et al. (2007). However, in both cases, self-location coincided with (or more accurately, was biased towards) the location where the touch was seen to occur (i.e. the seen location of the stroking stick).

It is not very surprising that the tactile sense appears to have the weakest role in determining self-location. Touch, after all, cannot give any reliable information regarding the location of the body in external space, except via tactile contact with external surfaces. There is, however, an additional important point to consider regarding the four cues. As pointed out by Blanke et al.'s (Blanke, Metzinger, & Lenggenhager, 2008) response to (Meyer, 2008), self-location was biased towards the virtual body more when the seen stroking was synchronous with the felt stroking than when it was asynchronous. Thus, the congruence between tactile and visual input is an additional important factor in determining self-location in this context. It seems that when vision and touch are incongruent, the influence of the 'visual information about stroking' is weaker and not pre-eminent as Meyer implies. Thus in the asynchronous condition, subjects' self-location is closer to where the touch is felt (i.e. where their physical body is actually located) than it is in the synchronous condition.

It should be cautioned that, since different methods were used in these studies (Ehrsson, 2007; Lenggenhager et al., 2007) it is difficult to make meaningful, direct comparisons between them. A recent paper (Lenggenhager et al., 2009) sought to directly compare the approaches presented in these studies by using identical body positions and measures in order to quantify the conscious experience of self-identification, visuo-spatial perspective, and self-location. The authors investigated these aspects of bodily self-consciousness while subjects were tested in the supine position (as OBEs usually occur in this position (Bünning & Blanke, 2005; Green, 1968). Subjects were again fitted with an HMD that displayed a video image of their body. Their virtual body thus appeared to be located below their physical body (see Fig.4). The dependent behavioral measure for the quantification of self-location was a new one: a 'mental ball dropping' (MBD) task in which subjects had to imagine that a ball fell from their hand, and they had to press one button when they imagined that it left their grasp, and then another button when they imagined that it hit the floor. The authors proposed that MBD estimation would be greater (i.e. the time that subjects imagined it would take for the ball to reach the ground would be longer) when subjects' self-location (where they perceived their self to be) was higher from the ground than when it was closer to the ground. The prediction in this study was that, compared to asynchronous stroking, (1) synchronous back stroking would lead to a 'downward' shift in self-location (towards the virtual body, seen as though below subjects) and an increased self-identification with the virtual body and (2) synchronous chest stroking would lead to an 'upward' shift in self-location ('away' from the virtual body seen below), and a decreased self-identification with the virtual body. As predicted, self-identification with the virtual body and referral of touch to the virtual body were found to be greater during synchronous than during asynchronous *back* stroking. In contrast, during synchronous *chest* stroking there was decreased self-identification with the virtual and decreased illusory touch. The MBD time estimates (quantifying self-location) were lower for synchronous back stroking than synchronous chest stroking, suggesting that, as predicted, self-location was more biased towards the virtual body in the synchronous back stroking condition and relatively more towards the location of the visuo-spatial perspective in the synchronous chest stroking condition. This study confirmed the earlier suggestion that self-location and self identification are strongly influenced by where the stroking is seen to occur. Thus, self-location was biased towards the virtual body located as though below (or in front) when subjects were stroked on the back, and biased towards the location of the visuo-spatial perspective (behind/above the virtual body) when subjects were stroked on their chests.

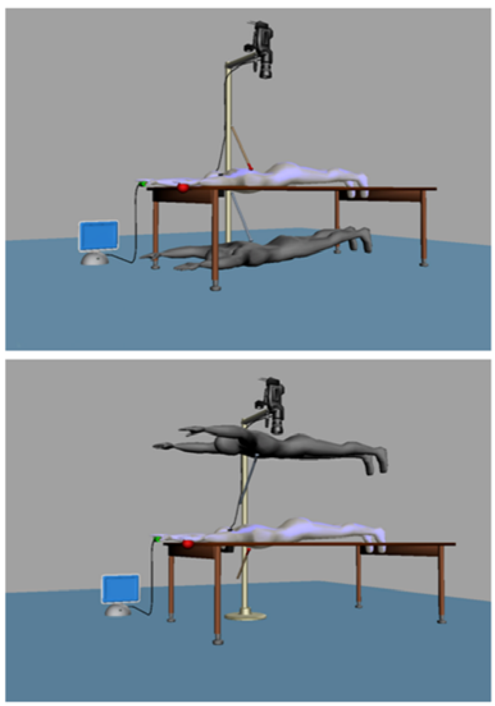


Figure 4. Experimental set-up in synchronous (back) stroking condition [top panel] and synchronous (chest) stroking condition [bottom panel] in (Lenggenhager et al., 2009). The subject was filmed from above and viewed the scene via an HMD. The light-colored body indicates where the subjects' real body was located and the dark-colored body, the hypothesized location of the perceived body (bodily self). [Modified version of a figure from (Lenggenhager et al., 2009)]

It is notable that the subjective upward drift in self-location during synchronous chest stroking was correlated with sensations of elevation and floating (as assessed by questionnaires). This suggests that when subjects adopt a relaxed prone position - synchronous visual-tactile events may interfere with vestibular processing. The importance of vestibular (otolith) input in abnormal self-location has already been demonstrated (Blanke et al., 2002; Blanke et al., 2004). Furthermore, there is evidence that vestibular cues may interfere with body and self-representation (Le Chapelain, Beis, Paysant, & Andre, 2001; Lenggenhager, Lopez, & Blanke, 2008; Sang, Jauregui-Renaud, Green, Bronstein, & Gresty, 2006). The relatively motionless prone body position of the subjects in this study would have minimized vestibular sensory updating and thus may have further contributed to the occurrence of such vestibular sensations, highlighting their potential relevance for bodily self-consciousness and OBEs (see also Lopez et al., 2008; Schwabe & Blanke, 2008).

VISUO-TACTILE INTEGRATION, OWNERSHIP AND SELF-IDENTIFICATION

What explains the importance of the synchrony of tactile and visual inputs for self-location? The role of visuo-tactile congruence has been studied for a related, though not identical phenomenon: the rubber hand illusion (RHI) (Botvinick & Cohen, 1998). In the RHI, a subject watches a fake hand that is being stroked by a paintbrush in synchrony with stroking on his own (occluded) corresponding hand. This can induce the illusion that the touch is felt in the fake hand and that the fake hand 'feels like it's my hand' (illusory ownership or self-attribution (Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004; Tsakiris & Haggard, 2005)). There is also a mislocalization of the subject's hand towards the fake hand (drift). The illusory ownership, tactile mislocalization and drift are all abolished when the stroking is asynchronous (Austen, Soto-Faraco, Enns, & Kingstone, 2004; Botvinick & Cohen, 1998; Ehrsson et al., 2004; Tsakiris & Haggard, 2005). It seems that the temporal congruence of the visual-tactile events is necessary for the change in felt arm position and ownership of the rubber hand to occur.

A recent paper on the RHI (Makin, Holmes, & Ehrsson, 2008) proposed an explanatory model that implicates the role of multimodal integration within peri-hand space. In this model, visual information about hand position is weighted more highly (especially when the hand is not moving) than information from other modalities (most likely because vision is superior at representing spatial location than proprioception). Because of the dominance of vision, the brushstrokes that are seen to occur on the rubber hand are processed as though they are occurring near the real hand, i.e. the central representation of the location of the hand is shifted towards the rubber hand (Lloyd, 2007). Given the temporal congruence of the seen and felt stroking these inputs are integrated together as a coherent multisensory event in spatial co-ordinates that are shifted towards those of the rubber hand. The authors propose that this may result in the sensation of touch being referred to the rubber hand. According to this model, it is the referral of touch that induces the feeling of ownership for the rubber hand. It should be noted that this direction of causality, although plausible in principle, has yet to be verified experimentally. Note also that the size of the drift is generally quite small compared to the actual distance between the fake and real hand.

It is possible that similar mechanisms could explain some aspects of the 'full body illusion' (FBI), but there are likely to be several important conceptual, behavioral, and neurobiological differences. The finding that in the FBI there appears to be referral of touch to a virtual body viewed as though at a distance of two meters away is in contrast to the finding that the RHI is abolished simply by changing the posture of the rubber hand to an implausible one (Tsakiris & Haggard, 2005). Viewing one's body from an external perspective at two meters distance is even less 'anatomically plausible' than a rubber hand with a misaligned posture, therefore it is perhaps surprising that the FBI occurs under such conditions. But perhaps this illustrates that the constraints operating in the FBI are in certain ways markedly different to those operating in the RHI. They appear similar in that there is a dependence of the strength of both illusions on the temporal congruence between seen and felt stroking. However, the constraints regarding the spatial relations between the location of the origin of the visuo-spatial perspective and the rubber hand are different to those between the location of the origin of the visuo-spatial perspective and the location of the seen virtual body. Moreover, in the RHI it is the hand with respect to the bodily self that is mislocalized. In the FBI the entire body (in effect, the bodily self) is mislocalized within external space. It is therefore to be expected that the spatial constraints operating in these two illusions should differ. Could it be that the 'volume' of peripersonal space (including personal space) is 'relocated' within extrapersonal space during the FBI? What exactly is the role of vestibular cues in these changes, and how do these changes relate to other aspects of the self, such as cognitive and conceptual aspects (Blanke & Metzinger, 2009)? At present we can only make very preliminary speculations.

THE MULTIMODAL FIRST- PERSON PERSPECTIVE

We have seen how the visuo-spatial perspective can be dissociated from self-location in healthy subjects (Lenggenhager et al., 2007), has this also been reported in patients with own body illusions such as OBEs and autoscopic hallucinations? A recent neurological study (De Ridder et al., 2007) showed that after a patient (with tinnitus) received electrical brain stimulation at the right TPJ he experienced an OBE during which his self-location was dissociated from his visuo-spatial perspective. The patient visually perceived the environment from his normal visuo-spatial perspective and not from a disembodied perspective, as is classically reported by people with OBEs. Furthermore, patients with heautoscopy – another type of autoscopic phenomenon - may experience two rapidly alternating visuo-spatial perspectives (and self-locations), leaving them confused about where their self is localized (Blanke et al., 2004; Brugger, Agosti, Regard, Wieser, & Landis, 1994). In such patients, the visuo-spatial perspective may sometimes even be experienced at two positions at the same time and this is often associated with feelings of bi-location: the experience of a duplicated or split self (i.e. not 'just' a split between body and self as in OBEs; see also Lopez et al., 2008). The visuo-spatial perspective is perhaps the only perspective that usually comes to mind, and yet vision is not the only modality with an inherent 'perspectivalness' (Metzinger, 2003; Metzinger, Rahul, & Bikas, 2007) – there is also an auditory perspective (and also "perspectives" based primarily on proprioceptive and motor signals; (Schwabe & Blanke, 2008)). Sounds are heard as occurring in spatial locations that are always in spatial relation to the bodily self. Again, in healthy subjects the auditory perspective and visual perspective are spatially congruent, and yet patients with heautoscopy may describe spatial incongruence between both perspectives (for further examples and discussion see (Blanke et al., 2004; Blanke & Metzinger, 2009).

CONCLUSION

Studies of OBEs have strongly influenced our scientific thinking on the nature of bodily self-consciousness. They have highlighted the fact that bodily self-consciousness can be broken down into several components, and the phenomenology of OBEs demonstrates that these components are dissociable, suggesting that they may have distinct neural bases. The investigation of OBEs has therefore inspired the first empirical studies on the global bodily self and the experimental findings so far have shown that it is also possible to dissociate the components of the bodily self - to a lesser extent - in healthy subjects. The systematic manipulation of the multisensory cues that the brain uses to create a representation of self-location and identity has begun to reveal the differing importance of these cues and the mechanisms underlying their integration. Future studies will seek to develop experimental settings in which the bodily self can be manipulated to an even greater degree in healthy subjects. In this way we may come to learn about the limits of bodily self-representation. It will also be important for future studies to characterize the neural correlates of the behavioral changes induced in the FBI paradigms. This will help us better understand the role of the TPJ as well as the roles of other cortical and subcortical brain regions in bodily self-consciousness. Patient and electrical stimulation studies, along with mental imagery studies, have implicated the TPJ, but it remains to be seen whether this area is activated in healthy subjects during full body illusions.

Will it ever be possible to experimentally induce full-blown OBEs in healthy subjects? OBEs have previously been induced using direct brain stimulation in neurological patients (Blanke et al., 2002; De Ridder et al., 2007; Penfield, 1955), but these clinical examinations can only be carried out in a highly selective patient population, and related techniques, such as transcranial magnetic stimulation do not induce similar effects (Blanke & Thut, 2007). Blackmore (Blackmore, 1982, 1984) has listed a number of behavioral procedures that may induce OBEs, and it may be interesting for future empirical research to employ some of these “induction” methods in a systematic manner in combination with scientific experiments. It is important to note that OBEs were not actually induced in the previously reported studies that used video-projection (Ehrsson, 2007; Lenggenhager et al., 2009; Lenggenhager et al., 2007), although there were measurable changes to bodily self-consciousness in these experiments. What changes to the experimental methods will be necessary to induce something even closer to an OBE? We believe that virtual reality technology, robotics, and techniques from the field of vestibular physiology will be important. The use of these techniques may also make it possible to study the effects of such procedures on other aspects of self, such as the cognitive and conceptual aspects that have typically been studied using self-reports and questionnaires, and that have been reported to be associated with the occurrence of OBEs (Blackmore, 1984; Irwin, 1985; Murray & Fox, 2005). For example, it has been shown that the occurrence of OBEs is associated with psychological absorption (engrossment in mental experience) and dissociation (Glickson, 1990; Irwin, 1985, 2000; Murray & Fox, 2005; Richards, 1991). Such findings suggest that there may be a pre-existing difference in the bodily experience of people who have had an OBE and those who have not had one. Murray and Fox (Murray & Fox, 2005) have argued that OBEs are more likely to occur in people who have a weaker than average sense of embodiment, i.e. a generalized dissociation between their sense of self and their body.

Many questions remain unanswered. Is there a spatial limit over which referral of touch to a virtual body can occur? What other modalities - apart from tactile - could be mislocalized during full body illusions? What is the role of sensorimotor contingencies? What role does interoception - the brain's representation of the heartbeat, blood pressure, the digestive system etc. - play in bodily self-consciousness? And how do the exteroceptive senses like vision and audition interact with interoception in the construction of the self and the self-centered world? Answering these questions will lead us closer to a tantalizing and important goal: a neuroscientific model of the 'I' of experience and thought and of our identity across a lifetime.

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