Alterations of Bodily Self-Consciousness: Autoscopic Phenomena and Methods for Inducing Full Body Illusions

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Abstract

The human brain must continuously integrate and prioritize incoming sensory information from multiple modalities to create a unified and cohesive representation of the body. The subjective experience of the self relies on the brain's ability to assimilate incoming sensory information proprioceptive, vestibular, tactile, and visual sensory signals. Multisensory disintegration can alter one's perceptual experience in numerous ways depending which modalities are affected. Conflicting sensory input alters perception and can cause the brain to misinterpret the body's location, identity, visual perspective, and even agency. Autoscopic phenomena are striking examples of how multisensory disintegration can alter one's sense of bodily self-consciousness. Bodily self-consciousness (BSC) is typically studied by inducing bodily illusions which redirect normal multisensory integration signals. Bodily illusions and autoscopic phenomena patients provide valuable insight into the multisensory mechanisms that enable the experience of phenomenal selfhood from the comfort of one's own body. In the future full body illusions may be a potential treatment option for individuals with body image disorders or chronic pain.

Autoscopic Phenomena: Alterations of Bodily Self-Consciousness

Consciousness is philosophically and scientifically difficult to define but consciousness arguably involves perception, feelings, awareness, and some level of cognition (Sutherland, 1995, as cited in Gazzaniga et al., 2019). All of these elements rely on the unification of sensory processing streams which ultimately result in the singular experiential ‘self’ (Faivre et al., 2015). Self-consciousness refers to a higher level of consciousness that includes one’s awareness of the mental/conceptual self and contains representations of the self. Thus, self-consciousness reflects minimal phenomenal self-hood which permits self-other differentiation.

Bodily Self-consciousness

At a basic level, bodily self-consciousness (BSC) can be described as the unification of the mental self and the bodily self. BSC relies on the non-conscious integration of multisensory signals which ultimately enable a singular experiential consciousness of a unitary self whereby the mental and bodily self are phenomenologically experienced as a singular entity (Blanke et al., 2015). BSC involves an inherently unitary experience resulting from the convergence of multimodal processing (Fairve et al., 2015).

The multisensory brain mechanisms that integrate and weigh signals from various exteroceptive and interoceptive sources enable BSC to emerge. BSC is often examined in relation to four primary elements: self-identification, self-location, visuospatial perspective, and sense of agency. Research has shown that these elements depend on different integrations of various multisensory signals (Tsakiris et al., 2010; Serino et al., 2013; Blanke et al., 2015).

Self-identification

Self-identification or body ownership refers to the conscious experience that one identifies with one’s own body or the experience of owning a body (Blanke, 2012; Gallagher, 2000). Studies are able to induce feelings of illusory ownership over a virtual or inanimate synthetic body via synchronous visual-motor or visual-tactile stimulation. Tsakiris et al. (2010)

suggest that body ownership relies on a network consisting of areas such as the superior frontal gyrus, posterior cingulate cortex, and precuneus. These researchers note the similarity between these areas and regions involved in the default network and self-referential processing.

Self-location

Self-location pertains to the spatial location in the world where one localizes the self (Blanke, 2012). Studies have shown self-location is at least partially reliant on the integration of visual-somatosensory processing (Ehrsson, 2007 as cited in Ionta et al., 2011; Lenggenhager et al., 2007).

Sense of Agency

The sense that one controls and is the author of one's own bodily actions (Kannape & Blanke, 2012) or that one is the author of one's thoughts in one's stream of consciousness (Gallagher, 2000). Some researchers assert that bodily awareness is inherently enactive and thus requires agency in order to combine the mental self and bodily self (Gallese & Sinigaglia, 2009). Gallagher (2000) details how sense of agency and sense of ownership are distinct as they pertain to one's action and cognition and that both are aspects of the minimal sense of self. He advocates that thought insertion, delusions of control, or auditory hallucinations exemplify this distinction. Some individuals who experience thought insertion as a symptom of schizophrenia also feel confused about the agency of their bodily movements (Gallagher, 2000). Additionally, some consider altered sense of agency as a form of altered BSC (Lopez, 2013) rather than an element necessary for BSC to emerge.

Visuospatial Perspective

Visuospatial perspective is the position from where one perceives the world. Usually, one experiences a consistent view of the world that is based within an egocentric view corresponding with the location of their bodily self (Blanke et al., 2005). It is often referred to as first-person perspective (Blanke, 2012). Visuospatial perspective (VSP) may also be described as the spatially located phenomenal self or the spatial point of visuo-attentional agency (Metzinger, 2005).

Pathologies that Interfere with Bodily Self-consciousness

Several anomalies in bodily experience can affect bodily self-consciousness. Bodily anomalies may only affect one aspect of BSC and the associated impairment may be localized to one limb rather than the whole bodily self. Xenomelia is a disorder which describes an individual's rejection of one or more limbs as a part of one's own body and the desire to completely remove the limb from the body (Brugger et al., 2013). Individuals with xenomelia display normal motor and sensory functioning in the limb but do not identify the limb as part of one's own body. In xenomelia there is a loss of partial bodily ownership while one's sense of agency is spared. In contrast, individuals with anarchic hand syndrome exhibit a lack of volitional control over the afflicted limb. The limb performs actions independent of the individual's intent. Interestingly, individuals with anarchic limbs still maintain a sense of bodily ownership for the rogue limb (Marcel, 2003, as cited in Tsakiris et al., 2010). In this case the sense of agency is lost for one limb while bodily ownership is preserved. Similarly, alien limb syndrome (AL) also describes the experience of one's limb performing semi-purposeful movements involuntary (Wolpe et al., 2020). However, in AL individuals report a feeling of dissociation or estrangement from the limb as well as unintentional and uncontrollable limb movement. The sense of agency for one's other limbs remains intact. AL can be inherently debilitating in that the loss of motor control of one limb may interfere with the individual's ability to perform simple tasks. This problem can be exacerbated seeing as the autonomous limb may push aside the controlled limb during a task in which the individual only intends to use only the controlled limb (Wolpe et al., 2020). AL syndrome illustrates a partial impairment of BSC whereby the individual experiences the loss of agency and loss of bodily ownership localized to one limb (Wang et al., 2021). In rare instances three or four aspects of BSC can be disrupted.

Autoscopic phenomena provide vivid examples of alterations in BSC that extend to whole-body (Brugger & Lenggenhager, 2014).

Autoscopic Phenomena

Illusory Reduplication of the Self

Autoscopic phenomena (AP) refer to a group of illusory own-body perceptions during which one perceives an illusory reduplication of one's own body in extrapersonal space (Brugger et al., 1997, as cited in Blanke, 2012; Heydrich & Blanke, 2013). Experts often reference AP as existing on a continuum based on phenomenological characteristics (Brugger et al., 1997, as cited in Anzellotti et al., 2011; Maillard et al., 2004). Brugger et al. (1997) developed the phenomenological criteria for AP classification that researchers largely use today. Three distinct types of visual[1] AP are identified: autoscopic hallucination, out-of-body experience, and heautoscopy (Brugger et al., 1997, as cited in Anzellotti et al., 2011). Further distinctions between each form of visual AP include vestibular dysfunction (Blanke et al., 2004) and the degree to which different elements of BSC are altered (Blanke et al., 2004; Heydrich & Blanke, 2013; Blondaiux et al., 2021).

Autoscopy

Autoscopy or autoscopic hallucination (AH) refers to the strictly visual hallucination of one's own body in extrapersonal space without a disturbance in BSC (Kölmel, 1985; Blanke & Mohr, 2005; Zamboni et al., 2005). The occipital lobe is significantly more involved as a lesion site in AH patients than in the other forms of AP (Blanke & Mohr, 2005). Occipital lobe damage in AH patients aligns with the relatively high incidence of hemianopia (i.e. loss of vision in one of the visual fields) observed in AH patients (Anzellotti et al., 2011). The hallucinated body is often lateralized to one side (Kölmel, 1985; Maillard et al., 2004; Blanke & Mohr, 2005). The 'double'

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[1] Other autoscopic phenomena include visual components but are much less prominent within the scientific literature than the main three types of autoscopic phenomena and are outside the scope of the present report. Other forms of autoscopic phenomena include inner heautoscopy (visual hallucination of one's internal organs in extrapersonal space), negative heautoscopy (failure to visually perceive one's own body directly or in a mirror) and feeling of a presence (heautoscopy without visual hallucination) (see Anzellotti et al., 2011)

typically appears within the patient's area of blindness or the contralateral visual field from the lesion site (Mishara, 2010; Hoepner et al., 2012). AH often involve only the reduplication of one's face or upper torso but can be vivid in color (Blanke & Mohr, 2005). Body schema disturbances (i.e. AB exhibits absence of limb or smaller or larger than normal body parts) are more rare in AH (10%) than other forms of AP (Blanke & Mohr, 2005).

Autoscopic body (AB) typically appears 2-dimensional (Heydrich & Blanke, 2013) and may appear expressionless and immobile (Blanke et al., 2004) or may mirror the movements of the individual (Zamboni et al., 2005) but does not typically display movement or actions (Blanke & Mohr, 2005). Individuals who experience AH often describe that seeing their AB is as if looking in a mirror (Maillard et al., 2004; Zamboni et al., 2005) and that the AB is always seen from a front view (i.e. facing the patient) (Blanke & Mohr, 2005). AH as a 'mirror image' hallucination is depicted in reports of the AB moving in correspondence with the patient and showing a left-right reversal (Zamboni et al., 2005). See Figure 1 below.

Figure 1. Illustration of a Patient's Autoscopic Hallucination. Note: Zamboni et al., (2005) describe that the patient, known as B.F., reported that her double always wore the same clothes as her. When an examiner drew a black circle on B.F.'s forehead the patient reported seeing something dark and round appear on the double's forehead. The same result occurred when an examiner placed his hand on the patient's shoulder. Patient B.F. is one example where the AB mirrored the movements of the patient. From "Seeing Oneself: a case of autoscopy" by G. Zamboni, C. Budriesi, & P. Nichelli, 2005, *Neurocase, 11*(3), 212-215.

AH is distinct from other forms of AP in that the AB is experienced as relatively unrealistic and AB movement is relatively uncommon (Blanke & Mohr, 2005). AH is classified as an AP because the visual hallucination is a reduplication of one's own body (Brugger & Regard, 1994, as cited by Anzellotti et al., 2011). AH is not characterized by major disturbances in BSC (Heydrich & Blanke, 2013). In the previous case study conducted by Zamboni et al., (2005) the patient was aware that her visual hallucination was completely unreal and was able to evaluate her experience critically. The researchers reported that the patient never considered the image as a double and never perceived the image as having thoughts or mental states. During AH one's self-location is stable and centered within one's physical body. The individual self-identifies with their physical body. One's sense of agency is stable within the self and visuospatial perspective remains centered within the physical body. Consequently, autoscopic hallucinations do not alter BSC (Heydrich & Blanke, 2013).

OBE

Out-of-body experiences (OBEs) consist of a visual, somatosensory, and vestibular hallucination and is often described as "a threefold deviation from the normal self" (Blanke & Arzy, 2005; Gazzaniga et al., 2019). This description refers to three phenomenological characteristics associated with OBEs. During an OBE the individual experiences an abnormal extracorporeal egocentric visuospatial perspective, a feeling of existing outside of one's body, and a visual hallucination of one's own body in extrapersonal space from the extracorporeal visuospatial perspective (Devinsky et al., 1989 as cited in Blanke et al., 2004).

Altered Elements of Bodily Self-consciousness

During an OBE the individual perceives their self-location and first-person visuospatial perspective as distanced and rotated, about two to three meters and 180° respectively, relative to the physical body's actual position (Blanke & Mohr, 2005). Patients report self-identifying with the illusory body indicating that body ownership is centered within the elevated location with the disembodied visuospatial perspective rather than the physical body (Heydrich & Blanke, 2013). During OBEs individuals describe being in control of the illusory body's actions indicating that one's sense of agency is also centered within the illusory disembodied self-perspective (Blanke & Arzy, 2005; Blanke & Mohr, 2005). During an OBE all major components of BSC are abnormal and centered within the illusory body.

OBE Phenomenology

Individuals report feeling awake during an OBE (Blanke & Mohr, 2005) or feeling as if they are 'awake in a dream' reminiscent of a lucid dream (Metzinger, 2005). Often individuals describe kinesthetic changes during the episode such as perceiving oneself as passively flying or floating upwards (Metzinger, 2005; Alvarado, 2000) followed by the feeling of being outside one's own physical body, known as disembodiment (Blanke & Mohr, 2005). In contrast to AH, OBE hallucinations and one's overall experience are reported as very realistic (Blanke & Mohr, 2005; Heydrich & Blanke, 2013). During an OBE the autoscopic body appearing in extrapersonal space appears 3-dimensional and takes on the apparent physical state of the individual prior to the episode (Metzinger, 2005). The physical state one hallucinates can be quite complex**;** Alvarado (2000) describes a police officer who experienced an OBE and hallucinated her physical body partaking in complex movement. The OBE occurred while she pursued an armed suspect on her first night on patrol. The officer reported the following account to Alvarado (2000):

> When I and three other officers stopped the vehicle and started getting to the suspect… I was afraid. I promptly went out of my body and up into the air maybe 20 feet above the scene. I remained there, extremely calm, while I watched the entire procedure - including watching myself do exactly what I had been trained to do (Alvarado, 2000).

The officer suddenly found herself in her body again after the suspect was subdued (Alvarado, 2000). Metzinger (2005) suggests that the accurate representation of the physical body during an OBE can reinforce the individual's belief that the experience was not merely a hallucination.

Most often OBEs are induced by seizure (Blanke & Mohr, 2005). Individuals often hallucinate their physical body lying motionless and asleep or seizing which can be distressing to see. Gavinsky et al. (1989) provide a case study in which a 29-year-old man reports that during his seizures:

> …He ascends to a corner of the room where he can then look down at his body, while feeling very cold and lightheaded. The [autoscopic] body below lay motionless on the floor or bed, while the 'mind above' could move around the house and see other family members in different rooms…the [autoscopic] body was dressed in the same clothes he was wearing, but curiously always had combed hair even when he knew his hair was uncombed before the onset of the episode…he had these out-of-body episodes with almost every aura and felt that they were the most distressing component of the seizures. (Devinsky et al., 1989, p. 1081, as cited by Mishara, 2010)

In another case provided by Devinsky et al. (1989) a patient recalled: "[being] up there looking at myself convulsing, and my mother and the maid were screaming… I felt so sorry for them and my body" (Devinsky et al., 1989, p. 1086, as cited by Metzinger, 2005). OBEs may be described as more negative in affect when they occur as an antecedent event to a seizure, but OBEs are often reported as positive experiences (Metzinger, 2005; Blanke & Mohr, 2005).

The alteration of BSC during an OBE is conceptualized as displaced from the physical body and placed into an illusory disembodied self-location whereby one's self-identification, sense of agency, and first-person visuospatial perspective reconfigure to accommodate the illusory self-location (Blanke et al., 2004).

Heautoscopy

Heautoscopy (HAS) refers to the multisensory illusory perception of one's own-body and the visual reduplication of one's own body in extrapersonal space (Brugger et al., 1994). In 1935 the term *Heautoskopie* was proposed to signify the seeing of the self and implicates the presence of two selves (Menninger-Lerchenthal, 1935, p. 6-7, as cited by Brugger, 2002). HAS refers to the doppelgänger phenomena as depicted in classical literature (Anzellotti et al., 2011). In one of the first neuropsychiatric reports Lhermitte (1939) asserts that HAS stems from a visual hallucination of the self as well as a disturbance of one's bodily self-consciousness (as cited in Keromnes et al., 2019). HAS is marked by a strong interference in normal BSC (Heydrich & Blanke, 2013) consisting of disruptions which alter one's self-identification, sense of agency, self-location, and visuospatial perspective (Brugger et al., 1994; Blanke & Mohr, 2005; Heydrich & Blanke, 2013).

HAS is associated with dissociation from one's own body and a strong self-identification with the AB (Devinsky et al., 1989, as cited in Heydrich & Blanke, 2013; Blanke & Mohr, 2005; Brugger, 2006). HAS patients often report experiencing multiple alternating or simultaneous visuospatial perspectives and self-locations, or the impression of being at two or more locations at the same time, known as bilocation (Blanke & Mohr, 2005). Sense of agency is also considered pathological in HAS. Often individuals report that agency seems to switch between one's physical body and the AB (Blanke & Mohr, 2005). Faivre et al. (2015) notes that patients with neurological simultagnosia (i.e. an inability to perceive more than one object at the same time) seem to display a disturbance in visual consciousness while HAS patients seem to exhibit a disruption in unitary consciousness (Faivre et al., 2015; Blanke & Mohr, 2005; Heydrich & Blanke., 2013).

Phenomenological Experience

HAS is distinguished from OBE and AH in several ways. In HAS the autoscopic body is typically described as appearing colorless, translucent, or pale (Anzellotti et al., 2011). Patients often report feeling unsure of where the self or center of consciousness is localized (Heydrich & Blanke, 2013). HAS is associated with one seeing the AB in many different views[2], feeling as if the self is split, and echopraxia in which the AB imitates one's own bodily movements (Blanke & Mohr, 2005). In autoscopic hallucinations the AB is a purely visual hallucination and when echopraxia is present the AB mirrors one's own movements (Brugger, 2002; Mishara, 2010). In contrast, in heatuscopic echopraxia the AB mimics one's own movements with the contralateral side and appears to have it's own egocentric coordinates (i.e. maintains sidedness) (Brugger, 2002) which contributes to the illusion that the AB may be the real self (Brugger, 2002; 2006; Anzellotti et al., 2011). Brugger (1994; 2002) describes a case study that illustrates the severity of confusion one can experience during an HAS episode where the patient provided the following account:

> He got up with a dizzy feeling. Turning around, he saw himself still lying in bed. He became angry about 'this guy who I knew was myself who would not get up and thus risked being late for work". He tried to wake the body in the bed first by shouting at it; then by jumping on his alter ego in the bed. The lying body showed no reaction. Only

[2] HAS patients often report seeing their autoscopic body from multiple different views such as a profile view (patient sees the side of the AB), or back view (patient sees the back of the AB).

> then did the patient begin to become puzzled about his double existence and become more and more scared by the fact that he could no longer tell which of the two he really was. Several times his bodily awareness switched from the one standing upright to the one still lying in bed; when in the lying bed mode he felt quite awake but completely paralyzed and scared by the figure of himself bending over and beating him. His only intention was to become one person again and, looking out of the window (from where he could still see his body lying in bed), he suddenly decided to jump out 'in order to stop the intolerable feeling of being divided in two'. At the same time, he hoped that 'this really desperate action would frighten the one in bed and thus urge him to merge with me again'. The next thing he remembers is waking up in pain in the hospital (Brugger et al., 1994)

In this case the patient's visuospatial perspective, self-location, self-identification, and sense of agency all alternated between his physical body and the AB. Later, Brugger (2002) notes that the patient's doppelgänger was right-handed, as was the patient when he was in the standing 'attacker' location.

Individuals who experience HAS describe a close emotional affinity with the AB and usually report intense negative emotions just before and/or during the episode (Brugger et al., 1994; Blanke et al., 2004; Heydrich & Blanke, 2013). No statistical evidence supports an association between HAS as a harbinger of death or suicide (Anzellotti et al., 2011). Although several studies acknowledge an anecdotal connection within the study's patient[3] (Kölmel, 1985;

[3] The patient in Anzellotti et al. (2011) study attempted suicide twice during the course of the study. The patient reported that the AB acted out the patient's own activities and that she had access to the AB's thoughts, words, and actions, and experienced bilocation. The patient reported these terrifying experiences were the reason for her suicide attempts. In addition to the primary patient case Brugger et

Brugger et al., 2006; Anzellotti et al., 2011; Brugger et al., 1994). HAS patients often report the AB partaking in autonomous actions, sharing thoughts, and speaking (Blanke & Mohr, 2005; Anzellotti et al., 2011). Some individuals report that the AB is supportive and comforting but most appear to display aggressive or offensive behaviors (Brugger, 2002). Blanke et al. (2004) describe a case in which the patient reported to experience a “slow rotation into a horizontal position” while in his hospital bed and an intense fear that his nurse was going to poison him. Suddenly he saw his younger self in different clothing standing behind the nurse. The patient experienced an impression of being examined by a doctor which was interrupted when he saw his AB begin to ‘physically’ fight the nurse and physician (Blanke et al., 2004).

This account describes one example of an illusory vestibular sensation during an HAS episode. HAS is associated with more variable and moderate vestibular dysfunction as well as abnormal interoceptive processing (Heydrich & Blanke, 2013). This case report from Brugger et al. (2004) also illustrates ways in which an AB may appear different from the physical body in several ways. Patients have reported their AB as wearing different clothes (Brugger, 2002), being a different age (Blanke et al., 2004), and being a different gender from themselves (Brugger et al., 2006). Some patients report seeing multiple ABs known as polyopic heautoscopy, the multiplication of the body and self (Brugger et al., 2006). Brugger et al., (2006) present an interesting case report of a who experienced a “family” of heautoscopic doubles. The patient (P.H.) was a 41-year-old man who described feeling as if he was split in three, his left half felt normal, his right half felt physically and emotionally detached, and he saw a man nearby to his right who he felt he was “sharing the same soul” with (Brugger et al., 2006). P.H. described five AB doubles with no resemblance to himself or his actual family’s appearance. The ABs all appeared to P.H.’s right side. When he tried to look at the closest man AB’s face

al. (1994) also reviewed several cases including one in which a man simultaneously *saw* himself falling and *felt* himself falling off a mountain, the man was found dead four years later at the bottom of a mountain.

the man's head would always turn to the right in unison with P.H.'s head. Beyond the man, P.H. saw a woman about 50 years-old two meters away, 4 meters away he saw two young women who appeared to be around 20 years-old (Brugger et al., 2006). Further still, P.H. could see a boy about 20 meters away. P.H. stated that he knew immediately that they were connected to one another as a "family". P.H. had immediately felt a close attachment with the man which continued as this sense of belongingness grew to include the woman ("lady") and then the young women ("daughters"). Although, interestingly PH never felt as emotionally connected with the "daughters" and even less connected with the boy ("son"). See Figure 2 below.

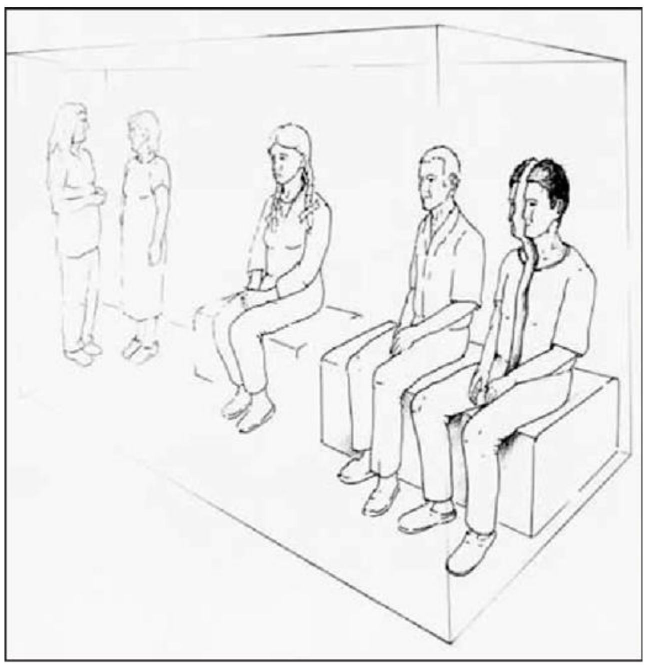

Figure 2. Artist's Illustration of Four of P.H.'s Polyopic "Doubles" Based on P.H.'s Description. Note: The autoscopic bodies displayed more autonomous movement the further away they were from P.H. From "Polyopic Heautoscopy: case report and review of the literature" by P. Brugger, O. Blanke, M. Regard, D.T. Bradford, & T. Landis, 2006, *Cortex, 42*(5), 666-674.

All of the ABs displayed echopraxia, especially with the “man” and “lady” who were closest in proximity to PH. The movements of the “man” and “lady” appeared to be synchronized with PH’s own movements. Interestingly, the “daughters'' and “son” exhibited seemingly autonomous actions as well as echopraxia. Brugger et al., (2006) shared PH’s recount:

> …when I looked to the right, so did all the others. Exceptionally, however, the girls, who were commonly talking to one another, would look towards me waving their hands as if inviting me to join their world. [...] Naturally, I could not see the persons any longer on closing my eyes, but the feeling remained that pieces of myself were located in precisely those places I knew the persons were standing (Brugger et al., 2006).

PH’s description provides a classic example of the strong sense of self-identification HAS patients feel towards the ABs. Soon PH reported feeling that each “family” member was a part of him and this coincided with the ABs starting to speak to him by sharing thoughts. PH stated that he only received positive and comforting thoughts from the ABs and that the topic of communication often revolved around death. PH recalled the ABs reassuring him “again and again…[that] I had such a lovely wife, that should I die, she would find a new partner in no time” (Brugger et al., 2006). PH’s HAS was arguably caused by a large lesion in his left insula which expanded into his fronto-temporal cortex, as indicated by a computed tomography (CT) scan. After the tumor removal operation the AB’s remained present for two days until disappearing.[4]

The case of patient PH is remarkable in several ways. This case is the first report of “heterosexual” HAS (i.e. an AB that is not the same sex as the patient) which has previously only been reported in psychiatric disorders (Letailleur et al., 1958, as cited by Brugger et al., 2006). Additionally, PH appears to be the only recorded case of polyopic HAS where the double’s consisted of both same sex and and other sex in respect to the patient (Brugger et al.,

[4] Interestingly, PH rejected a post-op examination in favor of spending more time with his loved ones “in order to prepare himself for dying”, Brugger et al., (2006) note that PH passed away 16 months after having this operation.

2006). Another interesting aspect in this case is the spatial-psychological relationship between PH and the doubles. The patient felt more intense self-identification with the ABs that were spatially closer to him (Brugger et al., 2006). The closer ABs also displayed the strongest echopraxia. The two ABs that were 4 meters away only rarely mimicked PH's movements. The furthest AB was 20 meters away and never imitated PH's movements (Brugger et al., 2006).

Heydrich & Blanke (2013) propose that the alterations of BSC associated with HAS are a result of the disintegration of emotional and interoceptive signals in the posterior insula with visual-somatosensory signals which leads to abnormal affective somatosensory processing thereby causing a disturbance in self-other discrimination. Interestingly, Brugger et al., (2006) speculated that patient PH's tumor originated in his posterior insula.

Etiologies and Contributing Factors

APs are very unique experiences in many ways. An AP episode may last seconds, minutes, hours, or occur longer term (Brugger et al., 2006). Note, patients report that the AB cannot be seen when one's eyes are closed (Brugger et al., 2006). AP can occur within a range of neurological and psychiatric disorders including epilepsy, brain trauma, tumors, schizophrenia, and depression (Dening & Berrios, 1994). Dening & Berrios (1994) examined 53 cases of AP published in the medical literature in what the researchers reported was the first systematic review. This review found almost 60% of patients with AP had a neurological disorder, most commonly epilepsy[5] (32%). Neurological disease was correlated with unilateral presence of the AB and impaired consciousness during AP episodes. They also found that psychiatric disorder was associated with non-lateralized AB. Depression and schizophrenia were the most common psychiatric disorders in this sample (Dening & Berrios, 1994). Unfortunately, this review did not distinguish between the different types of AP. A relatively

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[5] Epilepsy cases included one of a patient with an abnormal electroencephalogram (ECG) and a patient with post-ictal austoscopy resulting from electroconvulsive therapy.

more recent neurological review corroborates these previous findings. Blanke & Mohr (2005) indicate that within their sample the primary diagnosis for all three types of AP was epileptic seizure. Other etiologies were distributed relatively equally among each type of AP. These diagnoses included vascular stroke, tumor, and arteriovenous malformation (Blanke & Mohr, 2005).

Autoscopic Hallucination

Within the sample collected by Blanke & Mohr (2005) 70% of AH patients had a prior epilepsy diagnosis. Lesions affecting the temporoparietal junction are the most common lesion site in all AP patients but lesions within the occipital lobe are significantly more common in AH patients than in OBE and HAS patients (Blanke & Mohr, 2005). Blanke & Mohr (2005) found co-occurring hemianopia in 55% of the collected AH patient sample. The exact interaction between these two visual deficits is not completely clear. Blanke & Mohr (2005) speculate that both AH and hemianopia likely result from the same cortical damage. Most likely both are caused by a lesion or impaired connectivity in the extrastriate body area (Blanke & Mohr, 2005). Vestibular disturbances do not occur or are extremely mild and rare in AH patients (Heydrich & Blanke, 2013).

Heautoscopy

The anecdotal connection between HAS, depression, and death is abundant in literature as well as patient reports (Brugger et al., 1994). Seizure-related HAS is even more so associated with intense emotional distress (Brugger et al., 1994). Most of the understanding of HAS associated etiologies comes from studies describing single or a handful of case studies (Brugger et al., 1994; Brugger, 2002), studies that generalized all forms of visual AP together (e.g. Dening & Berrios, 1994), and/or focused on one neurological disorder such as focal epilepsy (e.g. Hoepner et al., 2012). Brugger et al. (2006) examined etiologies within 14 polyopic HAS patient cases. This review suggests that in polyopic HAS 64% of cases are neurological and 29% are related to psychiatric disorders[6]. The vast majority (88%) of cases of neurological origin were focal and due to either traumatic lesion, epilepsy or vascular infarction. Lesion sites did not show any hemispheric dominance (Brugger et al., 2006). Tumors have also been documented in HAS patients (Brugger et al., 2006).

Out-of-Body Experiences

In a relatively recent review Blanke et al. (2016) support previous estimates of about 5% to perhaps 10% of the general population having experienced an OBE (Blackmore, 1994, as cited in Blank et al., 2016) . Other researchers have estimated this number may be anywhere from 8-34% however Blank et al. (2016) clarify that these questionnaire studies are typically conducted via phone, mail, or in-person subject interviews. Additionally, the majority of these studies have a limited demographic sample[7] and the descriptive definition of OBE may change between surveys. Two of the requisite aspects of OBEs that are used in scientific and medical research (i.e. seeing one's own body in extrapersonal space and altered visuospatial perspective) are not necessarily included in questionnaires (Blanke et al., 2016). Accordingly, Blank et al. (2016) conclude that rates over 10% are overestimates. It is quite rare for any individual to experience more than one or two OBEs even if the episodes are pathological (Blanke et al., 2016).

OBEs are most commonly observed in patients with epilepsy and to a much lesser extent patients with migraine (Blanke & Arzy, 2005; Blanke et al., 2016). OBEs seem to be more rare in psychiatric patients relative to the other forms of AP. Although, OBEs may be more common in individuals with post-traumatic stress disorder and schizophrenia than the data

[6] Brugger et al. (2006) identified one case (7%) of polyopic HAS that occurred postpartum after a traumatic birth.
[7] OBE incidence studies predominantly survey young white adults in college psychology departments (Blanke et al., 2016).

currently shows[8] (Blanke et al., 2016). OBEs are also reported to occur when one is in a supine body position during rapid changes in acceleration or deceleration of the body. OBEs have been more commonly observed during car accidents, in mountain climbers who experience sudden substantial falls, and even in pilots (see Blanke et al., 2016 for a review). These observations align with the proposal of strong gravitational and otolithic vestibular dysfunctions in OBE patients (Heydrich & Blanke., 2013). OBEs are also associated with near-death experiences, general anesthesia, and drugs (Blanke et al., 2016). Although, as previously discussed OBE can occur during heightened or extreme physical states such as training for a marathon (Alvarado, 2000).

Neurological Associations

Mapping Bodily Self-consciousness

Studies employ functional neuroimaging, multisensory body illusions, and lesion mapping techniques to examine key brain areas involved in BSC. A large amount of this research focuses on the temporoparietal junction (TPJ) as this area has been shown to be vitally involved in the integration of tactile, visual, vestibular, and proprioceptive signals which collectively provide information about the orientation of one's body relative to the environment (Blanke et al., 2002; Blanke & Arzy, 2005; Lopez et al., 2008; Ionta et al., 2011; Serino et al., 2013).

Self-location & Visuospatial Perspective

Changes in self-location are typically expressed as changes in perceived drift or perspective. Changes in drift are associated with visuo-tactile conflicts whereas changes in perspective occur due to visuo-vestibular disintegrations (Lenggenhager et al., 2007; Pfieffer et al., 2013). Additionally, changes in self-location are reflected in the magnitude of TPJ activity

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[8] Blanke et al. (2016) present dated data showing low incidence of OBE in psychiatric patients (Hecaen & Green, 1957, Zutt, 1953, Blackmore, 1986, and Rohricht & Priebe, 1997, as cited by Blanke et al. 2016). Some more recent studies indicate OBEs may be correlated with schizophrenia-related symptoms (i.e. schizotypy personality) and more common in individuals with PTSD (see Blanke et al., 2016).

(Ionta et al., 2011). In order to investigate the role of the TPJ in self-location and visuospatial perspective Ionta et al. (2011) manipulated self-location in healthy subjects using robotic technology to present conflicting visuo-tactile and visuo-vestibular stimuli while measuring changes in TPJ activity with fMRI. Specifically, changes in self-location were manipulated by changing the synchrony between the tactile stroking of the subject's back[9] and the stroking of the virtual body's back that was visually presented to the subject. This study revealed the BOLD signal changes that reflected the illusory changes in self-location were only observed in the TPJ. Illusions of BSC will be further examined in a subsequent section.

More recently, it was found that multisensory processing associated with self-location seems to be largely dependent on a network consisting of bilateral TPJ, right insula, and right supplementary motor area (rSMA) (Blanke, 2012; Ionta et al., 2014). Coupled activity between the right temporoparietal junction (rTPJ) and the rSMA seem to reflect changes in conscious first-person perspective (Ionta et al., 2014). Interestingly, the right insula is shown to contribute to first person perspective, agency, and body ownership (as summarized by Ionta et al., 2014). External and internal signals may integrate in the bilateral superior marginal gyrus along with a right lateralized network including the superior temporal gyrus. These areas are involved in the convergence of multisensory signals and weighing multimodal signals and adjusting spatial frames of reference (Salvato et al., 2019).

Self-Identification

Petkova et al. (2011) found evidence which suggests that the inferior parietal cortex, premotor cortex (PMC), and the inferior parietal lobule are recruited to integrate proprioceptive, visual, and tactile signals to formulate one's sense of body ownership and that these

[9] The standard single mattress of the sliding scanner bed was replaced with two narrower custom-made mattresses that were placed side-by-side with a small gap between them to form a new mattress which would allow the robotic device to stimulate the participants back while the participant is laying in the fMRI machine

multisensory mechanisms use an ego-centered reference frame. This ego-centered reference may be enabled by bimodal neurons. Blanke (2012) suggests that tactile stroking may induce illusory body ownership because synchronous visuo-tactile stimulation may change the size and position of the receptive fields of trunk-centered bimodal neurons. Blanke (2012) proposes that enlarged receptive fields would enable the bimodal neurons to encode the abnormally distant position of the virtual body rather than just one's own bodily peripersonal space (Blanke, 2012).

Agency

Sense of agency relies on the sensorimotor system to contribute to BSC (Blanke et al., 2015). Tsakiris et al., (2010) found that agency may be dependent on the pre-supplementary motor area. This corresponds with previous work that indicates that the pre-supplementary motor area is significantly involved in conscious intention (Lau et al., 2004, as cited in Tsakiris et al., 2010).

One's sense of agency is at least partially dependent on one's ability to recognize oneself as the author of one's own actions (Gallagher, 2000). Agency requires a distinction between self and other. David & Cohen (2007) used fMRI to examine whether the extrastriate body area (EBA) in the occipitotemporal cortex discriminates between self-generated and other-generated motion. In this study subjects participated in a simple joystick movement task during which they were shown visual feedback. This design allowed the researchers to create incongruence between the subjects' actual movements and the visual movements being observed. Interestingly, visual feedback inconsistent with the subjects' own movement led to increased EBA activation while visual feedback that was consistent with the subjects' own movement resulted in increased functional connectivity between the EBA and the posterior parietal cortex. David & Cohen (2007) suggest this implicates the EBA's potential ability to recognize inconsistencies between one's internal body or actions and external visual signals.

These researchers propose that the EBA might support self versus other behavior attribution (David & Cohen, 2007).

Model of Bodily Self-Consciousness

Serino et al., (2013) propose a distributed model of BSC which involves the ventral premotor cortex (vPMc), primary sensory cortex (S1), posterior parietal cortex (PPc), insular cortex, temporoparietal junction (TPJ), and extrastriate body area (EBA). Ionta et al. (2014) proposes a similar network that includes the supplementary motor area (SMA) and emphasizes a right hemisphere dominance. The distributed network described by Serino et al. (2013) is shown below in Figure 3.

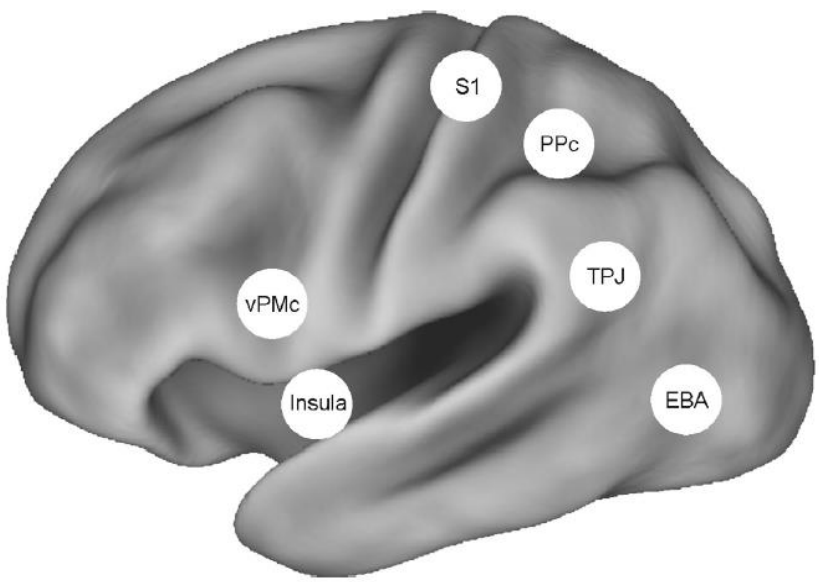

Figure 3. Distributed Model of Bodily Self-Consciousness. Note: Exteroceptive, somatosensory, and interoceptive signals from the insula, S1, and EBA converge and integrate in the PPc, vPMc, and the insula. The TPJ integrates vestibular and visual signals. From “Bodily Ownership and Self-location: components of bodily self-consciousness” by A. Serino, A. Alsmith, M. Constantine, A. Mandrigin, A. Tajadura-Jimenez, & C. Lopez, 2013, *Consciousness and cognition*, *22*(4), 1239-1252.

Autoscopic Phenomena

A recent study applied lesion network analysis to 26 patients with neurological AP in order to identify shared and distinct lesion areas associated with each type of AP (Blondiaux et al., 2021). In this study, all three visual forms of AP were associated with lesions within a network that included the bilateral temporo-parietal junction; specifically the bilateral posterior middle temporal gyrus (pMTG), right superior temporal gyrus (STG), and small bilateral clusters in the hippocampus and parahippocampus. See Figure 4 below.

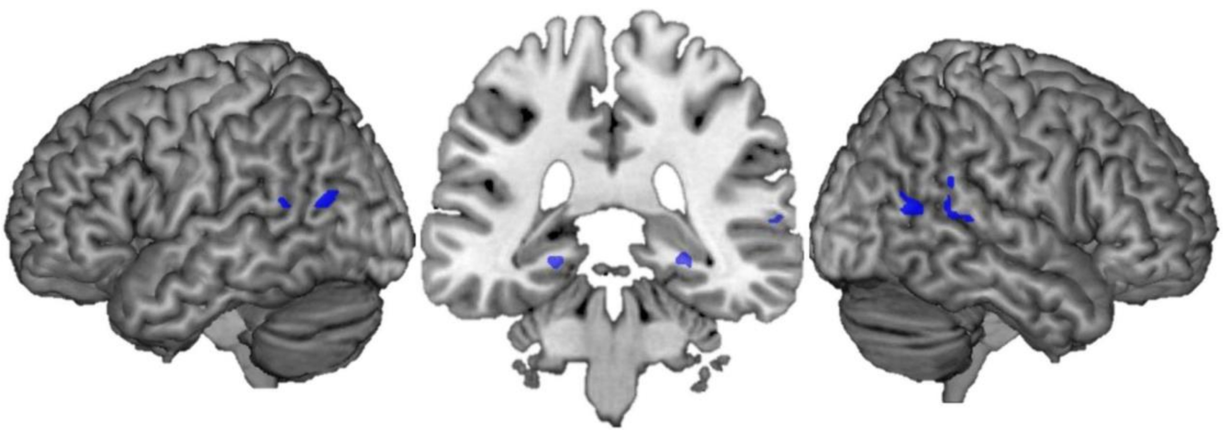

Figure 4. Areas of a Common Network Disrupted in all Three Autoscopic Phenomena. Note: The network connected to lesions causing all three forms of AP are depicted in blue. 90% of the lesions resulting in AP were part of a cortical network consisting of the bilateral pMTG, right STG and small areas within the hippocampus and parahippocampus. From “Common and Distinct Brain Networks of Autoscopic Phenomena” by E. Blondiaux, L. Heydrich, & O. Blanke, 2021, *NeuroImage: Clinical*, *30*, 102612.

These findings support the use of a continuum to categorize different forms of AP (Maillard et al., 2004). This data also corroborates previous work which has identified the bilateral temporo-parietal junction (TPJ) as having an instrumental role in processing related to one's self-location and visuospatial perspective (Blanke & Mohr, 2005; Blanke & Metzinger, 2009; Ionta et al., 2011; Heydrich & Blanke, 2013). Previous neuroimaging research also corresponds with the data from Blondiaux et al. (2021) indicating that lesions in the temporal lobe and parietal lobes are highly common in all types of AP[10] (Blanke & Mohr, 2005).

This research also provides evidence in support of the idea that each type of AP results from disrupted connectivity within different networks which all partially localize at the bilateral TPJ. Blondiaux et al. (2021) suggest that the TPJ is likely predominantly involved with the visual reduplication of one's own body which is shared amongst all AP. The authors speculate that the common lesion clusters within the bilateral hippocampus/parahippocampus may signify the importance of the medial temporal lobe for autobiographical memory, spatial navigation, and self-location (Gusterstam et al., 2015; Clower et al., 2001, as cited in Blondiaux et al., 2021).

Autoscopy

AH patients with occipital lobe lesions show that brain damage in the occipital cortex, particularly in the extrastriate visual cortex, can cause the hallucinatory reduplication of one's body without interfering with brain regions involved in self-location, visuospatial perspective, or self-identification (Heydrich & Blanke, 2013). Heydrich & Blanke (2013) speculate that the damage to the extrastriate visual cortex resulting in AH likely encompasses the extrastriate body

[10] Temporal lobe lesions were found in 55%, 80%, and 82% of AH, HAS, and OBE of sampled patients respectively. Parietal lobe lesions were found in 55%, 50%, and 45% of AH, HAS, and OBE samples respectively (Blanke & Mohr, 2005).

area and fusiform face and body areas. Blondiaux et al. (2021) revealed lesions in the precuneus as specific to AH patients. Interestingly, the precuneus plays a role in own face perception, own body processing, and self-location which corresponds with phenomenological AH symptoms such as seeing one's own face (Blondiaux et al., 2021). Decreased connectivity at the bilateral posterior inferior temporal gyrus (pITG) within the occipitotemporal cortex as well as bilateral cerebellum was also identified (Blondiaux et al., 2021). See Figure 5 below.

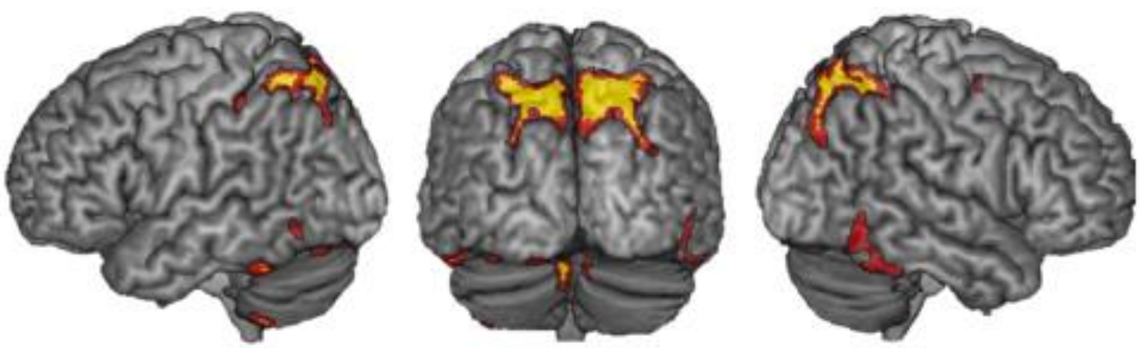

Figure 5. Lesion Derived Network for Autoscopic Hallucination. Note: Brain networks connected to AH lesions are represented by red. Network areas that are specific to AH lesions are represented in yellow. From "Common and Distinct Brain Networks of Autoscopic Phenomena" by E. Blondiaux, L. Heydrich, & O. Blanke, 2021, *NeuroImage: Clinical*, *30*, 102612.

Heautoscopy

Many of the alterations of BSC commonly reported in HAS are likely due to two types of multisensory disintegrations. Heydrich & Blanke (2013) suggest that the deep emotional affinity, heightened emotional states, visceroceptive symptoms[11] (i.e. heart palpitations, nausea), and abnormally strong self-identification with the AB are caused by a disintegration of somatosensory-visual signals and emotional-interoceptive signals and is universally present in HAS patients. An additional dysfunction of the integration of vestibular signals appears to be present in approximately 55% of patients with HAS (Heydrich & Blanke, 2013). Many of the common but not universally reported disturbances in BSC such as alternating first-person perspective and self-location or bilocation with the physical and AB are likely rooted in this vestibular disintegration (Blanke & Mohr, 2005; Heydrich & Blanke, 2013).

Blondiaux et al. (2021) identified left hemisphere lesion clusters specific to HAS patients. These clusters include the left inferior frontal gyrus (LIFG), the left insula, and the left parahippocampal gyrus/hippocampus (Blondiaux et al., 2021). See Figure 6 below.

Figure 6. Lesion Derived Network for Heautoscopy. Note: Brain networks connected to HAS lesions are represented by red. Network areas that are specific to HAS lesions are represented in yellow. From “Common and Distinct Brain Networks of Autoscopic Phenomena” by E. Blondiaux, L. Heydrich, & O. Blanke, 2021, *NeuroImage: Clinical*, *30*, 102612.

[11] Heydrich & Blanke (2013) acknowledge that only 33% of their patient data sample revealed visceroceptive sensations and recommend a case study of visceroceptive heautoscopy by Sollier (1903).

Previous voxel-based lesion mapping shows significant involvement of the left posterior insula in HAS as well (Heydrich & Blanke, 2013). Interestingly, the posterior insular cortex may provide a functional link between the secondary somatosensory cortex and the limbic structures given that the posterior insular cortex appears only to discriminate between the observation and physical experience of touch when the touch is affective (i.e. pleasant) (Friedman et al., 1986, Ebisch et al., 2011, as cited in Heydrich & Blanke, 2013). These studies propose that the posterior insular cortex encodes emotionally relevant somatosensory information for oneself and others and has the ability to distinguish if one's own body or someone else's body is experiencing the emotionally relevant somatosensory stimuli (Ebisch et al., 2011, Morrison et al., 2011, as cited in Heydrich and Blanke, 2013). Heydrich and Blanke (2013) theorize that lesions encompassing the posterior insular cortex impairs interoceptive and emotional processing likely leads to an impairment in self-other discrimination in HAS patients which ultimately results in emotional projection onto the AB, abnormal emotional affinity and abnormally strong self-identification with the AB (Heydrich & Blanke, 2013).

Interestingly, during inner speech the LIFG seems to be preferentially activated for conceptual self-reference tasks (i.e. accessing autobiographical memories, evaluating personality traits and emotions) rather than for perceptual self-tasks (i.e. sense of agency, voice/face self-recognition) (Morin & Michaud, 2007). The link between HAS and left hemisphere damage suggests that the language related phenomenology of HAS such as thought sharing may occur due to altered connectivity within the key areas concerning speech production and processing (Blondiaux et al., 2021).

Out-of-Body Experiences

Lesion studies typically indicate that OBE result from predominantly right hemispheric damage (Blanke & Mohr, 2005). Blondiaux et al., (2021) revealed OBEs were a result of lesions impacting a network composed of the bilateral angular gyrus (of the TPJ), bilateral MTG and inferior temporal cortex, right precuneus, and left cerebellum, as well as clusters in the right prefrontal cortex (rIFG). See Figure 7 below.

Figure 7. Lesion Derived Network for Out-of-Body Experience. Note: Brain networks connected to OBE lesions are represented by red. Network areas that are specific to OBE lesions are represented in yellow. From “Common and Distinct Brain Networks of Autoscopic Phenomena” by E. Blondiaux, L. Heydrich, & O. Blanke, 2021, *NeuroImage: Clinical*, *30*, 102612.

Interestingly, the bilateral angular gyrus was specific to OBE patients and is associated with the multisensory integration of visuo-tactile and vestibular information (Ionta et al., 2011). This may partially explain the severe disturbances in vestibular processing associated with the elevated visuospatial perspective reported by OBE patients (Blanke et al., 2004) and the reported drift in self-location induced in full body illusions (Ionta et al., 2011).

Inducing Illusory Changes in Bodily Self-Consciousness

Inducing an OBE through Focal Electrical Stimulation

OBEs can be induced with subdural electrical stimulation of the TPJ. Blanke et al., (2002) demonstrated that electrical stimulation at the angular gyrus near the TPJ induces OBE, distortions in body schema, and changes in perceived body location. During the lowest stimulation (2.0 - 3.0 mA)[12] the patient described sensations such as 'falling from the bed' and 'sinking into the bed' in reference to the induced vestibular illusions. Interestingly, an OBE was induced when the stimulation was increased by just .5 mA. The patient stated she felt as though she was floating and could see herself "lying on the bed from above" but could only see her legs and lower trunk. When stimulation was increased the patient reported that her legs were getting "shorter" while in reality they were lying flat. When her legs were physically bent prior to the stimulation she reported that her legs were "moving quickly towards her face" and she moved in order to not be hit by them (Blanke et al., 2002). Based on this patient's report the angular gyrus may play a role in vestibular integration (Blanke et al., 2002). This study denotes the angular gyrus as one critical area within the BSC network.

Illusory Self-Identification

Rubber Hand Illusion

The rubber hand illusion (Botvinick & Cohen, 1998) is a well-known method for inducing illusory bodily ownership of a noncorporeal object. In this procedure a rubber hand (e.g. right) is placed in front of the participant at a realistic distance and in the same orientation as one's real right hand, while their own right hand is visually concealed. An experimenter strokes both the participant's right hand and the rubber hand synchronously at the corresponding locations and speed. The change in bodily ownership for the rubber hand occurs when synchronous

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[12] Electrical stimulation in milliamperes (1mA = 1/1000 of an amp) indicative of the intensity of electron flow per second.

multisensory bodily signals become integrated over a period of time which illicit alterations in BSC (Blanke, 2012).

Interestingly, once participants self-identify with the rubber hand, threatening stimuli towards the rubber hand elicits a similar cortical activity response as when one's real hand is threatened (Ehrsson et al., 2007). Participants also show increased BOLD responses in the anterior cingulate cortex and insular cortex during induced rubber hand ownership which was correlated with perceived intensity of ownership of the rubber hand (Ehrsson et al., 2007). This finding indicates that the self-identification during bodily ownership illusions extends to interoceptive processing areas. Ehrsson et al. (2007) suggest that even illusory body ownership necessarily recruits emotional processing regions and that the vividness and feelings of intensity during the illusion are a result of the participation of interoceptive mechanisms. This finding sheds some light on the intense abnormal emotional processing associated with HAS.

Body-Swap Illusion

Trunk-related multisensory processing seems to be more involved in whole-body processing related BSC. In the body-swap illusion, illusory whole-body ownership is induced by applying visuo-tactile and visuo-vestibular stimulation. Similar to the rubber hand illusion, tactile stimulation is applied repeatedly to the participants' trunk or abdomen while the participant is concurrently watching a video on a head mounted display showing another body being stroked synchronously to the participant. The body being stroked in the video may be of another person or a virtual animation. Participants report self-identification with the virtual body (Petkova & Ehrsson, 2008).

Self-Location Illusions

Some studies take the full body ownership illusion a step further by inducing altered self-location as well. In these studies participants were shown either a video of their own backs being stroked or a video of a virtual body being stroked synchronously to the participants' own physical back. See Figure 8 below.

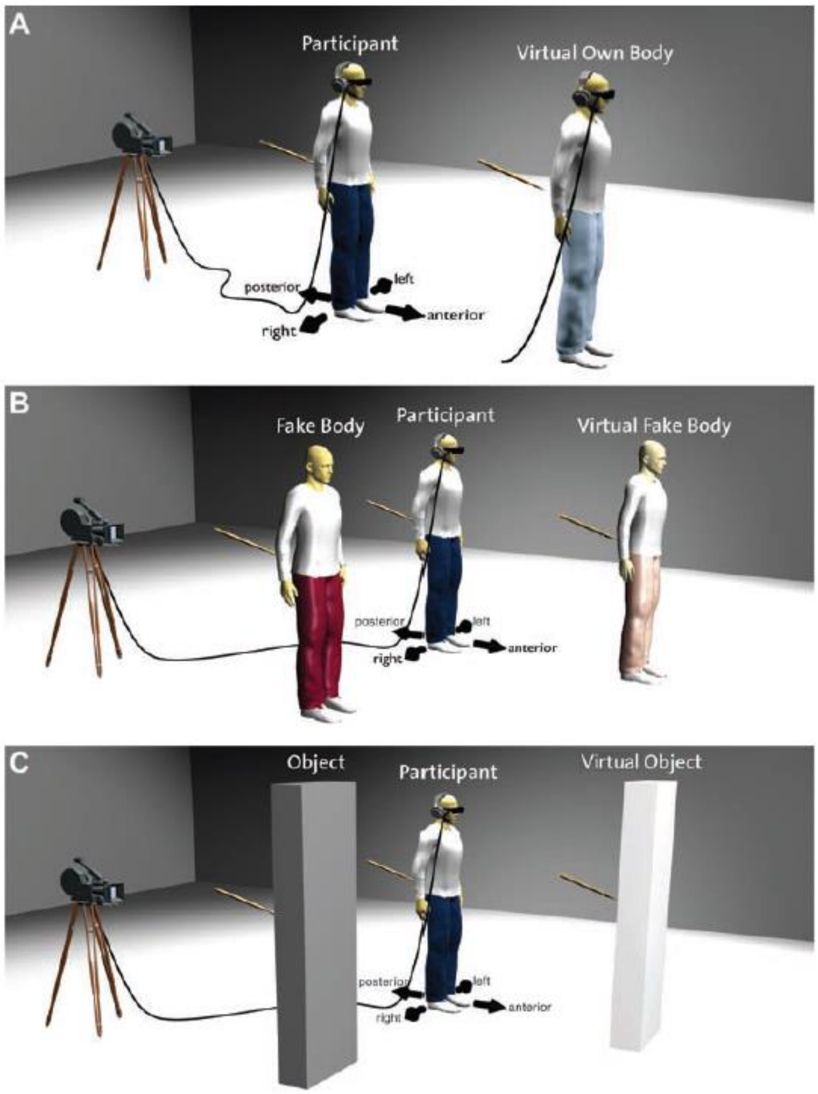

Figure 8. Depiction of Procedural set up in a Full Body Illusion. Note: The videos displayed the participants' own bodies/virtual bodies further away in front of the participants actual physical body in the room. Dark colors represent the real location of the participant or object. Light colors indicate the virtual body or object displayed on the VR headset. From "Video Ergo Sum: manipulating bodily self-consciousness" by B. Lenggenhager, T. Tadi, T. Metzinger, & O. Blanke, 2007, *Science*, *317*(5841), 1096-1099.

Interestingly, participants in both the human body and virtual body video conditions reported bodily ownership of and a drift in self-location towards the respective bodies shown in the video. However, participants in the object condition had been shown a video of an inanimate object being stroked synchronously and did not report any change in self-identification or self-location towards the object (Lenggenhager et al., 2007). These studies reveal that BSC can be separated from the position of one's physical body through the use of illusory self-location to an extracorporeal location (Lenggenhager et al., 2007).

Lenggenhager et al. (2009) conducted another study which investigated changes in self-location involving synchronous/asynchronous visuo-tactile stimulation which was applied to either one's back or one's chest. Participants either saw their own body through the head-mounted display (HMD) or were blindfolded. The results indicated that when stimulation was synchronous with visual input participants perceived the tactile stimulus at the location where they visually perceived it to be (Lenggenhager et al., 2009). In the synchronous condition participants reported a drift in self-location towards the location of the visually perceived stroking (i.e. the perceived location of the virtual body) and this led to more dissociation of the physical body (Lenggenhager et al., 2009). See Figure 9 below.

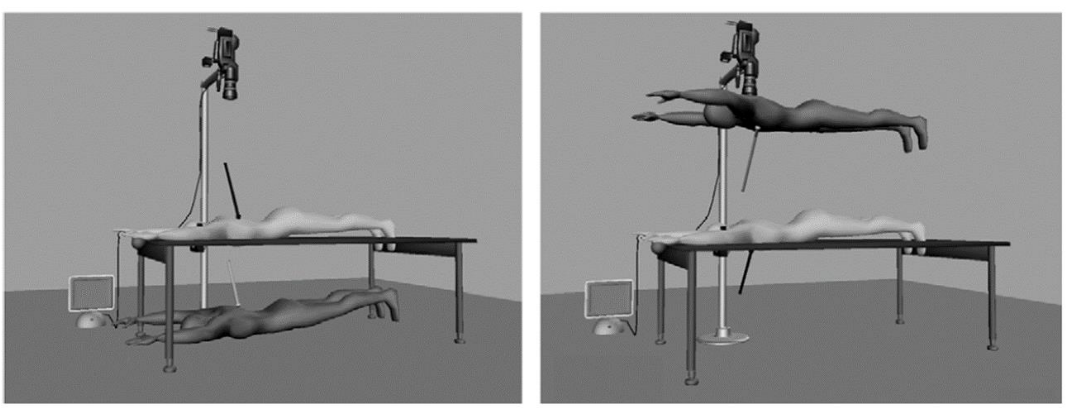

Figure 9. Experimental set-up for Illusory Self-location. Note: Each subject is filmed from above (subject's back) and the video is shown to the subject on the HMD. Light bodies represent the location of the subjects' actual physical body. Dark bodies depict an approximate location of the subjects' perceived self-location. From "Spatial Aspects of Bodily Self-consciousness" by B. Lenggenhager, M. Mouthon, & O. Blanke, 2009, *Consciousness and cognition*, *18*(1), 110-117.

Cardio-Visual Illusion

To investigate the impact of conflicting interoceptive and exteroceptive signals on BSC Aspell et al. (2013) created a cardio-visual illusion which allowed them to manipulate the temporal synchronicity/asychronicity of a flashing light with respect to the participant’s actual heartbeat. See Figure 10 below.

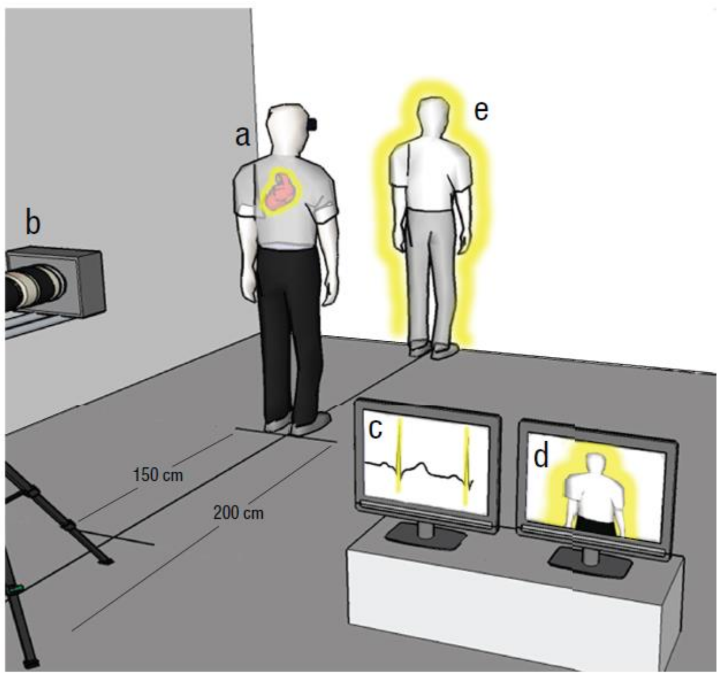

Figure 10. Experimental set-up for the Cardio-Visual Illusion. Note: Researchers recorded the participant’s ECG (c) while filming the video (b). The video of each participants’ body was displayed to them (a) in real time (synchronously) and participants were not informed that the flashing silhouette light was related to their heartbeat. Only the synchrony of the flashing outline (d) was manipulated. In the VR display participants could see their virtual body as if it were standing 200 cm in front of them (e). From “Turning Body and Self Inside Out: Visualized Heartbeats Alter Bodily Self-Consciousness and Tactile Perception” by J.E. Aspell, L. Heydrich, G. Marillier, T. Lavanchy, B. Herbelin, & O. Blanke, 2013, *Psychological science*, *24*(12), 2445-2453.

During periods of illumination (flashing) around the video body image that was synchronous with the participants’ heartbeats the participants reported stronger body ownership and a larger shift in self-location towards the video body image. Aspell et al. (2013) showed that conflicting interoceptive-interoceptive signals can modulate BSC and tactile perception. This study also supports similar findings that suggest that the brain uses correlations between multisensory signals to aid in self-other discrimination (Heydrich & Blanke, 2013; Aspell et al., 2013).

Another study explored the role of the insular cortex in heartbeat awareness and the impact of cardio-visual simulation on BSC in a patient before and after removal of a right insular lesion (Ronchi et al., 2015). This patient experienced strong illusory self-identification, reduplication, and bilocation and these alterations in BSC occurred without visuo-tactile stimulation. Ronchi et al. (2015) note that the patient spontaneously reported that he felt as though he was in two places at once (i.e. bilocation) and felt as if he had a twin (i.e. the visual body image). The insula appears to modulate interoceptive awareness and consequently alter BSC.

Future Directions and Concluding Remarks

The multisensory integration principles that enable the ‘body-swap’ illusion apply even in the absence of a second visual/virtual body. In the ‘invisible body’ illusion participants receive tactile stroking stimulation while wearing a virtual reality (VR) headset that displays empty space at the location of the participants’ body (Gusterstam et al., 2015). While wearing the VR headset participants are unable to see their bodies including the body area receiving tactile stroking. Instead the VR headset displays the same type of stimulus stroking an ‘invisible body’.

Participants not only experience a shift in self-identification towards transparency but also report lower social anxiety when in front of an audience (Gusterstam et al., 2015). These findings are relevant for understanding both BSC and it’s relationship with social-affective cognition. The ‘invisible body’ illusion may potentially be one tool used to treat social anxiety disorders (Gusterstam et al., 2015).

Another iteration of the full body illusion (FBI) used a VR headset to display a virtual avatar. Individuals suffering from anorexia nervosa exhibited less distortion of their estimated body size after experiencing the FBI and this effect was still observable at a follow-up almost three hours later (Keizer et al., 2016). This study indicates that temporarily altering body ownership may be an additional line of treatment for individuals with eating disorders in the future.

The FBI may also be useful for individuals suffering from chronic pain. In one study individuals with chronic pain reported a significant reduction in average level of pain (37%) after the body ownership illusion was complete (Pamment & Aspell, 2016). The authors of this study speculate that these results could stem from decreases in one's sense of body ownership and sense of embodiment of one's own body. Further research in this area is needed.

Concluding Remarks

Arguably, autoscopic phenomena may be some of the most difficult and mystifying experiences to study (Blanke et al., 2016). It can be difficult for individuals who have experienced AP to verbalize the episode exactly how they experienced it (e.g. Brugger et al., 2006). It is challenging to measure and record AP as they organically occur given that these illusory experiences most often occur during episodes of impaired consciousness (Blanke et al., 2005; Blanke et al., 2016). The mechanisms that result in disrupted bodily self-consciousness need to be studied further even with the present challenges. Full body illusions have become an increasingly fundamental method for understanding all types of phenomena that alter BSC. In recent years VR has become an asset for researchers investigating perceptual and sensory processing. A better understanding of BSC will permit more possible avenues for effective treatments for all types of patients including individuals dealing with social anxiety, eating disorders, and chronic pain.

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