Own-Body Perception

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Abstract.

"Own-body perception" refers to the perception of one's body as one's own body. We review various disruptions to own-body perception, including what is known about their neural correlates. We argue that it is crucial to distinguish between the sense of ownership for one's body as an object of perception—the *body-as-object*—and the sense of ownership for one's body as that by which and through which one perceives the world—the *body-as-subject*. Despite the fact that illusory own-body perception provides an excellent case for illustrating this distinction, most discussions to date of own-body perception have failed to make this distinction and apply it to the various clinical and experimental findings. We summarize one recent model of the body-as-subject, according to which the body-as-subject is based on sensorimotor integration. Finally, we use this model to clarify the phenomenon of illusory own-body perception, and we suggest directions for future research.

Keywords.

Own-Body Perception, OBE (Out-of-Body Experience), Embodied Perception, Sensorimotor Integration, Self.

Introduction

Our concern in this chapter is with four interrelated aspects of perception. First, perception is perspectival; you always perceive the world from a particular point of view. Second, the point of view from which you perceive the world is usually determined by the location of your body. Third, your body is one of the things you perceive, either from the outside, as when you look down at your hands, or from the inside, as when you experience your arms extended or your body as upright or inverted. Fourth, you do not merely experience your body as having these parts and properties; you also experience these body parts and properties as your own. In summary, one of the things you perceive from your first-person perspective is a particular body that you also perceive as your own. Psychologists and neuroscientists call this kind of perception "own-body perception."

Own-body perception is a type of bodily self-awareness. In perceiving your body as your own, you are aware of your bodily self. Besides own-body perception ("this body is mine"), bodily self-experience includes agency ("I'm the one making this movement"), self-location ("I'm in my body"), and egocentric perception ("I see the world from here"). Notice that these aspects of bodily self-awareness normally coincide—you feel that the body in which you are located (self-location) and through whose eyes you see the world (egocentric perception) is your own body (ownership) that you control from within (agency).

Illusory own-body perceptions, however, disturb this unity. For example, in the so-called rubber hand illusion, subjects locate a sensation produced by something that is touching their own hand in a rubber hand, outside their bodily space (Botvinick and

Cohen 1998). Illusory own-body perceptions have also been created using virtual reality images (Lenggenhager et al. 2007) or real-time video images (Ehrsson 2007). In these cases, subjects locate passively experienced touch sensations in a virtual body they see in front of them (Lenggenhager et al. 2007), or they experience themselves as displaced to a location behind where they are actually sitting (Ehrsson 2007). Finally, illusory own-body perceptions can also occur spontaneously without experimental induction, notably in so-called autoscopic phenomena, in which an individual sees his or her body from an outside perspective (Blanke and Mohr 2005).

In this chapter, we first review these kinds of disruptions to bodily self-awareness, including what is known about their neural correlates, and we consider their significance for understanding own-body perception. We then argue that it is crucial to distinguish between the sense of ownership for one's body as an object of perception—the *body-as-object*—and the sense of ownership for one's body as that by which and through which one perceives the world—the *body-as-subject* (Thompson 2005; Legrand 2006; Legrand and Ruby 2009; Christoff et al. 2011). Put another way, the body-as-subject can be described as the embodied and subjective perspective of perception, in contrast to the body perceived as one object among others from within that perspective. Despite the fact that illusory own-body perception provides an excellent case for illustrating this distinction, most discussions to date of own-body perception have been limited by a failure to make this distinction and apply it to the various clinical and experimental findings. Third, we summarize one recent model of the body-as-subject, according to which the body-as-subject is based on sensorimotor integration (Legrand

and Ruby 2009; Christoff et al. 2011). Finally, we use this model to clarify the phenomenon of illusory own-body perception.

The Rubber Hand Illusion

The rubber hand illusion, first reported by Botvinick and Cohen (1998), is the illusion of experiencing a rubber hand as being one's own hand. To induce the rubber hand illusion, subjects see a rubber hand being stroked in synchrony with the stroking of their own hand, which is hidden from view. Subjects report seeming to feel the touch of the brush that is stroking the rubber hand, instead of the hidden brush stroking their hand, as if the rubber hand had sensed the touch. Subjects also report feeling ownership over the rubber hand, that is, that the rubber hand is their own hand (Tsakiris and Haggard 2005, p. 80). This report might be interpreted in at least two ways: the rubber hand might replace the subject's own hand in her experience of her body; alternatively, the rubber hand might simply be incorporated into the body and experienced as a third hand over which the subject feels ownership without any loss of experience of and ownership over her actual hand. Both behavioural measures and introspective reports made by subjects suggest that the former is the correct interpretation of the illusion. Subjects deny that they feel as if they have three hands when they experience the illusion and agree with the statement that they feel their own hand to have disappeared (Longo et al. 2008). There are changes to homeostatic regulation of the subject's own hand when the subject experiences ownership over the rubber hand. Moseley et al. (2008) found that the skin temperature of the subject's own hand dropped during the illusion. The drop in skin temperature correlated with the intensity of the illusion, and was limited to cases in which subjects reported feeling ownership over the rubber hand. By contrast, subjects who see a rubber hand being stroked *asynchronously* from the stroking of their own hidden hand do not report feeling any such ownership over the rubber hand.

When asked to make a report on the location of their own hand post-illusion, and once both their own hand and the rubber hand are hidden from view, subjects mislocate their hand, deviating towards the location of the rubber hand. Subjects who receive asynchronous stroking on their own and on the rubber hand manifest a smaller drift effect—known as proprioceptive drift—towards the location of the rubber hand when they report on the location of their own hand. Both reports of felt ownership and measurements of proprioceptive drift as evidenced by reports on the location of one's hand after synchronous stroking are used as measures of the illusion when contrasted with the asynchronous condition.

Botvinick and Cohen (1998) explain the illusion in terms of multisensory integration (the integration of information from different sense modalities), specifically the integration of vision, touch, and proprioception. Temporally synchronous but spatially incongruent visual and tactile inputs are integrated together. The dominance of vision over touch results in the "mislocalization of the tactile percept towards the spatial location of the visual percept" (Tsakiris and Haggarad 2005, 80). The dominant role of vision over proprioception results in the subject judging that her hand is located closer to the position of the rubber hand. Similarly, Tsakiris states that the rubber hand illusion involves "a three-way weighted interaction between vision, touch, and proprioception: vision of tactile stimulation on the rubber hand captures the tactile sensation on the participant's own hand, and this visual capture results in a mislocalization of the felt location of one's own hand towards the spatial location of the visual percept" (Tsakiris 2010, p. 705).

Besides multisensory integration, however, representation of the body also seems to be involved in the rubber hand illusion, since the effect is diminished if the placement of the rubber hand is incongruent with that of the subject's own hand. Tsakiris and Haggard found that placing the rubber hand at a 90° angle relative to the position of the subject's own hand led to there being no significant difference in proprioceptive drift between synchronous and asynchonrous conditions (Tsakiris and Haggard 2005, 81-3). Moreover, after stimulation with a neutral, non-hand like object, in this case a wooden stick, in place of the rubber hand, the subjects' judgements about the location of their hand were not significantly different from their judgements after asynchronous stimulation. Tsakiris and Haggard amend the multisensory integration view by suggesting that although "bottom-up processes of visuotactile correlation drive the illusion," it is also the case that long-term body-scheme representations can modulate the illusion (Tsakiris and Haggard 2005, 91). The failure to induce the illusion when the rubber hand was placed at a posturally incongruent angle to the position of the actual hand, as well as when the rubber hand was replaced with a stick, suggests that when the visual stimuli in some way fails to cohere with a pre-existing representation of the body, then the illusion will be attenuated.

Seeing One's Body in Extra-Personal Space

In global versions of the rubber hand illusion, external representations of the body are used to induce a feeling in the subject that a tactile sensation is felt in an image of the body presented in extra-personal space (Ehrsson 2007; Lenggenhager et al. 2007). As with the rubber hand illusion, these experiments are used to investigate one's feeling of body ownership. The aim is to expand the illusion in order to investigate one's sense of ownership of the body as a whole rather than one's sense of ownership of a particular limb (Blanke and Metzinger 2008). Consistent with the rubber hand illusion, subjects report feeling that the genuine tactile sensations they receive are located on the perceived body, at some distance from the location of the stimulation.

These body illusion experiments, described in more detail below, seem to induce elements of a set of illusions collectively labelled "autoscopic phenomena," in which subjects report the experience of seeing their own body from an outside perspective (Blanke and Mohr 2005). Autoscopic phenomena are usually divided into the following three categories: (i) autoscopic hallucinations, in which the subject sees an illusory duplicate of her body from the perspective of her actual body but does not experience any ownership or control over this body; (ii) out-of-body experiences (OBE), in which the subject feels ownership for a body that she recognizes as her own body but that is seen from the outside; and (iii) heautoscopy, in which the subject reports that her visual perspective switches back and forth between her normal body and an illusory second body, for which she also reports feeling a sense of ownership.

In the case of out-of-body experiences, subjects report seeing their own body from an outside perspective and at a distance from their own body, often from an elevated perspective. A similar outside perspective occurs in the "observer perspective" of episodic memory, in which one sees oneself from the outside (typically from an elevated vantage point), in contrast to recalling the scene from the perspective of one's own eyes (the "field perspective") (Nigro and Neisser 1983; McIssac and Eich 2002). In the case of out-of-body experiences, however, the subject takes the experience to be an occurrent perceptual one, not a memory. Blanke and Mohr (2005) describe out-of-body experiences as generating a sense of disembodiment—a sense of oneself, as the subject of experience, being outside of one's body. In contrast, for subjects who experience autoscopic hallucinations, there is no sense of disembodiment. Despite the experience of seeing a duplicate of one's body, there is no shift in visuo-spatial perspective from the subject's genuine body to the perspective of the illusory duplicate. Finally, in heautoscopy, subjects report both seeing a double of their own body and a sense of shifting between two possible perspectives—the perceptual perspective from the body's actual location and the perspective from the double's location. Nevertheless, they do not have a clear sense of disembodiment, but instead report confusion about their spatial location and perspective (Blanke and Mohr 2005, p. 187).

Autoscopic phenomena can also be described in terms of the differences in the visuo-spatial perspective that subjects report in each case (Blanke and Mohr 2005, p. 187). In autoscopic hallucinations, the visuo-spatial perspective is body-centered; in out-of-body experiences, it is extra-corporeal; and in heautoscopy, it is extracorporeal and body-centered. Thus autoscopic phenomena can be classified according to the degree to which the subject experiences an alteration in her visuo-spatial perspective on the world. The more sustained the experience of displacement toward the duplicate body, the stronger the subject's sense of disembodiment.

Blanke and Metzinger (2008) offer another system of classifying autoscopic phenomena. They suggest that we should understand the changes to bodily self-awareness in autoscopic phenomena as changes to one's bodily sense of selfhood. According to Blanke and Metzinger, the simplest sense of self, which they call "minimal phenomenal selfhood," comprises (i) having a perspectival model of reality; (ii) locating oneself in space and time; and (iii) identifying oneself with a representation of the body as a whole. A more robust sense of self or "strong first-person perspective" occurs when one mentally represents oneself as a subject that is directed toward the objects of perception, including one's own body.

Using this framework, out-of-body experiences and heautoscopy can be understood as indicating a misrepresentation of one's location in space together with changes in one's experience of bodily possession, thereby interrupting one's bodily sense of selfhood and altering one's experience of having a perspective on the world. Blanke and Metzinger contend that, depending on which of the three contributing factors to minimal phenomenal selfhood is disturbed—the felt origin of one's perspectival model of the world, self-location in space and time, or body identification—the subject will report experiences consistent with out-of-body experiences or heautoscopy.

In the case of out-of-body experiences, subjects report feeling disembodied and having a displaced perspective on the world. According to Blanke and Metzinger's model, this type of experience is caused by a disturbance in spatial self-location and a distrubance in the felt origin of the weak first-person perspective—both are located at a position outside of the subject's actual body. In addition, Blanke and Metzinger suggest that one identifies oneself with an illusory body that seems to be located at this position, as opposed to identifying oneself with one's genuine body, which one perceives from the outside. Moreover, given that these aspects of minimal phenomenal selfhood are disturbed, so too is the strong first-person perspective.

In contrast, in heautoscopy, one's weak first-person perspective originates from either the real body or the illusory body, or alternates between them, and one locates oneself in and identifies with both bodies. Thus, all three aspects of minimal phenomenal selfhood are pathologically disrupted in heautoscopy.

Finally, in autoscopic hallucinations, since subjects experience no shift in visuo-spatial perspective and no sense of disembodiment, all three aspects of minimal phenomenal selfhood are normal: one locates oneself at the position of the represented body, one identifies with this represented body, and one's weak first-person perspective is represented as originating from the body. Presumably, then, according to Blanke and Metzinger's model, this type of illusion is merely a visual hallucination, one in which one sees a double of one's body in one's extra-personal space, but for which one experiences no sense of ownership. Nevertheless, in Blanke and Metzinger's model, both out-of-body experiences and heautoscopy can be understood as involving changes to one's bodily sense of selfhood through the disturbance of features that constitute minimal phenomenal selfhood.

Neural Correlates of Out-of-Body Experiences

Evidence from neuroscience suggests that out-of-body experiences depend on a particular area of the brain where the temporal and parietal lobes meet, known as the temporoparietal junction (TPJ). This area is known to be crucial for multisensory integration—for integrating signals from the different sensory modalities of sight, sound, touch, and self-movement—and for being able to switch between taking a first-person perspective and a third-person perspective in mental imagery.

The main evidence for the involvement of the TPJ in out-of-body experiences comes from studies of neurological patients. In 2002 Blanke and colleagues reported that they had repeatedly induced out-of-body experiences by electrically stimulating the brain of a patient being treated for a drug-resistant epilepsy (Blanke et al. 2002). During stimulation of the right angular gyrus—a structure belonging to the area of the TPJ—the patient reported having experiences resembling out-of-body experiences. The first stimulations produced vestibular feelings that the patient described as “sinking into the bed” or “falling from a height.” When the doctors increased the amplitude of the electrical current, the patient reported, “I see myself lying in bed, from above, but I only see my legs and lower trunk.” Two further stimulations produced the same experience, including an instantaneous feeling of “lightness” and “floating” about two meters above the bed, near the ceiling.

In a subsequent study (Blanke et al. 2004), Blanke and colleagues recorded detailed information about spontaneous out-of-body experiences in this patient and five other neurological patients. The following is a description of one patient's out-of-body experience just prior to surgery:

> The patient was lying in bed and awakened from sleep, and the first thing she remembered was "the feeling of being at the ceiling of the room." She "[…] had the impression that I was dreaming that I would float above [under the ceiling] of the room […]." The patient also saw herself in bed (in front view) and gave the description that "the bed was seen from above" and that "there was a man and that she [the patient] was very frightened." The scene was in colour, and was visually clear and very realistic (Blanke et al. 2004, p. 247).

Blanke and colleagues found that five of these patients had brain damage in the TPJ of the right hemisphere. In a later study, the same brain region was found to be activated within half a second when healthy individuals were asked to imagine seeing things from an out-of-body perspective (Blanke et al. 2005). Furthermore, interfering with this brain region by stimulating it magnetically impaired the ability to imagine this transformation of body position.

These findings along with others have helped neuroscientists to build up a picture of the TPJ as a key neural site for the integration of information related to own body perception, including how we recognize others on the basis of their bodies, as well as our sense of how our own body looks from the outside to other people (Arzy et al. 2006). The right TPJ includes the core region of the vestibular cortex, which is responsible for our sense of balance and spatial orientation. Other regions belonging to the TPJ coordinate proprioceptive, tactile, and visual information about the body. In addition, the TPJ is known to be involved in the perception of the human body, imagining one's own body, switching between first-person and third-person perspectives, and being able to distinguish between oneself and others.

In out-of-body experiences, vision, proprioception, and vestibular awareness come apart. One sees oneself as being at a location that does not coincide with the source of one's egocentric visual perspective and with the source of one's vestibular awareness. Since the TPJ is involved in integrating these different kinds of sensory information, it makes sense to suppose that out-of-body experiences depend on some kind of disruption to multisensory integration at the TPJ.

Blanke proposes that out-of-body experiences happen when the TPJ suddenly fails to integrate sensory signals from the body in the normal way (Blanke and Arzy 2005). Specifically, he proposes that two disturbances to multisensory integration combine to produce out-of-body experiences. On the one hand, proprioceptive, tactile, and visual signals about one's own body are not properly matched to each other. On the other hand, the vestibular frame of reference for one's personal space is not properly matched to the visual frame of reference for external space. These two sensory-integration disruptions combine to create the experience of seeing one's body in a position that does not coincide with its felt location, together with the experience of floating and seeing things from an elevated visuo-spatial perspective.

Methods of Inducing Autoscopic Illusions

Although the following experiments differ in their details, in general subjects are presented with tactile stimuli on their body in conjunction with a visual representation of a virtual body, a mannequin, or a video image of their own body being touched in the same way. The visual stimuli are presented either in synchrony with the tactile stimulation or asynchronously. Subsequently, subjects are asked a series of questions based on those used in the rubber-hand illusion experiment to investigate their sense of body ownership.

In the Lenggenhager experiments (Lenggenhager et al. 2007), a video image of the subject's back was filmed and presented to the subject through video-display goggles. The subject saw a video-enhanced image of his own back being stroked from the camera's view so that he was presented with an image of his back located in a position in front of him. In a further experiment, subjects viewed video images of a fake body or a non-body shaped object. Ehrsson's (2007) version of the illusion used a similar configuration but with two video cameras behind the subject to create an image of the subject's back. Rather than stroking the subject's back, as in the Lenggenhager experiment, Ehrsson had the experimenter perform a horizontal motion in space with a rod towards the subject, culminating in the rod touching the subject's chest. A second rod performed a similar motion back and forth in front of the video cameras, towards a point just below them. Subjects were thus presented with an image of a rod performing a motion that coincided temporally with the touching of their own chest, but also with their own bodies, perceived from the back, located in front of them. Lastly, in Petkova and

Ehrsson's (2008) experiments, subjects were presented with video footage, through head mounted video-display goggles, of a mannequin's chest being stroked from the viewpoint of the mannequin's head. An additional experiment, designed to induce what they describe as a "full-blown body-swap experience" (ibid., p. 4), involved an experimenter shaking hands with the subject while the subject wore a head-mounted camera. The subject, adorned with the head-mounted display, is presented with the visual image of his own hand from the perspective of the experimenter, thereby inducing, it is suggested, the experience of shaking hands with himself.

Across the differences in these experimental setups, subjects report that they experience the tactile sensation as located in the body that they visually perceive, and some subjects report that they experience a sense of being seated behind their own bodies, able to perceive their own body from a separate location (Ehrsson 2007, p. 1048). As in the rubber hand illusion, visual information seems to take precedence, inducing the sense that a tactile sensation one experiences is located on the body that one visually perceives at a distant location from the actual sensation and one's actual position.

The illusion induced by these experimental paradigms has been called a "full body illusion" (Blanke & Metzinger 2008). The adaptation of the rubber-hand illusion experimental design to incorporate a larger image of the body gives some support to this way of describing the illusion. In addition, the feeling that subjects report of being located at a different position in space from their own bodies provides some reason to think that the illusion involves the whole body. Nevertheless, without further investigation of the extent to which the illusion is localized to the particular parts of the body that are being stimulated, it is difficult to know whether subjects experience a full body illusion rather than a partial one (Smith 2010). Furthermore, it is worth considering whether subjects experience full body displacement, or rather whether they merely experience ownership over a body that is not their own. As with the rubber hand illusion, there is a question about whether the subject merely gains ownership over an extra body or body-part, or whether in addition the subject disowns their own body or body-part.

In a recent addition to this experimental work, Ionta, Blanke, and colleagues used functional magnetic resonance imaging (fMRI) to investigate neural activity during autoscopic illusions (Ionta et al. 2011). The subjects lay on their back in the scanner and looked upward at a virtual body, and they received tactile stimulation to their back while viewing tactile stimulation being given to the virtual body on its back. To investigate shifts in the experience of self-location after synchronous versus asynchronous stimulation, participants were asked to judge how long a ball they held in their hand would take to reach the ground if dropped. The subjects also made free reports about their feelings of body ownership and their perspective on the world. Only during synchronous stroking—when the subjects felt their back being stroked at the same time as they saw the virtual back being stroked—did the subjects report feeling as though the virtual body was their own. The mental ball-dropping time estimates also showed that the subjects perceived their physical body drifting toward the virtual one during synchronous stroking. Yet the subjects also reported striking differences in the direction of their visual perspective. Half the subjects had the impression of being below the virtual body and looking up at it (the Up group); the other half had the impression of being above the virtual body and looking down at it (the Down group). In other words, the visuo-spatial perspective of the Up group was consistent with their actual supine physical position and first-person perspective in the scanner, whereas these were inconsistent for the Down group, who experienced an elevated visuo-spatial perspective and sensations of floating, as in out-of-body experiences.

When Ionta and colleagues examined the brain activity, they found that the illusory changes in self-location correlated specifically with changes in activity at the TPJ. They also found there were different patterns of activity in this area for the Up and Down groups. Ionta and colleagues interpret these differences as showing that activity in the TPJ reflects not only how the integration of visual and tactile signals influences one's sense of self-location, but also how the integration of visual and vestibular information about self-location and the orientation of one's visuo-spatial perspective influences one's first-person perspective.

These results of combining brain imaging and virtual reality methods of manipulating bodily self-awareness support the idea that out-of-body experiences depend on how the TPJ deals with visual, tactile, and proprioceptive cues about one's own body, on the one hand, and visual and vestibular cues about one's bodily orientation in space, on the other hand. More generally, what these virtual reality experiments have done is to use the power of vision over other senses to manipulate bodily self-awareness in systematic ways that reveal different aspects of our bodily sense of self. We locate ourselves within our body, but we can be made to feel that we are located at places outside the borders of our body. We experience the world from the visuo-spatial perspective of our body, but we can be made to experience the world from perspectives outside our body with different "up" or "down" orientations. We feel that we own our bodies, but manipulating both our visuo-spatial perspective and the sensory cues we get from vision, touch, and proprioception can make us feel ownership for an artificial body or a purely virtual body.

Body-as-Subject versus Body-as-Object

Despite the experimental advances described in the previous sections, discussions of their significance for understanding own-body perception and bodily self-awareness have been hampered by a failure to distinguish clearly between two modes of bodily self-experience—the sense of ownership for one's body as that through which and by which one perceives the world—the body-as-subject—and the sense of ownership for one's body as a perceptually presented object (Legrand 2010). We suggest that greater clarity can be brought to our understanding of the experimental findings, as well as of spontaneous autoscopic phenomena, by making use of the conceptual and phenomenological distinction between the body-as-subject, which structures perceptual experience and grounds higher levels of self-consciousness (Bermudez 1998; Legrand 2006), and the body as a perceived object presented within the perspective that the body-as-subject provides.

The question we need to address is the extent to which the autoscopic experiments manipulate the body-as-subject versus the extent to which they manipulate the body-as-object. In other words, to what extent do the experimental manipulations alter how one experiences the body as that by which and through which one perceives—to what extent do they alter the embodied and subjective perspective of perception itself—versus to what extent do they alter how one's body appears as a perceptual object from within that perspective?

To answer this question we need to clarify exactly what the body-as-subject of perception is in contrast to the body-as-object of perception, and we need to provide a functional model of the body-as-subject that can be applied to the empirical investigations of own-body perception. We will then be in a better position to account for the feeling of disembodiment that subjects report in spontaneous out-of-body experiences as well as how this feeling relates to the manipulations of own-body perception in the experimentally induced cases.

A Sensorimotor Model of the Body-as-Subject

The concept of the body-as-subject of perception can be presented in terms of the systematic linkage of sensory and motor processes in the perception-action cycle (Legrand 2006; Legrand and Ruby 2009; Christoff et al. 2011). As a perceiver, one needs to be able to distinguish between sensory changes arising from one's own motor actions (self) and sensory changes arising from the environment (nonself). The central nervous system (CNS) distinguishes the two by systematically relating the efferent signals (motor commands) for the production of an action (e.g, eye, head, or hand movements) to the afferent (sensory) signals arising from the execution of that action (e.g., the flow of visual or haptic sensory feedback). According to various models going back to Von Holst (1954), the basic mechanism of this integration is a comparator that compares a copy of the motor command (information about the action executed) with the sensory reafference (information about the sensory modifications due to the action) (Wolpert et al. 1995).

Through such a mechanism, one can register that one has executed a given movement, and one can use this information to process the resulting sensory reafference. The crucial point for our purposes is that reafference is *self-specific*, for it is intrinsically related to one's own action (there is no such thing as a nonself-specific reafference). Thus, by relating efferent signals to their afferent consequences, the CNS marks the difference between self-specific (reafferent) and nonself-specific (exafferent) information in the perception-action cycle. In this way, the CNS implements a functional self/nonself distinction that implicitly specifies one's body as the perceiving subject and agent—as that through which and by which one perceives.

It bears emphasizing that the reafferent-efferent processes just described specify one's body not as a perceptual object, but instead as the perceptual subject and agent of action. For example, consider the visuo-motor act of looking up at the sky to track a bird and the resulting visual perception. This perceptual experience is characterized by (i) a specific content (the flying bird), (ii) a specific mode of presentation (seeing, not hearing), and (iii) a specific perspective (my experience of looking and seeing). The process of relating an efference (the head and eye movements of looking) to a reafference (the resulting sight of the bird) is what allows the perception to be characterized not only by a given content (the flying bird) but also by a self-specific perspective (I am the one looking at the bird) (Legrand 2006; Legrand and Ruby 2009).

The perceiver's embodied perspective is thus of central importance to this framework. Sensorimotor integration implements a unique embodied perspective on the world. Although the basic sensorimotor integration processes do not require any explicit representation of the bodily subject *per se*, the embodied perspective they implement is nonetheless *self-specific* in the strict sense of being both *exclusive*—it characterizes oneself and no one else—and *noncontingent*—changing or losing it entails changing or losing the distinction between self and nonself (Legrand and Ruby 2009). In the general case, one perceives and acts from one's self-specific perspective while implicitly experiencing oneself as a bodily subject. In some particular cases, what one perceives is one's body-as-object, as when one visually recognizes oneself. Whereas the body-as-object consists in the perceptual features one recognizes or attributes to oneself, the body-as-subject consists in the self-specific, embodied perspective from which such perceptions occur. Hence to explain the body-as-subject we need to explain how such an embodied perspective is implemented. Our proposal is that reafferent-efferent processes of sensorimotor integration implement a self-specific, embodied perspective that functions as that through which and by which one perceives the world. In this way, sensorimotor integration produces the body as subject and agent of perception.

Out-of-Body but Not Disembodied

As we have seen, scientists and philosophers often describe certain types of spontaneous autoscopic phenomena as experiences in which one seems to oneself to be disembodied. The sensorimotor model of the body-as-subject, however, indicates that this description is inaccurate and in need of substantial revision. The crucial point is that the experience of perceiving one's body as an object from the outside in out-of-body experiences and heautoscopy occurs within a phenomenal perspective that is embodied and sensorimotor in character, and thus implies a sense of oneself as a bodily subject, specifically a sense of ownership for one's body-as-subject.

Consider that subjects typically describe out-of-body experiences as happening in a bodily space that is perceived in an egocentric frame of reference and in relation to possible bodily movements. The first-person reports indicate that subjects experience themselves as having a visuo-spatial perspective (egocentric perception), as being located at the origin of that perspective (self-location), and sometimes as being able to move deliberately through space (agency). These features are present even in cases in which subjects report experiencing themselves as not having a body but as being a blob or a point of light (Blanke and Arzy 2005, p. 22). No matter what physical or spatial form one takes, to have a visuo-spatial perspective and to be able to move through space or to direct one's visual attention in space imply the experience of oneself as a bodily subject, at least in a minimal sensorimotor sense. In other words, even if one experiences oneself as a passive observational point of view, one still experiences oneself as able to look in this or that direction, that is, as being able to direct one's visual attention within phenomenal space. Having this ability implies experiencing oneself as being situated in space and as possessing some kind of sensorimotor repertoire, not as a disembodied self that lacks all bodily properties.

So far we have been describing the spatial perspective or frame of reference in out-of-body experiences as an egocentric visual perspective, but it is also a gravity-centered or geocentric spatial reference frame with vertical "up" and "down" directions. In general in ordinary experience and in out-of-body experiences, we have a constant knowledge of the vertical orientation and of which way is up. Sensory receptors in the inner ear, the otolith vestibular receptors, are sensitive to gravity, linear acceleration (the rate of change in velocity as one moves in a given direction), and horizontal movement. In out-of-body experiences, subjects usually report that they seem to be above their physical bodies, and they typically describe feelings of rising rapidly, floating, and flying horizontally. Such sensations all involve the vestibular system of the inner ear (the semicircular canals indicating rotational movements, and the otoliths indicating linear accelerations). In short, the sense of self in out-of-body experiences includes not just having a visual egocentric perspective but also a vestibular geocentric perspective with a bodily sense of balance, movement, and up-down orientation.

For these reasons, the term "out-of-body experience" is potentially misleading. A better term might be "out-of-own-body experience," where this term is taken to mean the experience of seeing one's body as an object perceived from a vantage point outside that body. To put the point another way, out-of-body experiences are not so much experiences of disembodiment as experiences of altered embodiment. In an out-of-body experience, one sees one's body as perceptually presented from the outside and as being in a location that does not coincide with the felt location of one's visual and vestibular awareness. In other words, one sees one's body as an object at a place that does not coincide with the felt location of one's awareness as a bodily subject.

In this way, out-of-body experiences illustrate the crucial distinction between the body-as-subject and the body-as-object. In spontaneous out-of-body experiences, the body-as-object is one's body seen from the outside, whereas the body-as-subject is oneself as perceiver. To put the distinction another way, the body-as-object is the external body image one identifies as one's own body, thereby also feeling a sense of ownership for that body, whereas the body-as-subject is the felt origin of the visual (egocentric) and vestibular (geocentric) perspective from which one makes that identification and for which one feels a different kind of ownership, namely, ownership of one's embodied perspective or body-as-subject.

We can now say in more precise terms what makes out-of-body experiences (and heautoscopy) experiences of altered embodiment rather than of disembodiment. In out-of-body experiences, there is a dissociation between one's body-as-object and one's body-as-subject. Normally one experiences one's body-as-object as being in the same place as one's body-as-subject. In out-of-body experiences, however, this unity comes apart, so that one's body-as-object and one's body-as-subject have different locations. What these experiences also show is that when one's body-as-subject and body-as-object do come apart this way, one's sense of self adheres to one's sense of attentional agency, and one's sense of self-location adheres to one's sense of visuo-spatial perspective. In other words, one's sense of agency and location are determined by one's body-as-subject and not one's body-as-object.

The Whole-Body Illusion Experiments Revisited

We are now in position to clarify how the sense of ownership for the body-as-subject versus the body-as-object are related in the experiments on illusory whole-body perception.

On the one hand, many of the principal experimental findings can be accounted for in terms of atypical perceptual experience of the body-as-object. The body is visually perceived as occupying a strange location relative to the usual position one sees it as occupying from one's embodied first-person perspective. This perceptual change implies a change in the perceptual presentation of the body-as-object, but does not necessarily require any change in the embodied perspective itself. Thus subjects report that they experience tactile sensations as located in a body that they visually perceive at a distance, and they report feeling a sense of ownership for this visually presented body. In this case, the sense of ownership being expressed is for the perceptually presented and experimentally manipulated body-as-object.

On the other hand, in some cases the experimental procedures do affect the body-as-subject of perception or the embodied perspective itself. Thus, subjects sometimes report changes to their sense of spatial location, as when they report experiencing a sense of being seated behind their own bodies or floating above and looking down on a virtual body presented above them while they lie in the MRI scanner. In these cases, the subjects experience changes to their embodied perspective or body-as-subject, specifically to their sense of self-location as perceiving subjects and to their egocentric (visuo-spatial and vestibular) perspective. Notice that these changes to the body-as-subject make these altered own-body perceptions closer to spontaneous out-of-body experiences than do the experimental manipulations that affect only the sense of ownership for the body-as-object (as in the rubber hand illusion).

Conclusion and Future Directions

A principal motivation for experimental research on own-body perception is to investigate how the sense of self is related to embodied experience. As we have seen, by changing the stimuli from a rubber hand to an image of the body as a whole, scientists aim to investigate “global, fully embodied self-consciousness… experienced as a single feature, namely a coherent representation of the whole, spatially situated body” (Blanke and Metzinger 2008, p. 9). Our discussion, however, reveals an important limitation in this approach to date. Researchers seem to have assumed that, by investigating the sense of ownership for the body as perceptually presented—the body-as-object—they are specifically targeting one’s bodily sense of selfhood. Yet, as we have seen, this assumption is unwarranted for two reasons. First, experimentally manipulating the sense of ownership for the body-as-object does not necessarily target the body-as-subject. To target the body-as-subject one needs to manipulate directly the reafferent-efferent loops that specify the body as subject of perception and action. Second, the body-as-object is not self-specific in the strict sense, that is, it is not exclusive to oneself and no one else (you and I can both be made to experience ownership for the same virtual reality image of the body); and it is not essential (noncontingent) to oneself (changing it does not entail changing one’s embodied perspective or body-as-subject). It follows that future research will need to investigate directly the body-as-subject and not simply the body-as-object in order to advance our understanding of the self-experience of being a bodily subject of perception and action.

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