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THE MEREOLOGICAL SELF
A Multisensory Description of Self-Plasticity

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The Mereological Self: A Multisensory Description of Self-Plasticity

Submitted by Patrick Fasthén to the University of Skövde as a final year project towards the degree of B.S. in the School of Humanities and Informatics. The project has been supervised by Stefan Berglund.

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I hereby certify that all material in this final year project which is not my own work has been identified and that no work is included for which a degree has already been conferred on me.

Signature: ____

Acknowledgment

"*The juvenile sea squirt wanders through the sea searching for a suitable rock or hunk of coral to cling to and make its home for life. For this task it has a rudimentary nervous system. When it finds its spot, it doesn't need its brain anymore – so it eats it!***"** – Daniel C. Dennett

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Abstract

What am "I"? To what does the word "I" refer? The Self is a concept that feels intuitively obvious to us, but is nevertheless elusive to describe. Against a backdrop of theoretical speculation, this essay presents a basic exposition of the Self with the aid of recent advances in cognitive neuroscience to address one of its most confounding problems: How does the brain sustain the Self – our sense of bodily identity? What informs the question then is dealt with by providing a frame of reference based on the philosophical theory of mereology to contain the analysis (i.e., the relationship of parts to wholes, and of parts to parts within a whole). In relation to the question "What makes us experience what we are?" the Self is put in a context of a multisensory description – a context in which the center very much fails to hold. Enacting such self-plasticity comes at the cost of explicit boundaries, and is in need of a theoretical and methodological framework – not *instead*, but *of* folk-psychological criteria – in determining the nature behind why and how we have the intuition of being a Self.

Keywords: Mereology, multisensory description, self-plasticity, identity, ownership, embodiment, perspective, agency

The Mereological Self

The Self is a concept that feels intuitively obvious to us, but is nevertheless elusive to describe. For that reason, it has always been considered the philosopher's pet. However, the understanding of how the brain works has always posed an unprecedented challenge to our sense of who – or what – we are. In addition, for that reason, cognitive neuroscience has begun to tease us with questions such as "What makes us experience what we are?", and to take us on a journey in search of a biological interpretation of the Self. A few years ago, this would not have been within the mainstream of scientific inquiry, whereas now there is no disputing its relevance to understanding our sense of Self. Nevertheless, the field is still in its infancy, and a long way from being able to answer the deeper questions of our existence. What this creates – as in all fledgling sciences – is a considerable terminological tangle that is in urgent need of conceptual differentiation. However laden with conceptual difficulties though, this problem cannot be articulated without relying on scientific inquiry. Since folk-psychology is a dubious adviser on such matters, this essay will seek to meet such demands by addressing the problem of how the brain sustains the Self – our sense of bodily identity?

Thus, the first goal of this essay – from a twofold aim – will be to review our efforts of a more empirical description, based on objective and sharp biological criteria that correspond to answering the question of "What makes us experience what we are?" In other words, this project has the first goal of exhibiting scientific and descriptive criteria – not *instead*, but *of* folk-psychological notions – in determining the nature of the *intuition* behind the bodily Self.

To clarify this, what if the Self has a vested interest in convincing itself that it is a lot more than it actually is? This is where cognitive neuroscience shine – in realizing our identity – not by revealing what the Self is, but rather how we have the intuition of being a Self. In other words, instead of focusing on its essential features – assuming its existence at the outset – it may show us the cause of how it has become such an illusory abstraction, in the first place.

To debate the appropriate pronouns to apply, in order to define and discriminate terms, it may strike some as cardinal bickering over “mere semantics” – yet, there are others for whom the debate raises important issues. Indeed, this is semantics in that it concerns the labelling of abstractions. However, since we are constantly trying to categorize the complexity of the world and to distil what really matters from any given situation, it determines our attitudes towards each thing. For that reason – and that reason alone – there is a need to stress the fact that the main restriction in the course of this essay will revolve exclusively around the Self (i.e., Subject), circumventing the deeper riddle of consciousness (i.e., Subjectivity).
Indeed, in the context of this essay, the Self will be defined exclusively as the Bodily Self, as a minimal requirement of self-consciousness, and will hence be referred to only as the ‘Self’. Thus, it will be important to remember that this essay will make no attempts to question the higher order nature of the Self, such as memory, self-awareness, or other executive processes. Consequently, criticism regarding those aspects will be rather fruitless since the Bodily Self makes no effort to actually argue for it being no more than a sufficient criterion of Selfhood.

Indeed, to some – or perhaps most of us – the ineffable sense of being an irreducible whole, or the feeling of being a subject of one’s experiences, seem to be the most veridical thing in the world. Yet, the question to ask oneself is whether Subjectivity necessarily implies the existence of a Subject? Acceptance of an indivisible entity – the Subject of experience – may just be a “cheap and nasty edition of the soul” (James, 1890/1957, p. 365), and perhaps many fail to discard the intuition of a center where it all “comes together”. Thus, the peripheral aim of this essay will be – in light of the evidence presented – to combat the strident intuitive notions of the Subject which end up contaminating our semantic water supply. The premise is not to wind up with a conclusive “take home message” – insomuch as to tie everything together in the end – but will instead furnish a blanket narrative in order to habituate the reader with intuitions that hopefully can sway some to look beyond the illusion.

Moreover, with this newly added *description* of the Self, we will also come to understand it from a different *level of description*, mostly because such sneaking suspicions seldom are considered explicitly – or at least not enough to justify going against such strong intuitions. We typically identify and describe an interesting phenomenon at one level of description in nature and then try to reduce it down to its components in order to explain how the system displays a particular function, which can only be observed at the level of the whole system. In other words, we normally describe what goes on around us, not in terms of particle physics, but in terms of ill-defined abstractions. This is *our* reality, due to limiting natural constraints.

This amounts to the second goal of this essay, which takes its inspiration from mereology. This is the philosophical theory of parthood relations – of the relations of parts to whole and the relations of part to part within a whole. Traditionally, it addresses the metaphysical question of the relation between composition and identity. However, we are not concerned with the metaphysical issue of personal identity, but rather in the epistemological description of the mereology of the Self. Thus, contrary to arriving at the usual reductionist description in terms of “the Self is nothing but…”, the goal is to put on display a more holistic description.

The reason for this is that there is no single localized “identity spot” in the brain. Although reductionist descriptions are a pivotal object of study, it betrays a limited perspective in terms of the grand picture of things, which is why cognitive neuroscience may be a discipline to look out for when it comes to merging reductionist and holistic agendas into a coherent framework when realizing such a high-level abstraction as the Self. In order to achieve this, what we need to do is – instead of asking *where* the Self is in our brains – we need to ask on *what* level of description the question of “What makes us experience what we are?” can be answered. How can we sketch the mereology of the Self such as to rival reductionism, and deem it less effective in the wake of scale and complexity? To reiterate, the second goal is not to descend the Self into something else, but rather to ascend it to a higher level of description.

Such an integrative picture is hard to imagine, but we certainly do not want to focus on the trees at the expense of the forest. The point is that, just as blunt as it is to search for the Self in individual neurons, is it to search for it on the level of individual regions. Identifying the brain as the multi-level integrated system it is, I think is key if we are to make any progress.

Thus, we now have a framework from which to depart in the analysis of the research, that includes both *(a)* a change in *description* from understanding what the Self is by already assuming its existence, to how we gain the intuition of being a Self; and *(b)* a change in the *level of description* from how we usually are trying to reduce the Self to a place proper, to exposing its proper place. In endorsing this, let us look at the structure of the essay at hand.

In the first half, under the main headings of “The Embodied Self” and “The Acting Self”, there will be presented a discussion of how the Self relates to the body and its parts in terms of being represented by the brain, as well as in creating a sense of ownership and agency. More specifically, we are going to take a look at the somatosensory and motor cortices, together with their hierarchical description of different body representations from the prospect of the two goals set out – namely *(b)* what is the relation between body parts and the body as a whole; and *(a)* what is the relation between the body as a whole and the Self.

In the second half, under the main heading of “The Plastic Self”, the profoundly plastic multisensory representation of the Self, will be presented together with an examination of the diverse dynamical structures that enable it to constantly shift and adapt. This heading will be divided into two sections: “Parthood” and “Selfhood”. They will both function as a division of analysis between body-*part*, and *whole*-body plasticity. Each section will further be subdivided into three distinct categories of exposition. As follows, the exhibit on body part plasticity will span “Modification”, “Separation”, and “Composition”; whereas the exhibit on whole body plasticity will span “Duplication”, “Projection”, and “Simulation”. The final analysis of the two goals presented will mainly be saved for the discussion in the end.

The Embodied Self

Prominent researchers from various disciplines have recently joined forces in trying to ground the concept of the Self in the organism and its physiology by investigating how the brain dynamically is able to represent its most basic properties, such as how we come to feel that we own our body (Gallagher, 2000). How does this sense of ownership relate to the Self? In our everyday reflections, memory is often considered to be the primary basis when it comes to our experience of being a Self. However, in contrast to what is to come – and put quite bluntly – memories do not remind us what we are, they remind us what we were.

Instead, consider the idea that you are the same Self as you were yesterday, even though your body has changed, yet remained yours. Given the fact that we have discarded the notion of a transparent Subject concealed somewhere within the boundaries of our body, what seems to remain is that the body is the only object in the world that we have the ability to experience both objectively, as well as subjectively. The sensory signals from our body are unique, and create a sense of intimacy. The fact that the brain is in the body is indisputable – but the reverse is also true – the body is in the brain in terms of being represented (Tsakiris, 2010). As will hopefully become clearly depicted, there is ample evidence to suggest that the continuity of the Self may be sustained by the integration of multisensory bodily inputs.

One of the main questions in mereology is to define the relevant parts of an object. This approach leaves open the possibility of investigating the Self by reviewing how recent research in the field addresses the two intimately related questions based on the goals: *(b)* What is the relation between body parts and the body as a whole – namely, how do we differentiate the body into parts (i.e., reductionism), and how are these parts organized into a whole body (i.e., holism); *(a)* what is the relation between the whole body and the Self? Can the way I experience myself as a whole be reduced to the way I experience each of my body parts? Now that we have a sense of the big picture, it is time to take a look at the basics.

Somatosensory Mereology

The somatic senses stand apart from the other senses at a basic level. They are distinct senses conveyed by receptors that perfuse the body's skin and inner tissues, and includes: Touch (pressure); Thermoception (temperature); Nocioception (pain); Proprioception (position and motion); and Vestibular (balance) (Gazzaniga, Ivry, & Mangun, 2008).

For the purpose of the current discussion, the focus will be mainly on proprioception, which is the sense that comes closest to the experience of being a Self (Haggard, Taylor-Clarke, & Kennett, 2003). It is the experience of where our body parts are located – both at rest and moving – and is elicited by receptors on muscles and joints that detect their dynamical displacements. These receptors send their sensory input by primary sensory neurons to the spinal cord where they synapse with secondary sensory neurons in the brainstem. They then cross over to synapse contralaterally with tertiary sensory neurons in the thalamus before being projected to the somatosensory cortex (Gazzaniga et al., 2008).

The initial cortical area to receive this sensory input is the primary somatosensory cortex (S1), and here somatosensory representations follow a topographic division of body parts, also known as the "Homunculus" (Penfield & Boldrey, 1937). Although this area – or map – is a representation of our body as a whole, all sensory input from each body part are here to be seen as individually distinct. At this low level of description, this is not nearly enough in order to create the experience of ownership, which calls for more complex representations.

The second cortical area to receive input is the second somatosensory cortex (S2), which integrates proprioceptive and tactile sensory inputs into more complex representations (e.g., size, motion, texture). At this level – and although this map is smaller – is where we get the experience of the position and size of body parts relative to each other in space as they move. We also get the continuous sense of inhabiting a body embedded within a larger context as it constantly gets updated from the lower-level sensory input (i.e., S1) (Maravita & Iriki, 2004).

The third – and final – cortical area to receive input is the posterior parietal cortex (PPC), which serves as a point of convergence between vision and the lower-level somatosensory representations (i.e., S1, S2). Probably more than any of the lower-level maps, this area is able to create the sense of ownership, and consequently the experience of a sense of Self (Haggard et al., 2003). It neatly enables us to determine where objects are in relation to our body, including the body as an object in and of itself (Metzinger, 2003). It is where my experience of wholeness "come together", the seamless sense of where and what "I" am.

Thus, the experience of a Self can be seen as a holistic construct characterized by part-whole relations originating from many separate sources. In mereological terms, consider the discrepancy between *(1)* we are composed of separable parts, and *(2)* we are not composed of separable parts, but are mereological sums. If we are going to adopt the previously skeptical – and slightly cynical – stance of James' here, the vast majority of us would try to invoke the simple intuition in what could be expressed as: "I experience myself as having no separable parts." Yet, Hume (1739/2004) recounts that: "…I may venture to affirm of the rest of mankind, that they are nothing but a bundle or collection of different perceptions" (p. 162).

What maybe is missing in this picture is the subtle notion that this part-whole relation, based on the different levels of representation in the somatosensory cortex, does not necessarily reflect the fact that the body is not naturally – or innately – differentiated. It seems misguided to me that the topographic map in S1 representing the individual body parts is somehow structured from fixed categories. Instead, the differentiation into distinct body parts in S1 may attest to how we interact with the external world, hence being functionally plastic and conditionally dependent on higher levels of body representations. A note of caution from Dennett (1991) also points to the risk of using the concept of "representation" since it implies that sensory input has to be *re*-discriminated to some centralized discriminator, which may be unnecessary to consider, and may eventually avoid using.

The Acting Self

We now go from a sense of ownership to a sense of agency – as both are intimately related and mutually viable – when it comes to the experience of being a Self (Gallagher, 2000; Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008; Tsakiris, Prabhu, & Haggard, 2006). In keeping with this, a sense of agency involves the experience of being in control of one's own voluntary actions and – through them – events in the external world. Thus, if we lose control over our actions, our sense of Self will be greatly diminished, as we will feel less of an actor of our actions – less of an agent "in charge" (Tsakiris & Haggard, 2005a). The field of motor control includes several extensive lines of research, and as a consequence of this, a direct limitation to the scope of this section – and to the essay as a whole – will inevitably be to avoid all discussion amounting to the tantalizing issue of free will. Instead we are going to ask ourselves whether agency is a necessary condition for the experience of being a Self.

It is presumably not necessary to have conceptual knowledge (e.g., the pronoun "I") for us in order to have the experience of being a Self, and it seems just as likely to assume that multisensory integration may be sufficient for the sense of ownership even in the absence of the sense of agency. That is, somatosensory input clearly relates to the Self in the absence of voluntary actions (Tsakiris, Haggard, Franck, Mainy, & Sirigu, 2005), and even though this issue becomes more complex involving intentionality and free will, the sense of agency will still be a sufficiently strong cue for it to justify being mentioned (Blanke & Metzinger, 2009).

The contention here is that our body is not just a vessel for our brains to cruise in, as such a notion would be similar to the same kind of dichotomy between the organism and the Self. The relationship between ownership and agency is mutual in all respects. We interact with the external world through the body because the body is the outpost that sets the limits of our experience of being a distinct entity (i.e., a Self). By acting, we carve out our sense of identity by situating ourselves in a context where we can be the authors, instead of being authored.

Motor Mereology

As with area S1, we have a motor "Homunculus" as well (Penfield & Boldrey, 1937). Instead of receiving inputs, this map sends output signals to our muscles in a top-down fashion. Hence, the first cortical area to send output is the secondary motor cortex (M2), which is divided into the premotor cortex (PMC), and the supplementary motor area (SMA). These areas are crucial for action planning and readiness potential before one is about to act, and paved the way for much of the research behind the issue of free will. The second cortical area to send output is the primary motor cortex (M1), which then translates the planned and ready action into movement with the assistance from the brain stem, cerebellum, and basal ganglia before being projected to the muscles via the spinal cord (Gazzaniga et al., 2008). Interestingly – and to the point – Penfield and Boldrey (1937) reported that their patients, when being stimulated, experienced movements induced by M1 as involuntary – like something had been done *to* them. The movements induced by M2, on the other hand, were reported being experienced as voluntary – like something had been done *by* them.

If the sense of agency – or the experience of being an agent – is to be seen as mere modification upon one's sense of ownership, then we can start invoking the ingenious remark from Wittgenstein (1953/1999): "What is left over if I subtract the fact that my arm goes up from the fact that I raise my arm?" (§621). From this I think we can infer that voluntary actions may provide a unique perspective in terms of the part-whole relation compared to somatosensory mereology. The starting point would be to differentiate body parts according to the muscle groups that we voluntarily are able to move. The difference here – compared to the topographic organization of S1 – is the fact that M1 seems to be more integrated and overlapping (Tsakiris et al., 2006). For example, if we move our arm, our hands will follow in that action. Thus – in action – multiple body parts are controlled as an integrated whole. In contrast, if we are touched on the arm, we consequently do not feel the touch on the hand.

The Plastic Self

Hopefully by now, we have a fairly clear view of the standard description of the Self as a multisensory representation, and can proceed to slowly begin to unravel the plastic – yet stable – nature of this representation. Our cortical body maps – as hinted upon above – have a profoundly dynamic structure, enabling them to constantly shift and adapt on every level of description. This degree of flexibility is crucial in order to endure dramatic changes to the system, either by damage or in response to experience (Maravita & Iriki, 2004). Yet, despite the plastic feat of these cortical body maps, the fact that it seems static to us may reflect their dynamic stability and our experience of ourselves as being identical over time. Admittedly, often the things that seem black or white to us actually come in shades, it is just that in most ordinary circumstances, we are implicitly discouraged from imagining such slow changes. The point is, we experience ourselves as seamless wholes when everything is working fine. It is usually not until we sustain damage large enough to make a difference – or is able to trick the brain somehow – that the illusion is spoiled, exposing us to all kinds of strange or unusual experiences. Here I will try to examine such events further, both in terms of parts and wholes.

Parthood

In this section, I will analyse how we bestow our sense of ownership to body parts from the distinct perspectives of modification, separation, and composition. Body representations do not merely receive input from our senses, but is an active process of multisensory integration – and as long as there is a natural harmony – they will provide a strong cue for experiencing body parts as belonging to us (Tsakiris, 2010). The body that we experience is always our own – but needless to say – we do not always experience it as such. Rather than accepting this, our cortical body maps are willing to make some undemanding interpretations – even if physically impossible – to maintain a sense of coherence (Haggard et al., 2003).

Modification. Proprioception – although fundamental to the position of body parts – is not able to convey the information of their relative size and shape without receiving some help from either touch in S2 (Lackner, 1988), or from vision in PPC (Taylor-Clarke, Jacobsen, & Haggard, 2004). Illusions of body part size stand to testify that the boundaries of our bodies do not always coincide with the way we experience them. One such illusion was discovered by Gandevia and Phegan (1999) who measured an increase in perceived body part size when interrupting incoming sensory signals with local anesthesia. This is familiar territory to anyone who has received dental anesthesia, which makes the mouth feel swollen. They were also able to demonstrate the plasticity of the somatosensory cortex by anesthetizing the thumb, only to discover an increase in perceived lip size due to their adjacent locations in S1.

Another – and a rather amusing – example stems from Lackner's (1988) Pinocchio Illusion, which relies on vibrating the muscle tendons in the arm in order to trigger illusory movement. For instance, vibrating the biceps tendon generates the illusion of elbow extension. The amusing part, however, comes from the fact that if holding on to the nose with the hand of the stimulated arm, often results in the illusory experience that the nose is getting longer. Under these conditions, a sensory conflict is created between proprioceptive signals of the moving hand, and touch signals from the fixed contact with the nose. In order to resolve this conflict, the cortical body maps try to interpret the signals according to a strict perceptual logic: If the hand was to be moving *for real* – while constantly maintaining contact with the nose – it would have to mean that the nose was growing in size and shape.

In similar fashion, Ehrsson, Kito, Sadato, Passingham, and Naito (2005) found that tendon vibrations of the wrists could also induce illusions of a shrinking waist in participants whose hands are placed on their hips. This study was supplemented by fMRI data establishing the involvement of the parietal cortex in resolving this conflict, giving a clear indication that the relative size and shape of body parts require some degree of multisensory integration.

Separation. Amputation provides us with the most obvious example of body part separation. Unfortunately for some, this is accompanied by "phantom" experiences of the absent limb – conveniently labeled as Phantom Limbs (Ramachandran & Hirstein, 1998). These experiences are characterized by a lingering sense of ownership over the amputated limb, like it is still being part of the body. This may perhaps be the most vivid exhibit to showcase the plasticity of our cortical body maps – since following this misfortune – they yield major topographical reorganization. Adjacent cortical areas in S1 will permeate the cortical area previously represented by the amputated body part in a hostile takeover to compensate for the loss of sensory input. Ramachandran and Rogers-Ramachandran (1996) could demonstrate this by touching the face of a patient on the contralateral side to the amputation, only to elicit topographically mapped sensations on the phantom limb.

What is more, there are a few reported cases of patients that have been born without limbs, but nevertheless have suffered from phantoms in the absence of ever having received any proprioceptive input (Ramachandran & Blakeslee, 1998; Ramachandran & Hirstein, 1998). Alas, what this seems to imply – in terms of mereology – is that body parts may be innately differentiated in our cortical body maps. This would obviously be contradictory to the previous discussion which didn't support the idea that there are fixed categories of body representations in the brain. However, if it wasn't for the fact that such reasoning seems to ignore the basic principle behind plasticity – namely context – the idea of "hardwired" body maps could prove seductive. Since Ramachandran and Rogers-Ramachandran (1996) made us bear witness to this remarkably contextualized interplay between our bodies and the external world, it would be deemed unnecessary not to take into account the fact that body parts cannot be understood in isolation from each other, but have to be related to other body parts (i.e., part-part relations) as well as to the body as a whole (i.e., part-whole relations). The next topic is thus going to emphasize how wholes relates to the sum of their parts.

Composition. Intriguingly – and as far as the brain is concerned – we have no boundaries. The Self does not end where the physical body ends, but suffuses with the space around us. There is a large "body" of evidence from experiments in support of the notion that the body is sufficiently plastic to incorporate new body parts, irrespective of their material composition.

As mentioned recently, body parts could be interpreted as contextualized multisensory representations that are assembled through the interplay between the boundaries of our bodies and our relationship with the external world. For this interaction to play out properly, we need to acknowledge three crucial aspects of the space surrounding our bodies – namely Personal Space, Peripersonal Space, and Extrapersonal Space (Holmes & Spence, 2004). Personal space is simply the representation of the body's surface. Perhaps of more interest is peripersonal space, which refers to the representation of the immediate space that is within our reach. Extrapersonal space is thus the representation of what lies beyond our reach. Our cortical body maps could thus be seen to incorporate the space around our bodies to be a part of us, seemingly blending our subjective and objective realities (Pavani & Castiello, 2003).

Recently conducted studies have further revealed that peripersonal space is plastic, and is able to shrink or expand to suit our preferences. Maravita and Iriki (2004) carried out some important work using single-cell recordings in monkeys, and were able to show that body representations in peripersonal space could be expanded to incorporate tools. For instance, the monkeys' normal visual receptive field only responded to stimuli as far away as its hands. But after using a rake for some time, their visual receptive fields now extended to the tip of the rake. In other words, the monkeys' representation of peripersonal space was extended to include a foreign object as a new recruit among its already owned body parts. This is a familiar feeling for everyone who has experienced the sensation of the texture of food with a knife or fork – or of gradually being less attentive to newly acquired jewelry or clothes. In mereological terms, tools either become a new body part, or part of an already existing part.

As convenient as this might sound, we do not have the associated sense of ownership over these tools, as few of us would actually mistake the tool for our real hand. But what if it was possible to mistake another hand for our hand? A particular model for investigating the sense of ownership is the well known Rubber Hand Illusion (RHI) (Botvinick & Cohen, 1998). It has since its discovery been utilized extensively by researchers trying to understand the mechanisms behind multisensory integration, and is a shining example of refined method. The hallmark of this model – compared to previous assessments – is the high emphasis on vision to “synthesize” the body as a whole from sensory input of the different body parts.

In the original experiment by Botvinick and Cohen (1998), as well as in subsequent versions (Ehrsson, Spence, & Passingham, 2004; Tsakiris & Haggard, 2005b) subjects were sat down with their left hand resting on a table, hidden behind a screen. Next they were asked to fixate their attention on a fake – yet realistic – rubber hand presented in front of them. The experimenter then use two small paintbrushes to stroke the rubber hand and the subjects’ hidden hand in synchrony with each other. After a short period (i.e., 10-30 sec.) they reported having the sensation of touch in the location of the rubber hand, as if it was their own hand. This illusion is very dramatic, often with subjects expressing strong reactions of surprise.

Beyond subjective reports, more objective measures have also been developed. One such measure is to register “proprioceptive drift” – or the degree to which subjects experience their hand to be closer to the rubber hand than it actually is. When asked to close their eyes and point toward their hidden hand, the subjects tend to be pointing at a location closer to the rubber hand (Botvinick & Cohen, 1998; Ehrsson et al., 2004; Tsakiris & Haggard, 2005b). Another test is to simulate a threat to the owned rubber hand to observe if subjects display any autonomic reactions, as measured by Skin Conductance Response (SCR). Registered changes to SCR occur both by forcefully bending a finger (Armel & Ramachandran, 2003), and by stabbing it with a needle (Ehrsson, Wiech, Weiskopf, Dolan, & Passingham, 2007).

Interestingly, although these findings seem to be consistent with the notion that the rubber hand is accepted as a part of one's body, recent studies have also been able to demonstrate that the real hand is rejected. Mosley et al. (2008) reported a decrease in temperature in the real hand, related to lowered metabolism; whereas Barnsley et al. (2011) reported an increase in histamine levels, related to heightened immune responses. However, as seductive as it is to refer to the Self here, there is already a long tradition in medicine relating to the theoretical notion of a Host that represents the body's ability to reject foreign pathogens and organs.

All the same, this would only help strengthen the notion of a Subject behind the scenes making choices as to which parts to include. Instead, the reason behind why and how the rubber hand is experienced as part of one's body can be explained solely in terms of the plasticity of body representations related to the multisensory integration between visual, tactile, and proprioceptive input. The first RHI studies even suggested that the integration between vision and touch alone were both necessary and sufficient for inducing the illusion (Botvinick & Cohen, 1998; Ehrsson et al., 2004; Tsakiris & Haggard, 2005b). The necessary criterion of a visuo-tactile explanation for ownership was nevertheless quickly disposed of as inaccurate given that the illusion could be induced in the absence of vision in a somatic version of the RHI involving blindfolded subjects (Ehrsson, Holmes, & Passingham, 2005). This points to the importance of proprioception in mediating a sense of ownership, which is further supported by studies stressing the fact that the illusion is spoiled as soon as the rubber hand is positioned anatomically incorrectly by rotating it 90° (Tsakiris & Haggard, 2005b), 180° (Ehrsson et al., 2004), or by placing it too far away from the real hand (Lloyd, 2007).

Now, given that we deem proprioception to be a necessary condition for the sense of ownership – along with the refuted necessity of vision – this does not mean that vision cannot be a perfectly sufficient criterion. For instance, Tsakiris and Haggard (2005b) established that the illusion is reduced – or does not work at all – with objects that do not resemble real hands.

As a consequence, both visuo-tacile and tacile-proprioceptive models of the RHI are now thought of as less effective for the intended purposes of developing a minimal requirement for inducing body ownership. Accordingly, this has recently led a few researchers to develop more refined models based around visuo-proprioceptive integration, with tactile stimulation just as an added measure (Blanke, 2012; Makin, Holmes, & Ehrsson, 2008; Tsakiris, 2010).

Whichever model of multisensory integration one chooses to adopt, the existence of an integrative process can be further strengthened with circumstantial evidence from a range of neuroimaging studies. Activity in key areas in the parietal and frontal lobes related to multisensory association (e.g., PPC, PMC) has been found using fMRI (Ehrsson et al., 2004; Ehrsson, Holmes, et al., 2005), and PET (Tsakiris, Hesse, Boy, Haggard, & Fink, 2007).

Armel and Ramachandran (2003) even go as far as to say that *any* object can become a part of our body, due to their strong opinion that *any* form of multisensory integration is both a necessary and sufficient condition for us to be able to trick the brain into conflict. Alas, on the back of this view – and in exchange – I think that the concept of the Self can be entirely disposed of. However, this is not the only view there is. A complimentary approach would count as to include the notion of an innate body representation that constitutes more than just the correlation of sensory input – more than the mere sum of its parts. Such a view would instead conveniently supplement the evidence provided by Tsakiris and Haggard (2005b), implying that there is a natural constraint as to what parts can be incorporated (i.e., hands).

In concluding this section, much of what has been presented here reveals that body part representations caused by multisensory integration are substantially more plastic than we are sometimes prepared to accept. For instance, some of the most fascinating new research on the topic includes precursors to being able to project the sense of ownership into advanced neuroprosthetics (Ehrsson et al., 2008; Rosén et al., 2009). Ultimately, this raises the fundamental question of how the brain is able to distinguish the Self from the external world.

Selfhood

If we really want to understand what the Self is, we also have to look beyond parthood relations, into what it really means to experience ourselves being located inside our bodies. What makes us experience what we are, given the fact that we under normal conditions have the temporal and spatial aspects of being a single entity that is identical to itself over time? This section, will present an entirely different description of the Self, one that will rival the earlier accounts of body *part* ownership in terms of being spatially situated to the *whole* body. In other words, what does it entail for a system as a whole to "own" itself?

In recognizing the ambiguous description of part-whole relations, we may also be inclined to ask whether there are body representations of larger regions (e.g., trunk, head, half-body)? Likewise, this may further lead us to ask: What about the whole body? There seem to be evidence to suggest an affirmative answer to this question. Indeed, neuronal populations in the somatosensory cortex manifest divergent receptive fields responding to different degrees of tactile stimuli (Rusconi, Gonzaga, Adriani, Braun, & Haggard, 2009). Hence, S2 and PPC neurons readily displays larger receptive fields responding to stimuli arrived at from the face (Sforza, Bufalari, Haggard, & Aglioti, 2010; Tsakiris, 2008), or the half body/upper body, as well as from the whole body (Heydrich, Dieguez, Grunwald, Seeck, & Blanke, 2010).

These whole body representations do not merely rely on the multisensory integration of vision, touch, and proprioception, but also incorporate a vestibular component (i.e., balance). Blanke and Metzinger (2009) and Blanke (2012) further informs us of converging evidence from double dissociations to suggest a division of the Self that conceivably cannot be seen as different parts of the body, a division that makes up for three important aspects of Selfhood:

(I) *Ownership:* (i.e., Self-attribution – "*What* I experience *as my body*");

(II) *Embodiment:* (i.e., Self-location – "*Where* I experience *to be*");

(III) *Perspective:* (i.e., Self-direction – "*Where* I experience *from*").

Duplication. One approach to investigate these three relevant aspects of the Self is to study patients with disturbances as a result of brain damage. For most of us – and under normal conditions – the boundaries between the Self and our body, and between our body and the external world are well defined. However, there are some neurological disorders in which these boundaries becomes disturbed, and rather dramatically. One such group of disorders are called Autoscopic Phenomena (AP) which includes Autoscopic Hallucinations (AH), Heautoscopy (HAS), and Out-of-Body Experiences (OBE). These are all especially relevant because they are illusory whole body representations, which also means that they have been studied at length and tested experimentally in healthy subjects, much akin to the RHI (Blanke, Landis, Spinelli, & Seeck, 2004; Brugger, 2002; Brugger, Agosti, & Regard, 1994; Brugger, Regard, & Landis, 1997; Devinsky, Feldmann, Burrowes, & Bromfield, 1989). What they all have in common for the patient is the rather bizarre experience of seeing an illusory second body – or duplicate – of oneself in extrapersonal space. In any case, let us take a closer look at each one of them, in order to determine their distinct characteristics.

During AH, patients experience seeing a duplicate of themselves in extrapersonal space without any sensations of abnormal embodiment (i.e., they do not localize themselves at the position of the duplicate), ownership (i.e., they do not attribute the duplicate as their body), or perspective (i.e., they do not direct their perspective as originating from the duplicate). Hence, AH is a purely visual illusion of a whole body representation (Blanke et al., 2004).

In contrast to AH, patients with HAS may experience all three aspects of embodiment, ownership, and perspective. However, they are often portrayed in degrees of spatial and temporal incongruence. This generates an unstable condition in which the Self either seems to jump between the physical body and the duplicate, or split between the two in a bizarre sense of co-existence (i.e., self-location without disembodiment). Thus, HAS can be seen to induce a *re*duplication of a whole body representation (Blanke et al., 2004; Brugger et al., 1994).

Lastly in the analysis of AP, during an OBE patients experience abnormal embodiment (i.e., they localize themselves in extrapersonal space) and perspective (i.e., they direct their perspective as originating from the localized position), whereas they maintain the sense of ownership over their physical bodies. Thus, OBEs creates for them the unnerving experience of being outside their body – from an elevated position – looking down at what is still felt to be them (Blanke et al., 2004; Blanke & Mohr, 2005; Brugger, 2002; Brugger et al., 1997).

Moreover, a couple of rare types of AP have also been reported, which adds some further depth to the analysis of what makes these neurological disorders so special in terms of self-plasticity. In relation to the aforementioned cases, patients sometimes experience multiple duplicates – generally two or three, but sometimes to the point of filling entire rooms – and is referred to as Polyopic Heautoscopy (Brugger, Blanke, Regard, Bradford, & Landis, 2006). Worth mentioning is also that patients with AP often suffer from a condition referred to as Depersonalization, which associates to the strange experience of detachment from one’s body or surroundings, as if being a mere spectator (Devinsky et al., 1989; Brugger et al., 1997).

Admittedly, these are all interesting experiences because they challenge our everyday intuitions of the Self as being “residents” in our bodies – of “I” being a Subject of experience. However, let us supplement such intuitions with some neural correlates. With respect to the neural correlates of AP, the earlier studies could merely demonstrate involvement of the temporal, parietal, or occipital lobes (Brugger et al., 1997; Devinsky et al., 1989). More recently, confirmed fMRI data from lesion studies specify the involvement of the temporo-parietal junction (TPJ) during HAS and OBE, as well as the parieto-occipital cortex during AH (Blanke & Arzy, 2005; Blanke et al., 2004; Blanke & Mohr, 2005; Bünning & Blanke, 2005). In support of this, electrical stimulation applied at TPJ in patients undergoing epileptic treatment has also been shown to induce OBEs. Stimulation of the same site – with smaller currents – further induced vestibular responses (Blanke, Ortigue, Landis, & Seeck, 2002).

The engagement of the vestibular system during AP has led Blanke and colleagues to the tentative hypothesis that AP will most likely result from the failure to integrate multisensory information, with balance as an added novel sensory component. More specifically, what they argue is that AP results from: *(a)* multisensory disintegration in personal space – due to visual, tactile, and proprioceptive conflicts; and a second *(b)* multisensory disintegration between personal and extrapersonal space – due to visual and added vestibular conflicts (Arzy, Seeck, Ortigue, Spinelli, & Blanke, 2006; Blanke & Arzy, 2005; Blanke et al., 2002).

The vestibular system remains enigmatic insomuch as it is the only sensory organ which obtains distributed pathways shared with all the other senses (Lopez, Halje, & Blanke, 2008). Although this makes perfect sense considering balance is constantly with us, the fact remains that if the vestibular system was to fail, it would have devastating consequences for any organism by virtue of not being able to deal with gravity. Our bodies are predisposed for living in terrestrial gravity, and we all learn to walk by calibrating it (Lopez & Blanke, 2011).

Clément, Moore, Raphan, and Cohen (2001) were able to present us with some striking reports of this from subjects who have had the privilege to experience zero gravity. For instance, astronauts who return from space need time to adjust to earth gravity again, and as a consequence can suffer from some rather demoralizing illusory whole body representations (i.e., like the feeling of the ground raising up from under their feet when doing knee bends).

Another instance stems from the fact that in the presence of gravity, weightlessness can only be obtained in prolonged free fall (i.e., microgravity) on aircrafts during parabolic flights. Reasonable to assume, data obtained from subjects aboard such flights report them having experiences of disorientation in terms of feeling upside-down relative to extrapersonal space – commonly referred to as the Inversion Illusion (Lackner, 1992). These experiences can be so compelling that the subjects assume an incorrect position when preparing themselves for landing, which have consequently led to some major accidents.

Projection. We have up until this point covered areas with special concern for plasticity in terms of ownership and embodiment, so it is now time to take a closer look at perspective. As can be inferred from above, and despite the fact that clinical patients with disturbed whole body representations present us with unique opportunities to study the Self, we nevertheless face difficulties of small sample sizes, as well as generalization of data to healthy subjects. As a result of this, a growing number of researchers have begun developing techniques to study whole body representations in healthy subjects, by exerting familiar principles on the back of the RHI. This provides the means for replicable measures in controlled settings.

Although embodiment and perspective share tight links and often coincide under normal conditions – as well as in most AP – there are cases in which some patients with HAS report strong dissociations between where they experience themselves to be located, and from where they perceive the world. What this seems to suggest is that these aspects rely on distinct neural mechanisms, with the added possibility to induce similar dissociations in perfectly healthy subjects (De Ridder, Laere, Dupont, Menovsky, & Van de Heyning, 2007).

In a study by Mizumoto and Ishikawa (2005), the authors installed a camera in the upper corner of a room and projected the visual feed from the camera to a subject wearing a Head Mounted Display (HMD). This way, the subject could see himself from a distance while walking around in the room, generating the curious experience of being in two places at once.

Aside from exploiting the displacement of perspective and embodiment by producing a spatial conflict between vision and proprioception, the HMD also enables researchers to induce variable alterations between a First Person Perspective (1PP) and a Third Person Perspective (3PP). Salamin, Tadi, Blanke, Vexo, and Thalmann (2010) managed exactly that, as they were able to improve upon the previous study by making the subtle move of mounting the camera on a rig worn by the subjects on their backs. This way they could view themselves from a 3PP behind their own head, which greatly enhanced the experience (See Figure 1.).

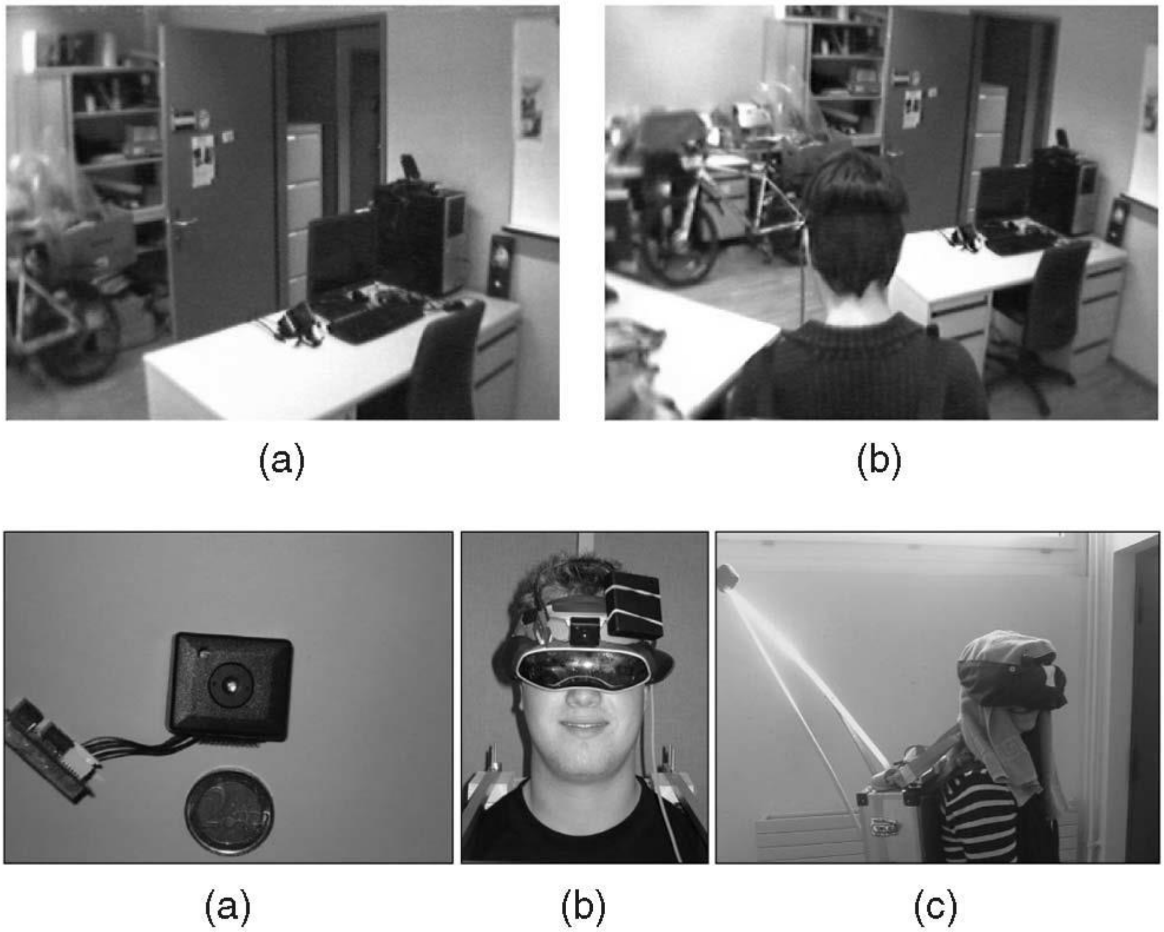

Figure 1. Experimental setup. *(a)* Camera projecting 1PP; *(b)* HMD projecting 3PP; *(c)* Mounted equipment. Reprinted from “Quantifying Effects of Exposure to the Third and First-Person Perspectives in Virtual-Reality-Based Training,” by P. Salamin, T. Tadi, O. Blanke, F. Vexo, and D. Thalmann, 2010, *IEEE Transactions on Learning Technologies*, *3*, 273. Copyright 2010 by IEEE. Reprinted with permission.

Even so, the breakthrough in this field came from two independent teams of scientists who produced similar results (Ehrsson, 2007; Lenggenhager, Tadi, Metzinger, & Blanke, 2007). Remarkably, they were able to come up with novel techniques to dissociate between all three aspects of selfhood in healthy subjects (i.e., ownership, embodiment, and perspective) by taking advantage of multisensory conflicts in order to manipulate whole body representations. Both teams utilized the same synchronous visuo-tacile stimulation employed in the research on the RHI, thereby extending the model from body parts to whole body representations.

In achieving this, Lenggenhager et al. (2007) implemented a similar experimental setup (See Figure 1 and 2B) but with some slight differences to the experimental procedure. Instead of a moving camera system, they used a fixed camera system mounted on the floor behind their subjects. That way the subjects had a clear view of their whole body from a 3PP looking at their backs. The experimenter thereupon stroked their backs with a stick, and since the stroking was both felt and seen in synchrony, the subjects reported a strong sense of ownership towards their seen body. What is more, they also reported feeling the touch of the stick on the location of the seen body. None of the subjects reported being disembodied in a strong sense, yet the data suggests a moderate drift – or projection – towards the location of their seen body, much akin to the proprioceptive drift as can be recalled from the RHI.

In the related study by Ehrsson (2007), his subjects were seated and stroked on their chest – which was out of view – while the experimenter jabbed a second stick toward a location just below the 3PP camera view (See Figure 2B). Again, since the felt jabbing and the visual impression of a hand approaching a point below the 3PP camera view were synchronous, the subjects were led to experience the illusion of being located at the position of the camera, instead of where their real body was located. Contrary to Lenggenhager et al. (2007), his subjects had no experience of either ownership or disembodiment towards their seen body. This was also verified with an elicited SCR by simulating threats to the embodied position.

In a follow-up study by Petkova and Ehrsson (2008), they also tested an hypothesis of what would happen if they connected the 3PP camera view to a mannequin and positioned it so that they were looking down on its body (See Figure 2A), as well as to another individual (See Figure 2C). To their satisfaction, shortly upon applying the visuo-tactile stimulation, the subjects experienced either a strong sense of ownership over the mannequin's body, or the lingering sense of embodiment towards the other individual, as if they were shaking hands with themselves. Both procedures could be verified by SCR when physically threatened.

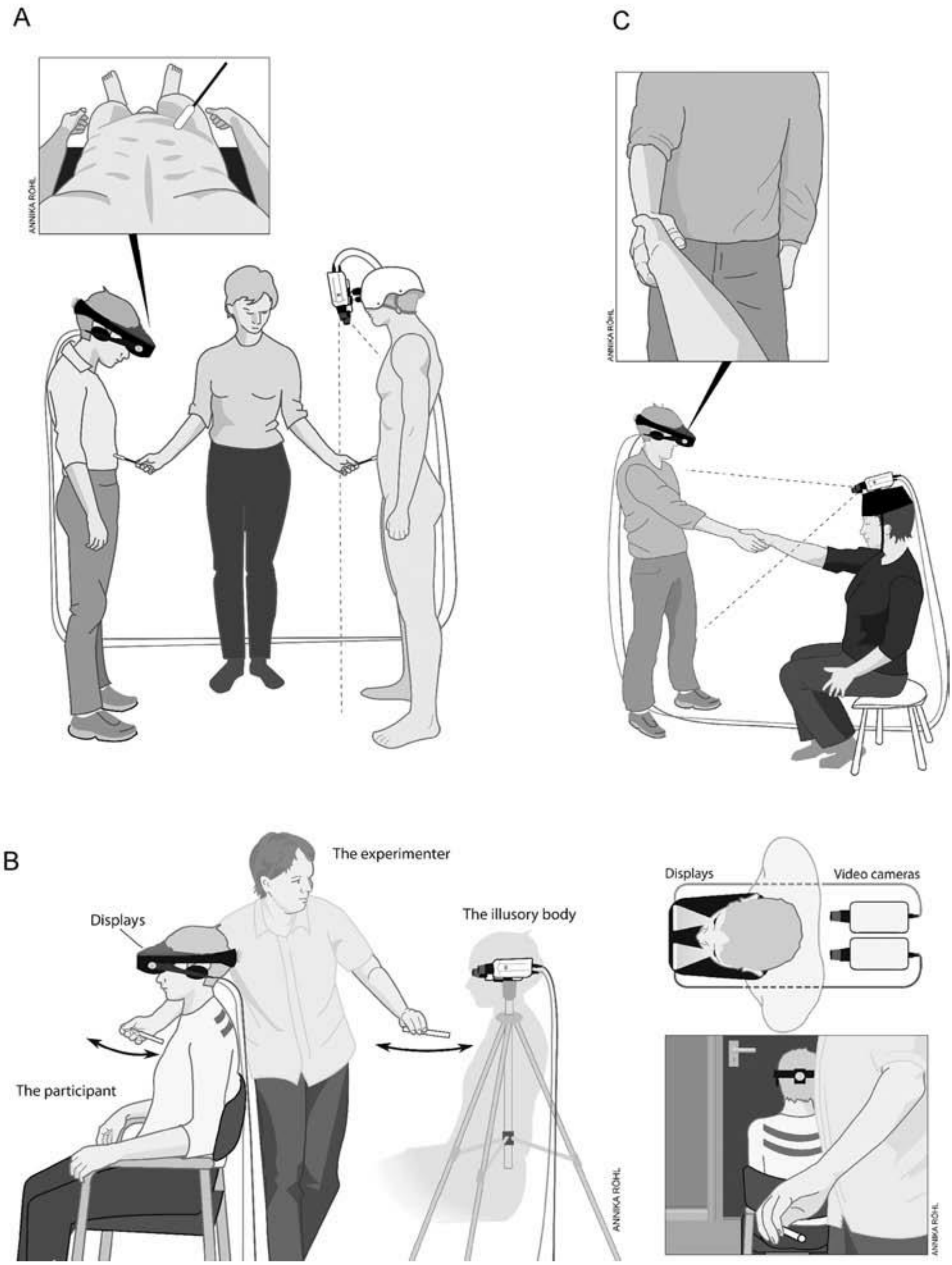

Figure 2. Experimental setup. *(A)* Mannequin Illusion; *(B)* Out-of-Body Illusion; *(C)* Body-Swap Illusion. Reprinted from *The New Handbook of Multisensory Processing* (p. 785), by B. E. Stein (Ed.), 2012, Cambridge, MA: MIT Press. Copyright 2012 by The University of Chicago and The MIT Press. Reprinted with permission.

Thus, what these studies have been able to show is that embodiment can be clearly dissociated from perspective, something that is not as distinctive in the clinical observations. Moreover, whole body representations are likely to be just as plastic as body part representations. Even so, they do not come without their fair share of constraint. For this reason, it may be worth emphasizing a principal difference between the studies in terms of them exerting diverse experimental procedures. In this fashion, Meyer (2008) has argued that what seems like the most important cue for ownership and embodiment might be biased toward where the stroking is *seen* to occur, which gives a certain priority to vision. Lenggenhager, Mouthon, and Blanke (2009) agree that this might be the case, and make a crucial observation. In contrast to the strokes delivered on the chest (Ehrsson, 2007), the strokes delivered on the back (Lenggenhager et al., 2007) are directly visible to the subjects. Allegedly, this may be the reason behind why the subjects had such contrasting experiences.

Despite such obstacles in the procedure, I reckon that these kind of constraints can also be seen as a form of liberation seeing that the results – if credible – show that we can project our sense of Self to a body in extrapersonal space observed from a 3PP, directly contradicting the kind of constraints and limitations that were shown in the research related to the RHI. It clearly illustrates the projective demeanor of perception – a kind of beneficial symptom in the sense that a structural loss is always followed by a perceptual gain of some sort. That said, it is still unclear what kind of structural loss brings about the experience of the spatial and temporal divorce between the body and the Self on the account of neural correlates, because there are only three sufficiently exhaustive brain imaging studies on this to date.

In short then, activity in key areas across the studies in the parietal, temporal, and frontal lobes related to multisensory association (e.g., PPC, PMC) has been found using fMRI (Ionta et al., 2011; Petkova et al., 2011) and EEG (Lenggenhager, Halje, & Blanke, 2011); as well as to vestibular responses (e.g., TPJ) has been found using fMRI (Ionta et al., 2011).

Simulation. The principles behind the projection of whole body representations described above should provide us with a clue as to the remarkable plasticity of the Self. This raises the question as to whether or not all this have an end – is there a limit to this self-plasticity? As it seems, we might have to wait for an affirmative answer on that one. Sophisticated understanding of the multisensory processes responsible for our sense of Self have recently paved way for research using Virtual Reality Technology (VR), in which the Self can become directly simulated and – without exaggeration – engineered to whatever purpose we see fit.

The experiments presented under this topic are different from those under the previous one in that they demonstrate the feasibility of inducing the sense of ownership over simulated bodies using VR, instead of physically real or artificial bodies using feed projecting HMD. VR uses a special HMD connected to a computer to change the subjects' 1PP to that of an immersive virtually rendered environment. Augmenting technology can also be adopted to increase the immersive qualities for the subjects (e.g., head tracking, motion capture). The digital representation of the body is also known as an avatar (Sanchez-Vives & Slater, 2005). The most striking advantage of this is that it is possible to conduct experiments that go beyond what is normally feasible in terms of stimuli manipulation due to physical constraints. The idea of it all is that it is easier to manipulate the perception of matter, than matter itself.

The first crucial steps in this direction derive from studies having successfully replicated the RHI with a virtual hand/arm illusion (Perez-Marcos, Slater, & Sanchez-Vives, 2009; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008). As a complement, a recent study also managed to modify arm length (Kilteni, Normand, Sanchez-Vives, & Slater, 2012). What is more, although these studies were effective under the usual visuo-tacile stimulation procedure (Perez-Marcos et al., 2009; Slater et al., 2008), it has also been demonstrated exclusively with visuo-motor synchrony, in which visual feedback correlates with the movement of the real hand (Sanchez-Vives, Spanlang, Frisoli, Bergamasco, & Slater, 2010).

To what extent can this be generalized to whole body representations then? Along the same lines as with body part ownership, visuo-tactile stimulation – together with 1PP – has since been the gold standard when it comes to whole body ownership (Petkova et al., 2011; Petkova, Khoshnevis, & Ehrsson, 2011). Slater, Spanlang, Sanchez-Vives, and Blanke (2010) nevertheless came to a different conclusion, once more hinging on visuo-motor synchrony.

In their experiment, subjects were equipped with VR-HMD along with augmented head tracking and motion capture to copy their movements to that of the avatar (See Figure 3A). The subjects were then presented – inside the virtual environment – with a virtual mirror in front of them (1PP) (See Figure 3B). At this point, the subjects could receive visual feedback from movement of the avatar as seen in the mirror (3PP), which could then be matched with their own (i.e., visuo-motor synchrony) to create a sense of ownership over the virtual body. As a control, they received synchronous, as well as asynchronous visuo-tacile stimulation, and could on *both* occasions experience a sense of ownership over the virtual body, which shows that visuo-tacile stimulation is not to be considered a necessary condition.

Figure 3. Experimental setup. *(A)* Head tracking and motion capture systems augmenting a VR-HMD; *(B)* 1PP from the virtual avatar, and 3PP from a virtual mirror. Adapted from "Simulating Virtual Environments Within Virtual Environments as the Basis for a Psychophysics of Presence," by M. Slater, B. Spanlang, and D. Corominas, 2010, *ACM Transactions of Graphics*, *29*, 1–9. Copyright 2010 by AMC. Adapted with permission.

These findings opens up a whole new avenue of possibilities in terms of freedom from constraint. After all, visuo-tacile stimulation puts a high demand on being able to deliver touch in the virtual environment, something that has proven to be a fairly difficult task. Because of this, the focus has been on vision to do much of the heavy lifting in terms of providing the right information. However, instead of visuo-tactile stimulation creating constraints as to what type of bodies are accepted or not, the use of visuo-motor synchrony breaks free from such constraints. Recall that agency – although only sufficient for the sense of ownership – still provides a very strong cue for it to trigger (Blanke & Metzinger, 2009).

Granted the proper use of humanoid bodies and avatars in providing us with easy and intuitive visuo-tactile and visuo-motor synchrony, VR further brings us seemingly endless opportunities for dramatically changing our virtual – and perceptually real – bodies. Some anecdotal observations of this comes from Lanier (2006) who was one of the early pioneers in the field of virtual reality – a term that he has actually been credited to have coined. Lanier and his team did many informal experiments with a variety of unconventional avatars to see how much distortion they could impose on behalf of our body representations. Notoriously, his most enticing – using visuo-motor synchrony – comes from his experience of trying to control a virtual lobster with six legs sticking out of his body. Since we normally do not come with six legs, the convenience of having a smooth visuo-motor synchrony goes out the window, and instead our brain has to find a way to interpret the situation. After he had played around with the lobster legs for some time – from what was first interpreted as random motion – they all slowly began to make sense. The visuo-motor synchrony helped set the stage for his body representations to incorporate the lobster avatar as being part of him, and soon he learned to command them. The first empirically based experiment to test was published this year, when Steptoe, Steed, and Slater (2013) successfully demonstrated that one can learn to control and own unconventional body parts – in this case a tail – using VR.

Discussion

To recap the two goals set out at the beginning of this essay: *(a)* a change in *description* from understanding the Self by already assuming its existence, to why and how we gain the intuition of being a Self; and *(b)* a change in the *level of description* from how we usually are trying to reduce the Self to a place proper, to exposing its proper place in nature.

From a mereological perspective, it translates into the analysis of: *(b)* What is the relation between body parts and the body as a whole – namely, how do we differentiate the body into parts (i.e., reductionism), and how are these parts organized into a whole body (i.e., holism); and *(a)* what is the relation between the body as a whole and the Self. Can the way I experience myself as a whole be reduced to the way I experience each of my body parts?

In keeping with the structure of the essay at hand – and before all else – allow me to scrutinize as much as I can from the perspective of the second goal *(b)*. Under the first two main headings of "The Embodied Self" and "The Acting Self" I appealed to the notion that body parts do not seem to be naturally – or innately – differentiated in either S1 or M1. All reviewed studies look as if to support such a notion, as they suggest that body representations obtain from the description of multisensory integration between many different sources, including other body parts, the whole body, and the interaction with the external world. Hence, the *way* the body is used may testify to the plasticity of the cortical body maps, and by studying multisensory integration, we may be able to understand how they represent the body in different ways depending on its function, putting high strain on the importance of agency.

Taken together, interpretation of these studies that have been presented favor an interaction between both reductionist and holistic influences in integrating sensory input. But what does it mean to be integrated? Are sensory input simply *combined* in an additive manner, or are they *integrated* at some localized area in the brain (e.g., PPC)? The problem, perhaps, is that we tend to arbitrarily demarcate what it means to be "localized".

Each sensory input, as we have seen, is processed at different levels of description in the somatosensory cortex (i.e., S1, S2, PPC). Consequently, it seems remote to assess that the brain just combines and averages out the converging sensory inputs, as it requires more complex representations. Instead, by insisting on integration, we nevertheless stumble in terms of opting to "localize" a correlation on some level of description for reasons of mere convenience. In other words, what are the reasons behind why we aim for "neural correlates" instead of "atomic correlates"? As localization is not explanation, why do we persist on trying to "localize" – or reduce – a particular phenomenon to certain areas or regions of the brain when clearly there is the prospect of integration without having to resort to localization?

One way to look at it, may be from the perspective of a more multilevel – or holistic – description. This way, we can break free from the tantalizing trap of having to analyse different levels in terms of being mutually exclusive, as either separated or correlated. What this means is that, if we cling to the notion of integration with reductionist undertones, the target phenomenon – in this case the Self – is seen to emerge at the pinnacle of such integration, and converge at a particular area in the brain responsible for such integration. However, this way of seeing things betrays a limited perspective in terms of not recognizing the fact that both low level sensory input and higher level body representations are on the same continuum of neural complexity, although on separate ends of the spectrum. Hence, whatever the target phenomenon is that we want to describe, its contribution stems from an integrative process – not just by being a *part* of the next level of description – but of each level being functionally dependent on each other in a dynamically non-linear fashion.

With these considerations underway, I now direct myself to reflect on the first goal *(a)*. Under the third main heading of "The Plastic Self" the spotlight was turned to the question of "What makes us experience what we are?" This is the question of whether the Self that we experience as a whole can be reduced to the way we experience each of our body parts.

Even if the Self can be described as being situated across different levels of multisensory integration rather than thought of as being localized, there still seems to be an ontological gap forcing us to ask “Does the Self exist or is it just an illusion?” However, maybe this question forces itself on us due to the fact that we have difficulties accepting the distinction between the experience of a coherent Self and a divisible brain – we certainly do not feel as illusions. By all means though, that is exactly how illusions work – they make believers of us all even in the presence of the most stubborn logic. Hence, just as the illusion of free will does not mean that we cannot make choices, the illusion of Self does not mean that we do not exist. Instead, the illusion is that the Subject is not what it seems to be from subjective experience. Thus, in an esoteric sense, we are what we seem to be, yet do not seem to be what we are.

So far, the result of this analysis could be considered nihilistic, because in a way, in keeping with this analysis, love, disgust, joy, and fear could be considered illusions as well. The point of all this is to insist on the idea that the Self is an intuitive high-level abstraction, whose existence we infer for a reason, and not just something we are tricked into believing. For instance, VR technology has made a strong case for the necessity to hide the actual underlying mechanisms from the user’s view in order to have a compelling and immersive experience. In a similar manner, perhaps this can be used as a good analogy for the brain also, in that the less conspicuous the interplay between the Self and the external world, and the more isolated the biological mechanisms, the more ideal it will turn out for the organism. Hence, one can reasonably conclude that it would be quite misleading to suggest that the underlying mechanisms are the only thing that is “real”. Social fabrication can be considered real by virtue of the representations pertaining to them, as hinted upon by the fact that the only reason a hand is a part of the arm is because we arbitrarily stipulate it as such. To such a degree, the Self is real insofar as it is a collectively shared high-level abstraction. Once established, it creates for an adamant – although exceedingly ill-defined – experience.

Such an unyielding conception of the Self has nevertheless been shown to be the real illusion, which I think calls for a new description. On the back of the reviewed research, the Self has proven to be remarkably – or even surprisingly – plastic. These findings reveal that it has a measurable structure, and can be decomposed into dissociable components – even from a phenomenological perspective – all seemingly dependant on separate brain mechanisms. However, from a terminological standpoint, the concept of ownership may be dangerously misleading in the sense that it introduces the problem all over again by postulating a relation between two distinct entities – the Self and its Body. Alas, body parts are not just seen as parts of one's body, but also as parts of one's *own* body. It would be a half-measure to at least be able to recognize that the body possesses itself, rather than some*thing* possessing the body. As my analysis draws itself to a close, I just want to call some attention to the fact that I think this type of research holds great potential – and almost deems it necessary – for a careful conceptual differentiation to carry us closer to a more seasoned understanding of the Self. For what it is worth, I have been chipping away at it, trying to undermine its conceptual authority.

As many questions remain unanswered, this last part of the essay presents what could be considered some future prospects within the field at large – namely that of VR technology. This essay has reviewed recent empirical findings suggesting that merging VR technology with state of the art neuroimaging is a monumental paradigm shift in terms of providing valuable insight on critical aspects of the Self. It has enabled researchers to dust off age old puzzles and tackle them in novel ways, due to improved control conditions. Since we are able to completely isolate the body from the external world, it means that the only constraint in stimuli manipulation is how we map the control condition from the real body to the avatar. Thus, the more we manage to hide from the user, the more we can manipulate and control for. In practice, this means that we can control for things that normally wouldn't be possible due to the laws of physics. For instance, time could be manipulated using slow-motion coding.

One area of interest that has generated some excitement for me recently is that of Empathy, so I will use that as an example to illustrate some of these prospects. I believe that VR technology can serve to simulate the experience of mental illness (e.g., autism), such as to effectively reduce implicit stereotypes. Interesting in this regard, Yee and Bailenson (2007) have found that the perception of our body can influence how we perceive others, specifically by manipulating the look and size of the avatar – in what they call the "Proteus effect". They randomly assigned avatars of different heights to their subjects, and stumbled upon a rather sensational correlation, that despite being tall or short in real life, the subjects negotiated less effectively and aggressively when they received a shorter avatar. This may not be that surprising behaviourally. What is sensational, on the other hand, is that with additional manipulations such as race and gender, I think this finding is able to cater for a potential entry into what it would feel like to don the perspective (1PP) of someone else, without having to rely on the identifying (3PP) mechanisms usually associated with the ability to empathize.

What is even more astounding, is that in a recently published study, Normand et al. (2012) were able to combine VR with Teleoperation (TO) in allowing for humans and smaller animals/insects to interact in real-time at the same spatial scale. TO is a system that places the user at a remote location in control of a robot (e.g., NASA's Mars Rovers), with the added sensation of being embodied at the location. The subjects with VR are represented by a small robot that is slaved to their actions within the animal's – in this case a rat – habitat. Similarly, the rat is represented by an avatar that is slaved to its action within the virtual environment. Hence, when the subjects move closer to the rat's avatar, so the robot moves closer to the rat.

The potential for VR in this field remains largely untapped, and holds great promise for future research on self-plasticity. It is a topic of exuberant speculation as to what is going to happen, but with the acuity of already being able to change the nature of our body representations through virtual avatars, one wouldn't be at fault for remaining optimistic.

References

Armel, K. C., & Ramachandran, V. S. (2003). Projecting sensations to external objects: Evidence from skin conductance response. *Proceedings of the Royal Society of London, 270*, 1499–1506. doi:10.1098/rspb.2003.2364

Arzy, S., Seeck, M., Ortigue, S., Spinelli, L., & Blanke, O. (2006). Induction of an illusory shadow person. *Nature*, *443*, 287. doi:10.1038/443287a

Barnsley, N., McAuley, J. H., Mohan, R., Dey, A., Thomas, P., & Moseley, G. L. (2011). The rubber hand illusion increases histamine reactivity in the real arm. *Current Biology*, *21*, R945–R946. doi:10.1016/j.cub.2011.10.039

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nature Reviews Neuroscience*, *13*, 556–571. doi:10.1038/nrn3292

Blanke, O., & Arzy, S. (2005). The out-of-body experience: Disturbed self-processing at the temporo-parietal junction. *The Neuroscientist*, *11*, 16–24. doi:10.1177/1073858404270885

Blanke, O., Landis, T., Spinelli, L., & Seeck, M. (2004). Out-of-body experience and autoscopy of neurological origin. *Brain*, *127*, 243–258. doi: 10.1093/brain/awh040

Blanke, O., & Metzinger, T. (2009). Full-body illusions and minimal phenomenal selfhood. *Trends in Cognitive Neurosciences*, *13*, 7–13. doi:10.1016/j.tics.2008.10.003

Blanke, O., & Mohr, C. (2005). Out-of-body experience, heautoscopy, and autoscopic hallucination of neurological origin: Implications for neurocognitive mechanisms of corporeal awareness and self-consciousness. *Brain Research Reviews*, *50*, 184–199. doi:10.1016/j.brainresrev.2005.05.008

Blanke, O., Ortigue, S., Landis, T., & Seeck, M. (2002). Stimulating illusory own-body perceptions. *Nature*, *419*, 269–270. doi:10.1038/419269a

Botvinick, M., & Cohen, J. (1998). Rubber hands “feel” touch that eyes see. *Nature*, *391*, 756. doi:10.1038/35784

Brugger, P. (2002). Reflective mirrors: Perspective taking in autoscopic phenomena. *Cognitive Neuropsychiatry*, *7*, 179–194. doi:10.1080/13546800244000076

Brugger, P., Agosti, R., Regard, M., Wieser, H. G., & Landis, T. (1994). Heautoscopy, epilepsy, and suicide. *Journal of Neurology, Neurosurgery, & Psychiatry*, *57*, 838–839. doi:10.1136/jnnp.57.7.838

Brugger, P., Blanke, O., Regard, M., Bradford, D. T., & Landis, T. (2006). Polyopic heautoscopy: Case report and review of the literature. *Cortex*, *42*, 666–674. doi:10.1016/S0010-9452(08)70403-9

Brugger, P., Regard, M., & Landis, T. (1997). Illusory reduplication of one's own body: Phenomenology and classification of autoscopic phenomena. *Cognitive Neuropsychiatry*, *2*, 19–38. doi:10.1080/135468097396397

Bünning, S., & Blanke, O. (2005). The out-of-body experience: Precipitating factors and neural correlates. *Progress in Brain Research*, *150*, 331–350. doi:10.1016/S0079-6123(05)50024-4

Clément, G., Moore, S. T., Raphan, T., & Cohen, B. (2001). Perception of tilt (somatogravic illusion) in response to sustained linear acceleration during space flight. *Experimental Brain Research*, *138*, 410–418. doi:10.1007/s002210100706

De Ridder, D., Van Laere, K., Dupont, P., Menovsky, T., & Van de Heyning, P. (2007). Visualizing out-of-body experience in the brain. *New England Journal of Medicine*, *357*, 1829–1833. doi:10.1056/NEJMoa070010

Dennett, D. C. (1991). *Consciousness explained*. London: Penguin Books.

Devinsky, O., Feldmann, E., Burrowes, K., & Bromfield, E. (1989). Autoscopic phenomena with seizures. *Archives of Neurology*, *46*, 1080–1088. doi:10.1001/archneur.1989.00520460060015

Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science*, *317*,

1048. doi:10.1126/science.1142175

Ehrsson, H. H., Holmes, N. P., & Passingham, R. E. (2005). Touching a rubber hand: Feeling of body ownership is associated with activity in multisensory brain areas. *The Journal of Neuroscience, 25*, 10564–10573. doi:10.1523/JNEUROSCI.0800-05.2005

Ehrsson, H. H., Kito, T., Sadato, N., Passingham, R. E., & Naito, E. (2005). Neural substrates of body size: Illusory feeling of shrinking of the waist. *PLoS Biology, 3*, e412. doi:10.1371/journal.pbio.0030412

Ehrsson, H. H., Rosén, B., Stockselius, A., Ragnö, C., Köhler, P., & Lundborg, G. (2008). Upper limb amputees can be induced to experience a rubber hand as their own. *Brain*, *131*, 3443–3452. doi:10.1093/brain/awn297

Ehrsson, H. H., Spence, C., & Passingham, R. E. (2004). That's my hand! Activity in premotor cortex reflects feeling of ownership of a limb. *Science*, *305*, 875–877. doi:10.1126/science.1097011

Ehrsson, H. H., Wiech, K., Weiskopf, N., Dolan, R. J., & Passingham, R. E. (2007). Threatening a rubber hand that you feel is yours elicits a cortical anxiety response. *PNAS*, *104*, 9828–9833. doi:10.1073/pnas.0610011104

Gallagher, S. (2000). Philosophical concepts of the self: Implications for cognitive sciences. *Trends in Cognitive Sciences*, *4*, 14–21. doi:10.1016/S1364-6613(99)01417-5

Gandevia, S., & Phegan, C. M. (1999). Perceptual distortions of the human body image produced by local anaesthesia, pain and cutaneous stimulation. *Journal of Physiology*, *514*, 609–616. doi:10.1111/j.1469-7793.1999.609ae.x

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (Eds.). (2008). *Cognitive Neuroscience: The Biology of the Mind*. New York, NY: W. W. Norton & Company Inc.

Haggard, P., Taylor-Clarke, M., & Kennett, S. (2003). Tactile perception, cortical representation and the bodily self. *Current Biology*, *13*, 170–173.

doi:10.1016/S0960-9822(03)00115-5

Heydrich, L., Dieguez, S., Grunwald, T., Seeck, M., & Blanke, O. (2010). Illusory own body perceptions: Case reports and relevance for bodily self-consciousness. *Consciousness and Cognition*, *19*, 702–710. doi:10.1016/j.concog.2010.04.010

Holmes, N. P., & Spence, C. (2004). The body schema and multisensory representation(s) of peripersonal space. *Cognitive Processing*, *5*, 94–105. doi:10.1007/s10339-004-0013-3

Hume, D. (2004). *A treatise of human nature.* New York, NY: Dover Publications Inc.

Ionta, S., Heydrich, L., Lenggenhager, B., Mouthon, M., Fornari, E., Chapuis, D., ... Blanke, O. (2011). Multisensory mechanisms in temporo-parietal cortex support self-location and first-person perspective. *Neuron*, *70*, 363–374. doi:10.1016/j.neuron.2011.03.009

James, W. (1957). *The principles of psychology*. New York, NY: Dover Publications Inc.

Kilteni, K., Normand, J. M., Sanchez-Vives, M. V., & Slater, M. (2005). Extending body space in immersive virtual reality: A very long arm illusion. *PLoS ONE*, *7*, e40867. doi:10.1371/journal.pone.0040867

Lackner, J. R. (1988). Some proprioceptive influences on the perceptual representation of body shape and orientation. *Brain*, *111*, 281–297. doi:10.1093/brain/111.2.281

Lackner, J. R. (1992). Spatial orientation in weightless environments. *Perception*, *21*, 803–812. doi:10.1068/p210803

Lanier, J. (2006). Homuncular flexibility [Group blog post]. Retrieved from http://www.edge.org/q2006/q06_pring.html#lanier.

Lenggenhager, B., Halje, P., & Blanke, O. (2011). Alpha band oscillations correlate with illusory self-location induced by virtual reality. *European Journal of Neuroscience*, *33*, 1935–1943. doi:10.1111/j.1460-9568.2011.07647.x

Lenggenhager, B., Mouthon, M., & Blanke, O. (2009). Spatial aspects of bodily self-consciousness. *Consciousness and Cognition*, *18*, 110–117.

doi:10.1016/j.concog.2008.11.003

Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum: Manipulating bodily self-consciousness. *Science, 317*, 1096–1099. doi:10.1126/science.1143439

Longo, M., Schüür, F., Kammers, M. P. M., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition*, *107*, 978–998. doi:10.1016/j.cognition.2007.12.004

Lopez, C., & Blanke, O. (2011). The thalamocortical vestibular system in animals and humans. *Brain Research Reviews*, *67*, 119–146. doi:10.1016/j.brainresrev.2010.12.002

Lopez, C., Halje, P., & Blanke, O. (2008). Body ownership and embodiment: Vestibular and multisensory mechanisms. *Clinical Neurophysiology*, *38*, 149–161. doi:10.1016/j.neucli.2007.12.006

Lloyd, D. M. (2007). Spatial limits on referred touch to an alien limb may reflect boundaries of visuo-tacile peripersonal space surrounding the hand. *Brain and Cognition*, *64*, 104–109. doi:10.1016/j.bandc.2006.09.013

Makin, T. R., Holmes, N. P., & Ehrsson, H. H. (2008). On the other hand: Dummy hands and peripersonal space. *Behavioural Brain Research*, *191*, 1–10. doi:10.1016/j.bbr.2008.02.041

Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in Cognitive Sciences*, *8*, 79–86. doi:10.1016/j.tics.2003.12.008

Metzinger, T. (2003). *Being no one*. Cambridge, MA: MIT Press.

Meyer, K. (2008). How does the brain localize the self? *Science, E-letter*.

Mizumoto, M., & Ishikawa, M. (2005). Immunity to error through misidentification and the bodily illusion experiment. *Journal of Consciousness Studies*, *12*, 3-19.

Moseley, G. L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., Spence, C. (2008).

Phychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. *PNAS*, *105*, 13169–13173. doi:10.1073/pnas.0803768105

Normand, J. M., Sanchez-Vives, M. V., Waechter, C., Giannopoulos, E., Grosswindhager, B., Spanlang, B., … Slater, M. (2012). Beaming into the rat world: Enabling real-time interaction between rat and human each at their own scale. *PLoS ONE*, *7*, e48331. doi:10.1371/journal.pone.0048331

Pavani, F., & Castiello, U. (2003). Binding personal and extrapersonal space through body shadows. *Nature Neuroscience*, *7*, 14–16. doi:10.1038/nn1167

Penfield, W., & Boldrey, E. (1937). Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain*, *60*, 339–448. doi:10.1093/brain/60.4.389

Perez-Marcos, D., Slater, M., & Sanchez-Vives, M. V. (2009). Inducing a virtual hand ownership illusion through a brain-computer interface. *Neuroreport*, *20*, 589–594. doi:10.1097/WNR.0b013e32832a0a2a

Petkova, V. I., Björnsdotter, M., Gentile, G., Jonsson T., T. Q, Li., Ehrsson, H. H. (2011). From part- to whole-body ownership in the multisensory brain. *Current Biology*, *21*, 1118–1122. doi:10.1016/j.cub.2011.05.022

Petkova, V. I., Ehrsson, H. H. (2008). If I were you: Perceptual illusions of body swapping. *PLoS ONE*, *3*, e3832. doi:10.1371/journal.pone.0003832

Petkova, V. I., Khoshnevis, M., & Ehrsson, H. H. (2011). The perspective matters! Multisensory integration in ego-centric reference frames determines full-body ownership. *Frontiers in Cognition*, *2*, 35. doi:10.3389/fpsyg.2011.00035

Ramachandran, V. S., & Blakeslee, S. (1998). *Phantoms in the brain: Probing the mysteries of the human mind*. New York, NY: William Morrow & Co.

Ramachandran, V. S., & Hirstein, W. (1998). The perception of phantom limbs. The D. O.

Hebb Lecture. *Brain*, *121*, 1603–1630. doi:10.1093/brain/121.9.1603

Ramachandran, V. S., & Rogers-Ramachandran, D. (1996). Synaesthesia in phantom limbs induced with mirrors. *Proceedings of the Royal Society of London*, *263*, 377–386. doi:10.1098/rspb.1996.0058

Rosén, B., Ehrsson, H. H., Antfolk, C., Cipriani, C., Sebelius, F., & Lundborg, G. (2009). Referral of sensation to an advanced humanoid robotic hand prosthesis. *Journal of Plastic Surgery and Hand Surgery*, *43*, 260–266. doi:10.3109/02844310903113107

Rusconi, E., Gonzaga, M., Adriani, M., Braun, C., & Haggard, P. (2009). Know thyself: Behavioral evidence for a structural representation of the human body. *PLoS ONE*, *4*, e5418. doi:10.1371/journal.pone.0005418

Salamin, P., Tadi, T., Blanke, O., Vexo, F., & Thalmann, D. (2010). Quantifying effects of exposure to the third and first-person perspectives in virtual-reality-based training. *IEEE Transactions on Learning Technologies*, *3*, 272–276. doi:10.1109/TLT.2010.13

Sanchez-Vives, M. V., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews Neuroscience*, *6*, 332–339. doi:10.1038/nrn1651

Sanchez-Vives, M. V., Spanlang, B., Frisoli, A., Bergamasco, M., & Slater, M. (2010). Virtual hand illusion induced by visuomotor correlations. *PLoS ONE*, *5*, e10381. doi:10.1371/journal.pone.0010381

Sforza, A., Bufalari, I., Haggard, P., & Aglioti, S. M. (2010). My face in yours: Visuo-tactile facial stimulation influences sense of identity. *Social Neuroscience*, *5*, 148–162. doi:10.1080/17470910903205503

Slater, M., Perez-Marcos, D., Ehrsson, H. H., & Sanchez-Vives, M. V. (2008). Towards a digital body: The virtual arm illusion. *Frontiers in Human Neuroscience*, *2*, 6. doi:10.3389/neuro.09.006.2008

Slater, M., Spanlang, B., Corominas, D. (2010). Simulating virtual environments within virtual environments as the basis for a psychophysics of presence. *ACM Transactions on Graphics*, *29*, 92. doi:10.1145/1778765.1778829

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS ONE*, *5*, e10564. doi:10.1371/journal.pone.0010564

Stein, B. E. (Ed.). (2012). *The new handbook of multisensory processing*. Cambridge, MA: MIT Press.

Steptoe, W., Steed, A., & Slater, M. (2013). Human tails: Ownership and control of extended humanoid avatars. *IEEE Transactions of Visualization and Computer Graphics*, *19*, 583–590. doi:10.1109/TVCG.2013.32

Taylor-Clarke, M., Jacobsen, P., & Haggard, P. (2004). Keeping the world a constant size: Object constancy in human touch. *Nature Neuroscience*, *7*, 219–220. doi:10.1038/nn1199

Tsakiris, M. (2008). Looking for myself: Current multisensory input alters self-face recognition. *PLoS ONE*, *3*, e4040. doi:10.1371/journal.pone.0004040

Tsakiris, M. (2010). My body in the brain: A neurocognitive model of body-ownership. *Neuropsychologia*, *48*, 703–712. doi:10.1016/j.neuropsychologia.2009.09.034

Tsakiris, M., & Haggard, P. (2005a). Experimenting with the acting self. *Cognitive Neuropsychology*, *22*, 387–407. doi:10.1080/02643290442000158

Tsakiris, M., & Haggard, P. (2005b). The rubber hand illusion revisited: Visuotactile integration and self-attribution. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 80–91. doi:10.1037/0096-1523.31.1.80

Tsakiris, M., Haggard, P., Franck, N., & Sirigu, A. (2005). A specific role for efferent information in self-recognition. *Cognition*, *96*, 215–231. doi:10.1016/j.cognition.2004.08.002

Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R. (2007). Neural signatures of body ownership: A sensory network for bodily self-consciousness. *Cerebral Cortex*, *17*, 2235–2244. doi: 10.1093/cercor/bhl131

Tsakiris, M., Prabhu, G., & Haggard, P. (2006). Having a body versus moving your body: How agency structures body–ownership. *Consciousness and Cognition*, *15*, 423–432. doi:10.1016/j.concog.2005.09.004

Wittgenstein, L. (1999). *Philosophical investigations* (G. E. M. Anscombe, Trans.). New Jersey, NJ: Prentice Hall.

Yee, N., & Bailenson, J. (2007). The proteus effect: The effect of transformed self-representation on behaviour. *Human Communication Research*, *33*, 271–290. doi:10.1111/j.1468-2958.2007.00299.x