What is it like to have a body?

Journal Article

Citation:

Longo, M.; Haggard, P. (2012)
What is it like to have a body? –
Current Directions in Psychological Science (In Press)

RUNNING HEAD: What is it like to have a body?

What is it like to have a body?

Matthew R. Longo[1] and Patrick Haggard[2]

[1]Department of Psychological Sciences, Birkbeck, University of London

[2]Institute of Cognitive Neuroscience, University College London

Direct correspondence to:

Matthew R. Longo

Department of Psychological Sciences

Birkbeck, University of London

Malet Street

London WC1E 7HX

United Kingdom

m.longo@bbk.ac.uk

Word count: 2,674

Abstract

Few questions in psychology are as fundamental or as elusive as the sense of one's own body. Despite widespread recognition of the link between body and self, psychology has only recently developed methods for the scientific study of bodily awareness. Experimental manipulations of embodiment in healthy volunteers have allowed important advances in knowledge. Synchronous multisensory inputs from different modalities play a fundamental role in producing 'body ownership', the feeling that my body is 'mine'. Indeed, appropriate multisensory stimulation can induce ownership over external objects, virtual avatars, and even other people's bodies. We argue that bodily experience is not monolithic, but has measurable internal structure and components that can be identified psychometrically and psychophysically, suggesting the apparent phenomenal unity of self-consciousness may be illusory. We further review evidence that the sense of one's own body is highly plastic, with representations of body structure and size particularly prone to multisensory influences.

“Everyone”, William James (1890) famously asserted, “knows what attention is.” The same is true of the experience of embodiment: everyone knows what it’s like to have a body. Our body is ubiquitous in our perceptual experience and is the most familiar object we encounter. The ubiquity of this experience, however, has not translated into clarity or agreement about its fundamental nature. On the contrary, research on bodily awareness has historically been plagued by disagreement, confusion, and inconsistent terminology. Despite these continuing difficulties, recent investigations have shed new light on bodily awareness, providing rich insight into this fundamental underpinning of psychological life.

The central difficulty in any empirical study of bodily awareness is the control condition. An ideal experimental investigation would compare two conditions, one in which the participant has a body, and another in which they do not. Obviously, such ‘brain in a vat’ studies are restricted to thought experiments, since the crucial control condition in which the body is absent is impossible to realise. The body, in James’s (1890) memorable phrase, is “always there.” Recent progress has resulted from development of novel methods for circumventing this dilemma and allowing experimental manipulation of bodily awareness and of our conscious model of our body (the *body image*), including perceptual techniques, such as the rubber hand illusion (Botvinick & Cohen, 1998), and emerging technologies such as virtual reality (VR; Slater et al., 2009) in which the usual physical laws affecting our bodies can be altered.

In the rubber hand illusion (Figure 1), a prosthetic hand touched synchronously with one’s own unseen hand produces the compelling feeling that the rubber hand *actually is* one’s hand. In contrast, following asynchronous touch no such experience arises. Thus, comparing these conditions provides an elegant experimental manipulation of embodiment. Using VR, the illusion has recently been extended to the whole body (Lenggenhager et al., 2007). Such techniques have transformed research on bodily awareness allowing researchers to begin systematically investigating human embodiment. We review recent research investigating the fundamental structure of bodily awareness, and show how specific components of bodily awareness are influenced by various experimental manipulations.

Components of Bodily Awareness

Is embodiment a single, monolithic experience? At first sight, the phenomenal unity of self-consciousness suggests that it is: we experience a single coherent conscious self, continuously linked to our body. However, recent evidence converges on the interpretation that bodily awareness is a rich, complex experience which can be decomposed into distinct and dissociable components, with important functional differences. Clearly, these elements cannot simply be the different *parts* of the body: the experiences that I have of my left leg are similar to those of my right leg. Rather, the constituent elements of bodily awareness are the different feelings, beliefs, and attitudes one has towards one's body.

Psychometric Decomposition of Subjective Reports

Another approach to decomposing bodily awareness emphasises measurement of psychometric dependent variables, rather than experimental manipulation of independent variables. While many rubber hand studies use questionnaires assessing subjective experiences (e.g., Botvinick & Cohen, 1998), recent studies have employed formal methods to systematically reveal the characteristic structure of bodily awareness. For example, we (Longo et al., 2008a, 2008b, 2009) used the rubber hand illusion to combine experimental manipulation of embodiment with psychometric decomposition of structured questionnaire data using principal components analysis. In a large sample of 131 participants, we identified four distinct components of bodily awareness during both synchronous and asynchronous visuo-tactile stimulation. These were termed *embodiment of rubber hand*, *loss of own hand*, *movement*, and *affect* (Longo et al., 2008a). Further analysis of the *embodiment of rubber hand* component revealed that in both conditions it could be further decomposed into three subcomponents we termed, *ownership*, *agency*, and *location*. The synchronous and asynchronous stimulation conditions differed in terms of how strongly each component was *present or absent*, confirming that this manipulation succeeds in manipulating bodily awareness. Nevertheless, the common set of components suggests a shared underlying structure to both experiences. A further component, *deafference*, emerged only following asynchronous stimulation, indicating that experiences of embodiment may differ qualitatively as well as quantitatively.

Stimulation of Distinct Sensory-Motor Pathways

One method for decomposing bodily awareness is to induce bodily illusions by stimulating different sensory and motor pathways. This method has been used to investigate perhaps the most salient distinction between aspects of bodily awareness, between the sense of *ownership* over the body, the feeling that my body is my own, and the sense of *agency*, the feeling that I am in control of my body and its actions. Tsakiris and colleagues (2006) showed participants a video image of their hand, displayed in real-time or delayed, while their finger moved either actively or passively. In the passive condition, their finger was lifted by a thread, like a marionette, producing a purely sensory match between proprioception and vision. In the active condition, participants moved the finger themselves, adding a motor command to visual and proprioceptive feedback. Subjective reports in the passive condition confirmed that participants felt like they were looking directly at their own hand, but did not feel that they had control over the hand: an experience of ownership without agency. In the active condition, in contrast, participants reported clear experiences of both ownership and agency (Longo & Haggard, 2009; Tsakiris, Longo, & Haggard, 2010).

Such results provide empirical support for the dissociability of ownership and agency, previously distinguished on purely conceptual grounds. Agency and ownership have also been found to have different functional consequences on proprioception (Tsakiris et al., 2006; Kammers et al., 2009b) and manual reaction time (Longo & Haggard, 2009). Further, neuroimaging studies have identified largely independent brain networks underlying these experiences. Ownership has been linked to the insula, frontal operculum, and cortical midline areas (Ehrsson et al., 2004; Tsakiris et al., 2007, 2010), agency to motor preparatory areas and the inferior parietal lobe (Nahab et al., 2011; Tsakiris et al., 2010).

These results reveal that bodily awareness has measureable structure and can be decomposed into dissociable components. At one level, this suggests that the apparent phenomenal unity of bodily awareness, linking the body to a single "I", is illusory. However, these individual elements could form holistic Gestalts, experienced as distinct from the sum of their parts. Understanding the processes producing such Gestalts is an interesting topic for future research. While illusions such as the rubber hand may not reflect the full diversity of embodiment, they nevertheless provide a valuable model case. In this sense they may be to bodily awareness what the fruit fly is to genetics.

Plasticity of Embodiment

Our bodily form is generally stable from moment to moment. Changes in physical body structure nevertheless do occur, both during development, and due to diet, exercise, or trauma. Veridical body representation thus requires some degree of plasticity, so that changes in actual body form are mirrored by corresponding changes in both the brain's maps of somatosensory inputs, and also in the conscious body image. Understanding how such plasticity arises and, is important both for understanding normal development, and also for understanding pathological distortions of body image in conditions such as eating disorders (Eshkevari et al., in press). Recent studies have found striking evidence for remarkably rapid and profound plasticity of bodily representation.

Measuring Bodily Plasticity

Gandevia and Phegan (1999) measured the perceived size of body parts by having participants select from an array of body part pictures, the one most closely matching their own body part. Cutting off sensory signals using local anaesthesia led to an increase in perceived body part size. This phenomenon will be familiar to many of those who have experienced dental anaesthesia, in which the mouth and teeth often feel swollen, a result experimentally confirmed by having participants match their own tooth size from arrays of tooth images (Türker, Yeo, & Gandevia, 2005). Intriguingly, anaesthesia of the thumb also produced a smaller increase in perceived lip size (Gandevia & Phegan, 1999). While the thumb and lips are not adjacent on the actual body, they *are* adjacent in maps of the body in somatosensory cortex (the 'Penfield homunculus'), suggesting that body image changes may result from plasticity in somatosensory cortex.

Studies using postural illusions further suggest that conflict between sensory signals can also induce plastic change in body representation. In the 'Pinocchio illusion' (Figure 2), illusory arm movement is generated by vibrating muscle tendons, which generates signals specifying muscle lengthening, though no actual muscular change occurs, causing postural illusions. Thus, vibrating the biceps tendon produces illusions of forearm extension, while vibrating the triceps tendon produces illusions of forearm flexion. But what if the hand perceived as moving is touching another body part, such as the nose? For the forearm to be moving away from the face while maintaining contact with the nose, the nose would have to be growing. Dramatically, many participants do indeed report feeling that their nose is getting longer (Lackner, 1988)! Similarly, by placing hands on one's hips, illusions of one's waist becoming fatter or thinner can be produced (Ehrsson et al., 2005), as can illusions of individual fingers shortening or lengthening (de Vignemont, Ehrsson, & Haggard, 2005). In these situations, immediate proprioceptive input requires an adjustment in body representation to resolve an apparent conflict. Recently, we showed that plasticity occurs as a result of such conflict, even when the altered percept does not directly resolve the conflict (Longo et al., 2009a). We vibrated tendons of antagonistic muscles (biceps and triceps) simultaneously. In this case, the brain receives contradictory signals indicating that the arm is flexing and simultaneously extending. Such proprioceptive conflict produces perceived arm *contraction*, as if lack of coherent sense of body location leads body representation to shrink inwards on itself. While we experience our body as a stable object with spatio-temporal continuity from one moment to the next, our experience of what our body is like is, to a large degree, constructed on the basis of the real-time signals continuously reaching the brain from throughout the body.

The rubber hand illusion also provides evidence for plasticity of embodiment, given that the rubber hand generally differs in appearance from participants' own hands. Indeed, visual characteristics of the rubber hand, such as skin colour (Holmes, Snijders, & Spence, 2006; Longo et al., 2009b) have surprisingly little influence on the illusion. Similarly, participants can easily be made to experience embodiment over graphical arms in VR (Slater et al., 2008; Perez-Marcos et al., 2009). The rubber hand illusion can even be induced in amputees who have no actual hand at all (Ehrsson et al., 2008).

VR allows especially dramatic manipulations of embodiment, given that virtual worlds are not necessarily subject to the usual laws of physics. Recent studies have shown that embodiment can be elicited not just over individual parts, but over entire virtual bodies (Slater et al., 2009), even bodies radically different from one's own. Petkova and Ehrsson (2008) attached cameras to a mannequin where the eyes would be, and fed the signals to a head mounted display. Thus, participants saw the mannequin, in stereo, from a first-person perspective. Synchronous touch of the mannequin's and participant's torsos produced the illusion that the mannequin's body actually was the participant's body: a whole-body analogue of the rubber hand illusion. Similar illusions were generated by attaching cameras to another person, even of the opposite sex, producing an illusion of 'body swapping'. Thus, participants could experience themselves as being inside another person's body and shaking their own hand. Similarly, Slater and colleagues (2010) found that adult male participants could experience ownership over an avatar of a young girl.

Limitations on Bodily Plasticity

We are intimately familiar with our body. The English idiom “to know something like the back of one’s hand” suggests that we have an excellent representation of the actual back of our hand! Nevertheless, the preceding results show remarkable lability of bodily awareness. The representation of our body flexibly incorporates body parts and even whole bodies very different from our own, even when this conflicts dramatically with stored knowledge about our body. Such results may give the impression of bodily awareness as infinitely malleable, inconstant, and ever-changing. Are there any limits on embodiment?

In fact, recent results demonstrate that there are limits on embodiment. Both the rubber hand illusion (Tsakiris & Haggard, 2005) and whole-body analogues (Lenggenhager et al., 2007) are eliminated when the body is replaced with a non-body object. This suggests that some form of ‘body model’ serves as a perceptual filter allowing certain things to become incorporated while filtering out others. Interestingly, though, similarity of skin colour between the participant’s hand and the rubber hand has no reliable effect (Holmes et al., 2006; Longo et al., 2009b). This suggests that the body model is relatively generic, consistent with anything that looks like *a body* regardless of whether it looks like *my body*. While we know what our body is like, the limits of bodily awareness appear to be set by a categorical representation of what people generally are like.

Other studies have suggested different limitations on bodily plasticity. Tsakiris, Tajadura-Jimenez, and Costantini (2011) found reduced susceptibility to the rubber hand illusion in participants with high interoceptive awareness on a heartbeat detection task. Analagously, Eshkevari and colleagues (in press) found heightened sensitivity to the same illusion in individuals with eating disorders, with interoceptive deficts being a highly significant predictor. These results suggest that our conscious awareness of the physiological state of our body serves as a limiting factor on body plasticity. Plasticity of body representation may occur when internal signals from the body itself are weak, and external, visual evidence about the body therefore dominates.

Finally, a different sort of limit seems to be which class of body representation is modified in illusions such as the rubber hand illusion. For example, while the illusion generates clear proprioceptive biases when measured perceptually (e.g., Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005; Longo et al., 2008a), Kammers and colleagues (2009a) found no such biases when participants made reaching movements immediately after induction of the rubber hand illusion, suggesting that the motor system might resist the illusion. However, this dissociation goes away if the induction of the illusion is itself based on viewing one’s own active movement (i.e., agency, Tsakiris et al., 2010). In that case, clear effects of the illusion have been found on subsequent manual reaction time (Longo & Haggard, 2009) and on pointing (Newport et al., 2010). Similarly, Kammers and colleagues (2010) showed that when participants make grasping actions following illusion induction, grip aperture is scaled according to the rubber hand’s grip aperture. These findings suggest that active motor control can both induce bodily illusions, and can also be sensitive to them.

Conclusion

The experience of having a body is so familiar and so fundamental as to be inexpressible. Nevertheless, significant progress has recently been made in developing measures and manipulations of bodily awareness. These studies reveal that bodily awareness has measureable structure, with distinct and dissociable components, and that the body image shows remarkable plasticity, flexibly changing in response to the immediate sensory-motor context. Investigating how this structure and plasticity arise, interact, and develop remain important goals for future research, and may contribute to understanding the many psychological conditions in which bodily awareness is disturbed.

Recommended Reading

Blanke, O., & Metzinger, T. (2008). (See References). A philosophical perspective on the implications of the rubber hand illusions, and analogous full-body illusions, for our understanding of self-hood.

Longo, M. R., Schüür, F., Kammers, M. P. M., Tsakiris, M., & Haggard, P. (2008a). (See References). This study combines an experimental manipulation of bodily awareness (the rubber hand illusion) with a psychometric decomposition of structured questionnaire data to reveal the underlying structure of bodily awareness.

Longo, M. R., Azañón, E., & Haggard, P. (2010). More than skin deep: Body representation beyond primary somatosensory cortex. *Neuropsychologia*, *48*, 655-668. A broad overview of the different types of higher-order body representations.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). (See References). A recent study provides dramatic evidence for plasticity of the body image, in which male participants in a virtual reality situation perceive the avatar of a young girl as their own body.

References

Blanke, O., & Metzinger, T. (2008). Full-body illusions and minimal phenomenal selfhood. *Trends in Cognitive Sciences, 13*, 7-13.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391*, 756.

de Vignemont, F., Ehrsson, H. H., & Haggard, P. (2005). Bodily illusions modulate tactile perception. *Current Biology, 15*, 1286-1290.

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.

Ehrsson, H. H., Kito, T., Sadato, N., Passingham, R. E., & Naito, E. (2005). Neural substrate of body size: Illusory feeling of shrinking of the waist. *PLoS Biology, 3*, e412.

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.

Eshkevari, E., Rieger, E., Longo, M. R., Haggard, P., & Treasure, J. (in press). Increased plasticity of the bodily self in eating disorders. *Psychological Medicine*. DOI: 10.1017/S0033291711002091

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.

Holmes, N. P., Snijders, H. J., & Spence, C. (2006). Reaching with alien limbs: Visual exposure to prosthetic hands in a mirror biases proprioception without accompanying illusions of ownership. *Perception and Psychophysics, 68*, 685-701.

James, W. (1890). *The principles of psychology*. New York: Dover.

Kammers, M. P. M., de Vignemont, F., Verhagen, L., & Dijkerman, H. C. (2009a). The rubber hand illusion in action. *Neuropsychologia, 47*, 204-211.

Kammers, M. P. M., Longo, M. R., Tsakiris, M., Dijkerman, H. C., & Haggard, P. (2009b). Specificity and coherence of body representations. *Perception, 38*, 1804-1820.

Kammers, M. P. M., Kootker, J. A., Hogendoorn, H., & Dijkerman, H. C. (2010). How many motoric body representations can we grasp? *Experimental Brain Research, 202*, 203-212.

Lackner, J. R. (1988). Some proprioceptive influences on the perceptual representation of body shape and orientation. *Brain, 111*, 281-297.

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

Longo, M. R., & Haggard, P. (2009). Sense of agency primes manual motor responses. *Perception, 38*, 69-78.

Longo, M. R., Schüür, F., Kammers, M. P. M., Tsakiris, M., & Haggard, P. (2008a). What is embodiment? A psychometric approach. *Cognition, 107*, 978-998.

Longo, M. R., Cardozo, S., & Haggard, P. (2008b). Visual enhancement of touch and the bodily self. *Consciousness and Cognition, 17*, 1181-1191.

Longo, M. R., Kammers, M. P. M., Gomi, H., Tsakiris, M., & Haggard, P. (2009a). Contraction of body representation induced by proprioceptive conflict. *Current Biology, 19*, R727-R728.

Longo, M. R., Schüür, F., Kammers, M. P. M., Tsakiris, M., & Haggard, P. (2009b). Self awareness and the body image. *Acta Psychologica, 132*, 166-172.

Nahab, F. B., Kundu, P., Gallea, C., Kakareka, J., Pursley, R., et al. (2011). The neural processes underlying self-agency. *Cerebral Cortex, 21*, 48-55.

Newport, R., Pearce, R., & Preston, C. (2010). Fake hands in action: Embodiment and control of supernumerary limbs. *Experimental Brain Research, 204,* 385-395.

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.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS One, 3*, e3832.

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.

Slater, M., Perez-Marcos, D., Ehrsson, H. H., & Sanchez-Vives, M. V. (2009). Inducing illusory ownership of a virtual body. *Frontiers in Neuroscience, 3*, 214-220.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS One, 5*, e10564.

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

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.

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.

Tsakiris, M., Longo, M. R., & Haggard, P. (2010). Having a body versus moving your body: Neural signatures of agency and body-ownership. *Neuropsychologia, 48*, 2740-2749.

Tsakiris, M., Tajadura-Jiménez, A., & Costantini, M. (2011). Just a heartbeat away from one's body: Intenoceptive sensitivity predicts malleability of body-representations. *Proceedings of the Royal Society of London B, 278*, 2470-2476.

Türker, K. S., Yeo, P. L., & Gandevia, S. C. (2005). Perceptual distortion of deletion by local anaesthesia of the human lips and teeth. *Experimental Brain Research, 165*, 37-43.

Acknowledgments

ML was supported by EU FP7 project BEAMING. PH was supported by a Research Fellowship from the Leverhulme Trust, and by EU FP7 projects BEAMING and VERE.

Figure Captions

Figure 1: A canonical setup to elicit the rubber hand illusion. The participant sees a right rubber hand aligned in a similar orientation to their actual unseen right hand. In the ‘Synchronous’ condition, the two hands are touched with identical brushes at identical locations at the same time. In many participants, this visuo-tactile match generates the compelling feeling that the rubber hand really is their hand (i.e., the sense of ownership). In the ‘Asynchronous’ condition, in contrast, the two hands are touched at different times, eliminating the multisensory match between vision and touch, and abolishing the feeling of ownership over the rubber hand. Reprinted from *Neuropsychologia*, 47(1), M. P. M. Kammers, F. de Vignemont, L. Verhagen, & H. C. Dijkerman, ‘The rubber hand illusion in action’, pp. 204-211, 2009, with permission from Elsevier.

Figure 2: Examples of participants’ experiences in the ‘Pinocchio illusion’. In both test configurations shown here, vibration is applied to the tendon of the biceps muscle (vibrator shown as black triangle), generating the proprioceptive illusion that the elbow joint is extending. The participant’s hand, however, remains in constant contact with another body part, such as the nose (top panel) or the scalp (bottom panel). This creates a sensory conflict, since the only way that the moving hand could remain in contact with the other body part is if that body part were actually growing. Many participants indeed report feeling like their nose or head is getting longer, suggesting that the perceptual conflict is resolved by altering the representation of bodily form. Adapted from J. R. Lackner, ‘Some proprioceptive influences on the perceptual representation of body shape and orientation’, *Brain*, 1988, *111*(Pt. 2), 281-297, by permission of Oxford University Press.