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Short Communication

# Disowning one's seen real body during an out-of-body illusion

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ABSTRACT

Under normal circumstances, we experience that our center of awareness is located behind our eyes and inside our own body. To learn more about the perceptual processes that underlie this tight coupling between the spatial dimensions of our consciously perceived self and our physical body, we conducted a series of experiments using an 'out-of-body illusion'. In this illusion, the conscious sense of self is displaced in the testing room by experimental manipulation of the congruency of visual and tactile information and a change in the visual perspective. We demonstrate that when healthy individuals experience that they are located in a different place from their real body, they disown this body and no longer perceive it as part of themselves. Our findings are important because they reveal a relationship between the representation of self-location in the local environment and the multisensory representation of one's own body.



## 1. Introduction

Why do we experience that our 'self' is located inside our physical body; and what is the exact relationship between the body and the center of conscious awareness? Studies on neurological patients suggest that the normal alignment of the consciously experienced self and the physical body can be disrupted by brain pathology, such as during autoscopic phenomena and out-of-body experiences (Blanke, Landis, Spinelli, & Seeck, 2004; Brugger, 2002). Recently, it has been made possible to elicit similar experiences in healthy participants in laboratory experiments involving multisensory stimulation and perceptual illusions (Ehrsson, 2007; Lenggenhager, Tadi, Metzinger, & Blanke, 2007). These studies suggest that multisensory integration in egocentric coordinate systems and the first-person visual perspective are fundamental factors for the creation of a unified experience of oneself in space. An important unresolved question, however, relates to how the real body is represented in the brain during an out-of-body experience. While this question remains extremely difficult to tackle in neurological patients, it can be examined in healthy participants during multisensory 'full-body illusions' which engage the perceptual processes likely to be involved in out-of-body experiences in patients (Blanke & Metzinger, 2009; Ehrsson, 2007; Lenggenhager et al., 2007).

In this study, we investigate how the sense of being located at single place in the environment (self-location) and the perception of owning a body, relate to the representation of one's seen real body when healthy subjects experience the 'out-of-body illusion' (Ehrsson, 2007). This experimental setup uses virtual reality technology and a real-time video feed to change the participant's visual perspective to that of a pair of cameras placed 2 m behind their physical body. The experimenter then repetitively touches the participant's chest using a small rod out of view from the cameras (and thus, the subject), while the participant observes an identical rod approaching and disappearing just below the field of view of the cameras. Because the seen movement of the rod and felt touches on the chest are synchronous and spatially congruent from the first-person point of view, this setup creates a vivid illusory experience that one's own body is located in the position of the

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cameras, 2 m behind the real body, and that the rod approaching the cameras is directly causing the felt touch (Ehrsson, 2007). Thus, two basic experiences are involved in this illusion: the feeling of having an unseen body being touched below the cameras (which we refer to as 'illusory body') and the experience of being located in this position in the room ('illusory self-location').

It is worth emphasizing the principal differences between the 'out-of-body illusion' (Ehrsson, 2007) and other published full-body illusions; namely the 'body-swap illusion' (Petkova & Ehrsson, 2008) and the full-body illusion described by Lenggenhager et al. (2007). In the latter experiment, participants receive tactile stimulation on their back simultaneously as they view the back of their own body being touched by an object, filmed from a distance of 2 m (Lenggenhager et al., 2007). Thus, in contrast to the 'out-of-body illusion' (Ehrsson, 2007), the touches delivered to the real body are directly visible to the participants, and there is no visual stimulation directed towards the cameras. In fact, this setup results in self-identification with the own body presented in visual extra-personal space (Lenggenhager et al., 2007), rather than the feeling of having an 'illusory body' at the location of the cameras (Ehrsson, 2007). In the 'body-swap illusion' (Petkova & Ehrsson, 2008), participants experience a *mannequin's* body as their own. In this illusion, the subjects look down and directly observe a mannequin's body being touched through the head-mounted displays (HMDs), in synchrony with tactile stimulation applied to the real body (Petkova & Ehrsson, 2008). Moreover, the participant's physical body is not within the field of view, and neither is the spatial context in which the artificial body is placed. These two factors distinguish the 'body-swap illusion' from the 'out-of-body illusion,' in which the 'illusory body' is not directly visible but felt in the location just below the field of view of the cameras.

In the study presented here, we use the 'out-of-body illusion' (Ehrsson, 2007) to test the hypothesis that when people perceive that they are located in a different place from their real body, the seen physical body is disowned and no longer represented as one's own (as if the conscious self had 'left the body'). The importance of the findings are twofold. First, they reveal a relationship between the representation of self-location in the local environment and the multisensory representation of one's own body. Second, to our knowledge they constitute the first evidence of full-body disownership in healthy individuals, which has important implications for theories of body ownership (de Vignemont, 2011; Makin, Holmes, & Ehrsson, 2008; Tsakiris, 2010).

## 2. Methods and results

We used a modified version of the experimental setup described in Ehrsson (2007), which is illustrated in Fig. 1 (left panel; see Supplementary material for full description of the experimental procedures). The participants sat on a chair, wearing a set of HMDs, in which they saw a real-time video feed from a pair of cameras located 2 m behind them. The left eye displayed the video image from the left camera, and the right eye displayed the video image from the right camera. Thus, the participants observed their own back with stereoscopic vision from the perspective of a person sitting 2 m behind them. The experimenter was located just behind the participant's right shoulder, and for 1 min simultaneously touched the participant's chest, which was out of view, and the space below the cameras (i.e., the chest of the 'illusory body') with two small plastic rods. The touching of the participant's real chest and the 'illusory chest' was either synchronous, a condition that induces the out-of-body illusion, or asynchronous, a mode of stimulation which significantly reduces the illusion and allows for the comparison of otherwise equivalent conditions.

### *2.1. Experiment 1 and 2: evidence for changed self-location*

In Experiment 1 (16 naïve healthy participants; 10 females, 27 ± 7 years), following 1 min of visuo-tactile stimulation to elicit the illusion as described above, the participants were given a map of the experimental room and were asked to indicate

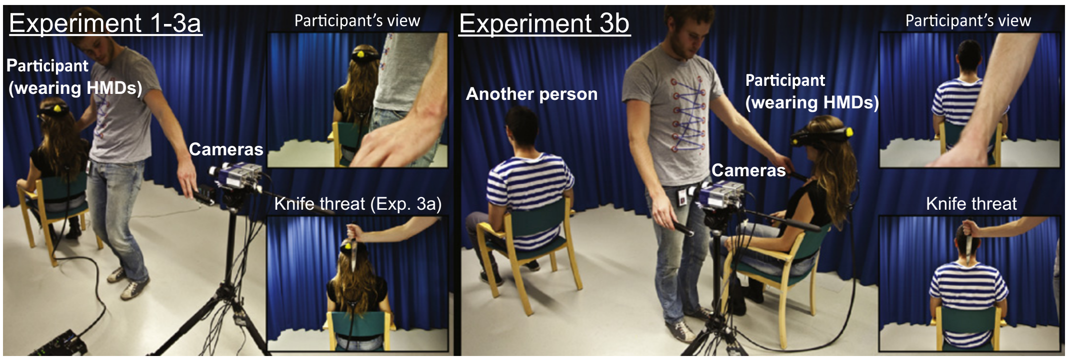


**Fig. 1.** Experimental setup. In Experiment 1–3a, the subject sat in front of the cameras and observed her own back through a pair of head-mounted displays (HMDs). After 1 min of synchronous or asynchronous touching of the subject's chest and the chest of the 'illusory body' below the cameras, the participant indicated her perceived self-location on a map (Experiment 1), filled out a questionnaire about her experiences (Experiment 2), or as an objective measure of body ownership, observed her own back being threatened by a knife while the evoked skin conductance response (SCR) was recorded (Experiment 3a). In Experiment 3b (which serves as a control to Experiment 3a) the participant was placed out of view of the cameras and observed another person's back being threatened while all the other conditions used in Experiment 3a were kept constant.

where they had experienced themselves to be located. This map was a proportional representation of the testing room and had key objects and landmarks indicated (the cameras, the experimenter, the chair, the entrance door, and the walls; see Fig. S1). The participants were asked to rate how strongly they experienced themselves to be located at their veridical location (in the chair) and at the 'illusory location' (the cameras' position) on a continuous visual analog scale ranging from 0 ("I did not experience being located here at all.") to 100 ("I had a very strong experience of being located here."). The results, displayed in Fig. 2A, show that the experience of being located at the veridical location was dramatically reduced by synchronous stimulation (20.6, compared to 67.3 in the asynchronous condition; $t = -6.095$, $P < .001$, paired $t$-test), while the feeling of being located at the illusory location significantly increased (76.2 in the synchronous condition compared to 28.4 in the asynchronous condition; $t = 6.226$, $P < .001$, paired $t$-test). Thus, synchronous visuo-tactile stimulation induced a shift in the participants' experienced self-location in the room from the veridical to the 'illusory' location. By contrast, during the asynchronous condition, they experienced themselves to remain at their veridical position. Additionally, we observed a linear relationship between the degree of self-location at either of the locations (Fig. 2B; $\rho = -0.930$, $P < .001$). This was also true when individually analyzing the synchronous condition ($r = -.896$, $P < .001$), where the data-points are clustered at the bottom right quadrant of the graph (strong sense of self-location at the cameras' position), and asynchronous condition ($r = -.885$, $P < .001$), in which the data point are clustered in the top left quadrant (strong sense of self-location at the position of the chair). These correlations would not be observed if the experienced self-location had been strong in both the veridical and the illusory location (data-points clustered at the top right quadrant), or at a different location in the room (data-points clustered at the bottom left quadrant). Thus, the participants had a strong sense that their perceived self was located at either the veridical or the illusory location, but never simultaneously at both or at neither.

In Experiment 2, which was conducted with a different group of naïve participants (21 subjects; 13 females, 29 ± 4 years), we administered questionnaires to quantify the strength of the subjective experience of being located at the illusory location and feeling ownership of a body being touched at this place in the testing room. The participants were asked to affirm or deny four different statements using a seven-point visual analog scale ranging from −3 ("I do not agree at all") to +3 ("I agree completely"). The participants more strongly affirmed the illusion statements (S1 and S2) after the synchronous illusion condition when compared to the asynchronous control condition ($Z = -3.969$, $P < .001$ for S1, Wilcoxon signed-rank test, and $t = 3.099$, $P = .006$ for S2, paired $t$-test) as seen in Fig. 2C. No significant difference was observed for the control statements S3 and S4 ($t = 1.228$, $P = .234$ for S3 and $t = 0.621$, $P = .542$ for S4, paired $t$-tests). These findings are consistent with the subjectively reported data obtained by Ehrsson (2007) and demonstrate that in addition to changes in self-location, the participants experienced ownership of an unseen 'illusory body' at the new location.

### *2.2. Experiment 3a and 3b: evidence for body disownership*

In Experiment 3a (26 healthy, naïve participants; 12 females, 29 ± 8 years), following an illusion induction period of 1 min (see above), the experimenter threatened the participant's real body with a knife, by making a slow well-controlled stabbing

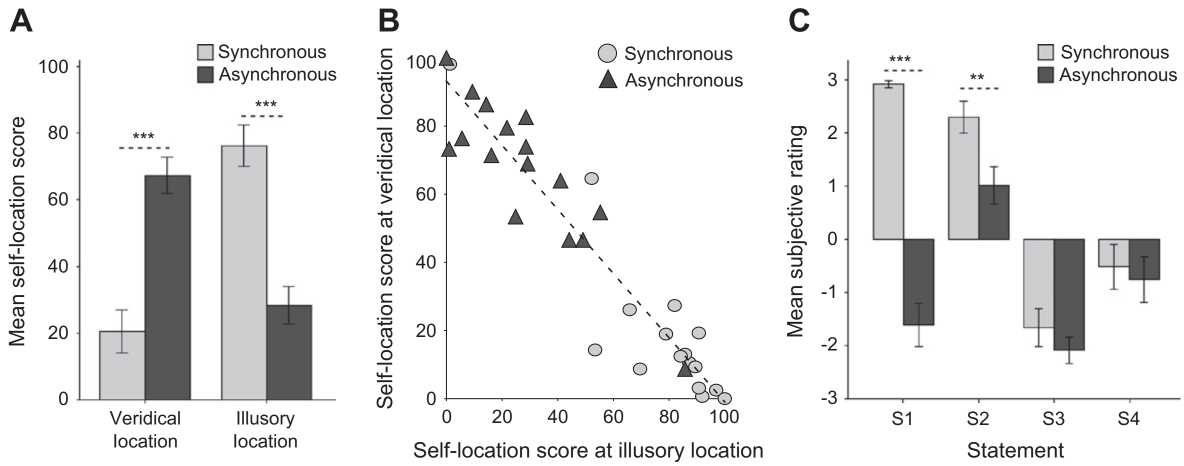


**Fig. 2.** Evidence for changed self-location. (A) Mean score of the self-location task in Experiment 1. Participants indicated on a map the strength of the experience of being at their veridical (the chair) and the illusory (the cameras) location respectively. The experience of being located at the veridical location was strongly reduced by synchronous stimulation ($P < .001$), while the feeling of being located at the illusory location was dramatically increased ($P < .001$). (B) There was a linear relationship between the degree of self-location at either of the locations ($\rho = -0.930$, $P < .001$). Thus, the subjects experienced themselves to be located either at their veridical or the illusory location, but never simultaneously at both or at neither. (C) Questionnaire results from Experiment 2. The difference in subjective ratings between the synchronous illusion condition and asynchronous control condition was highly significant for the illusion statements S1 ("I experienced that the hand I was seeing approaching the cameras was directly touching my chest [with the rod]."; $P < .001$) and S2 ("It felt as if my head and eyes were located at the same place as the cameras, and my body just below the cameras."; $P = .006$), but was not significant for the control statements S3 ("The visual image of me started to change appearance so that I became [partly] transparent."; $P = .234$) and S4 ("I felt as if my head and body were at different locations, almost as if I had been 'decapitated.'"; $P = .542$). Error bars denote standard error of the mean.

motion towards the upper back. To quantify the physiological fear response elicited by this threat, we measured the evoked skin conductance response (SCR), which constitutes an objective measure of subjectively experienced body ownership (Armel & Ramachandran, 2003; Ehrsson, Wiech, Weiskopf, Dolan, & Passingham, 2007; Petkova & Ehrsson, 2008; for details about the SCR registration procedure see Supplementary material). We expected to find a lower SCR in the synchronous condition, in accordance with the hypothesis that the participants would have disowned their real body. Indeed, as can be seen in Fig. 3 (left panel), when the participants observed their own body being threatened with a knife, a significantly lower evoked SCR was detected in the synchronous condition compared to the asynchronous condition ($t = -2.884$, $P = .008$, paired *t*-test). Thus, the participants disowned their physical body when experiencing the illusion in the synchronous condition.

In a control experiment (Experiment 3b; setup illustrated in Fig. 1, right panel), which was performed on a different group of participants (22 healthy, naïve subjects; nine females, 26 ± 7 years), we substituted the participant's body with another person's body (a member of the lab) while keeping all other procedures identical to Experiment 3a. We reasoned that the illusion should not produce disownership of another person's body because this body should not be owned in the first place; therefore, we expected to find no difference in SCR between the synchronous and asynchronous conditions. The results, displayed in Fig. 3 (right panel), show that when the participants observed another person's body being threatened in the control experiment, there was no significant difference in threat-evoked SCR between the synchronous and asynchronous conditions ($t = -0.085$, $P = .933$, paired *t*-test). The inclusion of this control experiment allowed us to rule out non-specific effects on SCR related to experiencing a full-body illusion and also permitted the exclusion of other confounding factors related to the synchronicity of the touches *per se* (e.g., associative learning).

## 3. Discussion

In the present illusion, temporally and spatially congruent visual and somatic signals in egocentric reference frames (defined by the first person visual perspective provided by the HMDs), caused a change in perceived self-location from the veridical location in the room to the location where the cameras were placed. In this perceptual state, the participants experienced ownership of an illusory body at the location of the cameras; and, importantly, disowned their veridical body. These findings go beyond previous studies (Ehrsson, 2007; Lenggenhager et al., 2007; Petkova & Ehrsson, 2008) in that they provide objective evidence for disownership of the real body during the illusion and evidence for a shift in perceived self-location in the testing room with respect to environmental landmarks. The results demonstrate that ownership of a 'new' illusory body comes at the price of losing ownership of the real body. As a result, rather than experiencing ownership of the real and the illusory body simultaneously, the out-of-body illusion involves an experience of one united self at the location of the illusory body.

It is interesting to discuss the present results in the context of how the multisensory representation of space surrounding the body is organized. During the asynchronous control condition, the participants experience that they are located within their veridical body and that the experimenter is standing directly behind their back moving the knife within the space immediately surrounding the body ('near-personal space'; Graziano, 1999, 2000; Guterstam, Petkova, & Ehrsson, 2011;

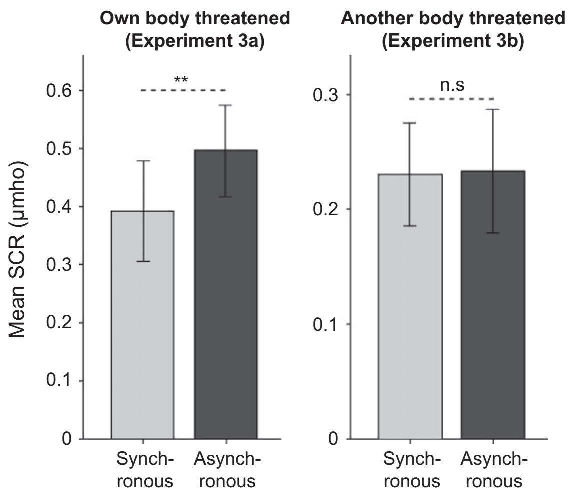


**Fig. 3.** Evidence for body disownership. The mean threat-evoked SCR in the synchronous illusion condition and the asynchronous control condition, when either the participant's own body (Experiment 3a, left panel) or another person's body (Experiment 3b, right panel) was threatened. A significantly lower SCR was observed in the synchronous condition when the participant's own body was threatened ($P = .008$). However, there was no significant difference in SCR when another person's body was threatened ($P = .933$), implying that the observed SCR decrease in Experiment 3a was due to disownership of the participants' physical body induced by synchronized multisensory stimulation. Error bars denote standard error of the mean.

Làdavas & Farnè, 2004; Maravita, Spence, & Driver, 2003). This produced a strong SCR as physically threatening objects near the body are encoded in body part-centered reference frames and automatically trigger motoric and emotional defense reactions to protect the body surface from attack or collision (Graziano & Cooke, 2006). By contrast, during the synchronous condition the participants' experienced self-location shifted to the position of the cameras. The knife threatening the physical body is consequently perceived 2 m in front of oneself in far extra-personal space, thereby generating a weaker SCR. Thus, the experience that the sense of self has moved from the real body to the illusory location seems to be coupled with a corresponding relocation of near-personal space and the origin of the body-centered reference frames.

These results extend earlier studies that investigated illusions of limb ownership, which have failed to produce conclusive evidence for limb disownership (de Vignemont, 2011; Folegatti, de Vignemont, Pavani, Rossetti, & Farnè, 2009; Moseley et al., 2008), although the local temperature changes in the arm reported by Moseley and colleagues deserves further investigation in this respect. A crucial difference between illusions of limb ownership and the present out-of-body illusion is that the former only needs to involve spatial recalibration in body part-centered reference frames (Ehrsson, Spence, & Passingham, 2004; Makin et al., 2008), whereas the present illusion also involves changes in self-location with respect to the local environment. As discussed above, the present disownership effect is therefore likely to be the result of seeing the real body at a distance of 2 m in front of one's perceived self (i.e., in far extra-personal space). This disownership effect is consistent with illusions of owning an entire artificial body being much stronger when the body is viewed from the first person perspective and is present in near-personal space, compared to when the same body is viewed from the third-person perspective in far extra-personal space (Petkova & Ehrsson, 2008; Petkova et al., 2011; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Thus, unlike the case when people experience ownership of a right rubber hand while maintaining ownership of their visible real right hand (Guterstam et al., 2011), our data indicate that it might not be possible for a healthy brain to perceive the self to be located at two different places at the same time and owning two different bodies at these locations.

The present perceptual effects can be interpreted within existing neuro-scientific frameworks, and our results are particularly interesting from a cognitive neuroscience perspective because they generate testable hypotheses about the underlying neuronal mechanisms. The illusion of having a body just below the cameras that is directly being touched by the experimenter's hand is probably mediated by populations of multisensory neurons in premotor cortex, posterior parietal cortex and putamen (Petkova et al., 2011). These regions have the capacity to integrate visual, tactile and proprioceptive information in body part-centered reference frames (Brozzoli, Gentile, Petkova, & Ehrsson, 2011; Graziano, 1999, 2000) and construct central multisensory representations of one's limbs and body parts (Ehrsson et al., 2004; Petkova et al., 2011). We further hypothesize that circuits in the medial temporal lobe and posterior parietal cortex, which are associated with spatial cognition and spatial navigation (Burgess, 2006; Spiers & Maguire, 2006), might be involved in generating the sense of self-location in the environment. This may be supported by areas in the temporo-parietal junction, in particular with respect to representing the orientation of the body in the gravity field (Blanke et al., 2004; Ionta et al., 2011). Finally, the reduced emotional responses when the real 'disowned' body is physically threatened are probably due to attenuated threat-evoked activation in the anterior insula and the anterior cingulate cortex (Ehrsson et al., 2007). The activity level in these structures, which are central for the generation of bodily emotions (Craig, 2002), correlates with the strength of ownership of a body part that is being physically threatened by a sharp object (Ehrsson et al., 2007). Other non-specific emotional responses associated with seeing a knife move near a person (e.g., the visual impression of aversive stimuli, empathy, or surprise) cannot explain our results because these factors were controlled for in the experimental design.

Together, the present experiments support a model of the self that emphasizes the integration of sensory information from different sensory modalities, as well as the fundamental importance of the first person perspective (Blanke & Metzinger, 2009; Ehrsson, 2012; Gibson, 1986; Makin et al., 2008; Merleau-Ponty, 1945; Tsakiris, 2010). These experiments also illustrate the remarkable malleability and dynamic nature of our self-representation, and how easily the center of awareness can be moved to a location outside one's veridical body. We propose that interference with the perceptual processes that localize the center of awareness to within the physical body in the healthy brain might explain occurrences of out-of-body experiences in neurological and psychiatric patients. Furthermore, by obtaining an understanding of perceptual factors that determine the normal 'in-body experience,' computer scientists and engineers may be able to use this knowledge to develop a new generation of virtual reality technologies in which the spatial sense of self is directly manipulated to enhance the feeling of having a body that is localized within a simulated world (Minsky, 1980; Sanchez-Vives & Slater, 2005; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2009; Slater et al., 2010).

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.concog.2012.01.018.

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