PUBLISHED E-LETTER RESPONSES:

How Does the Brain Localize the Self ?

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Respond to this E-Letter:
Re: How Does the Brain Localize the Self ?

The sight of oneself on a stadium screen when filmed as part of the crowd at a football game comes as a pleasant surprise to most people and usually does not cause any confusion. The brain recognizes the artificial nature of the image and deals adequately with the apparent conflict caused by seeing a visual representation of its own body where it should not be. However, when a carefully designed experimental setup eliminates most of the clues about the synthetic nature of the visual scenery, processing of contradictory sensory information concerning the localization of one's own body can produce astonishing results.

Recently, two research groups (Reports, "Video ergo sum: Manipulating bodily self-consciousness," B. Leggenhager et al., 24 August 2007, p. 1096; Brevia, "The experimental induction of out-of-body experiences," H. Ehrrson, 24 August 2007, p. 1048) manipulated self-localization by filming human subjects from behind their back and relaying the captured images in real-time to stereoscopic goggles worn by the participants. Thus the subjects saw a virtual copy of their body in front of themselves. In the study by Lenggenhager and colleagues (1), the experimenters stroked the back of their subjects so that they could see the application of this tactile stimulation on the virtual body. Participants reported feeling the strokes at the location at which they saw them being applied to the virtual body, rather than to their real body, and they indicated that it seemed as if the virtual body was their own. In the study by Ehrsson (2), on the other hand, the author stroked the chest of his subjects, invisibly to them, and applied synchronous strokes to a location just below the camera standing behind the participants (the rod approached the lens and then disappeared just below it with each stroke). In this situation, the subjects reported feeling as if the rod approaching the camera touched their real chest; they said they had the impression of being located at the camera's position, and that seeing their virtual body from behind was almost like looking at someone else.

In both situations, the brain localizes the self based on four different lines of sensory information: (i) the origin of the visuo-spatial perspective; (ii) the location of the visual representation of the body; (iii) the location of the somatosensory perception of the strokes; and (iv) the location of the visual perception of the strokes. In both experimental setups, however, as opposed to everyday experience, these four sensory cues do not provide congruent information. I suggest that careful re-examination of the data collected in these two fascinating experiments allows us to gauge the relative importance of each of these cues with respect to self-localization, and that, by doing so, we can both extend and in part contradict, the conclusions drawn by the authors themselves.

In (1) the subjects localized the self where they visually perceived both their body and the application of somatosensory stimulation. However, this location coincided neither with the origin of the visuo-spatial perspective nor with the actual location of somatosensory stimulation. In (2) the self was localized at the origin of the visuo-spatial perspective, which also coincided with the location of the visual perception of somatosensory stimulation. This location, however, was neither identical to that of the visual representation of the body nor to that of the somatosensory stimulation. Therefore, it appears that self-localization depends foremost on the visual perception of the application of somatosensory stimuli. On the other hand, in neither experiment did the actual location at which somatosensory stimuli were applied correspond to self-localization, although the strokes were subjectively perceived at the location of the self in both situations. As for the other two sensory cues supporting self-localization, namely, the visuo-spatial perspective and the location of the visual representation of the body in space, they both corresponded to self-localization in one case and did not in the other. Why should tactile information play a subordinate role in this competition of sensory cues? The subordinate role appears reasonable when one considers that localization of tactile cues pertains to one's own organism exclusively and cannot possibly provide information as to the position of the body with respect to surrounding space. When somatosensory and visual information about a single action are not congruent, the brain therefore shifts the reference frame of the somatosensory system in order to obtain a rematch, as suggested by the subjects' statements that they felt the strokes on the virtual body (1), or that the touch felt on their chest was attributed to the rod approaching the camera (2). A similar dominance of visual over tactile (and proprioceptive) information is apparent in the rubber-hand illusion (3). However, it is important to note that the visual information with which the brain is confronted in these experimental setups cannot be considered as a whole but must be subdivided into the components listed further above. Thus the pseudo-congruent visuo-tactile input about the brush strokes seems to triumph over two other cues contained in the visual input, namely, the first-person perspective inherent to it—the origin of which did not match self-localization in (1); and the visual representation of one's body in space—the location of which did not match self-localization in (2). Contrary to Ehrsson's (2) conclusion, I believe that it is the visual description of the brush strokes which is used to update the body-centered reference frames rather than the visuo-spatial perspective; the visuo-spatial perspective does not necessarily coincide with self-localization, as is clearly apparent from (1).

It is interesting to note that the overridden visual information, such as the noncongruent visual representation of the body in space, may be modulated by the brain at high cognitive levels in a further effort to attain coherence. In Ehrsson's (2) experiment, subjects reported that looking at their own body from behind felt like looking at someone else, the result of perfectly logical reasoning: How could this body possibly be mine if it is not where I am?

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2. H. H. Ehrsson, Science 317, 1048 (2007).

3. M. Botvinick, J. Cohen, Nature 391, 756 (1998).

4. I thank Antonio Damasio for his mentorship and support. K. M. was supported by the Swiss National Science Foundation.

Olaf Blanke et al.’s Response to Kaspar Meyer’s E-Letter

20 June 2008

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Respond to this E-Letter:
Re: Olaf Blanke et al.’s response to Kaspar Meyer’s E-Letter

We welcome K. Meyer's comparative analysis of two recent data sets on how the brain localizes the conscious self (Brevia, "The experimental induction of out-of-body experiences," by H. H. Ehrsson, 24 August 2007, p. 1048; Reports, "Video ergo sum: Manipulating bodily self-consciousness," by B. Lenggenhager et al., 24 August 2007, p. 1096) highlighting four relevant cues: the visual representation of the body (Fig. 1, white body),the origin of the visual perspective (Fig. 1, white cone), as well as the visual (Fig. 1, white stick) and the tactile perception (Fig. 1, black stick) of the applied touch (stroking). Meyer concludes that in this situation self-localization (Fig. 1, yellow sphere) most importantly depends on the visual perception of the pseudo-congruent event (stroking) since participants localized the self at the location where they visually perceived somatosensory stimulation (visual dominance). He adds that in (2) self-localization may also coincide with the location of the visual representation of the body or in (1) with the location of the visual perspective, but not with the location of somatosensory stimulation. We partially agree and propose that his insightful analysis should be extended by incorporating additional results from both studies (using temporally incongruous cues that have been tested during asynchronous stroking conditions (1, 2).

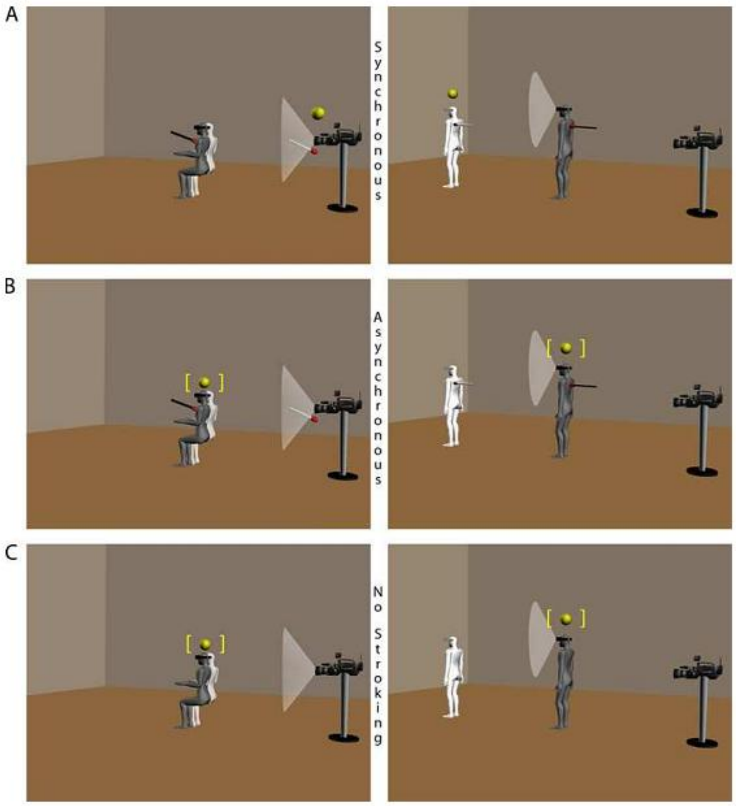

Figure 1: Experimental set-up of Ehrsson [(1), left column] and Lenggenhager et al. [(2), right column] is shown. This is shown separately for the following experimental conditions: A) synchronous visuo-tactile stimulation (stroking), B) asynchronous stimulation, and C) the respective set-ups without any stroking. Real objects and the real body of the participants are indicated in dark colors whereas the virtual objects and the virtual body of the participants are indicated in light colors. The cone indicates the location of the visual perspective. The light body corresponds to the visual representation of the body (virtual). The light stick represents the location of visual "stroking" and the dark stick the tactile stroking. The yellow sphere indicates self-location (slightly elevated in order to facilitate its graphical depiction). Yellow brackets were added when self-location was not explicitly tested in (1, 2) (Illustration by Michael Mouthon).

In the asynchronous stroking conditions (Fig. 1b) participants received the same four cues, but the pseudo-congruent cues of the stroking are no longer temporally synchronous, leading to important differences in self-localization. Even if not explicitly tested, participants seemed under this condition to localize the self where they felt the somatosensory stimulation (and not where they perceived it visually) coinciding (2) with the origin of the visual perspective (Fig. 1b, right) and (1) with the spatial visual representation of the body (Fig. 1b, left). This shows that the temporal incongruence of a pseudo-congruent event alters self-localization, allowing tactile cues to "triumph" over the other tested cues. We caution that self-location has been evaluated by different survey questions and behavioral measures (locomotion vs. emotional response to threat); further studies are needed to compare self-location directly using identical experimental conditions, questions, and behavioral measures.

What about self-location without any stroking applied to one’s body? We agree with Meyer that seeing one's body on a screen usually does not lead to disturbed self location especially when other surrounding cues are available. Yet, viewing a visual representation of one's body in 3D standing in front of one's body and without direct sight of one's actual body (even without any stroking) is characterized by a spatial conflict between the visual perspective and the visual representation of one's body. Where would participants now localize the self—to the origin of the visual perspective, the visual representation of the body, or another location? It also seems to us that we [Lenggenhager et al. (2)] and Ehrsson (1) had different assumptions about self-localization when considering the situation without visuo-tactile conflict (Fig. 1c). We (2) assumed that participants would localize their self at their actual body position while matching the virtual visual perspective (from the camera located behind) to their actual body position and feeling as though they see their body standing in front of them (Fig. 1c, right). Only through synchronous (back) stroking did participants identify with the location of their visual body representation (Fig. 1a, right). We believe that Ehrsson (1) assumed that participants would match the visual body representation [and not the visual perspective as in (2)] with the actual body (Fig. 1c, left). Only through synchronous (chest) stroking do participants localize the self at the location of the visual perspective (Fig. 1a, left). We think that explicit experimental testing in this additional baseline condition is crucial for further understanding the localization of the conscious self. For example, applying threat as done in (1) not only to the visual perspective (Fig. 1c, white cone) but more importantly also to the visual body representation (Fig. 1c, white body) will allow researchers to disentangle experimentally where the conscious self is localized in conditions with spatial conflict between the visual perspective and the visual body representation.

What other cues might be utilized for self-location in addition to the ones discussed by Meyer? In 1899, Stratton described "self"-observations when walking with a portable device of mirrors that were aligned in such a way that he could see a projection of his body below him (3). Mizumoto and Ishikawa (4) installed a fixed camera in the corner of a room and projected the filmed scene (including the participant's body) onto the participant's head-mounted display so that participants could see their body while walking. Both experiments created a spatial conflict comparable to those described above (with no stroking; between the visual representation of the body and the visual perspective) as well as a spatial conflict between the visual perception of the moving body and the associated sensori-motor cues from the actual body movements (tactile, proprioceptive and vestibular cues). Interestingly, Stratton experienced self-location simultaneously at an elevated visual perspective and at position of the visuomotor body representation, associated with the feelings of "being out-of-body." Similarly, Mizumoto and Ishikawa (4) mention the experience of the self at the location of visual perspective and at the location of the visual body representation. Such sensations of disembodiment of the self and even bilocation of the self have also been described in neurological patients with heautoscopy and out-of-body experiences (5), but not in the studies by Lenggenhager et al. (2) and Ehrsson (1). These observations and comparable experimental strategies for body part ownership (6) suggest that future studies on self-location should also manipulate motor commands and associated sensori-motor cues as such additional conflicts will allow researchers to describe the multisensory and sensorimotor representations of body and self more comprehensively.

As mentioned above, additional insights about self location, representation, and perspective have been gauged from studies in neurological patients. These reports suggest even more complex interactions of different integration processes. Patients with self disturbances report, for example, separable auditory and visual perspectives [i.e.(5); patient 4]. Moreover, a recent study based on electrical cortical stimulation shows a clear separation of self-location and visual perspective (7). In other patients, two rapidly alternating or even simultaneous visual perspectives may be experienced [(5); patient 2 and (8)], leaving patients perplexed as to where the self is: At the location of the visual body representation, or the visual perspective? Also, self-location and the perspective of patients with congenital blindness and normally seeing humans with closed eyes further testify to the various multisensory and not exclusively visual perspectives, likely to be utilized in self-location. Collectively, these observations suggest that visual dominance is an important, but not exclusive, mechanism with respect to body representations as well as perspectives. When visual cues are missing or unreliable, other cues gain importance, leading to predictable shifts in phenomenal self-localization; this depends, for example, on whether spatially and temporally incongruent cues are employed. We predict that the merging of cognitive science with neuroimaging and virtual-reality based technology should make it possible to study brain mechanisms in a way that will generate the experience of a unitary conscious self localized at one single position and possessing a unified perspective that has eluded philosophical and scientific scholarship.

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H. H. Ehrsson and V. Petkova’s Response to Kaspar Meyer’s E-Letter

19 June 2008

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Respond to this E-Letter:
Re: H. H. Ehrsson and V. Petkova’s response to Kaspar Meyer’s E-Letter

Kaspar Meyer has compared the results of Ehrsson (1) and Lenggenhager et al. (2) and come to the conclusion that "self-localization depends foremost on the visual perception of the application of somatosensory stimuli," and therefore, that the visual perspective plays a subordinate role. Meyer's argument is based entirely on the study of Lenggenhager et al. (2) in which "participants reported feeling the strokes at the location at which they saw them being applied to the virtual body, rather than to their real body." As pointed out by Meyer and Lenggenhager (2), this would indeed correspond to a whole-body version of the rubber-hand illusion (RHI) (3) from the third-person perspective, which would suggest that the first-person visual perspective plays little role in how we perceive our own bodies (4).

One problem with this view is that it goes against what we know about the RHI. The elicitation of this illusion does not only require simultaneous tactile and visual stimulation on corresponding parts of the rubber hand and the hidden real hand, but also that the fake arm is anatomically aligned with the real one so that it looks like the person's real hand from the first-person perspective. Importantly, if the rubber arm is rotated so that it looks like someone else's arm, the illusion breaks down (5–7). Likewise, the illusion only works if the fake arm is placed within 30 to 40 cm of the real arm (8), making the projection of touch over several meters, as in Lenggenhager's study, unlikely (2). Therefore, we are of the opinion that the projection of touch sensations and body ownership onto external objects only works within reaching distance from the real body (near-personal space) and from a first-person perspective (8, 9).

A second problem with Meyer's argument is that it predicts that it should be possible to induce a whole body rubber hand illusion with a mannequin placed a couple of meters in front of a participant, even without the use of virtual reality technology. However, we have tested this in 10 naïve participants and many of our colleagues without ever being able to induce such an illusion. We are therefore skeptical about the possibility that the RHI might work on whole bodies viewed from the third-person perspective.

We believe the results of Lenggenhager's study depend on the use of video-cameras and head-mounted displays. We can not see how this technology would facilitate the multisensory mechanisms of the rubber-hand illusion. Instead, we propose the alternative interpretation that people were experiencing that their back was being filmed by two CCTV cameras placed behind them, and that they were looking at a video reconstruction of their own body projected in front of themselves (the virtual body). Indeed, in Lenggenhager's first experiment this was exactly what was happening. In the second experiment, the participants misidentified a mannequin as themselves, which is of course a quite extraordinary finding in its own right. But we do not think that this is a perceptual illusion like the RHI (3) or the out-of-body illusion (1). It is more an example of the human’s ability to understand complex spatial transformations in video-systems and mirrors, such as when recognizing yourself on the CCTV surveillance monitor in a shop.

This alternative interpretation could be consistent with the questionnaire data and spatial drift measure presented in Lenggenhager's article. The problem with the questionnaire is that the questions are somewhat ambiguous when applied to the virtual reality set-up. Specifically, they were not designed to differentiate between genuine projection of ownership and touch to the mannequin/virtual body, or self recognition in a video system. The experiment of Groenegress and colleagues (10) is directly relevant to this discussion. These authors carried out a set of experiments in virtual reality using a very similar protocol to that of Lenggenhager et al (2). However, no reliable illusion of ownership of the virtual body or sensation of touch originating from it was reported in the questionnaire. Furthermore, nowhere in Lenggenhager's study was any mention made of whether the participants ever stopped feeling the touch on their on real back (see Meyer's main comment above).

With respect to the spatial drift measure, Lenggenhager and colleagues (11) recently pointed out that their participants did not actually feel that they were located inside the virtual body, but rather, they mislocalized their own body by 17 to 25 cm from its actual location in the direction towards the virtual body, which is considerably less than the actual distance of two meters between the bodies (2). It is also unclear how well this spatial drift measure correlates with the actual feeling of being the virtual body because the spatial drift in the virtual body's condition did not differ substantially from the condition where the virtual body was replaced with an object that did not resemble a body [see Fig. 3 in (2)].

From this discussion it should be evident that there are a number of outstanding questions with respect to how to relate the results from the studies of Lenggenhager et al. (2), Ehrsson et al. (1), and Botvinick and Cohen (3). What is needed now are new experiments that directly compare changes in ownership and touch location on artificial bodies using first- and third-person visual perspectives within the same experimental design. We also need to acquire more knowledge about the perceptual and brain processes that mediate the spatial transformations when seeing one's body from the third-person perspective in mirrors, video systems and immersive virtual reality environments (12, 13). However, as described so clearly by Gibson (14), the first-person perspective is how we normally see our bodies and the correlations of visual, tactile, and proprioceptive signals from this perspective play a critical role in the perception of our own bodies.

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1. H. H. Ehrsson, Science 317, 1048 (2007).

2. B. Lenggenhager, T. Tadi, T. Metzinger, O. Blanke, Science 317, 1096 (2007).

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4. We take Meyer's statement to mean the visual perception of somatosensory stimuli applied in synchrony with tactile stimuli delivered on the corresponding part of the real body, because otherwise it could not explain the lack of illusory own-body percepts in the asynchronous control conditions.

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