

How do different aspects of self-consciousness interact?

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Bodily self-consciousness consists of three components: the feeling of owning the body, the perceived location of yourself in space, and a first-person perspective. A recent study shows which neural areas subserve two components, body ownership and self-location, and crucially, how they can be integrated.

An important aspect of who we are is determined by our bodily experiences. The feeling of my body belonging to me (body ownership), with this body being at a specific location in space (self-location) and perceiving the world from a first-person's perspective all contribute to a conscious experience of yourself [1]. These three aspects of bodily self-consciousness usually match, that is, you own the body that is located at the position where you are and from where you perceive the world and it seems counterintuitive to consider that this may not be the case. However, studies of neurological patients and, during the past two decades, investigations using bodily illusions have provided evidence that each component can be manipulated separately, without affecting other components. Therefore, a crucial question is how integration of different components of bodily self-consciousness is achieved and where this is implemented at a neural level. A recent study by Guterstam and colleagues [2] has provided some important answers to these questions by studying the neural processes underlying two components (body ownership and self-location) of bodily self-consciousness and their integration in the brain.

Evidence for independent components of bodily self-consciousness originally came from neurological patients. Following stroke, patients can deny a body part belongs to them (somatoparaphrenia) [3]. Similarly, the feeling of owning a body part can be manipulated in healthy participants also through the extensively investigated rubber hand illusion. Furthermore, patients with epilepsy can experience viewing their own body from a different perspective (e.g., out of body experience) [1].

The different components of bodily self-consciousness have been investigated more extensively following the introduction of illusions that affect the experience of not just a body part (e.g., the rubber hand illusion) but of the entire body (i.e., a full-body illusion) [4]. Different variants of this illusion exist, either allowing participants to feel that they own another (entire) body (change in body ownership)

or that they experience being located at a different position than their physical body is (change in self-location). In both types of manipulation, participants wear a head-mounted display (HMD) to see their own, or another (virtual) body from a different perspective and receive multisensory stimulation. Self-location can be manipulated by providing the participant a view of the back of his own body on the HMD as if it is located a few meters in front [4]. The experience of owning a different body can be invoked independently by viewing the stomach of the other body from a first-person's perspective through the HMD and receiving multisensory input (seeing the virtual stomach being stroked while simultaneously feeling stroking on one's own stomach) [5]. Recent behavioral studies have also suggested that self-location and body ownership can be altered selectively without affecting the other [6]. These manipulations of different components of bodily self-consciousness have enabled scientists to study their underlying neural mechanisms by inducing full-body illusions in an MRI environment. Whereas body ownership was related to premotor and parietal cortex activation [7], self-location has been linked to temporoparietal junction activity [8].

Of course, as mentioned earlier, the different components of bodily self-consciousness ultimately need to be integrated to achieve a unitary entity ('I') that reflects bodily self-consciousness [1]. The neural mechanisms that underlie such integration have been cleverly investigated in the study by Guterstam and colleagues [2]. They induced an out-of-body illusion while the participant was lying in the scanner. The participant viewed the body of a stranger from a first-person perspective through the HMD. This stranger's body was inside the scanner room (but obviously outside the scanner itself) (Figure 1). Multisensory synchronous stimulation allowed the participant to gain ownership over the mannequin's body. Crucially, the mannequin was placed at two locations in the scanner room, and at one location with the body being positioned at two orthogonal orientations. This provided a different first-person's perspective as well as a different perceived location of the body in space. Comparing synchronous with asynchronous visuotactile stimulation resulted in activation of ventral premotor and parietal cortical areas, which have previously been implicated in body ownership experience [7]. Decoding self-location involved left hippocampal, left posterior cingulate areas, and the right intraparietal sulcus (IPS). Perceived head direction was coded by the right IPS, the left precuneus and left retrosplenial cortex (RSC), and right posterior cingulate cortex (PCC). Crucially, psychophysiological interaction analysis revealed that decoding accuracy in the PCC associated with body ownership involved significant effective

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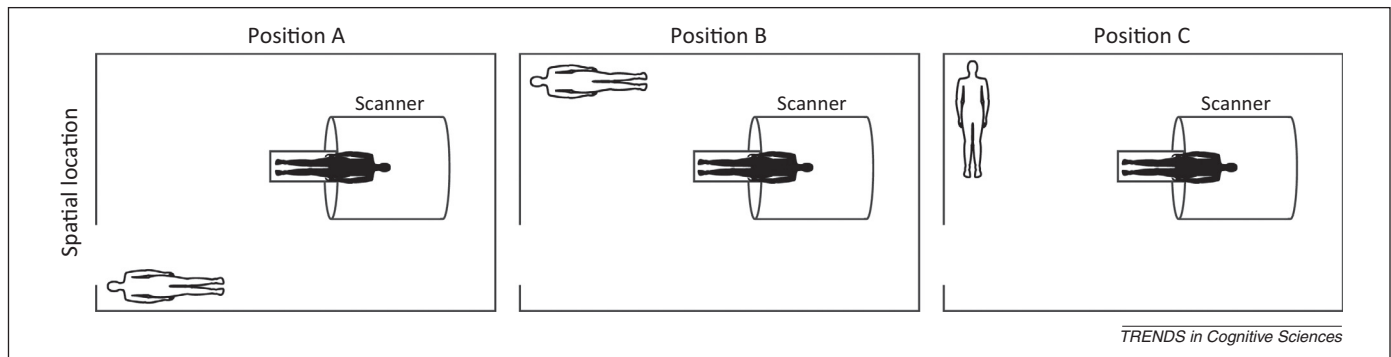


Figure 1. The experimental setup of the Guterstam *et al.* study. The position of the participant's body is given in black, the stranger's body is in white. Note that there are two different positions of the stranger's body and that for one position, two orthogonal body orientations were presented. Reprinted from [2] with permission from Elsevier.

connectivity to the left IPS, right RSC, and left hippocampus. These findings suggest that the PCC is important for integrating self-location and body ownership signals.

This study advances our understanding of bodily self-consciousness significantly as it shows how different components can interact and the neural processes involved in such interaction. One might try a similar approach to investigate interactions between other components of bodily self-consciousness, for example, the relationship between first-person's perspective and body ownership. Indeed, previous behavioral studies suggest that these two components influence each other [9].

One possible caveat of using bodily illusions to study body self-awareness is that they provide information about the processes involved in owning another body and not those subserving owning your own body [10]. Corroborative evidence from other sources would therefore be important. One such source may be patients who show deficits for one of the components of self-consciousness. So far, patient studies do not show involvement of the PCC in self-consciousness disorders. Rather they seem related to right premotor-parietal or insular areas for body ownership [3], or posterior superior temporal gyrus for self-location [1]. Future studies with patients who have PCC damage should test whether integrating self-location and body ownership may be impaired.

More importantly, a model of how different components relate to each other would be crucial to be able to test their interactions systematically. Although interactions and selective manipulations of components of self-consciousness have been reported previously (see earlier and [1,6]), the necessary conditions for independent processing and for

interaction still require further specification. For this, a functional and neural model of how the three components of bodily self-consciousness relate to each other is crucial. The study of Guterstam *et al.* [2] provides some important building blocks for such a model.

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