



Peripersonal space as the space of the bodily self



Jean-Paul Noel^{a,b}, Christian Pfeiffer^{a,b}, Olaf Blanke^{a,b,c,1}, Andrea Serino^{a,b,d,1,*}

^a Laboratory of Cognitive Neuroscience (LNCO), Brain Mind Institute, Faculty of Life Sciences, Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland

^b Center for Neuroprosthetics (CNP), Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland

^c Department of Neurology, University Hospital, 1214 Geneva, Switzerland

^d Department of Psychology, ALMA MATER STUDIORUM – Università di Bologna, 40123 Bologna, Italy

ARTICLE INFO

Article history:

Received 27 August 2014

Revised 4 July 2015

Accepted 22 July 2015

Keywords:

Peripersonal space

Full Body Illusion

Self-location

Self

Multisensory integration

ABSTRACT

Bodily self-consciousness (BSC) refers to experience of one's self as located within an owned body (self-identification) and as occupying a specific location in space (self-location). BSC can be altered through multisensory stimulation, as in the Full Body Illusion (FBI). If participants view a virtual body from a distance being stroked, while receiving synchronous tactile stroking on their physical body, they feel as if the virtual body were their own and they experience, subjectively, to drift toward the virtual body. Here we hypothesized that – while normally the experience of the body in space depends on the integration of multisensory body-related signals within a limited space surrounding the body (i.e. peripersonal space, PPS) – during the FBI the boundaries of PPS would shift toward the virtual body, that is, toward the position of experienced self-location. To test this hypothesis, we used synchronous visuo-tactile stroking to induce the FBI, as contrasted with a control condition of asynchronous stroking. Concurrently, we applied an audio-tactile interaction paradigm to estimate the boundaries of PPS. PPS was measured in front of and behind the participants' body as the distance where tactile information interacted with auditory stimuli looming in space toward the participant's physical body. We found that during synchronous stroking, i.e. when participants experienced the FBI, PPS boundaries extended in the front-space, toward the avatar, and concurrently shrunk in the back-space, as compared to the asynchronous stroking control condition, when FBI was induced. These findings support the view that during the FBI, PPS boundaries translate toward the virtual body, such that the PPS representation shifts from being centered at the location of the physical body to being now centered at the subjectively experienced location of the self.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

A fundamental aspect of our sense of self as subject of conscious experience is the experience of the bodily self, that is, the feeling of being located within a body we own and control (Blanke & Metzinger, 2009; Gallagher, 2005; Jeannerod, 2006). Empirical data demonstrate that the feeling of owning a body (self-identification), as well as the sense of being located within the boundaries of that body (self-location), are fundamentally rooted in the congruent and cohesive integration of multiple sensory modalities within the spatio-temporal dimensions of the physical body (Blanke, 2012). In fact, manipulating the spatio-temporal congruency of different sensory modalities can induce different bodily illusions,

such as the Rubber Hand Illusion (RHI: Botvinick & Cohen, 1998), the Full Body Illusion (FBI: Lenggenhager, Tadi, Metzinger, & Blanke, 2007) and Out-of-Body illusions (Ehrsson, 2007). During the FBI subjects see a virtual body (avatar), placed 2 m in front of them, being stroked, while synchronously receiving a congruent tactile stimulation on their physical body. Under such circumstances participants report to identify with the virtual body (change in self-identification), and feel displaced toward the virtual body (change in self-location). These effects are absent, or reduced, when tactile and visual stimulation are asynchronously administered. Bodily illusions such as the RHI and the FBI reveal that both body-part and full-body representations are malleable in that a sense of ownership can be induced for physical or virtual replacements of our body and that the spatial limits of self-experience can go beyond those of our physical body.

While similar findings have been repetitively reported for different multisensory manipulations (see Blanke, 2012; Ehrsson, 2012; Serino et al., 2013 for reviews), the brain mechanisms underlying these effects are not yet known. It has been proposed that, during the FBI, synchronous tactile stimulation on the participants'

* Corresponding author at: Laboratory of Cognitive Neuroscience (LNCO), Brain Mind Institute, Faculty of Life Sciences, Ecole Polytechnique Fédérale de Lausanne (EPFL), Station 19, CH-1015 Lausanne, Switzerland.

E-mail addresses: jeanpaulnc@gmail.com (J.-P. Noel), Christian.Pfeiffer@epfl.ch (C. Pfeiffer), Olaf.Blanke@epfl.ch (O. Blanke), andrea.serino@epfl.ch (A. Serino).

¹ OB and AS contributed equally to the study.

body and visual stimulation from the avatar seen at an extracorporeal location might enlarge the visual and receptive fields of neurons coding for peripersonal space (PPS) (Blanke, 2012). Multisensory PPS neurons integrate tactile, visual, and auditory stimuli when presented at a limited distance from the body (Bremmer, Duhamel, Ben Hamed, & Graf, 2002; Gentile, Petkova, & Ehrsson, 2011; Graziano & Cooke, 2006; Makin, Holmes, & Ehrsson, 2008; Rizzolatti, Fadiga, Fogassi, & Gallese, 1997), but not when further away. This limit defines the boundary of PPS, that have also been reported to be plastic in that the space where multisensory stimuli are integrated extends when individuals interact with far locations, for instance, by using tools (Làdavas & Serino, 2008; Maravita & Iriki, 2004; Serino, Canzoneri, Marzolla, di Pellegrino, & Magosso, 2015). It is possible that feeling touch on one's own body, while viewing tactile stimulation administered on a virtual body at a distance may also alter the boundaries of the PPS representation. Accordingly, previous studies have shown that the spatial constraints of multisensory integration between vision and touch vary during the FBI (Aspell, Lenggenhager, & Blanke, 2009) or the RHI (Pavani, Spence, & Driver, 2000; Zopf, Savage, & Williams, 2010). Here we describe how the boundaries of PPS shape during the FBI. In particular, we test the hypothesis that, while normally the PPS representation is bound to the physical body, during the FBI PPS becomes referenced at the illusory self-location.

To test that hypothesis, we induced the FBI (Lenggenhager et al., 2007), while we concurrently measured the spatial extent of PPS representation by means of a dynamic audio–tactile interaction task (Canzoneri, Magosso, & Serino, 2012; Noel et al., 2014; Galli, Noel, Canzoneri, Blanke, & Serino, 2015). In order to experimentally induce a change in BSC, we administered tactile stimulation on the participant's physical body, while synchronously showing (visual stimuli) spatially conflicting tactile stimulation on a virtual body. In the control condition, tactile and visual stimulation were administered asynchronously. Change in BSC was reported through a questionnaire. Concurrently, in order to define the boundary of PPS representation, participants were asked to respond as fast as possible to vibro-tactile stimuli administered on their trunk, while task-irrelevant sounds loomed toward their trunk. Based on previous findings (Canzoneri, Marzolla, Amoresano, Verni, & Serino, 2013; Canzoneri et al., 2012; Canzoneri et al., 2013; Teneggi, Canzoneri, di Pellegrino, & Serino, 2013), we predicted that reaction times to tactile stimuli would decrease once the sound overcame a particular distance from the body, which can be taken as a proxy for the boundary of PPS. In Experiment 1, dynamic sounds were presented in the participants' front-space. In this way, we tested whether during synchronous visuo-tactile stroking inducing the FBI, the PPS boundary extends in the front, toward the virtual body, as compared to the asynchronous control condition. In Experiment 2, moving sounds were presented in the participants' back-space, to test whether the extension of PPS toward the virtual body in the front-space (as predicted in Experiment 1) was associated with a concurrent shrinkage of PPS in the back-space (or whether it was rather associated with no change). Such findings would indicate a shift of PPS representation from the physical body to the illusory perceived location of the self. We predicted no changes in PPS boundaries (either in the front or in the back) during the asynchronous stroking condition, where no FBI was induced.

2. Material and methods

2.1. Participants

Nineteen and fifteen students from the Ecole Polytechnique Federale de Lausanne participated in Experiment 1 (9 females, mean age = 23.0 years, range 18–29) and in Experiment 2 (4

females, mean age 24.2 years, range 19–31), respectively. Sample size for Experiment 1 was derived from power analysis of prior studies (Leggenhager et al., 2007, 2009) and for Experiment 2 based on the effect size in Experiment 1. All participants were right-handed, had normal or corrected-to-normal eyesight, normal hearing, and no history of neurological or psychiatric disease. The study was approved by Brain Mind Institute Ethics Committee for Human Behavioral Research of the EPFL and conducted in line with the Declaration of Helsinki. All participants gave informed consent prior to participation and were remunerated with 20 Swiss Francs for their time.

2.2. Stimuli and apparatus

Fig. 1A shows the experimental setup. In order to measure the boundaries of PPS representation, participants stood in the middle of two arrays of 8 speakers each, placed besides their chest, one on the right and one on the left, at 50 cm distance from their midline. Four speakers on each side were placed in the participant's front-space, and were utilized in Experiment 1 to map the front PPS, and 4 speakers on each side were placed in the participant's back-space and were utilized in Experiment 2 to map their back-space PPS. The loudspeakers extended from 100 cm in front of the subjects to 100 cm in the back. The sounds were perceived as if coming from the center (in between the two arrays). A control experiment (i.e., sound localization, $n = 7$) validated the paradigm demonstrating that participants perceived the sounds as dynamically approaching their body (see further detail in [Supplementary Material](#)).

In addition, participants were outfitted with a vibro-tactile device (Precision MicroDrives shaftless vibration motors, model 312-101), which was placed on the participant's chest in Experiment 1 and on his/her back in Experiment 2, at stern level. Participants were handed a wireless gamepad (XBOX 360 controller, Microsoft, Redmond, WA), which they held in their right hand and used to respond to vibro-tactile stimulation.

In order to induce the FBI, two video cameras (Logitech HD Webcam C270, 1280 × 720 pixels, Logitech Fluid Crystal Technology) recorded the participant from a distance of 200 cm (in the back), and this signal was relayed stereoscopically to a Head Mounted Display (HMD, Oculus Rift SDK, Oculus VR, 100° field of view, 60 Hz) worn by the subject. Synchronous visuo-tactile stroking was achieved by direct real-time (<50 ms delay) display of visual signals from the cameras to the HMD. During asynchronous visuo-tactile stimulation the camera signal was delayed by 500 ms before feeding it to the HMD.

2.3. Experimental manipulations and outcome measures

2.3.1. Full Body Illusion manipulations

For each experiment, synchronous and asynchronous visuo-tactile stroking were presented in separate blocks, whose order was counterbalanced between participants. These conditions differed in the temporal synchrony between felt and seen touch (synchronous: <50 ms delay; asynchronous: 500 ms delay, where tactile stimulus preceded the visual stimulus). Participants stood straight and, through a video feed relayed to the HMD, passively watched a virtual body, i.e. a video recording of their own body from 200 cm behind their actual location. The experimenter randomly stroked the participants' upper back at approximately 2 Hz. At the end of each condition, the FBI questionnaire (adapted from Lenggenhager et al., 2007) was administered to quantify the subjective experience associated with the FBI. Questions were: Q1. How strong was the feeling that the rod you saw was directly touching you? Q2. How strong was the feeling that the touch you felt was where you saw the stroking? Q3. How strong was the

Download English Version:

<https://daneshyari.com/en/article/7286598>

Download Persian Version:

<https://daneshyari.com/article/7286598>

[Daneshyari.com](https://daneshyari.com)