Response to “Limb Ownership Experience and Peripersonal Space Processing”

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We are pleased to respond to the excellent review by Robert Bekrater-Bodmann and Jens Foell that focused on our recent study in The Journal of Neuroscience characterizing the link between fronto-parietal neuronal populations encoding the peri-hand space and the sense of ownership experienced over the hand. Their Journal Club article aptly summarizes the key findings of our study, and we would like to take the opportunity to discuss two interesting points raised by the authors.

As the commentators indicated, there is pervasive debate about whether the use of a tool to extend the reach of our actions induces an expansion of the peri-hand space representation. Despite convincing evidence demonstrating that the active use of a tool induces an update of the implicit body representation for actions (‘body schema’, see Cardinali et al. 2009a, b), the picture appears less clear when turning to the potential expansion of the peripersonal space representation immediately after tool use (Holmes 2012). Behavioral evidence is primarily derived from neuropsychological studies on patients presenting cross-modal extinction (for examples, see Farnè et al. 2004; Bonifazi et al. 2007) and studies assessing visuo-tactile interactions in healthy individuals in the form of distance-modulated interference exerted by visual over tactile stimuli (Maravita et al. 2002; Holmes et al. 2004). The neuroimaging evidence concerning tool use is instead limited to a few well-conducted studies (i.e., Gallivan et al. 2009; Jacobs et al. 2010; Valyear et al. 2012). However, these studies have primarily focused on the sensorimotor bases of reaching and grasping actions rather than on the effects of tool use on the remapping of body-centered spatial representations. In our study, we showed that inducing illusory ownership of a prosthetic device perceived as part of one’s own body (Ehrsson et al. 2004) entailed a remapping of the body-centered representation of space. The question of whether a similar dynamic shift or expansion of the hand-centered visual receptive fields can be induced by tool use remains an important question for future studies. We believe that the fMRI adaption protocol that we developed for the rubber hand could readily be adopted for experiments with tools.

The second interesting point discussed by Bekrater-Bodmann and Foell concerns the size of one’s peripersonal space and, in particular, the distance from a static hand at which we can draw a theoretical boundary between peripersonal space and external space. Electrophysiological recordings in monkeys have revealed peripersonal neurons with different receptive field (RF) sizes (Rizzolatti et al. 1981; Graziano and Gross 1993). Some RFs are restricted to the immediate proximity of the body surface (‘near peripersonal space neurons’), while others extend up to 30 cm from the skin. Graziano and colleagues (Graziano et al. 1997) reported neurons with visual RFs extending up to 1 m from the body surface. However, to the best of our knowledge, no data are available regarding a parametric measure of the size of peripersonal space in humans. Nonetheless, previous neuropsychological studies have reported weaker interactions between visual and tactile signals when the visual stimulus was presented approximately 30 or 45 cm from the body surface compared with near the body surface (Làdavas et al. 1998; Farnè et al. 2003). Additionally, Makin and colleagues (Makin et al. 2009) have shown a differential visuo-motor encoding of an object appearing 30 cm lateral from the hand compared with directly above it. In light of these considerations, we would like to clarify the advantage of using a distance of 30 cm between the Near and Far positions in our study. This choice ensured that the visual stimulation was always presented within reaching space; that is, the object could be reached even when presented in the Far position. This arrangement allowed us to isolate neuronal populations with receptive field properties specific to hand-centered spatial coding and not merely encoding the reachability of the object.

In summary, we thank Bekrater-Bodmann and Foell for drawing the readers’ attention to our work and highlighting the contributions that we hope our work makes to the study of peripersonal space and body ownership.
References


