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Visual processing and the bodily self

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Abstract

The 'body schema' has traditionally been defined as a passively updated, proprioceptive representation of the body. However, recent work has suggested that body representations are more complex and flexible than previously thought. They may integrate current perceptual information from all sensory modalities, and can be extended to incorporate indirect representations of the body and functional portions of tools. In the present study, we investigate the source of a facilitatory effect of viewing the body on speeded visual discrimination reaction times. Participants responded to identical visual stimuli that varied only in their context: being presented on the participant's own body, on the experimenter's body, or in a neutral context. The stimuli were filmed and viewed in real-time on a projector screen. Careful controls for attention, biological saliency, and attribution confirmed that the facilitatory effect depends critically on participants attributing the context to a real body. An intermediate effect was observed when the stimuli were presented on another person's body, suggesting that the effect of viewing one's own body might represent a conjunction of an interpersonal body effect and an egocentric effect.

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1. Introduction

The body constitutes a fundamental component of our sense of self. For example, the infant learns that it is an object separate from the world by experiencing the special relationship between its motor commands and the movements of its body. This foundation subsequently supports the development of more complex psychological concepts such as that of the 'self' (Brewer, 1992). Disorders such as phantom limb syndrome (Ramachandran & Hirstein, 1998) and body dysmorphia (Phillips, 2004) suggest that neural representations of the body continue to have a profound link to our sense of self throughout our lives. These representations exhibit both independence of the exact state of the body, and flexibility to enduring or dramatic changes. Thus, the sense of our own body does not reflect our particular clothing or posture, but does adapt to major injuries or change in body size. For example, 'I' remain the same when my hand moves, or even when my hand is cut, but my sense of self might change profoundly if I become disfigured or if I have a limb amputated.

This contrast relates to the description of psychological body representation in terms of two components; 'body image' and 'body schema' (see Haggard & Wolpert, 2005). The former refers to a largely conscious, visual representation of our body, often from an external perspective, which would be affected by severe changes in the body. The 'body schema' is a passively updated proprioceptive representation of the positions of body parts in space. Since the body schema is largely unconscious, it does

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not strongly affect our sense of self, and is the framework in which transient bodily changes are represented.

The existence of the body schema has traditionally been supported by neuropsychological case studies. For example, Halligan and Marshall (1991) reported visual–spatial neglect for extrapersonal space, but not for the space associated with the body and its parts. By contrast, Guariglia and Antonucci (1992) reported the opposite pattern of results. This double dissociation has been used as evidence for a separate, body-related attentional system (Reed & Farah, 1995; Weiss et al., 2000). Indeed, Head and Holmes (1911) developed the original concept of the 'body schema' through a consideration of such disorders.

However, these neuropsychological studies suffer from some of the classical problems of interpretation. For example, there is usually uncertainty concerning the exact anatomical extent of any lesion, and concerning any compensatory neural plasticity or cognitive strategies. In addition, the uniqueness of each patient makes interpretation of double dissociations difficult (Caramazza & Coltheart, 2006). A better understanding of these concepts in normal participants is necessary, both to overcome these problems, and to help researchers to probe their basis in the normally functioning brain. In the present study, we investigated the effects of body representation on visual perception, as a tool for asking how egocentric and interpersonal representations of the body might represent different aspects or components of the body schema, and for investigating their properties.

Whiteley, Kennett, Taylor-Clarke, and Haggard (2004) showed a facilitation of speeded visual discrimination reaction times (RTs) for visual stimuli viewed in the context of the body. Participants in their study viewed two LEDs, which were attached either to their hand or to a neutral object, and had to make a speeded proximal–distal decision when one of the LEDs was flashed. The LEDs were not viewed directly – instead a real-time video image of the set-up was projected on a screen directly in front of the participants. The hand and object were filmed in separate blocks of experimental trials, and were projected onto the same location. This paradigm controlled for spatial-attention effects, and allowed us to closely control the physical parameters of the visual scene.

Whiteley et al.'s (2004) results complement the work of Kennett, Taylor-Clarke, and Haggard (2001), and earlier work of Tipper et al. (1998, 2001), showing that non-informative vision of the body can selectively enhance *touch*. Kennett et al.'s (2001) interpretation was that vision of the body might activate some kind of abstract body scheme, which then pre-sets unimodal somatosensory cortex. Support for this interpretation comes from a recent transcranial magnetic stimulation (TMS) study (Fiorio & Haggard, 2005), in which the visual-enhancement of touch was shown to be disrupted by TMS to SI, but not to SII. Whiteley et al.'s (2004) study suggests that a similar perceptual facilitation from viewing the body might take place for vision as well as for touch.

Studies of tool use show that this link between vision and touch is not fixed but is mediated via a plastic, rapidly adapting body scheme. For example, Iriki, Tanaka, and Iwamura (1996) showed that bimodal visuo-tactile neurons that represent the fingers of a monkey extend their receptive fields to incorporate tools (though see Holmes & Spence, 2004). Behavioral studies in humans have found similar results in neuropsychological populations (Berti & Frassinetti, 2000; Farnè & Làdavas, 2000), and in healthy adults (Maravita, Spence, Kennett, & Driver, 2002). A recent experiment suggested that this effect may be closely related to, and influenced by, the functional role that the tool plays in linking our bodies to the external world (e.g., Holmes, Calvert, & Spence, 2004).

In tool use, this kind of plasticity might appear to be driven purely by the motor aspects of the task, due to the changing relationship between one's motor commands and the displacement of the effector. However, parallel visual effects also occur. For example, Iriki, Tanaka, Obayashi, and Iwamura (2001) trained monkeys to recognize themselves in real-time video images displayed on a monitor, and then trained them to perform the tool-use task via such images. Bimodal neurons then developed receptive fields that responded to stimuli on the monitor, suggesting that the relevant body scheme can also involve indirect representations of the body. In Whiteley et al.'s (2004) study, we suggested that these kinds of plasticities should lead to a reconsideration of the concept of 'peripersonal space'. Instead of being defined in terms of the physical boundaries of the body, this region (in which stimuli receive 'special' processing) can incorporate indirect representations of the body. It seems that the traditional 'body schema' may encompass both a canonical proprioceptive scheme, and a more plastic, potentially amodal scheme that responds to the participant's motor and perceptual interactions with the world (see Holmes & Spence, 2006).

Viewing the body thus seems to cause wide-ranging effects on perceptual processing, but it is at present less clear *why* these effects occur. Answering this question is crucial to understanding the nature of the neural representations responsible. In this paper, we report three experiments using a simple speeded visual discrimination RT task in which participants respond to identical stimuli that vary only in their context: either being presented on the body or not. We then ask which aspect of the context is key – biological saliency, egocentric body representation, or a social/interpersonal body scheme.

In Experiments 1 and 2, we used an attribution technique (Tsakiris & Haggard, 2005) to either encourage or discourage participants from treating a representation of a body as their own. This acts as a control, helping us to rule out saliency effects by presenting a body context in both conditions. Studies of the body schema in action observation (Kilner, Paulignan, & Blakemore, 2003) and in a social context (Reed & Farah, 1995) suggest that there is often an interpersonal aspect to body-related processing. It is therefore important to assess whether body-related