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The 'Enfacement' illusion: A window on the plasticity of the self

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ABSTRACT

Understanding how self-representation is built, maintained and updated across the lifespan is a fundamental challenge for cognitive psychology and neuroscience. Studies demonstrate that the detection of body-related multisensory congruency builds bodily and facial self-representations that are crucial to developing self-recognition. Studies showing that the bodily self is more malleable than previously believed were mainly concerned with full-bodies and non-facial body parts. Crucially, however, intriguing recent evidence indicates that simple experimental manipulations could even affect self-face representation that has long been considered a stable construct impervious to change. In this review, we discuss how Interpersonal Multisensory Stimulation (IMS) paradigms can be used to temporarily induce Enfacement, i.e., the subjective illusion of looking at oneself in the mirror when in fact looking at another person's face. We show that Enfacement is a subtle but robust phenomenon occurring in a variety of experimental conditions and assessed by multiple explicit and implicit measures. We critically discuss recent findings on i) the role of sensory extero/proprio-ceptive (visual, tactile, and motor) and interoceptive (cardiac) signals in self-face plasticity, ii) the importance of multisensory integration mechanisms for the bodily self, and iii) the neural network related to IMS-driven changes in self-other face processing, within the predictive coding theoretical framework.

Abbreviations: AC, Asynchronous Congruent; AI, Asynchronous Incongruent; ECG, Electrocardiogram; EEG, Electroencephalography; fMRI, functional Magnetic Resonance Imaging; HCT, Heartbeat Counting Task; HEP, Heartbeat Evoked Potential; IAcc, Interoceptive Accuracy; IMS, Interpersonal Multisensory Stimulation; IOG, Inferior Occipital Gyrus; IPS, Intra-Parietal Sulcus; lpSTS, left posterior part of the Superior Temporal Sulcus; MTS, Mirror Touch Synesthesia; PPS, Peripersonal Space; RHI, Rubber Hand Illusion; RTs, Reaction Times; SC, Synchronous Congruent; SI, Synchronous Incongruent; TPJ, Temporo-Parietal Junction; VAS, Visuo-Analogue Scale; VEPs, Visual Evoked Potentials; vmPFC, ventro-medial Prefrontal Cortex; VR, Virtual Reality; VRT, Visual Remapping of Touch.

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1. Plasticity of the bodily self: the Enfacement illusion challenges the notion that self-face recognition is hardly modifiable

How and when the sense of self (i.e., the unified experience of being in a certain place at a certain time; Toda & Platt, 2015) and, more specifically, the sense of bodily self (i.e., the feeling of being a unitary identity driven by a non-conceptual representation of body-related information (Lenggenhager, Tadi, Metzinger, & Blanke, 2007)), is developed and constantly updated is a highly debated topic in cognitive and social neuroscience. At a very basic level, the sense of bodily self is built upon the neural representation of facial (e.g., Devue & Brédart, 2011; Platek, Wathne, Tierney, & Thomson, 2008) and non-facial body parts (e.g., Ionta et al., 2011). The face holds a special importance for our sense of identity because it is the most distinctive feature of our physical appearance. In line with this, behavioral and neural evidence show that the self-face has a special status in human cognitive and emotional systems (Devue & Brédart, 2011; Keenan, Falk, & Gallup, 2003). One's own face is recognized faster (Tong & Nakayama, 1999), grabs and retains attention longer than even highly familiar faces (Brédart, Delchambre, & Laureys, 2006; Devue, Van der Stigchel, Brédart, & Theeuwes, 2009; except in identical twins: Martini, Bufalari, Stazi, & Aglioti, 2015) and is processed in a dedicated, right-dominant, cortical circuit (Platek et al., 2008; but see; Devue & Brédart, 2011). Being the representation (and the processing) of self-face so hard-wired, it is rarely impaired by neurological or psychiatric disorders.

Self-face recognition is based upon the representation of the self-face. A coherent representation of one's own face is formed and continuously updated on the basis of congruent multisensory (exteroceptive and interoceptive) signals that are constantly experienced and integrated. For example, when we look at ourselves in the mirror, our self-reflection moves and is touched in perfect temporal and spatial synchrony with our own sensory-motor experience. Given that one's own face constantly changes throughout life, our brain should allow a plastic self-face representation.

Here, we will discuss the role of multisensory integration processes with respect to the construction of bodily (especially facial) self representation and its plasticity.

That multisensory integration is critical to the development of self-recognition and self-awareness is suggested also by recent animal and developmental studies. Indeed, despite evidence that non human primates fail to pass the *mark test*[2] (see Anderson & Gallup, 2011 for a review) recent results show that rhesus monkeys are able to do so after visuo-somatosensory training (Chang, Fang, Zhang, Poo, & Gong, 2015). Congruently, human infants seem to develop a sense of bodily self on the basis of contingent intermodal perception (Rochat & Striano, 2002): they look more at an infant face (Filippetti, Johnson, Lloyd-Fox, Dragovic, & Farroni, 2013) or body (Zmyj, Jank, Schütz-Bosbach, & Daum, 2011) being stroked synchronously (*vs* asynchronously) respectively with their own face or body.

That multisensory integration underlies plasticity of bodily self representation is suggested by the recent discovery of bodily illusions which are able to temporary change not only our body (Botvinick & Cohen, 1998; Lenggenhager et al., 2007), but also our face (Sforza, Bufalari, Haggard, & Aglioti, 2010; Tsakiris, 2008) representation. Recently, various research groups (e.g., Paladino, Mazzurega, Pavani, & Schubert, 2010; Tsakiris, 2008) including our own (Sforza et al., 2010), used visuo-tactile multisensory interpersonal stimulation (IMS) procedures to study the plasticity of self-face representation and showed that self-face representation can be updated to temporary include another person's facial features, which in turn challenges self-face recognition. We named this effect *Enfacement* (Sforza et al., 2010). In the Enfacement illusion, a participant is synchronously touched on the same part of the face as another person standing in front of him or her, and has the impression of seeing him or herself in the mirror and feeling the tactile stimuli observed on the other person's face (Sforza et al., 2010). Crucially, these sensations are accompanied by a misattribution of the others' facial features to the self-face (i.e., the so-called *self-face attribution bias*) in self-other discrimination and recognition tasks (Sforza et al., 2010; Tsakiris, 2008), please see next section.

Several studies replicated the Enfacement illusion under a variety of experimental conditions and showed that synchronous IMS over self-face produces implicit (Fig. 1B) and explicit (Fig. 1C) changes of bodily self (please see section 2). Although multifaceted, the pattern of results converges to indicate that not only the body but also the face representation is consistently and unexpectedly malleable.

In the first part of our review, we aim to highlight the importance of the Enfacement as a powerful tool to change the bodily self-representation (section 2). We will first review the literature to highlight which are or could be the most effective procedures to increase the strength of the Enfacement and compare the efficacy of the most commonly used IMS procedures (section 3). In particular, we will highlight the importance of multisensory integration mechanisms, the relative contribution of different sensory extero/proprioceptive (visual, tactile and motor; section 3) and interoceptive (cardiac; section 4) inputs for the plasticity of the self-face recognition and which are the minimal conditions, besides IMS, necessary to induce the illusion (section 5).

In the second part of our review, we will discuss results from theoretical, behavioral and neural studies on bodily illusions and specifically on the Enfacement illusion (Apps, Tajadura-Jiménez, Sereno, Blanke, & Tsakiris, 2015; Sel, Azevedo, & Tsakiris, 2016; Serino et al., 2015) within a unifying predictive coding account (Apps & Tsakiris, 2014) (section 6). In order to provide a critical and comprehensive description of the different mechanisms that contribute to the establishment and maintenance of the Enfacement illusion, we will propose a novel and coherent, although tentative, neuro-cognitive model of all the key components characterizing the Enfacement (section 7).

We are aware that beyond self-face recognition, there are several interesting studies on the effects of the Enfacement

[2] In the *mark test* (or "*rouge test*") (Gallup, 1970), an odorless dye is covertly placed on the face of an individual. The test is passed if the individual touches the dye mark after seeing itself in the mirror.