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Review article

Real, rubber or virtual: The vision of "one's own" body as a means for pain modulation. A narrative review

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A R T I C L E   I N F O

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A B S T R A C T

In the last few years a branch of pain research has been focussing on the modulatory effects of the vision of the body on pain perception. So, for instance, the vision of one's own real body has been proven to induce analgesic effects. On the other hand, bodily illusions such as the rubber hand illusion have provided new tools for the study of perceptual processes during altered body ownership states. Recently, new paradigms of body ownership made use of a technology that is going places both in clinical and in experimental settings, i.e. virtual reality. While the vision of one's own real body has been proven to yield compelling analgesic effects, slightly more controversial are those attributed to the vision of "owned" dummy bodies. This review will discuss the studies that examined the effects on pain perception of the vision of the own body, with or without body ownership illusions.

Contents

1. Introduction

With more than six hundred thousand articles published on the topic, pain is certainly one of the best studied areas in the realm of medicine and neuroscience. Yet, due to its intrinsic subjective nature and the plethora of factors that may modulate it, much is left to be discovered. It is widely accepted that pain is both a sensorial and emotional conscious experience and it has a protective function, steering attention toward a potential threat, thus facilitating the avoidance of dangerous situations. However pain can also occur in the absence of actual tissue damage and "nociception and pain should not be confused,

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because each can occur without the other" (Loeser & Treede, 2008). At the neural level, a set of brain areas have been identified as being specifically recruited to encode the pain experience. These areas form the so-called "pain matrix" and are commonly the primary and secondary somatosensory cortices (SI and SII), the insula, the anterior cingulate cortex (ACC), prefrontal cortex (PFC), thalamus, basal ganglia, and cerebellum (Schweinhardt & Bushnell, 2010). The same brain areas have been shown to be active even during the observation of pain in others, in empathy for pain studies (Botvinick et al., 2005; Lamm, Batson, & Decety, 2007; Saarela et al., 2007). Nevertheless, the existence of a specific set of brain areas selectively dedicated to encode the pain experience is still a matter for debate. The "pain matrix" has been lately challenged in favour of a neural network that mainly responds to salient stimuli, i.e. stimuli capable of engaging one's attention and motivational status, requiring the subject to make a prompt decision (Apkarian, Hashmi, & Baliki, 2011). So, if on one hand evidence exist in favour of neural structures selectively responding to nociception and pain (Vierck, Whitsel, Favorov, Brown, & Tommerdahl, 2013; Wager et al., 2013), on the other hand studies suggest that the activation of the putative "pain matrix" is prompted by all salient stimuli, regardless of the sensory channel involved (Mouraux, Diukova, Lee, Wise, & Iannetti, 2011; Mouraux & Iannetti, 2009). In such theoretical framework this salience-detection system would have a protective function detecting and reacting to possible threats, not merely painful, to ensure the physical integrity of the body (Legrain et al., 2012). Further reading on the theoretical frameworks about pain perception can be found in the historical overview of the main pain theories written by Moayedi and Davis (2013).

The great interest in pain research can be easily explained by the fact that pain significantly represents a social and economic burden, as well as by the negative impact that it has on the sufferer's life. Indeed, not only is pain an unpleasant sensory and emotional experience but, in some cases, it can deeply affect person's life leading to suicidal ideation and behaviour (Campbell et al., 2015). Many studies have therefore attempted to find ways to manage pain states via pharmacological or non-pharmacological interventions. Of particular interest are the non-pharmacological interventions as they bypass the significant adverse side effects reported by conventional drug use (Carter et al., 2014). Belonging to this category are a series of studies that focussed their attention on the analgesic effects of cross-modal perception, for example pain and vision. In particular, from a seminal work with phantom limb pain published twenty years ago (Ramachandran & Rogers-Ramachandran, 1996), a series of studies in the pain research have concentrated their attention on the role played by the vision of one's own body in the modulation of pain. Bodily illusions like the rubber hand illusion (Botvinick & Cohen, 1998) and its virtual counterpart (Sanchez-Vives, Spanlang, Frisoli, Bergamasco, & Slater, 2010) have provided new avenues for investigating pain perception during body ownership paradigms. Exploiting the principle that, provided synchronous multisensory cues, one can feel a new fake body part as part of his/her own body, the feeling of body ownership can be extended to body parts that differ from the original. However, while the vision of one's own real body part has been shown to be analgesic (Longo, Betti, Aglioti, & Haggard, 2009), there has been a recent debate on whether the analgesic effects of seeing one's own body part holds true also during the vision of fake (rubber/virtual) "owned" body parts (Gilpin, Bellan, Gallace, & Moseley, 2014; Martini, Perez-Marcos, & Sanchez-Vives, 2015).

The present work aims to review the research articles that so far have focussed on the effects on pain perception of the vision of one's own body, either real, rubber or virtual.

2. The vision of one's own body in pain

Cross-modal interactions between the vision of the body and somatosensation have been extensively investigated (Macaluso & Maravita, 2010; Medina & Coslett, 2010; Serino & Haggard, 2010; Wesslein, Spence, & Frings, 2014). A seminal study by Tipper for instance, showed how the vision of one's own body part influences tactile perception (Tipper et al., 1998). However, regarding pain perception, it was only 10 years after Tipper's work that the possible effects of the vision of the body were investigated in healthy subjects. In 2008, Valeriani and co-workers found that when their participants observed clips of another's hand receiving painful stimuli, while they concomitantly were getting painful laser stimulations on their hands, the early nociceptive-related neural processing was modulated, compared to the observation of the controlled stimuli (Valeriani et al., 2008). A step forward on this line was taken by Longo and collaborators in another laser-evoked potentials (LEPs) study (Longo, Betti, et al., 2009). In their work, these authors reported the first evidence that the vision of one's own body part in pain is analgesic. In three different experiments they showed how while their participants were looking at their own painfully stimulated hand (but still keeping vision non-informative of the painful stimulation that was occurring), they felt less pain compared to when they were looking at a box or even at somebody else's hand. The analgesic effect related to the vision of their own body part was also accompanied by a reduction of the late N2/P2 components of the LEPs (Longo, Betti, et al., 2009). The authors proposed that this effect was likely to be due to a visually-induced activation of the inhibitory GABAergic interneurons in the somatosensory areas. In support of this idea are the findings from a somatosensory evoked potentials investigation. Here Cardini and coworkers found that the vision of the hand, compared to the vision of a box, produced a suppression of the early somatosensory potential when two fingers were stimulated at the same time, thus revealing an augmented inhibitory interneuronal activity within the somatosensory cortex (Cardini, Longo, & Haggard, 2011). This result was later supported by another EEG study showing that the vision of the body, compared to the vision of a neutral object, increased noxious-related beta oscillatory activity bilaterally in the sensorimotor cortices, likely reflecting cortical inhibitory activity of nociceptive stimuli processing (Mancini, Longo, Canzoneri, Vallar, & Haggard, 2013). Furthermore, in a following neuroimaging study, it was found that the vision of the body part subjected to painful stimulations increased