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Corporeal illusions in chronic spinal cord injuries

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ABSTRACT

While several studies have investigated corporeal illusions in patients who have suffered from a stroke or undergone an amputation, only anecdotal or single case reports have explored this phenomenon after spinal cord injury. Here we examine various different types of bodily misperceptions in a comparatively large group of 49 people with spinal cord injury in the post-acute and chronic phases after the traumatic lesion onset. An extensive battery of questionnaires concerning a variety of body related feelings was administered and the results were correlated to the main clinical variables. Six different typologies of Corporeal Illusion emerged: Sensations of Body Loss; Body-Part Misperceptions; Somatoparaphrenia-like sensations; Disownership-like sensations; Illusory motion and Misoplegia. All of these (with the exception of Misoplegia) are modulated by clinical variables such as pain (visceral, neuropathic and musculoskeletal), completeness of the lesion, level of the lesion and the length of time since lesion onset. In contrast, no significant correlations between bodily illusions and personality variables were found. These results support data indicating that at least some cognitive functions (in particular the body, action and space representations) are embodied and that somatosensory input and motor output may be necessary to build and maintain a typical self-body representation.

1. Introduction

Implicit and explicit awareness of one's own body is fundamentally important, not only for the sense of self but also for people to be able to carry out actions in the external space around them and to interact with other people and objects. The representations underlying body awareness are the result of the continuous integration of information coming from somatic, interoceptive, vestibular, visual and acoustic sources. This integration process provides immediate feedback on the current state of the body. This information is also integrated with higher-order cognitive functions (e.g. spatial perception and memory) to obtain a detailed map of the body and its relationships with the environment. Thus, body representations are the complex result of multiple components (Berlucchi & Aglioti, 2010). However, while the specific role of each of these components in the body representation has been studied, the subject is still a matter of debate. A relevant contribution to the topic of bodily representations comes from the field of neuropsychology. Disorders in body representation after brain damage

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have been described since the beginning of the 20th century (Head & Holmes, 1911), with both "negative" symptoms (e.g. anosognosia for hemiplegia and limb disownership) and "productive" symptoms (e.g. supernumerary limbs and illusory movements) (Berlucchi & Aglioti, 2010; Gandola et al., 2012; Moro, Pernigo, Zapparoli, Cordioli, & Aglioti, 2011; Vocat, Staub, Stroppini, & Vuilleumier, 2010). Contemporary research on body representations has moved from the mere observation of the effects of brain activity on corporeal perception towards the investigation of how motor disabilities can change high level bodily representations (Glenberg, 2015). To date, body illusions in healthy participants have been extensively described and investigated, showing a wide manipulability of body representations and perceptions (Botvinick & Cohen, 1998; Maravita, Spence, & Driver, 2003; Pavani, Spence, & Driver, 2000; Pavani & Zampini, 2007; Tieri, Tidoni, Pavone, & Aglioti, 2015a, 2015b; Tsakiris & Haggard, 2005; Tsakiris, Longo, & Haggard, 2010). Previous studies suggest that the amputation of upper (Aglioti, Smania, Atzei, & Berlucchi, 1997; Cruz, Nunes, Reis, & Pereira, 2003; Elbert et al., 1994; Flor et al., 1995; Knecht et al., 1996) and lower (Aglioti, Bonazzi, & Cortese, 1994) limbs as well as of the breast (Aglioti, Cortese, Franchini, & Franchini, 1994) may induce a neuroplastic reorganization of the somatosensory and/or the motor cortex. Convergent evidence indicates that the brain networks involved in body-related high cognitive functions (e.g. body, space and action representations) are heavily influenced by sensory and motor-feedback coming from the body (Canzoneri, Marzolla, Amoresano, Verni, & Serino, 2013; Conson et al., 2008; Coslett, Medina, Kliot, & Burkey, 2010; Fiori et al., 2013; Fiorio, Tinazzi, & Aglioti, 2006).

A recent series of studies (Arrighi, Cartocci, & Burr, 2011; Fuentes, Pazzaglia, Longo, Scivoletto, & Haggard, 2013; Fusco, Tidoni, Barone, Pilati, & Aglioti, 2016; Lenggenhager, Pazzaglia, Scivoletto, Molinari, & Aglioti, 2012; Lenggenhager, Scivoletto, Molinari, & Pazzaglia, 2013; Pernigo et al., 2012; Scandola, Aglioti, Bonente, Avesani, & Moro, 2016; Scandola, Aglioti, Pozeg, Avesani, & Moro, 2016; Scandola et al., 2014; Tidoni, Grisoni, Liuzza, & Aglioti, 2014) suggested that an investigation of people with spinal cord injury (SCI) may provide important insights on all the above issues. Indeed, information regarding the topography of the damage (i.e. whether the lesion level is above the first thoracic spinal level – T1: tetraplegia or below T1: paraplegia), allows a direct comparison between the cognitive activity relating to the intact body part and the cognitive activity relating to the de-afferented/de-efferented body parts. For example, a topographic remapping across sensory modalities and body parts has been found in visual body discrimination (Pernigo et al., 2012) and in the visual perception of human locomotion (Arrighi et al., 2011). Topographically organized changes in motor imagery and space representation have also been described (Ionta et al., 2016; Manson et al., 2014; Scandola, Aglioti, Bonente et al., 2016; Scandola, Aglioti, Pozeg et al., 2016).

Distortion and reorganization processes relating to the perception of one's own body after SCI have been investigated using both experimental (Lenggenhager et al., 2012; Scandola et al., 2014) and clinical approaches (Conomy, 1973; Curt, Yengue, Hilti, & Brugger, 2011). In the latter, patients report phantom limb sensations and movements and more rarely position illusions and supernumerary phantom limbs (Curt et al., 2011). Misperceptions may be striking and profound and seem to be more frequent in the first days after the lesion onset (Conomy, 1973). However the real incidence and duration of these symptoms remain largely unexplored and have probably been underestimated (Curt et al., 2011).

In this study we investigated a relatively large sample of people with SCI to determine whether corporeal illusions and body misperceptions followed deafferentation and deefferentation. More specifically, the aim was to identify the various different types of corporeal symptoms and illusions and assess their frequency. In addition, we analyzed the effects of personality traits and clinical variables such as the level and completeness of the lesion, the time interval since lesion onset and the presence of neuropathic, visceral or muscular pain. The study capitalizes on the seminal descriptions provided by Conomy (1973) who investigated a sample of 18 cases of SCI in order to study body image disturbances involving the perception of the body in space (Proprioceptive body image), posture and movement (Kinetic body image) and body bulk, size and continuity (Somatic Body image). Using these clinical observations as a starting point, we devised an ad-hoc self-reporting questionnaire to be used in in-depth, individual interviews. Through a battery of questionnaires, emotions and affective feelings that the participants had towards their own body were also recorded.

2. Materials and methods

2.1. Participants

49 people suffering from chronic (>1 year) spinal cord injury (SCI) and a control group of 24 neurologically healthy participants (age, gender and education matched) participated in the study. The demographical and clinical data of the participants with SCI were previously described (Scandola, Aglioti, Pozeg et al., 2016) and are reported in Table 1. The Completeness and Neurological Level of Injury (NLI, ASIA Kirshblum et al., 2011) and daily life functional independency (SCIM-III, Invernizzi et al., 2010) were assessed. Based on these clinical variables, four groups were identified: paraplegics with (i) complete (n.12) or (ii) incomplete (n.12) lesions below T1 and tetraplegics with (iii) complete (n.12) or (iv) incomplete (n. 13) lesions above T1.

The sample size was computed by means of the pwr.f2.test function of the pwr package. By setting $\alpha = 0.05$, a power of 0.8, f2 = 0.35 and the degrees of freedom at numerator u = 1, the function estimated a sample size of 42 subjects.

The study was approved by the Local Ethics committee (CEP, Prot. N. 40378) and was conducted in accordance with the ethical standards of the 2013 Declaration of Helsinki.