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Review

Sensing the body in chronic pain: A review of psychophysical studies implicating altered body representation

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ABSTRACT

There is growing evidence that chronic pain conditions can have an associated central pathology, involving both cortical reorganisation and an incongruence between expected and actual sensory–motor feedback. While such findings are primarily driven by the recent proliferation of neuroimaging studies, the psychophysical tasks that complement those investigations have received little attention. In this review, we discuss the literature that involves the subjective appraisal of body representation in patients with chronic pain. We do so by examining three broad sensory systems that form the foundations of the sense of physical self in patients with common chronic pain disorders: (i) reweighting of proprioceptive information; (ii) altered sensitivity to exteroceptive stimuli; and, (iii) disturbed interoceptive awareness of the state of the body. Such findings present compelling evidence for a multisensory and multimodal approach to therapies for chronic pain disorders.

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1. Introduction

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In health, we possess a certain affinity with our limbs, whose posture we can easily discern, even without looking at them. Indeed we take the spatial perception of our body for granted, as it operates largely in the absence of any apparent awareness. However,

Abbreviations: CLBP, chronic low back pain; CRPS, complex regional pain syndrome; EMG, electromyography; HRV, heart rate variability.

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this may not be the case for the 1 in 5 adults living with chronic pain-related disorders (Breivik et al., 2006), many reporting that the mental representation of their affected body part is somehow distorted—either in size, posture or even absent entirely (Melzack, 1990; Lewis et al., 2010; Wand et al., 2011).

Chronic pain is defined as pain that has persisted for more than 3 months or beyond the expected time for healing (Merskey et al., 2011). This encompasses conditions such as complex regional pain syndrome (CRPS), phantom limb pain, chronic low back pain (CLBP) and fibromyalgia syndrome. It is unlike acute pain, which plays a protective role by eliciting motivation to minimise harm. Rather, chronic pain is considered a disease in itself (Niv and Devor, 2004). Due primarily to the recent proliferation of neuroimaging studies, there is growing evidence of a central pathology associated with chronic pain (Wiech et al., 2000; Lima and Fregni, 2008), as distinct from acute pain profiles (Apkarian et al., 2005). While such evidence has been reviewed previously, particularly the associated cortical changes (Flor et al., 2006; Lotze and Moseley, 2007; May, 2008; Apkarian et al., 2011; Wand et al., 2011), the psychophysical tasks that are used clinically and in research to assess these disturbances have received little attention.

In this review, we discuss the literature that involves the subjective appraisal of body representation in patients with chronic pain by exploring the possible mechanisms by which a distortion of body representation might occur. Psychophysical tasks are of particular importance because they possess considerable potential for translational outcomes in clinical practice. In addition, these tasks provide a non-invasive and clinically-viable method of assessing cortical reorganisation—without the complexities and expense associated with neuroimaging. We have adopted the classification system described by Sherrington (1906), where the sense of one's physical-self comprises three inter-related physiological systems. We begin by discussing sensory inputs generated by the body itself (proprioception), and from the surrounding environment (the exteroceptive senses). Finally we discuss awareness of sensations within the body (interoception) and changes in autonomic regulation in common chronic pain disorders. Distinctions between these sensations have been made for the purposes of the review. In reality, however, there is probably considerable overlap between the interoceptive, exteroceptive and proprioceptive systems in generating the central representation of the body.

2. Proprioception

Proprioception refers to sensations generated by the body's own actions (Proske and Gandevia, 2012). By convention, these include four senses: (i) the sense of movement and limb position (kinaesthesia); (ii) the sense of tension or force; (iii) the sense of effort; and (iv) the sense of balance.

It is now widely accepted that information from proprioceptors project to the cerebral cortex of the brain (Oscarsson and Rosen, 1963; Landgren and Silfvenius, 1969; McIntyre, 1974; McIntyre et al., 1984), contributing to and maintaining a mental map of the body (Head and Holmes, 1911). While there is evidence for multiple body maps (Schwoebel and Coslett, 2005; Kammers et al., 2006), their role and function has historically remained ambiguous (de Vignemont, 2010). In this review, we refer to them collectively as *body representations*. One such map is the body schema (Head and Holmes, 1911) – or postural schema (Longo and Haggard, 2010) – an internal representation of the body's posture, which appears to be constantly updated based on current experiences (Matthews, 1988; Berlucchi and Aglioti, 2010). Hence, the role of the body schema is to guide motor actions as distinct from the conscious perception, belief and attitude of the body by its owner—i.e. body image (Gallagher and Cole, 1995; de Vignemont, 2010). It is known that the experimental manipulation of afferent signals can lead to false impressions of limb position (Lackner, 1988) that temporarily disrupts the body schema (Melzack and Bromage, 1973; de Vignemont et al., 2005; Inui et al., 2011). The idea that changes in afferent signalling may cause distorted body representation in chronic pain has been raised before (Melzack, 1990). Indeed, there is evidence that large-diameter afferents are responsible for the pain commonly experienced after exercise, implicating access to the pain pathway by spindle afferents (Weerakkody et al., 2001, 2003b). However, recordings of afferents in healthy human subjects during stimulation of group III and IV afferents, via hypertonic saline, does not alter fusimotor excitability or muscle spindle discharge (Birznieks et al., 2008; Fazalbhoy et al., 2013). In light of such observations, the associated changes in chronic pain patients regarding proprioception more likely involves upstream disturbances, such as the neural processing of proprioceptive signals (Brumagne et al., 2004; Popa et al., 2007; McCabe and Blake, 2008). Conversely, higher-order alterations in body representation (Bultitude and Rafal, 2010) through cortical reorganisation have also been implicated (Moseley and Gandevia, 2005).

2.1. Kinaesthetic awareness

Historically, the sensations of limb position and movement were considered a single sense, termed kinaesthesis (Bastian, 1880). This is because both senses share inputs from the same mechanoreceptors within the muscle, i.e. the muscle spindles, which project to the cerebral cortex to provide information regarding the posture of the body and whether or not it is moving (Proske and Gandevia, 2009; Proske and Gandevia, 2012). However, it is now generally regarded that kinaesthesia consists of two distinct senses, comprising both position and movement sense (McCloskey, 1973). Of these two senses, position sense is the most widely tested sense in people with chronic pain, often involving the reproduction of a remembered posture or limb position (generally, in the absence of visual feedback). While there is evidence of reduced acuity during joint position sense tasks in those with chronic pain (Gill and Callaghan, 1998; Brumagne et al., 2000; Newcomer et al., 2000b; O'Sullivan et al., 2003; Pötzl et al., 2004; Cuomo et al., 2005; Knox et al., 2006; Paulus and Brumagne, 2008; Lewis et al., 2010; Ha et al., 2011; Sheeran et al., 2012), there are also a number of studies that have found no significant differences in limb repositioning acuity between patient and control groups (Lam et al., 1999; Newcomer et al., 2000a; Descarreaux et al., 2005; Asell et al., 2006; Lee et al., 2010; Mörl et al., 2011).

Such contrasting views may be explained by differences in posture during the experimental protocols, such as whether participants were standing, sitting or lying down during the task. This is based on the premise that the latter postures would minimise the proprioceptive information available to the participant (Gill and Callaghan, 1998; Gooey et al., 2000; Lee et al., 2010). However, the available literature suggests that kinaesthetic acuity is not influenced by the posture adopted at the time of testing in these groups (Gill and Callaghan, 1998; Lee et al., 2010). That is, repositioning errors were no greater when patients with CLBP were seated, lying on their side or supine (Lee et al., 2010); likewise, the reproduction of trunk position was not significantly different when standing compared to kneeling (Gill and Callaghan, 1998).

A possible explanation for the lack of an effect between postural conditions comes indirectly, through studies that elicit muscle lengthening illusions. One method of examining the effects of altering afferent signals is to apply a vibration stimulus to the muscle, which leads to a dramatic increase in spindle afferent firing rates (Goodwin et al., 1972; Lackner, 1988). For example, Brumagne et al. (2000) assessed lumbosacral position sense in seated CLBP patients by vibrating the lumbar multifidus muscle. Given that

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