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Brain activity for visual judgment of lifted weight

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ABSTRACT

It is well established that humans can recognize high-level aspects from point-light biological motion, such as gender and mood. If the task is to judge the manipulated weight we expected that sensorimotor regions should be recruited in the brain. Moreover, we have recently shown that chronic pain in a limb that is involved in the presented movement disturbs the weight judgment. We therefore hypothesized that some cortical regions usually activated during the processing of pain will also be activated while viewing point-light biological motion with the instruction to judge the manipulated weights. We investigated point-light biological motion of two types of movements performed with different weights in a blocked fMRI experiment in healthy subjects. In line with our a priori hypothesis, we found strong activity in the regions known as the neuromatrix of pain, such as the anterior cingulate (ACC), insula, as well as primary and secondary somatosensory regions. We also found activation in the occipital and temporal regions that are typical for biological motion, as well as regions in the cerebellum and prefrontal cortex. The activation of the somatosensory regions probably serves the judgment of the biological motion stimuli. Activation of the anterior cingulate and the insula might be explained by their role in the integration of behaviorally relevant information. Alternatively, these structures are known to be involved in the processing of nociceptive information and pain. So it seems possible that the interference between judgment of weights and perception of pain in chronic pain patients occurs in the somatosensory areas, anterior cingulate and/or insula. This finding provides important information as to the underlying mechanisms used for the weight judgment task, but also why chronic pain interferes with this task.

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1. Introduction

Point-light biological motion is a highly impoverished visual display of human movements (Johansson, 1973). Interestingly, this kind of stimuli are easily recognized in such detail that naive observers spontaneously report how many people are displayed and what each of them does. In an experimental setup subjects can judge the weight of an object that is manipulated by the actor in the point-light display (Runeson & Frykholm, 1981). Since this early study the weight-judging task has been used frequently, especially because it provides an interesting link between the visual and the sensorimotor systems (Alaerts, Swinnen, & Wenderoth, 2010; Auvray, Hoellinger, Hanneton, & Roby-Brami, 2011; Bingham, 1987; Bosbach, Cole, Prinz, & Knoblich, 2005; de Lussanet et al., 2012; Hamilton, Wolpert, & Frith, 2004; Marquez, Ceux, & Wenderoth, 2011; Poliakoff, Galpin, Dick, & Tipper, 2010; Shim, Carlton, & Kim, 2004). However, although a number of these studies applied transcranial magnetic stimulation (TMS) (Alaerts et al., 2010; Marquez et al., 2011; Senot et al., 2011), no study has yet addressed the brain activity that is evoked by the task of judging weight from visually perceived stimuli. The visual observation of actions activates regions in the premotor and inferior parietal cortex (Rizzolatti & Craighero, 2004). The measurement of brain activity from imaging studies to biological motion is well established in a large number of studies, which have typically found blood oxygen level dependent (BOLD) activity in occipital, temporal, and intraparietal regions (Grossman et al., 2000). BOLD activity in premotor and somatosensory regions has been found as well for point-light biological motion stimuli (Saygin, Wilson, Hagler, Bates, & Sereno, 2004).

Motion and its perception are strongly affected in individuals suffering from chronic pain (de Lussanet et al., 2012, 2013). Chronic pain patients strongly change the way they move and coordinate (Hodges & Tucker, 2011). Also, patients with chronic pain often suffer from kinesiophobia and depression (Vlaeyen, Kole-Snijders, Boeren, & van Eek, 1995). Despite these changes in chronic pain patients, it is known that changes in the brain are detectable. Structures typically involved are the anterior cingulate cortex (ACC), the insula, somatosensory regions (primary and secondary somatosensory cortex SI and SII), and the cerebellum (Apkarian, Bushnell, Treede, & Zubieta, 2005; Price, 2000). Thus, chronic pain is associated with problems of the sensorimotor system as well as with altered processes and structures in the brain.

It is well accepted that chronic pain may interfere with high-level cognitive processes (Kunz, Prkachin, & Lautenbacher, 2009; Rainville et al., 2011; Seminowicz & Davis, 2007). For example, pain-related words are processed differently in different populations of chronic pain patients (Eck, Richter, Straube, Miltner, & Weiss, 2011; Weiss, Miltner, & Dillmann, 2003). Also, patients with chronic back pain are specifically impaired when judging the manipulated weight from visually presented actions (de Lussanet et al., 2013). Due to this impairment chronic pain patients cannot judge the differences in the manipulated weight if the movement involves the body part that is affected in the patient (de Lussanet et al., 2012, 2013). In the latter study, two kinds of movements were presented with a range of different weights: manual transfer where a weight was transferred from the right to the left side using the upper extremities (Fig. 1B) and a trunk rotation where a weight is lifted and transferred from the right to the left side using the whole body (Fig. 1A). Subjects with shoulder pain were specifically impaired in weight assessment for manual transfer while subjects with low back pain were specifically impaired in weight assessment for trunk rotation.

How can this result be explained? We hypothesized that chronic pain interferes with the cortical regions that are usually recruited when viewing point-light biological motion with the instruction to judge the manipulated weights. We expected that the weight judgment task in healthy subjects should recruit the brain regions that are known to be affected in chronic pain patients. Thus, the goal of the present study was to measure the BOLD activity of healthy subjects in a functional MRI (fMRI) experiment during the presentation of point-light biological motion where different weights were lifted with the task to rate these weights.

We aimed to characterize the structures that are activated during the weight lifting tasks. We were also interested in the difference of activation between the two different kinds of movement, i.e., manual transfer versus trunk rotation. Finally, we wanted to compare those structures activated during the