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The neural correlates of movement intentions: A pilot study comparing hypnotic and simulated paralysis

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ABSTRACT

The distinct feeling of wanting to act and thereby causing our own actions is crucial to our self-perception as free human agents. Disturbances of the link between intention and action occur in several disorders. Little is known, however, about the neural correlates of wanting or intending to act. To investigate these for simple voluntary movements, we used a paradigm involving hypnotic paralysis and functional magnetic resonance imaging. Eight healthy women were instructed to sequentially perform left and right hand movements during a normal condition, as well as during simulated weakness, simulated paralysis and hypnotic paralysis of the right hand. Right frontopolar cortex was selectively hypoactivated for attempted right hand movement during simulated paralysis while it was active in all other conditions. Since simulated paralysis was the only condition lacking an intention to move, the activation in frontopolar cortex might be related to the intention or volition to move.

1. Introduction

1.1. Investigating the neural correlates of volition

We feel that we act based on what we want or intend, and this is an integral part of how we conceive ourselves as humans. Volition – or the will – has therefore been debated in a wide range of disciplines. In motivational psychology, volitional control processes are defined as mechanisms enabling us to pursue and attain goals, for example by overcoming

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automatic behaviours (Achtziger & Gollwitzer, 2006; Baumeister, Vohs, & Tice, 2007; Goschke, 2002; Kuhl, 1996). In cognitive neuropsychology, these processes are studied under the umbrella term 'executive functions' (Cummings & Miller, 2007). In philosophy, relevant discussions concern the free will (Walter, 2009), willpower (Holton, 2009), and mental causation (Heil & Mele, 1993; Mele, 2009; see also Tse, 2013).

What are the neural correlates of wanting to act, or, more specifically, of wanting to move? In previous studies, the neural basis of volition has been studied by paradigms in which participants freely choose *whether* to act (Brass & Haggard, 2007), *when* to act (Libet, Gleason, Wright, & Pearl, 1983), or *what* action to carry out (Haggard & Eimer, 1999; Haynes et al., 2007; van Eimeren et al., 2006). Another approach has been to compare externally guided to internally initiated actions (e.g., Cunnington, Windischberger, Deecke, & Moser, 2002; Gilbert, Gollwitzer, Cohen, Oettingen, & Burgess, 2009; Mueller, Brass, Waszak, & Prinz, 2007; van Eimeren et al., 2006).

Although these studies have yielded important insights about the localisation of these aspects of volition in the brain, some of which are described below, Brass, Lynn, Demanet, and Rigoni (2013) have pointed out that studies investigating the *subjective*, first-person experience of volition are scarce. That is, many studies measure objective pre-actional decision processes (i.e., whether or not to act, how, and when to act). However, it is often unclear how these processes relate to the subjective experience of wanting to act, this elemental feeling of "being our own master" that is so tightly linked to our self-perception as free persons (Searle, 2004). The conscious first-person experience is crucial for volition and therefore deserves explicit investigation. Furthermore, understanding the neural correlates of this experience better might also be relevant for understanding the mechanisms of conversion disorder (Bell, Oakley, Halligan, & Deeley, 2011; Cojan, Waber, Carruzzo, & Vuilleumier, 2009; Marshall, Halligan, Fink, Wade, & Frackowiak, 1997; Vuilleumier et al., 2001). In this psychiatric condition people experience an inability to move despite a lack of a localizable neurological cause and subjectively experienced intentions to move. In the current study, we aimed to study the neural basis of subjective intentions by using hypnosis.

In the next section, current knowledge about the neural correlates of wanting or intending to move will be reviewed and subsequently, our experimental approach to this question involving hypnotic paralysis will be described.

1.2. Findings regarding the neural correlates of subjective aspects of volition

Studying subjective aspects of volition and linking these to brain processes is a difficult endeavour. However, some studies have already yielded relevant results (for reviews see Brass et al., 2013; Haggard, 2005, 2008). Most famously, Libet et al. (1983) asked participants to indicate the time point of their decision to act, leading to the finding that voluntary movements are preceded by preparatory or anticipatory brain activity well before a participant consciously experiences the intention to act (see also Alexander et al., 2014; Deecke, Eisinger, & Kornhuber, 1980; Haggard & Eimer, 1999; Kristeva, Keller, Deecke, & Kornhuber, 1979; Schneider, Houdayer, Bai, & Hallett, 2013; Soon, Brass, Heinze, & Haynes, 2008).

Furthermore, the supplementary motor area (SMA) and the pre-SMA have been associated with urges, the involuntary or even compulsive experience of "being about to do something" (Jackson, Parkinson, Kim, Schüermann, & Eickhoff, 2011). When stimulating these regions electrically, patients may report that they are about to carry out highly specific movements such as lifting their right elbow (Fried et al., 1991). If stimulation is increased, patients may carry out the action. Supporting a role of the SMA in the experience of conscious urges, lesions in SMA may lead to the "alien hand syndrome" in which people move without consciously intending to (Goldberg, Mayer, & Toglia, 1981; Scepkowski & Cronin-Golomb, 2003). It has been proposed that the SMA induces movement by a release of inhibition of the primary motor cortex (M1; Ball et al., 1999). In support of this, Ball et al. showed that immediately before a movement there is a decrease of SMA-activation and a simultaneous increase of M1 activation. In line with these findings, Brass et al. (2013) link the SMA to *when*-decisions, that is decisions regarding the moment in which a movement will occur (see also Brass & Haggard, 2008). A final important piece of evidence with regard to the SMA comes from Lau, Rogers, Haggard, and Passingham (2004) who showed that paying attention to one's intentions as opposed to one's actions activates the pre-SMA.

Another key region for the subjective experience of volition is the inferior parietal lobule (IPL). The IPL has been linked to a highly general feeling of "wanting to move" (Desmurget & Sirigu, 2012). Desmurget et al. (2009) stimulated this region electrically in patients who were undergoing awake brain surgery. Upon stimulation of the right IPL, patients reported a desire to move contralateral body parts, but without indicating in what specific way they would like to move. Of note, stimulation of this region did not lead to actual movement, in contrast to stimulation of the SMA which does initiate movement (Fried et al., 1991). However, similarly to patients with SMA lesions, also patients with IPL lesions may experience "alien movements" which are not preceded by a conscious intention to move (e.g., Assal, Schwartz, & Vuilleumier, 2007), also speaking in favour of a role of the IPL in conscious intending. Moreover, in a Libet-type of experiment, patients with parietal lesions reported the onset of their intention to move to occur much later (only 55 ms before movement onset) compared to healthy controls and to patients with cerebellar lesion (both more than 200 ms before movement onset; Sirigu et al., 2004). These findings led Desmurget and Sirigu (2009, 2012) to hypothesise that early awareness of one's intentions is related to IPL activation while the feeling of an imminent movement (urge) of an already planned movement is related to SMA activation which occurs later in the processing pipeline.

Finally, the experience of "making up your mind" or choosing a course of action ("what decisions") have been associated with the rostral anterior cingulate cortex (rACC; Brass & Haggard, 2008; Brass et al., 2013; Mueller et al., 2007), while