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The mirror neuron system under hypnosis – Brain substrates of voluntary and involuntary motor activation in hypnotic paralysis

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ABSTRACT

Introduction: The neurobiological basis of non-organic movement impairments is still unknown. As conversion disorder and hypnotic states share many characteristics, we applied an experimental design established in conversion disorder to investigate hypnotic paralysis.

Methods: Movement imitation and observation were investigated by functional magnetic resonance imaging (fMRI) in 19 healthy subjects with and without hypnotically induced paralysis of their left hand. Paralysis-specific activation changes were explored in a multivariate model and functional interdependencies of brain regions by connectivity analysis.

Results: Hypnotic paralysis during movement imitation induced hypoactivation of the contralateral sensorimotor cortex (SMC) and ipsilateral cerebellum and increased activation of anterior cingulate cortex (ACC), frontal gyrus and insula. No paralysis-specific effects were revealed during movement observation.

Conclusions: Hyperactivation of ACC, middle frontal gyrus (MFG), and insula might reflect attention (MFG), conflict-detection (ACC) and self-representation processes (insula) during hypnotic paralysis. The lack of effects in movement observation suggests that early motor processes are not disturbed due to the transient nature of the hypnotic impairment.

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1. Introduction

Conversion paralysis cannot be explained by organic disorders and is not intentionally produced or feigned by the patient. As no ‘structural’ abnormalities of the motor system could be revealed, the concept of altered functioning of neuronal networks generating the symptoms arose. This is substantiated by a couple of functional imaging experiments under active or passive motor movement tasks, leading to the hypothesis of frontal regions inhibiting motor and premotor areas (Marshall et al., 1997; Tiihonen et al., 1995) or an alteration of subcortical brain regions essential for voluntary motor preparation and action (Vuilleumier et al., 2001). Alternatively, alterations of movement generation or conceptualization (Burgmer et al., 2006; Spence et al., 2000) or self-related representations and emotion regulation (Cojan et al., 2009a) as impaired cognitive or visual self-monitoring processes (de Lange et al., 2008; Roelofs et al., 2001) were suggested.

Hypnosis and conversion disorder share many clinical characteristics, including a lack of concern, perceived involuntariness, the display of “implicit knowledge”, and an apparently compliant nature (Oakley, 1999). At a clinical level, both hypnosis and conversion disorders are based on the induction of a dissociative state (Nemiah, 1991; Oakley, 1999). Two functional imaging investigations on hypnotic paralysis revealed increased activation of the orbitofrontal and cingulate cortex (Halligan et al., 2000) and of the orbitofrontal cortex, cerebellum, thalamus, and putamen under the attempt to move the hypnotically paralysed limb (Ward et al., 2003), both supporting the idea of a top–down inhibition of motor function in hypnotic paralysis. In contrast, Cojan et al. (2009b) could not confirm movement inhibition in hypnotic paralysis, but reported evidence for preserved motor intentions and enhanced self-monitoring processes.

Thus, hypnosis and conversion paralysis may share common mechanisms. Motivated by previous work by our group suggesting impaired movement representation and conceptualization during movement observation (Burgmer et al., 2006), we carried out this study to investigate cerebral networks for movement observation during hypnotically induced paralysis. The experimental approach of passive viewing seems specifically suited for the investigation of non-organic paralysis, as it does not rely on active movement execution. Nevertheless, movement observation activates the same neuronal pathways than movement initiation, imagery, and movement execution (Grezes and Decety, 2001; Rizzolatti and Craighero, 2004). On a neuronal level, these pathways might rely on mirror neurons firing during execution and observation of goal-directed actions (Gazzola and Keysers, 2009; Jarvelainen et al., 2004; Raos et al., 2004). We will therefore use the term mirror neuron system here to describe the concept of cerebral areas involved in both action observation as well as movement execution.

Based on Oakleys hypothesis (Oakley, 1999) of a unifying model of conversion disorder and hypnosis we expected network changes comparable to those we previously described (Burgmer et al., 2006). More specifically, we expected (a) activation of the mirror neuron system i.e., the motor cortex as a core region of the mirror neuron system (Hari et al., 1998; Jarvelainen et al., 2001) during movement observation, (b) general effects of hypnosis on cortical areas correlated with attentional and executive function, and (c) decreased motor cortex activation during movement observation when movies of the hand corresponding to the hypnotically induced paralysis are shown.

2. Methods

2.1. Participants

Nineteen healthy right-handed student volunteers (mean age = 22.6 years, range = 20–28 years; 16 females) were enrolled in the study. They did not fulfil any psychiatric disorder and showed a score greater than 7 (mean score = 9.5±1.2 out of maximal 12) in an individual screening procedure testing the hypnotic susceptibility with the *Stanford Hypnotic Susceptibility Scale* (Weitzenhoffer and Hilgard, 1959).

All subjects received a financial compensation of 9 €/h. Full written consent was obtained from all subjects in accordance with the declaration of Helsinki and in agreement of the local ethics committee.

2.2. Experimental protocol

Subjects were scanned once in normal state and under hypnosis in a counterbalanced order. In the hypnosis session, the suggestion of a left-hand paralysis was carried out before scanning. Scanning started after testing the hypnotic depth according to a levitation procedure. After scanning the paralysis was dissolved by reversing the suggestion.

In both sessions, identical stimulation was performed as previously described (Burgmer et al., 2006). In brief, videos of 12 sec duration of either a left or a right hand were presented in a block design. In the control condition, subjects observed a photo of a resting hand without performing any movement. Afterwards, they observed a moving hand opening and closing at 1 Hz. In the imitation condition subjects viewed the same video, and tried to imitate the movement. Blocks were presented in a fixed-order (control – observation – imitation) for each hand and were repeated six times in a pseudo-randomised order for each hand (see Fig. 1).

2.3. Behavioural performance monitoring

The degree of movement of the subject’s hands during each block was observed and rated by the experimenter according to the following scheme: 0 = no movement, 1 = barely visible slight twitch of the fingers or hand, 2 = indicated movement, 3 = slight but uncoordinated or cramped movement, 4 = fluent movement without any impairment. No movements were observed during control or observation blocks. During hypnotic imitation, fluent right-hand movements and visible impairments of left-hand movements were detected (0 = nine subjects, 1 = three subjects, 2 = five subjects, 3 = two subjects, 4 = no subject).