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Activation of thalamus in motor imagery results from gating by hypnosis ☆

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ABSTRACT

The ability to mentally imagine the performance of automatic movements has been well-established being employed in sports and physiotherapy as a tool for motor learning and rehabilitation. This is probably mediated by engagement of the same brain areas as during real motor performance. Here we investigated the effect of hypnotic trance on the cerebral activation pattern engaged in motor imagery in 16 healthy, right-handed subjects using fMRI. Motor imagery as compared with rest was related to activations in the left medial frontal areas (preSMA/SMA), prefrontal- and frontal areas, putamen and inferior parietal areas. When compared with performance of the same movements motor imagery resulted in activation of the left middle frontal cortex, precuneus, and posterior cingulate. Under hypnotic trance there was one extra-activation in the left thalamus which occurred specifically in the motor imagery condition. The regional beta indices were highly correlated among the areas of the cortical-subcortical motor network. Our data accord with the notion that hypnotic trance enhances the motor control circuit engaged in motor imagery by modulating the gating function of the thalamus.

Introduction

Mental imagery has been defined as "imagined rehearsal of a motor act with the intention to learn and improve but without any sensory input or any visible muscular movement" (Richardson, 1967). Based on behavioural studies the concept of functional equivalence of motor imagery with the real motor act was developed (Jeannerod, 1994, 1999). In fact, neuroimaging studies revealed that motor imagery involves virtually the same cortical areas which are active during movement execution (Binkofski et al., 1999; Iacoboni and Dapretto, 2006; Lehericy, 2004; Rizzolatti et al., 1998; Seitz et al., 1997; Solodkin et al., 2004; Stephan et al., 1995a).

Furthermore, studies in cognitive psychology, sports, psycho- and neurophysiology in healthy human subjects were able to show that mental imagery of motor performance improves motor functions profoundly and, thus, can be considered as an alternative strategy in motor learning (Decety et al., 1997; Hall, 2001; Maxwell et al., 2000; Page et al., 2001). Also, mental imagery of simple finger movements was shown to enhance the excitability of motor cortex during the process of motor skill acquisition (Pascual-Leone et al., 1995). Functional neuroimaging suggested that motor imagery engages those brain areas which are candidate structures of the so-called human "mirror-neuron-system" (Sharma et al., 2009). Interestingly, motor imagery appears to play an important role also in functional recovery of patients after stroke (Page et al., 2001; Sharma et al., 2006). In a previous behavioural study in subacute stroke patients mental training was shown to be at least as effective as repetitive training overcoming the training effect of conventional rehabilitation methods (Müller et al., 2007). Thus, mental imagery is a well-documented tool to improve motor performance in healthy subjects and neurological patients by virtue of enhanced activity of the cerebral motor system. On this background virtual reality scenarios have been shown to influence the cortical movement circuitry in relation to imagery of virtual arm movements (Decety et al., 1994; Dohle et al., 2011; Seitz et al., 2011).

Following this topic, a further approach to modulate brain activity is hypnosis. Thereby, imagination procedures are part of the basic principles of hypnotic trance induction. To circumscribe the term hypnosis concerning our study context, hypnosis can be defined as attentive receptive concentration (Raz et al., 2006). There is compelling evidence from reports in neuropsychological practice that in hypnotic trance behaviour can be dramatically influenced. Interestingly, this was reported to be the case even when the ability of the patients to imagine movements was severely impaired (Fritz, 2011). Moreover, patients with defined loss of motor abilities were described to achieve successful rehabilitation when subjected to imagery of repetitive finger movements (Müller et al., 2007). The impact of hypnosis on the brain is poorly understood. Nevertheless it has been proposed that under hypnosis the hypnotized subjects have an increased attention towards certain afferent signals which help them to perform specific

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motor tasks while the general level of attention is decreased (Halsband, 2006).

In this fMRI study we aimed at identifying areas which are specifically activated in relation to channelling of attention towards specific perceptual cues during movement execution in the hypnotic trance. We hypothesized that brain areas should become activated which are part of the so-called "human mirror-neuron-system". In addition, we hypothesized that the combination of motor imagery and hypnotic trance would show additional activations related to enhanced selective attention. We suggest that these activations support the notion that hypnosis can be instrumental to facilitate motor imagery thereby turning out as a promising tool for motor rehabilitation in neurologically impaired patients.

Materials and method

Subjects

16 healthy volunteers (14 female, 2 male) were included into the study. Subjects were aged from 21 to 49 years (mean = 30.3 years).

All subjects underwent a selection screening to determine the individual degree of suggestibility. Therefore, the subjects were each exposed to the German version of the "Harvard Group Scale of Hypnotic Susceptibility — Form A" (HGSHS A; Bongartz, 1985) presented by a professional hypnotherapist. The HGSHS A consists of 12 items with ideomotor suggestions lasting 45 min. Subsequently, subjects had to give a subjective estimation of their hypnotic reaction with respect to the 12 items and an all over rating of the depth they achieved during the trance. The accrued individual scores varied between 0 and 10 points and were used as decisive criteria for participation in the study. Only subjects with a score higher than 6 were included. Experiments were approved by the Ethics Committee of the Heinrich-Heine-University Düsseldorf and conducted according to the Declaration of Helsinki. All subjects gave informed consent to participate in this study.

Experimental procedure

Before the fMRI study all subjects ran through a training session in which they practiced performing and imagining the finger sequence. All tasks were performed with the right dominant hand and subjects were instructed to keep their eyes open. In a first step, the subjects performed the repetitive finger sequence while watching a video showing a right hand executing the finger sequence. After about 30 cycles and after accurate performance, subjects had to close their eyes going on with the movement for another 30 cycles. Subsequently, they were required to imagine executing the sequence with their eyes closed. They had to go on until they were asked by the experimenter which finger was on turn in their imagination. In comparison with the video sequence, the correct sequential imagery performance could be ensured.

On two different days the subjects were presented with two independent runs of a motor imagery paradigm in the fMRI-scanner. Again, all tasks were performed with the right dominant hand and eyes open. In the first control experiment they performed a motor imagery paradigm while they were exposed to a neutral travel report via headphones. The travel report lasted about 30 min altogether and was matched with respect to duration and word number of the instruction of the hypnotic trance (see below). Thus, analogous to the hypnosis run, after 9 min 30 of listening to the travel report the motor imagery paradigm was started together with the functional scanning. The travel report and the instruction of the hypnotic trance were pre-corded and re-played during scanning.

In the second fMRI-experiment the subjects got a hypnotic trance induction via headphones. Hypnotic trance was induced by requiring the subjects to imagine going slowly downstairs while the therapist counted down from ten to zero suggesting the relaxation is becoming progressively deeper with every step. This was followed by the suggestion provided to the subjects to focus attention onto the different parts of their body and to go deeper and deeper into the hypnotic trance with every suggestion. The focus was always sourcing to keep the concentration inside the body and to go deeper and deeper into the trance, without taking notice of disturbing noise or other external factors. After 9.5 min when the subjects reached the "end of the stairs" and we could suppose that they had achieved a satisfying hypnotic state the ultimate imagery paradigm was started together with the functional scanning while the hypnotic trance suggestions continued in the background. After the task was finished the subjects were woken up by a ringing alarm clock and with the request to go the steps up and to become more and more awake with every step.

After the hypnosis run, the subjects had to fill a questionnaire with subjective estimations of their individual trance deepness on scales ranging from 0 (the lowest) to 10 (the highest) to ensure the examiner that the hypnotic trance induction worked.

Subjects with trance scores lower than 6 were excluded from analysis (1 subject).

The hypnosis run lasted about 30 min altogether (in analogy to the control run).

During the fMRI-study, the subjects had to perform either repetitive finger movements with their right dominant hand (Fig. 1) or to imagine their right hand performing this task. Thus, there were three different conditions — (1) movement (B), (2) imagery of movement (V), and (3) rest (+). Each condition was presented 8 times in a pseudo randomized order in a block design with block duration of 40 s each. The letters and the cross of the 'rest' condition blinking at a frequency of 1 Hz indicated each condition to the subjects. This provided the subjects also with a pacing cue.

The two experimental conditions, control run and hypnosis run, were presented in a random order such that 8 subjects had the control experiment before the hypnosis experiment and 8 subjects the hypnosis experiment before the control experiment. After the experiments, the subjects had to fill a questionnaire to give an estimation of their individual trance deepness during the session. The questions included aspects which are typically used in judgements of hypnotic states as feelings of gravity, thermal sensations and the degree of relaxation. In adaptation to the HGSHS-Scores scales ranged from 0 to 10 with 0 representing the lowest and 10 representing the highest score.

MRI scanning

All subjects underwent MRI using a 3 T Siemens Trio MRI scanner (Erlangen, Germany) with a standard radio-frequency head coil for

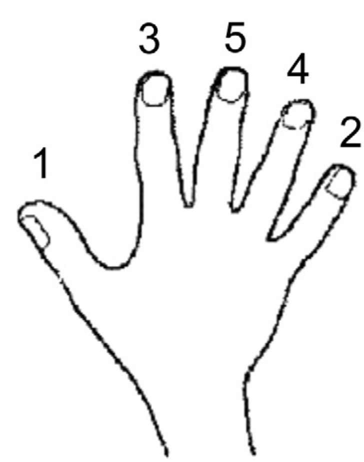

Fig. 1. Repetitive finger sequence during motor performance and motor imagery.