Determining specificity of motor imagery training for upper limb improvement in chronic stroke patients: a training protocol and pilot results

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Motor imagery (MI) refers to the mental rehearsal of a movement without actual motor output. MI training has positive effects on upper limb recovery after stroke. However, until now it is unclear whether this effect is specific to the trained task or a more general motor skill improvement. This study was set up to advance our insights into the efficacy of MI training and the specificity of its effects. We investigated whether MI training affected the trained hand exclusively, or both hands. Four stroke participants received a 15-min MI training four times a week for 3 weeks. Hand function was measured before and after the training using three measurements of increasing complexity. Hand function improved after MI training, thus confirming the earlier studies. Second, we found specific effects of the MI training for two of the three measurements. These results suggest that MI specificity is dependent on the complexity of the hand function task. ***International Journal of Rehabilitation Research*** **33:359–362 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Upper limb motor impairment is a common deficit after stroke. Approximately 40–45% of stroke survivors experience motor problems when using one of their hands after stroke, a condition that has major effects on daily life (Dijkerman *et al.*, 1996). In a recent study of Galvin *et al.* (2009), it was examined how people with stroke and their interventionists experience poststroke rehabilitation. Results showed that both the patients and the interventionists found that people with stroke could benefit from more physiotherapy than is routinely provided in the rehabilitation setting. As motor imagery (MI) training is relatively easy to conduct and low in time and costs, MI training may provide a promising new (additional) technique to upper limb rehabilitation.

The term motor imagery refers to a mental rehearsal of a movement without actual motor output and may be regarded as an off-line activation of the motor system in the brain (Johnson-Frey, 2004). This facet of MI suggests that it can be used to train motor performance after stroke (Mulder, 2007). Indeed, positive effects of MI training for upper limb improvement have been reported (Braun *et al.*, 2006; Sharma *et al.*, 2006; Dickstein and Deutsch, 2007; Steenbergen *et al.*, 2009). For example, positive effects of MI training after stroke were not only found after the training of relatively simple movements, such as finger sequences (Mueller *et al.*, 2007), wrist movements (Stevens and Phillips Stoykov, 2003), or grasping a cup (Crosbie *et al.*, 2004), but also were found after the training of complex tasks of daily life, such as putting clothes on a hanger or using the telephone (Liu *et al.*, 2004) and walking (Dunsky *et al.*, 2008).

At present it is not clear whether the effects of MI are specific to the trained task, or whether it is a more general motor skill improvement. Until now this topic has been investigated in participants without neurological damage using transcranial magnetic stimulation. Typically, participants are instructed to imagine a particular movement, after which transcranial magnetic stimulation is applied and movement facilitation is assessed by measuring the motor evoked potentials in peripheral muscles. Some studies reported an unspecific effect of MI, that is, imagining that moving one digit facilitated the excitability of other digits as well (Fadiga *et al.*, 1999; Stinear *et al.*, 2006). In contrast, other studies found a one-to-one relationship between the imagined and the performed movements (Rossini *et al.*, 1999; Li, 2007).

A next important step in the potential application of MI for rehabilitation is to scrutinize the specificity of its effects. Here, we present pilot results in which the specificity of MI training was assessed on a behavioral level in stroke patients. To that aim, we developed a MI training protocol and used this protocol in four stroke

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patients. Our specific research question was as follows: is MI training specific for the trained hand, or does performance also improve in the other hand?

Methods

Participants

Four right-handed participants (1 male, mean age 61 years, range 52–68 years) agreed to participate in the study. They were all diagnosed with a unilateral cerebral vascular accident 6–30 months earlier (for participant information see Table 1). Exclusion criteria were (i) aphasia, (ii) severe cognitive deficits, and (iii) visual field problems (i.e. neglect). To measure participants' capability to use MI, we administered the Kinesthetic and Visual Imagery Questionnaire (10 questions on a 5-point Likert scale; Malouin *et al.*, 2007). The aim of the Kinesthetic and Visual Imagery Questionnaire is to determine the extent to which individuals are able to visualize and feel imagined movements. First, participants have to perform an instructed movement (e.g. moving the thumb to the finger tips or lifting the heel of the foot while the toes stay on the ground). Subsequently, participants have to imagine themselves performing the same movement and afterwards indicate the clarity of the visual image (visual imagery) and the intensity of the sensation (kinesthetic imagery). On the visual imagery scale a score of 5 indicates that the image was 'as clear as seeing,' whereas 1 indicates 'no image.' On the kinesthetic imagery scale, a score of 5 indicates that the image was 'as intense as executing the action' and 1 indicates 'no image.' All participants reported that they were able to mentally represent movements (mean visual imagery score = 1.6, SD = 0.3; mean kinesthetic imagery score = 2.0, SD = 0.5). The study was approved by the local ethics committee and was carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Motor imagery training protocol

Participants received a 15-min MI training at home four times a week for 3 weeks. The duration of 15 min was used to make sure that the participants could remain concentrated during the whole intervention (Dickstein and Deutsch, 2007). Three aspects of upper limb performance were trained with an increasing complexity per week. These three aspects were week 1, reaching; week 2, grasping; and week 3, fine dexterity. Every week, different tasks were used to maintain participants' interest (Page *et al.*, 2001). The trained movements were related to activities of daily living to make it as easy as possible to imagine the movements (Dickstein and Deutsch, 2007); see Table 2 for the tasks used. Participants were instructed to use MI from a first-person perspective, as this is most beneficial for MI training (e.g. Simmons *et al.*, 2008).

Design

Hand function assessments were measured at a premeasurement and a postmeasurement. To measure whether MI training effects were general or specific to the trained hand, we measured the performance in both the affected hand and the unaffected hand. The following three assessments were made:

(1) 'Reaching' was measured by a custom made pointing task, where participants made reaching movements between dots on a touch screen. The time between releasing the first dot and pressing the second dot was measured.

Table 1 **Participant information**

Participant	Sex	Age (years)	Time since stroke (months)	Affected body side	Etiology	Barthel Index score	Degree of paralysis	Sensory impairment	Spasticity	Contractures
P1	Female	52	8	Left	Ischemic	70	4	Unaffected	No spasticity	None
P2	Female	68	13	Right	Ischemic	95	4	Serious	No spasticity	None
P3	Female	66	11	Left	Ischemic	85	4	Serious	No spasticity	None
P4	Male	61	24	Left	Hemorrhagic	95	2	Unaffected	No spasticity	Mild (thumb arthrosis)

The Barthel Index score is a score that measures the functioning of daily life activities, with a minimum score of 0 and a maximum score of 100. Degree of paralysis was measured using the Medical Research Council Scale for Muscle Strength, assessed on the forearm flexor and extensor muscles, with a minimum score of 0 and a maximum score of 5. Sensory impairment was categorized as unaffected, mild or serious (practically absent sensibility of all qualities, e.g. pain, fine tactile sense, temperature).

Table 2 **Overview of the motor imagery training per week**

	Week 1- 'reaching'	Week 2- 'grasping and manipulating'	Week 3- 'fine dexterity'
Day 1 (Monday)	Pointing at something in the newspaper	Picking up the telephone receiver	Turning a page in a book
Day 2 (Tuesday)	Pressing the button to switch on the television	Turning the door handle	Putting money in a money box
Day 3 (Wednesday)	Pressing the door bell	Turning the water tap	Grasping a pencil to write
Day 4 (Thursday)	Pointing at an object on the table	Grasping a cup to drink	Placing a matchstick in a match box
Day 5 (Friday)	Hand function tests	Hand function tests	Hand function tests

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(2) ‘Grasping’ was measured by the Box and Blocks test (i.e. number of blocks transported from one box to another in 30 s; Mathiowetz *et al.*, 1985).
(3) ‘Fine dexterity’ was measured by the Perdue Pegboard test (i.e. number of pegs placed in tight fitting holes in 30 s; Tiffin, 1985).

Changes in hand function were measured using the percentage improvement. This percentage was calculated by the formula: (Score Post − Score Pre)/Score Pre. Using one-sample *t*-tests we calculated whether the improvement differed from zero (one-tailed).

Results

The results of the MI training are presented in Table 3 (individual data) and Fig. 1 (average percentage of improvement).

We found significant improvements in the affected (trained) hand for reaching [$t(3) = -2.164$, $P < 0.07$] and for grasping [$t(3) = 2.98$, $P < 0.05$]. Of note, performance of the unaffected (untrained) hand did not improve significantly. However, for fine dexterity, performance of the unaffected hand improved significantly [$t(3) = 15.23$, $P < 0.01$], but not in the affected hand.

Discussion

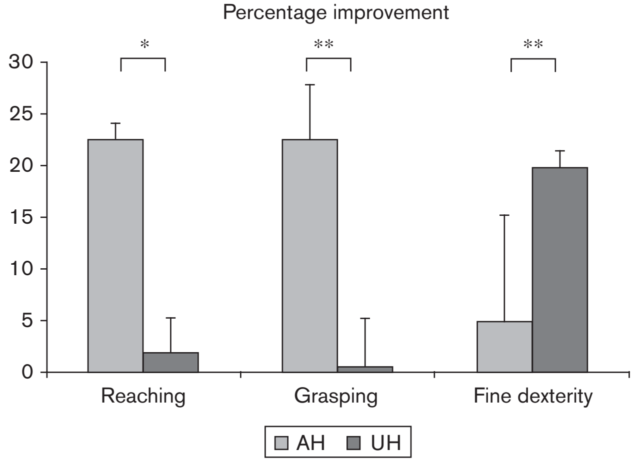
In this study, we investigated the specificity of MI training for upper limb improvement in stroke patients. We found specific effects of the MI training (i.e. hand function improvement in the trained hand only) for reaching and grasping, but not for fine dexterity. This suggests that MI specificity is dependent on the complexity of the hand function task measured. For the affected hand, we found an improvement in the relatively easy tasks, but not in the more complex motor task. We think this finding may be due to training duration. It may be suggested that easy hand function skills are more suitable to learn with MI training during a short intervention period. Thus, MI training is specific for the affected hand only when simple tasks are trained. These findings have implications for the use of MI training for rehabilitation. If MI training in rehabilitation is aimed at improving upper limb functioning of the affected hand, positive effects on a relatively simple hand function task can be expected after a short intervention period (i.e. 3 weeks in our study). However, for more complex hand function tasks a longer training period may be necessary.

Table 3 Percentage improvement in each participant on reaching, grasping, and fine dexterity

	Reaching	Grasping	Fine dexterity
Participant 1			
AH	17	30	28
UH	0	0	23
Participant 2			
AH	18	0	−20
UH	0	0	20
Participant 3			
AH	50	32	0
UH	1	1	20
Participant 4			
AH	1	28	11
UH	0	0	16

Positive scores represent improvements compared with the premeasurement. Negative scores represent deteriorations.
AH, affected hand; UH, unaffected hand.

Fig. 1



The average percentage improvement for the different upper limb measurements reaching, grasping, and fine dexterity. Error bas represent 1 SE. *$P<0.07$; **$P<0.05$. AH, affected hand; UH, unaffected hand.

The individual results showed that effects of MI training were different among participants. In particular, participant 2 did not seem to benefit much from the training. Participant 2 was affected on the right body side (i.e. left hemisphere damage), whereas the other participants were affected on the left body side (i.e. right hemisphere damage). An explanation for this finding may be that motor problems after left hemisphere damage are more severe, corroborating findings of left hemisphere dominance for action planning (Haaland and Harrington, 1998; Haaland *et al.*, 2000).

Unexpectedly, we found a significant improvement in fine dexterity for the untrained hand. There may be two likely explanations for this finding. First, improvements in the untrained hand are expected when MI training is unspecific, a general motor skill improvement after training. Second, the finding may be due to a general learning effect, due to task repetition. Further research is required to investigate this topic.

Collectively, the present findings and earlier studies in stroke (Braun *et al.*, 2006; Dickstein and Deutsch, 2007) clearly exemplify the added value of MI training for the improvement of the upper limb functioning. Therefore,

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further research on the specificity of the training effects and the types of tasks to be used is warranted. The protocol that is described here can be used for this purpose.

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