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A Systematic Review on the Effectiveness of Mental Practice with Motor Imagery in the Neurologic Rehabilitation of Stroke Patients

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ABSTRACT
Background: Mental practice with motor imagery entails an individual to symbolically rehearse a physical activity within working memory in the absence of overt body movement. It has been proven to be useful in sports training and other skills training. However, much is yet to be determined if the same promising results may be gained when this training method is used with persons with brain lesions, like stroke patients. Objectives: The aim of the study is to investigate evidence for the effectiveness of mental practice with motor imagery in the neurological rehabilitation of stroke patients in improving their impairments and functional limitations, and to identify variations in mental practice protocols (duration, type of imagery employed, etc) and characteristics of participants, (age of subjects, duration of stroke prior to intervention) that may have affected the results gathered. Methods: Literature search was accomplished with electronic databases such as Science Direct, Pub Med, Proquest, MEDLINE, CINAHL, Cochrane Library for Systematic Reviews and OVID. Criteria used in selecting articles included (1) Clinical controlled trials or RCTs, (2) adult stroke patients, except with cerebellar or basal ganglia pathology, (3) intervention given was mental practice with motor imagery without external aids. Two peer reviewers individually rated the quality of each study using checklists used by JBI. Results:. A total of 7 articles were included for this systematic review after quality appraisal. This included 5 randomized controlled trials and 2 CCTs. All studies reported improvement of UE function after the intervention. Conclusion Although researches done with this intervention have yielded equivocal results, a relatively small body of evidence for mental practice with motor imagery in rehabilitation of UE of stroke patients still exists. Future studies employing quality research endeavors with research designs at the upper levels of the hierarchy of evidence are recommended to strengthen the present evidence.

INTRODUCTION
One of the major goals in rehabilitation for survivors of central nervous system (CNS) trauma is the return to independence in activities of daily living. The success of achieving plastic changes in the CNS after skill training appears to be dependent on the amount of practice from that particular skill. It has been proposed that positive changes in the cortical representations at the primary sensory-motor areas are “activity-dependent,” stressing therefore the importance of practice in acquisition of skill. Practice may be accomplished with overt movement, i.e. actual performance of the task, or with covert movement, i.e. mental imagery, which is used with mental practice.

Jackson et al. distinguishes the terms mental imagery and mental practice. Mental imagery is the umbrella term for the active process of reliving sensations with or without external stimuli.[1] This is facilitated by the use of images brought about by combinations of the different modalities, i.e. visual, auditory, tactile, kinesthetic, olfactory, gustatory. When movement of an action of a person or object is imaged, this is referred to as movement imagery. Specifically when it is the human body that is imaged by the internal reactivation of the action within working memory without overt motor output, it is called motor imagery. Mental practice, on the other hand, is defined as a symbolic rehearsal of a physical activity in the absence of any gross muscular movement, serving as a training method in utilizing motor representations with the use of motor imagery to improve motor performance.

Images generated could vary from a person seeing themselves or another do the action using a third person perspective, as if watching a movie, called visual imagery. Or, it could be facilitated through a first person perspective where the individual internalizes the sensations that accompany the imagined movement. This is referred to as kinesthetic imagery.

The success of mental imagery has been well documented in the fields of sports psychology in enhancing athletic performance. This has encouraged the application of mental imagery for other skill development for normal individual's i.e. surgical skills, playing instruments, or balance training for elderly women. The use of such techniques has only recently been explored in rehabilitation settings. Carr and Shepherd have emphasized the importance of engaging in motor or physical practice of tasks for as much time as possible during rehabilitation programs.[2] However, practice sessions are usually confined to the few hours of therapy in the clinic per day, and the possibility of ensuing fatigue and staff availability further limits practice sessions. Thus, mental practice with motor imagery may serve as an avenue for patients to continue their skills training even when they are already physically exhausted, or when supervised therapy sessions have finished.

With the growing number of studies on this intervention for the stroke population, there is the need to consolidate this evidence to determine the potential use of mental practice with motor imagery in neurological rehabilitation particularly for stroke patients.

Objectives

- The general objective of this study is to investigate evidence for the effectiveness of mental practice with motor imagery in the neurological rehabilitation of stroke patients to improve their function.
- This study also aims to identify variations in mental practice protocols (duration, type of imagery employed, etc) and characteristics of participants, (age of subjects, duration of stroke prior to intervention) that may have affected the results gathered

CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

Types of Studies

To determine the evidence of the effectiveness of mental practice with motor imagery in neurological rehabilitation of stroke patients, randomized controlled clinical trials (RCTs) were the study design of choice. Clinical controlled trials (CCTs) and quasi experimental trials were also considered in the absence of RCTs. Non-analytical studies, such as case studies and case series, were used for additional information on the use of interventions for stroke patients.

Types of Participants

This review included any study involving any adult person with stroke, except those with pathology of the cerebellum or the basal ganglia.

Types of Interventions

Mental practice utilizing "mental practice with motor imagery", without external aids, i.e. mirrors and computer generated images.

Outcome Measures

Fugl-Meyer for Upper Extremity
Action Research Arm Test

SEARCH STRATEGY FOR IDENTIFICATION OF STUDIES

Language

Published and unpublished English language studies were sought.

Bibliographic Databases and Keywords
The following keywords were used to search for studies to be included in this review (concept 1 AND concept 2 AND concept 3):

Concept 1	Concept 2	Concept 3
Mental practice OR	Neurological rehabilitation OR	Stroke OR
Motor imagery OR	Therapy OR	Cerebrovascular accident
Kinaesthetic imagery AND	Rehabilitation AND	

Studies identified during the database searches from 1990 to October 2007 were assessed for relevance from a review of the title, abstract and descriptors of the study. A full text report was obtained for all studies deemed to be relevant. The databases that were searched included:

- CINAHL
- Cochrane library
- EMBASE
- MEDLINE
- Proquest
- Science Direct
- Ovid

Hand Searching
The reference lists of all publications of included and excluded trials were searched for additional trials. Hand searching of relevant conference proceedings was also conducted.

Content Experts
Content experts in Australia and the Philippines were contacted in order to obtain additional references, unpublished trials and ongoing trials.

METHODS OF REVIEW
Validity assessment
Level of evidence

The evidence of the retrieved studies were assessed using the Joanna Briggs Institute's (JBI) levels of evidence (Table 1).

Table 1. Levels of Evidence: Effectiveness

Levels of evidence	Effectiveness E (1-4)
I	Systematic review (with homogeneity) of experimental studies (eg RCT with concealed allocation)
II	Quasi experimental studies (eg without randomisation)
III	3a Cohort studies (with control group) 3b Case controlled 3c Observational studies without control groups
IV	Expert opinion without explicit critical appraisal, or based on physiology, bench research or consensus

Assessment of Methodological Quality
Two reviewers critically appraised the studies independently. A third reviewer was not consulted since no disagreement between reviewers occurred. The 'Joanna Briggs Institute (JBI) Critical Appraisal of Evidence Effectiveness' tool was used to critically appraise each study. This JBI tool consisted of eleven items, each requiring a dichotomous yes/no response, with a yes response being allocated one point, and a no/unclear response being allocated zero points. Only studies scoring six or above on the JBI critical appraisal tool were categorized as good quality, and thus included in the study.

Data Extraction

Data were extracted independently by two reviewers using the "JBI data extraction tool." A third reviewer was asked to review the data. Data collected included: type of design, details of randomisation (if used), study population, intervention, control, outcomes, and quality and result of study analysis. Authors were contacted for missing or incomplete data, i.e. weighted mean difference and standard deviations.

Data Synthesis

Data were summarised in narrative form only since no statistical pooling of results was possible.

RESULTS

Sixty relevant articles were identified based on abstract, title and keywords. Out of this number, only 7 met the inclusion and exclusion criteria. This was composed of 5 RCTs and 2 CCTs. However, only 3 of these were included in the final selection of studies based on quality appraisal scores.

Table 2. Appraisal scores based on the JBI Protocol appraisal tool

Criteria	Page et al (2001) [3]	Page et al (2005) [4]	Page et al (2007) [5]
Was the assignment to treatment groups random?	Yes	Yes	Yes
Were participants blind to treatment allocation?	Yes	Yes	**Unclear**
Was allocation to treatment groups concealed from the allocator?	**No**	**No**	**No**
Were the outcomes of people who withdrew described and included in the analysis?	Yes	Yes	Yes
Were those assessing the outcomes blind to treatment allocation?	**No**	**No**	Yes
Were the treatment and control group comparable at entry?	**No**	**Unclear**	Yes
Were groups treated identically other than for the named intervention?	Yes	Yes	Yes
Were outcomes measured in the same way for all groups?	Yes	Yes	Yes
Were outcomes measured in a reliable way?	Yes	**No**	Yes
Was there adequate follow-up (>80%)?	Yes	Yes	Yes
Was appropriate statistical analysis used?	**No**	**No**	Yes
Appraisal score	7	6	9

As seen in Table 2, the 3 studies are both of good quality scoring 6, 7, and 9 on the JBI protocol. A common item that these studies failed to meet was the concealment of allocation from the allocator. The works of Page et al in 2001and 2005 also lacked blinding of the assessors, as well the assurance of the homogeneity of the study population.[3,4] Despite the positive results in favour of the intervention, the reviewers noted that these 2 studies did not use appropriate statistical analysis, which may affect support for the stated conclusions.[3,4] On the other hand, the most recent work of Page et al was not able to completely report the blinding of the treatment allocation of the participants.[5] The data synthesis of the three studies that satisfied the inclusion criteria for this review are provided in Appendix 1.

Motor imagery (MI) finds its relevance in improving motor performance as it is believed that MI shares common neural substrates with the execution of movement. This has been well substantiated by brain mapping techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG), and magnetoencephalography (MEG), all of which allow precise anatomic localization of brain activity. Overlapping cortical excitability between physical practice and MI have been implicated to occur in the supplementary motor area (SMA), cerebellum, prefrontal and sensorimotor areas, cingulate, superior and inferior parietal area lobes, caudate nucleus and thalamus. Though the sub-processes involved in the skill phase of training are unique, execution (physical practice) relies heavily on the precentral/postcentral gyri, superior temporal lobe extending to the rolandic operculum, while motor imagery activates frontal premotor areas, inferior parietal lobe, and medial temporal lobe extending to the supramarginal and angular gyri.[6] However, common to all these brain-imaging studies is the involvement of cortical regions underlying motor planning and motor preparation functions during MI and physical training.

Whether the primary motor area (M1) is activated during motor imagery is still debatable. Dechent et al. re-examined the involvement of the M1 during imagination of finger to thumb opposition using blood oxygenation level-dependent (BOLD) MRI.[7] Six healthy participants physically performed the task of finger to thumb opposition (EM), and were instructed to imagine themselves performing the same task (IM). EM activated multiple cortical areas including contralateral M1, SMA and bilateral premotor areas intraparietal cortex, whereas, in IM, lesser activation was detected in SMA and premotor and intraparietal areas. In contrast to EM, no activation was found in M1 during IM. However, the study recognizes that participants have engaged in external imagery or visual motor imagery. Lacourse and colleagues seem to have observed otherwise with M1 during novel and skills training using motor imagery.[6]

Lacourse et al. studied the areas of stimulation during execution and motor imagery of novel and skilled sequential hand movement.[6] The authors have observed congruence of brain activities between execution and imagery during the different phases of learning. As the participants became more skilled, more functional anatomy congruence was seen. Moreover, the same decrease in cerebellar activation and increased striatal activation in execution at the skilled learning phase was seen during MI as well.

It has been believed MI can produce similar but not identical results as physical practice. Gentili, Papaxanthis and Porro compared the improvement in arm motor performance using mental practice with motor imagery.[8] Subjects in the physical practice (P) and mental practice (M) groups improved significantly in the pointing task by decreasing their duration time as compared to the passive (PC) and active control (AC) group that engaged in eye-movement training of the pattern. As expected the P group took less time to accomplish the pointing task for the trained path (i.e. right path) than the M group, but both groups were not significantly different in their performance for the untrained left path. This implied that gains from mental practice with motor imagery can be generalized to similar motor tasks, as could physical training.

However, the above mentioned studies had participants with intact nervous system function. This review aims to find the evidence of mental practice with motor imagery in improving function of stroke patients. Mental practice requires the conscious and active participation of patients without overt movement. Cerebrovascular accident (CVA) patients seem to be eligible to use this intervention since motor representations remain intact in hemiplegics regardless of the duration of their condition. Johnson pioneered research which tested motor imagery ability of acute and chronic stroke patients.[9,10] In 2000, acute stroke patients were investigated who lacked the ability of executing reaching or grasping movements with their impaired limb. A photo-realistic image of a dowel with a pink half and a tan half was presented in 8 different orientations on a computer monitor. Subjects determined whether an overhand or underhand grip would be used. No overt movements were allowed and the subjects reported their decision by indicating where the thumb side of the hand fell – on the pink or on the tan. Results showed that both right and left hemiplegics had a good correlation of grip preferences between their healthy and paralyzed limbs. In 2002, the same investigator teamed up with Sphren and Saykin to carry out the same power grip selection task with the addition of 2 experimental tasks (identification of rotated hands and a precision grip task) on chronic hemiplegics.[10] Results showed that accuracy of motor imagery did not differ significantly between affected and unaffected limbs. The authors concluded that duration of limb immobility does not compromise the ability to represent movements internally. This then may justify the application of the intervention in acute and chronic stroke patients in the 3 studies included.

However, mental practice being a cognitive task is logically dependent on the person's abilities of perception and understanding. John Annett created a model which coordinates verbal instruction and imitation, to motor skill acquisition.[11] In his model, the perceptual-motor and verbal systems are linked, and is referred to as the action-language bridge, such that "in receiving & following instructions, a route is established between the auditory-verbal representational system across the action-language bridge to the motor representational system and then to the motor executive system".[11] The implication of this model to imagery intervention is the importance of the ability to receive and understand instructions in order to retrieve the necessary motor representations. For the included studies, Page et al screened for the presence of cognitive deficits using the Modified Mini-Mental Status Examination before enrolment to the study.[3-5]

Still, it is essential that imagery ability be taken as a separate cognitive function. Behavioural research has pointed out the importance of the ability to control the action of the image, as well as the clarity and vividness, when using imagery to affect the motor system.[12] Imagery ability may have been proven to remain intact after stroke however, the area of lesion can compromise this cognitive ability.

As stated earlier, mental practice facilitates similar brain areas closely related with overt movement, particularly those areas involved with motor planning. Thus, it is expected that lesions on areas underlying this function may impair the person's ability to engage in motor imagery as well. For example, patients with lesions involving the dorsolateral frontal and/or parietal lobes showed more imagery impairments than those affected in other brain areas.[13] This is in agreement with the findings of Butler and Page.[14] No significant improvements were seen with their patient who suffered stroke affecting the left parietal area even after receiving constraint-induced movement therapy (CIMT) + mental practice training after 2 weeks. The authors believed that the underlying mechanism to generate movement representations is inherent to the parietal cortex. Frey cited that the ability to internally simulate reaching with the upper limb is still possible as long as the “reach circuit” in the frontal and parietal lobes are spared.[15] Since motor imagery utilizes visuo-spatial information, lesions in the occipito-parietal areas resulting in neglect may implicate a negative impact on the efficacy of mental practice secondary to this impairment.

Unilateral cortical brain lesions seem to affect the internal representation of both the contralateral and ipsilateral limbs. Kimberley et al. cited the finding of Sabate et al that left brain lesions showed a decreased velocity for imagined movement in both hands, whereas right brain lesions showed a disturbance of imagination of the contralateral hand only.[13] Malouin et al. however found impairments of both execution and imagery of affected and unaffected limbs regardless of the side of the lesion.[16] Twenty five stroke patients were tested on an arm pointing task and a leg stepping task using both limbs in a physical condition and imagined condition. Results showed that there is a bilateral slowing of imagery on both the affected and unaffected limbs. This study also suggested that cerebral dominance was not an advantage during imagination of movement, since there was no significant difference in imagination/execution ratios when cerebral dominance was considered to account for the slowing of the unaffected side.

On the other hand, some brain lesions from the beginning disturb the mechanism of motor imagery and its functions of motor preparation and planning. Gonzalez et al. had 11 cerebellar stroke patients and 10 age-matched controls perform a sequence of finger movements in actual movement and in simulated version using kinesthetic imagery. [17] Control subjects showed high correlated times between real and simulated conditions. Cerebellar patients showed bilateral slowing of finger movements in both test conditions. The authors attribute this delay to the role of the cerebellum in movement initiation. Lesions of this brain structure prolonged actual execution of the task, and the delay during kinesthetic imagery was believed to be the effect of the disruption of cerebellar function to predict consequences of behaviour (nonexecutive motor function, noEMF) even during simulated conditions.

The consequences of damage to the cerebellothalamo-cortical loop on motor imagery were also observed by Battaglia et al.[18] Seven patients with unilateral cerebellar stroke secondary to posterior inferior cerebellar artery block performed sequential thumb oppositions from the 2nd to the 5th fingers of both hands in physical and kinesthetic motor imagery conditions. Compared to normal controls, these patients showed an increased mean cortical silent period and less pre-movement facilitation implying a decrease in the excitability of the motor cortex contralateral to the side of the lesion. Interestingly, this translated also into a disruption of preparation and imagination of the sequential movement. In support of the previous study by Gonzalez et al, this study suggested that unilateral cerebellar lesions involving the dentate nucleus disturb kinesthetic imagery ability.[17]

A similar disruption of motor imagery was observed with Parkinson’s disease (PD) patients. Dominey et al. studied PD patients perform sequential finger movement in motor execution and motor imagery conditions.[19] These patients showed more slowing of the affected hand in both conditions. The authors attribute such observation to the dependence of both the motor system and motor imagery to the integrity of the fronto-striatal pathway in the control of the “internal state.” It seems that lesions at the basal ganglia disturb motor planning and initiation, as well as ongoing control of the internal state. Such impairments are evident in both actual performance and imagination of movement.

It can be inferred, therefore, that not all stroke patients may be successful with imagery training. As for the 3 studies gathered, Page et al included the presence of bilateral cortical lesions in their exclusion criteria; they also administered the Movement Imagery Questionnaire as part of their selection process.[20] On the contrary, the other 2 studies failed to report any attempt to consider the site of lesions, presence of other neurologic conditions, i.e. cerebellar affectation, PD and assessment of imagery ability prior to commencement of imagery training. The 2 latter works may be fortunate to get the positive gains out of the intervention, and it may be assumed that their stroke patients had intact motor imagery ability. However, a meticulous assessment of stroke patients may avoid frustration of both patient and therapist should the imagery intervention prove a futile task.

Another factor that is postulated to affect imagery ability is the patient’s age. Eighty nine individuals recruited by Jarus and Ratzons were divided in 3 age groups: children (9 to 9.11 years old), adults (21 to 40 years old) and older adults (65 to 70 years old).[21] Participants were trained in a 2-arm coordination task and each group was subdivided into a physical practice group and a mental-physical practice group. Results showed that during the acquisition stage, older adults’ physical and mental-physical practice groups were slower than adults. In children and older adults, mental-physical groups made fewer errors than their physical group counterparts. Similar results were observed with the older adults during the retention phase. Adults and children's mental-physical and physical groups did not perform differently from each other at the retention stage. The clinical implication of these findings is that response to imagery training may vary from one person to another as an effect of age in normal individuals. However, for patients with neurologic deficits, imagery ability becomes a complicated task, rather than a mere function of aging. The area of the lesion seems to have greater influence on this cognitive ability than the patient's chronological age. Unfortunately, such hypothesis cannot be proven with the 3 studies gathered since no age stratification was done with the patients.

The diversity of training protocol in all available studies makes it difficult to group these all under one umbrella of "mental practice." Some have a rigid structure laid down, i.e. training with a familiarization phase to the use of motor imagery, others provided feedback, while others fail to indicate definite instructions given to the patients. One particular training instruction that varied among the studies was the use of internal/kinesthetic imagery or external/visual imagery, or a combination of the two. Supplementary to the investigation of the effectiveness of mental practice is the search for the difference and advantage of one form of imagery over others. Solodkin et al. observed the closely related network brain activation between executed movement and kinesthetic imagery of thumb opposition on M1, S1, superior parietal lobule, dorsal lateral premotor cortex (LPMC), SMA and cerebellum.[22] However, during visual imagery of the task, the relevant activity was primarily seen in the occipital followed by the LPMC, parietal lobule, SMA and cerebellum. M1 and S1 activity were absent.

A study by Stinear et al. worked on the same hypothesis that kinesthetic, and not visual imagery, modulates corticomotor excitability.[23] Ten subjects were tested while they imagined tapping their thumbs in 2 testing conditions – visual motor imagery (VMI) and kinesthetic motor imagery (KMI). Significant MEP amplitude of the abductor pollicis brevis was recorded during KMI but not during VMI. The investigators concluded that only KMI can produce muscle-specific and temporally modulated facilitation of corticospinal excitability above resting conditions. Others have seen greater somatic arousal in subjects who employed kinesthetic imagery than those that used visual imagery; and positive effects on motor performance were observed in Olympic gymnasts who engaged in internal kinesthetic imagery.[24] More so, kinesthetic imagery was suggested to be more effective when duration and/or timing are the parameters of importance during tasks requiring greater motor control.[25]

Areas of application of imagery training have been varied in order to address the different functional limitations following stroke. As for the included studies the primary focus was on upper limb functioning. The 3 studies utilized the same training regimen for their patients. Both experimental (MP+PP) and control (Relaxation + PP) groups received conventional therapy, where they were able to practice the activities of daily living. Emphasis was given on these bimanual activities: reaching for and grasping a cup, turning a page in a book, and proper use of a writing utensil. After therapy, the MP+PP mentally practiced the said tasks, while the control group listened to an audiotape of a progressive relaxation program or stroke information. Those in the experimental group were instructed to use internal, polysensory images (e.g combination of visual images of reaching for a cup, and kinesthetic images by letting patients "feel" their arm reaching for the cup) during their mental practice sessions. It was observed that 3 to 6 weeks of mental practice training translated into significant improvements in the Fugl-Meyer and ARA scores of the experimental group as compared to patients in the control group. It would have been ideal, though, that a meta-analysis was done on the Fugl-Meyer and ARA scores to support the positive gains after mental practice training. Unfortunately, the lack of data from the contacted authors for the three included studies made this impossible.

Page et al also observed increased scores in the amount of use scale of the Motor Activity Log (MAL) and improved quality of movement of the affected arm in the mental practice group as compared to the control group.[4] It seems that the MAL is a very useful tool since the separate interview of the caregivers from the patients may in fact be an objective measure of the use of the affected hand of the patients in their homes. However, the authors have failed to report the validity and the reliability of this tool.

Dijkerman et al, on the other hand, have attempted to investigate the effect of mental practice in an upper extremity motor task, along with other outcome measures.[26] However, this study was excluded primarily because of confusing results.

Mental practice with motor imagery has also been applied for the rehabilitation of the lower extremity, particularly on weight bearing and gait. Jackson et al observed a marginal improvement (2.2%) by their 38 year old patient in the performance of the foot-sequence task after two weeks of mental practice.[27] Malouin et al had a single-day mental practice training of 12 stroke patients in sit-to-stand and sitting down tasks.[28] Results showed that at 1-day post-intervention and 1-day follow up, stroke patients were able to increase limb loading on their affected limb during these mobility activities.

Dickstein et al. investigated the effect of motor imagery training on the gait of a 69 year old stroke patient. [29] The patient received the intervention for 6 weeks. Gait analysis showed that after imagery training, improvements were seen with step length, cadence and speed, as well as, enhanced flexion ranges on the paretic knee. However, the patient's Tinetti ambulation score and symmetry of single limb support between the paretic and nonparetic sides were unchanged from baseline. At follow up, though, the improvements on temporospatial and kinematic parameters were marginally sustained.

Four chronic stroke patients were trained with motor imagery for their gait in the study of Dunsky et al.[30] After 6 weeks of training, improvements in walking ability was measured through increased cadence gait speed, step and stride length, increased time for single limb support on the affected limb and a decreased period of double-support. Tinetti ambulation scores improved by one point, however, Fugl-Meyer scores remained unchanged post-intervention. These studies on the lower extremity are worth mentioning since these implicate the potential use of imagery to gait training. Unfortunately, the study designs employed rendered these ineligible for the review.

The complex combination of upper and lower extremity function in daily tasks was investigated by Liu et al.[31] These authors focused on retraining stroke patients in performing activities of daily living. Patients were trained on 5 tasks per week for 3 weeks. These included putting clothes on a hanger, folding laundry, preparing tea, washing dishes, carrying out money transactions, preparing fruit, making the bed, taking medication, using the telephone, seeing the doctor, sweeping the floor, cleaning the table after a meal, frying vegetables with meat, going outdoors and going to the canteen. Five untrained tasks, which were considered as measures of generalization of training, were assessed during post-intervention at the 3rd week. Competency in performing the tasks was observed more with the patients in the imagery group than in the functional retraining (control) group, despite the fact that their Fugl-Meyer UE and LE scores remained relatively unchanged. This and the results from the previous study of Dunsky et al (2006) may imply that the Fugl-Meyer tool may not always be sensitive to the gains after imagery training, and task specific outcome measures are needed to see these improvements.[30]

Duration and means of providing mental practice training varied among studies, too. For the studies included in this review, the intervention was given though an audiotape, however the earlier work of Page et al was given for 10 minutes as compared to the 2 most recent works which applied 30 minutes of imagery training.[3-5] In some studies, 15-20 minutes was allotted for imagery training. It seems, therefore, that at least 10 minutes of imagery training can enhance the gains of rehabilitation.

Some have applied external aids such as mirrors, visual aids or computer images to provide feedback and facilitate imagery training. Liu et al, for example, utilized computer-generated pictures to facilitate the patients' analysis of task sequences. [31] Video playback at picture cards helped patients recall the identified problems so that more correct task modifications were done during physical and mental practice sessions. Stevens et al applied 2 kinds of imagery tasks to their stroke patients.[32] The first task was classified as computer-facilitated imagery, wherein, computer generated movies using the arm were presented to the patient followed by a blank screen. During the time that no image is showed, patients were instructed to explicitly imagine themselves doing the task previously shown. The patient presses the space bar after they finish imagining the task in order to proceed to the next trial. The second task uses a mirror box apparatus. In this task, patients observed the unaffected limb's reflection and were instructed to imagine that limb as their paretic limb. The advocates of this imagery training believed that "the reflected limb provided a direct perceptual cue for the paretic limb."[32] Results showed improvements of their two patients in terms of Fugl-Meyer and Chedoke-McMaster Stroke assessment scores.

Whether imagery training proceeds with or without external aids, mental practice with motor imagery may present as a cost-effective adjunctive tool in rehabilitation of stroke patients. Although only 3 studies are "eligible" to substantiate such claims, these studies have established some evidence for the effectiveness of this intervention in improving upper extremity function. The positive results from feasibility and case studies on its application to lower extremity can only suggest its potential use for gait and mobility training. However, the evidence in this area is yet to be determined by future quality and well-designed randomized controlled trials.

CONCLUSION

Mental practice with motor imagery may improve synchronization of movement by enhancing motor planning and activating the nonconscious processes that can prepare an individual for movement, similarly found with physical execution of movement. However, being limited to priming the internal feedback system of the task, this intervention proves inferior with overt training (i.e. actual movement) of the task in yielding better performance.

With the absence of external feedback from the musculoskeletal system inherent with this intervention, mental practice can complement actual training of neurologic patients like CVA patients with physical limitations. More often than not, these patients present with weakness, sensory and tone problems, insufficient range of joint motions, compounded by cardiovascular and respiratory conditions that all together limit the physical practice sessions that the patients can sustain for extensive skills training. It should be noted that mental practice with motor imagery presents only as an adjunctive therapeutic tool. Through motor imagery the amount of practice for skills training is increased. Also, as the physical demands of actual movement are removed, motor imagery presents as a means to extending the practice sessions that the patient can utilize safely and independently outside their therapy sessions in the clinic. Success of the intervention may be achieved provided that therapists have considered well the effect of the area of brain lesions to the patient's ability to follow instructions and mental imagery ability.

Although research conducted with this intervention yielded equivocal results, a relatively small body of evidence for mental practice with motor imagery in rehabilitation of stroke patients exists. With the review done, the presence of 3 good quality RCTs suggests the effectiveness of the intervention in upper limb function. On the other hand, its use on lower limb functioning is still inconclusive. However, this premise is understandable since the novelty of the intervention requires experimental designs at the lower levels in the hierarchy of evidence for the "initial" evidence of its clinical use. Future studies employing quality research designs at the upper levels of the hierarchy of evidence are recommended to strengthen the present evidence.

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Appendix 1 Data Synthesis of Qualified Studies.

Title/ author/year	Patients	Outcome measures	Methodology	Results	Other comments
A randomized efficacy and feasibility study of imagery in acute stroke Page S, Levine P, Sisto S, Johnston M 2001[3]	- ages 54-79 exclusion criteria: stroke was less than 4 weeks, or more than a year serious sensory or cognitive deficits, less than 20 on the Modified Mini Mental Status Test hemorrhagic lesions on both hemispheres excessive spasticity as greater than 2 on the Modified Ashworth Scale at the elbow, wrist or hand receptive aphasia inability to imagine with lesser than 25 on the Movement imagery questionnaire -8 MP, 5 controls	Fugl-Meyer Scale for UE Action Research Arm Test (ARA)	random assignment, therapy 3x/wk for 6wks T group- OT listened to a 10 min tape of instruction and info on stroke T + I – Usual OT therapy plus Imagery: 10 mins : 2-3 mins relaxation, 5-7 mins external, cognitive visual images	Substantial increases in Fugl meyer and ARA scores with T +I group while T group scores remained stable	Imagery and mental ability tested - used audiotape for 10 mins - used visual imagery
Effects of Mental practice on affected limb use and function in chronic stroke Page S, Levine P, Leonard A 2005[4]	inclusion: stroke > 1 year >10 deg active wrist flexion as well as in the 2 digits of the affected hand >70 score in Mini mental Status exam no excessive spasticity defined as 3 or lower in modified ashworth scale d/c from rehab, not participating in any rehab or experimental studies no excessive pain on affected limb 18-95 y/o - 6 MP, 5 controls	motor activity log – amount of use scale - quality of movement - ARA test	emphasis on selected ADL reaching and grasping a cup/object turning a page in a book Control group- 30 mins taped relaxation sequence	Highest score changes in the MP group	Mental ability tested; Imagery ability no -used audiotape for 30 mins -used kinesthetic imagery
Mental Practice in Chronic Stroke Page S, Levine P, Leonard A 2007[5]	Inclusion (1) hx of no more than 1 stroke, (2) ability to flex at least 10 deg from neutral at the affected wrist, MCP and IP of the 2 digits (3) stroke experienced >12 mos before enrolment (4) > 69 MMSE score (5) age 18-80 Exclusion (1) excessive spasticity, >3 on the Modified Ashworth spasticity scale, (2) excessive pain on the affected limb, > 4 on a 10-pt VAS, (3) still enrolled in any form of physical rehabilitation (4) participating in any experimental rehabilitation or drug studies -16 MP, 16 controls	Fugl-Meyer Scale for UE Action Research Arm Test	Relaxation + Physical Practice (R +PP) Physical practice of Bimanual tasks of reaching for and grasping a cup, turning a page in a book, proper use of a writing utensil. - 30 min tape on relaxation Mental practice + Physical Practice (MP + PP) Physical practice of Bimanual tasks of reaching for and grasping a cup, turning a page in a book, proper use of a writing utensil. - recorded 30 min MP intervention composed of 5 mins relaxation, followed by internal cognitive polysensory images using visual imagery of the 1st person perspective and the sensations associated with it on the tasks practiced during therapy, refocusing back in the room	Significant improvement seen in MP + PP group	Mental ability tested, imagery not Use if kinesthetic imagery