Evaluation of Mental Imagery as an Intervention for Arm Dysfunction Post-Stroke

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Introduction

Strokes are caused by a disruption of blood to the brain (ischemic stroke) or the bursting of blood vessels in the brain (hemorrhagic stroke). Individuals who experience stroke may experience symptoms like neglect, paralysis, spasticity, weakness, tightness, sensory loss, and decrease in arm movement.[1,2] Among the areas of the body impacted, the most commonly affected area due to stroke is the upper extremity, or the arm. [2] Conventional physical therapy interventions such as stretching, splinting, electrical stimulation, constraint-induced movement therapy, and mirror therapy have proven effective and have been integrated into many stroke patients' rehabilitation plans. However, new treatments such as mental imagery are emerging as potential interventions to induce plastic changes in the brain and provide functional improvements for those affected by arm dysfunction post-stroke. While research in neurologic rehabilitation post-stroke has often improved the quality of life for many of those who have had a stroke, newer treatments like mental imagery have shown conflicting results in many studies. This scoping review aims to present 10 randomized control trials on mental imagery and explain current and future applications of this new intervention.

Overview of Treatment

Mental imagery, also known as motor imagery, mental rehearsal, and mental practice, is an intervention that utilizes the visualization of a purposeful movement in a subject's imagination to improve movement physically over time.[3] In theory, this intervention activate motor pathways affected by stroke, thereby increasing arm function in the patient.[4] Mental imagery is usually executed with pre-recorded audio guides that allow the stroke patient to follow the steps while simultaneously activating neural pathways through their imagination. [4] Mental imagery has its roots in the field of sport psychology, where it has been used to improve performance of specific skills as well as increase the athlete's confidence in performance. [5] In sports psychology, two types of mental imagery are commonly used: kinesthetic and visual imagery; kinesthetic imagery involves recreating the feeling of a movement in one's mind, while visual imagery involves straightforward visualization of a goal-oriented action in the subject's mind. [5] These two styles of mental imagery are used in rehabilitation of upper arm injury post-stroke as well.

Mental imagery poses a few challenges in clinical use. One common challenge is therapist and patient adherence to guidelines of treatment,[6] an issue that causes disruption and accuracy of treatment. Another issue discussed in detail later in this review is the lack of standardization of studies on mental imagery. Without sufficient study rigor and strict guidelines, the quality of evidence and variability in studies creates challenges in making conclusions on the true effectivity of MI. When considering the available evidence, however, mental rehearsal appears to be effective in collaboration with conventional physical interventions, such as mirror therapy and constraint-induced movement therapy. [3]

Purpose

The purpose of this scoping review is to investigate the potential extents of applicability and effectivity of mental imagery, a new intervention, on arm dysfunction after stroke.

Literature Review and Summary of Evidence for Treatment

Motor Function

MI has been shown to improve motor function in stroke-affected upper extremities. Of the 10 studies analyzed in this review, 8 studies found an increase in scores of assessments of motor function after the use of mental imagery (in conjunction with physical practice).[7–14] The studies found significant increases in scores of the FMA when MI was practiced along with the traditional physical interventions, suggesting that MI as a supplementary intervention may provide increased motor control. Additionally, it appears that higher dosages of mental at distributed time intervals (smaller sessions at higher frequencies) may be the most beneficial dosage in improving test scores relating to motor function. Additionally, a recent systematic review by Barclay et al. [15] reviewed 25 studies, spanning 676 participants, and concluded that supplementary MI therapy appears to improve upper extremity activity and upper extremity impairment after stroke as compared with other treatment without MI. In addition, some studies have found that MI may activate motor pathways affected by stroke; treatments utilizing MI were found to have increased motor evoked potentials (MEPs) post treatment. [17,18] The same studies associated improved motor function test scores, including FMA and MAL scores, with the increased activation of motor pathways, a mechanism that may aid in recovery of other areas of arm dysfunction as well. These findings call for further studies confirming the effectivity of

MI on increasing mental imagery ability, and therefore inducing a mechanism of increasing motor function.

Effects of Mental Imagery on Symptoms of Neglect

MI appears to activate motor pathways and may prove beneficial in improving symptoms of neglect, as well as motor function, in hemiplegic stroke. As previously discussed, experimental treatment utilizing MI showed a significant increase in motor evoked potentials (MEPs) compared to the control group, indicating activation of motor pathways through MI-aided treatment.[10] This potential activation of motor pathways may explain another study's finding on MI-aided treatment in symptoms of neglect in stroke.[19] The study by Li et al. showed that MI and physical therapy combined resulted in better performance in the drawing and copying segments of neglect tests, as well as in visual arm imagery, body touching, and sensation tests.[19] The significant pre-post score increases in this study encourage further studies to support the role played by MI in rehabilitating motor pathways and aiding in rehabilitation of neglect symptoms. Given the significant safety concerns associated with unilateral spatial neglect in stroke survivors, [20] these positive findings of MI may be especially useful to investigate further in clinical studies of neglect symptoms due to the accessibility and low-cost of MI-aided treatment.

Stroke Acuity

As seen in "Table 1: Studies Discussed in Literature Review", 6 of 10 studies worked with chronic stroke patients,[8,9,11,13,14,21] 2 of 10 worked with sub-acute stroke patients,[10,19] 1 of 10 worked with acute to sub-acute patients,[22] and 1 of 10 worked with sub-acute to chronic

patients.[12] This disproportionate number of studies in chronic stroke may be due to the accessibility and stability of patients in chronic stages of stroke, and lack thereof in earlier stages. However, this intervention especially would benefit from studies in early stroke to see any impacts on motor pathway activation.

Dosage

Mental imagery appears to be most effective when performed in a distributed and repetitive regiment (breaking up large sessions into smaller, more frequent sessions).[11,13] A study by Page et al. in 2011 found that PT in conjunction with MI at 20, 40, and 60 minute doses resulted in an increased FMA-UE score, with the 60 minute MI sessions showing the most improvement in FMA-UE scores. The 40-minute dose showed a greater score increase than the 20-minute dose as well, suggesting that longer dosages of mental imagery after physical interventions may produce better results.

Evaluation of Evidence Rigor

One possible area of concern in the studies conducted on mental imagery, given the variability in administration of the intervention, is the quality of the studies conducted. To evaluate the 10 studies reviewed in this paper and determine the rigor of evidence, PEDro scores were noted. PEDro uses a score between 1-10 (higher numbers corresponding to greater rigor) to evaluate the quality of an RCT by considering factors such as random allocation, blinding of subjects, and adequate follow-up.[23] The PEDro scores and evaluations of the studies in this scoping review are found in Table 2: Levels of Evidence. Of the 10 studies, 7 had PEDro scores published.[10,12–14,19,21,22] Of these seven, three studies had PEDro scores of 7, indicating a good

quality of evidence.[13,19,22] Three other studies had a PEDro score of 4 or 5, indicating a fair quality of evidence.[10,14,21] Only one study, that of Butler et al., had a PEDro score of 2, indicating a poor quality of evidence. Therefore, overall, the studies reviewed in this paper are of acceptable rigor and their respective results may be interpreted along with the PEDro scores provided for each reviewed study.

Summary of Evidence on Mental Imagery

Overall, given the quality/rigor of evidence as measured by PEDro Scores of the 10 identified studies (see Table 2), mental imagery appears to have potential as a supplementary intervention to upper extremity post-stroke. Mental imagery in conjunction with PT appears to significantly increase upper limb function and motor function in chronic stroke.[9,10,21] Additionally, in an RCT using the Bimanual Coupling Task (Ovalization Index), mental imagery as demonstrated through the I-L (imaginary line) appears to improve amount of use and quality of movement in the upper limb.[8] Kinesthetic mental imagery may help with neglect symptoms in subacute stroke patients and improve body awareness/perception, perhaps through the activation of neural pathways previously affected by stroke. [24] This activation of motor pathways was seen in one RCT, where increased MEPs (motor evoked potentials) indicated the possible activation of motor pathways following MI treatment in conjunction with PT.[10] MI appears to be more beneficial in chronic stroke patients when performed with distributed dosing.[11]Additionally, longer dosages of MI may improve motor function in conjunction with PT, but do not show significant change in upper limb function.[13] MI could be beneficial in conjunction with conventional neurorehabilitative treatments.[14] However, as multiple systematic reviews noted, the quality of evidence regarding mental imagery as an intervention remains mediocre to low, contributing to the inconclusive evidence on this treatment. Further studies with standardized

measures and rigorous study designs should be performed to confirm or refute existing findings on the impact of MI on motor pathways and upper arm function.

Table 1: Studies Discussed in Literature Review

Author(s), Year Sample Size Time Post-Stroke	Experimental, Control, and Placebo Groups Duration	Measures Results
Page et al. 2007 N_{end}=32 Chronic	E: PT+MI C/P: PT+ Relaxation 30 min/d, 2d/wk, for 6 wks	• FMA-UE (+exp) • ARAT (+exp)
S Morioka et al. 2019 N_{end}=31 Chronic	E1: I-L (imaginary line): Draw lines with functional arm while imagining drawing circles with paralyzed arm. E2: BC-L (bimanual circle line): Draw straight lines with functional arm, attempt to draw circles with paralyzed arm. C: U-L (unimanual line): Draw straight lines with functional arm, no imagining.	• Bimanual Coupling Task-Ovalization Index ($+exp_1$, $+exp_2$) • FMA-UE (+associated with high OI) • MAL-AOU (+associated with high OI) • MAL-QOM (+associated with high OI)
Kim et al. 2015 N_{end}=24 Chronic	E: MI+ PT C: PP 30 min/session, 3 session/wk, for 4 wks (MI) + 30 min/session, 5 session/wk, for 4 wks (PT)_	• FMA-UE (+exp) • WMFT (+exp)
Li et al. 2018 N_{end}=20 Sub-acute	E: MI+PT C: PT 45 min/day, 5 day/wk, for 4 wks	• FMA-UE (+exp) • ARAT (+exp) • Transcranial magnetic stimulation (+exp)
Welfringer et al. 2011 N_{end}=30 Sub-acute	E: MI+PT C: PT	• ARAT (-) • Neglect Tests 1. Clock drawing (+)

	2 30 min sessions/day, 7 days/wk, for 3 weeks	2. Flower copying (+) 3. Bells Cancellation (-) • Representation/Sensation tests 1. Visual arm imagery (+) 2. Body touching (+) 3. Sensation (+)
Ietswaart et al. 2011 N_{end}=121 Acute to Sub-acute	E: Guided and independent mental imagery P/C: Guided and independent visual imagery C: PT 12 45 min sessions+ 8 independent sessions	• ARAT (-)
Page et al. 2016 N_{end}=27 Chronic	E1: Massed MI+PT 60 min/day, 7day/wk, 10 wks E2: Distributed MI+ PT 3 20 min sessions/day, 7 day/wk, 10 wks	• FMA-UE ($+exp_1$<$+exp_2$) • ARAT ($+exp_1$<$+exp_2$)
Butler et al. 2006 N_{end}=4 Sub-acute to chronic	E1: MI E2: MI+CIMT C: CIMT 3 hrs/day, 7 days/wk, for 2 wks	• FMA-UE ($-exp_1$), ($-exp_2$), (-con) • MAL-AOU ($-exp_1$), ($+exp_2$), (+con) • MAL-QOM ($-exp_1$), ($+exp_2$), (+con) • WMFT ($-exp_1$), ($+exp_2$), (+con)
Page et al. 2011 N_{end}=29 Chronic	E1: PT+ 20 min MI E2: PT+ 40 min MI E3: PT+ 60 min MI C/P: PT+ sham 30 min PT+ MI in different dosages/day, 3 day/wk, for 10 wk	• FMA-UE: ($+exp_3$> $+exp_2$> $+exp_1$) • ARAT: ($-exp_1$, $-exp_2$, $-exp_3$)
Riccio et al. 2010 N_{end}=36 Chronic	E1: Conventional rehabilitation for first 3 weeks, conventional	• Motricity Index • Arm Functional Test

	rehabilitation +MI for another 3 weeks E2: MI+OT for first 3 weeks, only conventional rehabilitation for another 3 weeks 3 hr/day, 5 days/wk, 6 wk total T1: 3 wks T2: 6 wks	

Table 2: Rigor of Evidence in Reviewed Studies (PEDro)

Author(s), Year	Design of Study	PEDro Score
Page et al. 2007	RCT	5/10
S Morioka et al. 2019	RCT	N/A
Kim et al. 2015	RCT	N/A
Li et al. 2018	RCT	4/10
Welfringer et al. 2011	RCT	7/10
Ietswaart et al. 2011	RCT	7/10
Page et al. 2016	RCT	N/A
Butler et al. 2006	RCT	2/10
Page et al. 2011	RCT	7/10
Riccio et al. 2010	RCT	5/10

Suitable/ Unsuitable Patients

MI is an intervention that appears to be accessible regardless of patient resources. Given the evidence that MI may improve motor function and lessen symptoms of neglect when used in conjunction with usual physical therapy regiments, [7–14] the addition of mental imagery sessions to stroke patients may prove beneficial. Some studies suggest that use of MI in acute stroke may provide a more neuroplastic foundation for further treatment at later stages in stroke rehabilitation; [15] however, it appears that MI may be beneficial in subacute and chronic stroke as well. [8–12,14,19,21] The minimal cost of adding mental imagery to existing physical therapies that work best for each individual patient further adds to its suitability in the aiding of upper extremity rehabilitation.[25]

Some studies reviewed in a 25 RCT-based systematic review by Barclay et al. excluded patients due to excessive spasticity, significant visual/auditory impairments, and/or behavioral and attention impairments.[15] These factors, if present in patients performing mental imagery interventions, may result in less significant improvements in rehabilitation of the upper extremity; however, there is no evidence to show that the three factors listed may cause patients to have adverse or negative reactions to mental imagery-aided interventions. As long as patients are able to follow mental imagery instruction, the treatment may be carried out.

Mental imagery and visual imagery as a skill may be impaired in patients post-stroke,[26] but this does not appear to disqualify patients from receiving mental imagery as a treatment. In fact, the use of mental imagery treatments in the acute to sub-acute timeframe post-stroke appears to improve the ability of stroke patients to perform motor/visual imagery as measured implicitly by the hand laterality tasks and explicitly by detailed mental imagery tasks.[26] These

findings confirm the high accessibility of mental imagery as a possibly successful supplementary treatment to individualized physical treatment in most stroke patients.

Comparison of Mental Imagery to Mirror Therapy

Compared Factor	Mental imagery	Mirror Therapy
Estimated Cost	$0 (covered by insurance & no equipment cost in treatment)	Up to $300 or more based on cost of mirror
Required Time	20-60 minutes/day, 7 days a week, for at least 3 weeks	15-90 minutes a day, 3-7 days a week, for at least 3 weeks
Required/ Specialized Equipment	N/A	Specialized box mirror, or a regular mirror with a stand
Recommended Stroke Stage	Mental imagery appears to be effective in sub-acute to chronic stages of stroke.	Mirror therapy appears to be effective in acute to sub-acute stages of stroke and shows no significant improvements in chronic stroke patients.
Where can treatment be done?	Anywhere, including at home with guided audio treatments.	In both clinical settings and home.
Does the treatment require extra assistance?	No, mental imagery only requires instructions or guided audio programming. However, initial guidance/training from a clinical professional should happen for independent sessions to happen effectively. Some studies have found that mental imagery, due to its intangible nature, has produced better results when highly monitored, even when performed independently.	No, mirror therapy is an intervention often practiced by patients independently. However, initial guidance/training from a clinical professional should happen for independent sessions to happen effectively.

Implications for Future Research and Unanswered Questions

Variability and Standardization in Scientific Research

Before proposing research, the issue of standardization of research must be discussed. In this intervention, the standardization of rigor of each RCT would allow the quality of results to be isolated from high variability in execution of the research. In mental imagery, high variability can be caused by terminology, study design/rigor (as measured by PEDro and CONSORT guidelines), inclusion criteria, and amount/ quality of care (i.e., monitoring independent sessions, following up, and additional guidance). This scoping review provided PEDro scores in order to highlight that not all RCTs are carried out equally, and that it is always beneficial to the science community to be transparent and adhere to set guidelines by reputable organizations like PEDro and CONSORT to ensure consistency and low variability in reporting of results. Additionally, the standardization of procedures, measurement, and inclusion guidelines in scientific research is an issue that applies to topics beyond mental imagery as an intervention post-stroke. Standardization of treatment and measures to a realistic extent will allow for more interventions like MI to be studied in comparable and significant ways in future studies.

Proposed Directions/Questions for Research in Mental Imagery

1) **Using MEPs as a Biomarker in Further MI Research**

   Understanding the mechanism through which mental imagery affects arm dysfunction would allow efficient improvement of its execution in clinical settings if further studies with high qualities of evidence find MI to be significantly effective for arm dysfunction after stroke. To do this, the use of motor evoked potentials (MEPs) as a biomarker in mental imagery research should be explored further. Motor evoked potentials are used as

biomarkers for the integrity of the motor system[27] and is measured through transcranial magnetic stimulation and measurement of motor signals on the receiving end at limb muscles. MEPs would prove beneficial in confirming or refuting the theory that MI is effective due to activation of motor pathways post-stroke.

Surprisingly, of the studies analyzed in this scoping review, only one used MEPs as a biomarker for studying the role of mental imagery served in activating motor pathways. More studies utilizing this valuable biomarker would allow for determination of the mechanism of MI and clarify whether increased neuroplasticity plays a role in retainment of arm function through this treatment. Furthermore, MEPs could be used as an inclusion criterion: a positive result for MEPs as measured when screening for study candidates could allow for researchers to see whether motor pathways are intact in each candidate, thereby predicting the prognosis of each patient regardless of the intervention studied. While this would call into question the research ethics of disqualifying patients with negative MEPs, this possibility may allow for decreased variability and increased efficiency in stroke studies, which as previously discussed, is valuable. Overall, the use of valuable and underused biomarkers like MEPs in MI and stroke research would allow for better clinical understanding of such interventions.

2) **Does patient acuity result in varying degrees of improvement of motor function after mental imagery as an intervention post-stroke?**

In theory, stroke patients at earlier stages of stroke (acute, sub-acute) have increased neuroplasticity and therefore may be able to make more significant improvements in prognosis and motor function than in chronic patients. Studying the use of MI in acute and

sub-acute populations would allow for a clearer picture on this question. A possible way to study this is by using an equal number of subjects in earlier versus chronic stages of stroke and subjecting them to a high dosage at high frequency, with increased monitoring and independent MI sessions as well. The control group would consist of a similar number of early versus chronic patients respectively, but use a sham intervention such as relaxation. The study design would follow suggested guidelines by PEDro, CONSORT, and NINDS Common Data Elements, ensuring highest quality of evidence, and would utilize MEPs as a biomarker along with conventional tests such as the FMA and ARAT. The comparison of results of this study would produce multiple findings, including the significance of stroke acuity in MI treatment and the effectivity of MI as a treatment overall.

Conclusion

Given the available research, it appears that mental imagery has a tangible positive effect on upper extremity dysfunction post-stroke. Specifically, in higher, repeated doses, MI in conjunction with conventional treatment may better improve arm control and motor function when compared to conventional treatments alone. Additionally, the treatment does not appear to have any harmful effects and is accessible to patients of any economic background. The accessibility and possible effectivity of this treatment calls for further research to confirm and specify the mechanisms in which mental imagery may assist in improving upper extremity impairment post-stroke.

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