Use of Mental Practice to Improve Upper-Limb Recovery After Stroke: A Systematic Review

Dawn M. Nilsen, Glen Gillen, Andrew M. Gordon

KEY WORDS
- imagery (psychotherapy)
- mental healing
- outcome and process assessment (health care)
- recovery of function
- stroke
- upper extremity

OBJECTIVE. We sought to determine whether mental practice is an effective intervention to improve upper-limb recovery after stroke.

METHOD. We conducted a systematic review of the literature, searching electronic databases for the years 1985 to February 2009. We selected studies according to specified criteria, rated each study for level of evidence, and summarized study elements.

RESULTS. Studies differed with respect to design, patient characteristics, intervention protocols, and outcome measures. All studies used imagery of tasks involving movement of the impaired limb. The length of the interventions and number of practice hours varied. Results suggest that mental practice combined with physical practice improves upper-limb recovery.

CONCLUSION. When added to physical practice, mental practice is an effective intervention. However, generalizations are difficult to make. Further research is warranted to determine who will benefit from training, the dosing needed, the most effective protocols, whether improvements are retained, and whether mental practice affects perceived occupational performance.

People who have sustained a stroke are often left with residual motor impairments that limit their ability to engage in meaningful occupations such as self-care, work, and leisure activities. Sensorimotor deficits in the upper limb, such as weakness (Bourbonnais & Vanden Noven, 1989; Dewald & Beer, 2001; Tyson, Chillala, Hanley, Selley, & Tallis, 2006), decreased speed of movement (Trombly, 1992), decreased angular excursion and impaired temporal coordination of the joints (Cirstea & Levin, 2000; Levin, 1996), impaired upper-limb and trunk coordination (Cirstea & Levin, 2000; Michaelsen, Luta, Roby-Brami, & Levin, 2001), and impaired hand function (Lang, Wagner, Edwards, Sahrmann, & Dromerick, 2006; Welmer, Holmqvist, & Sommerfeld, 2008), may limit the ability to use the affected upper extremity to perform various tasks.

Consequently, occupational therapists working with this population use approaches that aim at optimizing motor behavior to restore occupational performance. Treatment interventions such as materials-based occupations (Lang, Nelson, & Bush, 1992), constraint-induced movement therapy (Wolf et al., 2006), modified constraint-induced movement therapy (Lin, Wu, Wei, Lee, & Liu, 2007), and task-related (Thielman, Dean, & Gentile, 2004; Thielman, Kaminski, & Gentile, 2008) or task-specific training (Ada, Canning, Carr, Kilbreath, & Shepherd, 1994; Michaelsen, Dannenbaum, & Levin, 2006) are common training methods for remediating impairments and restoring function in the upper limb. These training methods stress the person’s active participation, manipulation of goal-oriented tasks or environmental characteristics to drive motor behavior, and practice of the whole task or components of the task under varying conditions.
Although after stroke, people appear to benefit from substantial time spent in practice (Kwakkel, 2006; Wolf et al., 2006), it appears they may not be getting enough of it. When compared with other patient populations, patients who have sustained a stroke spend more time alone and inactive on rehabilitation units (Bear-Lehman, Bassile, & Gillen, 2001; Bernhardt, Dewey, Thrift, & Donnan, 2004). Thus, there appears to be a “practice gap” between the amount of training these patients need and the amount they receive. What accounts for this practice gap is unclear. Many factors may contribute, but it is likely that a reduced sensorimotor capacity plays a substantial role in this inactivity (Bear-Lehman et al., 2001). Therefore, it is of benefit to investigate adjuncts to physical practice that may assist in filling the gap. Recently, the literature has proposed the use of mental practice as an addition to physical practice or when physical practice is not possible (Jackson, Lafleur, Malouin, Richards, & Doyon, 2001).

Mental practice is a training method during which a person cognitively rehearses a physical skill using motor imagery in the absence of overt, physical movements for the purpose of enhancing motor skill performance (Annett, 1995; Driskell, Copper, & Moran, 1994; Feltz & Landers, 1983; Jackson et al., 2001). The use of mental practice to benefit motor skill performance in healthy people has been well established in the literature (Driskell et al., 1994; Feltz & Landers, 1983).

Why does mental practice work? Simulation Theory, elaborated by Jeannerod (2001), suggests that actions have a covert stage. This covert stage is a representation of the action, which includes the purpose of the action, the information needed to produce it, and the possible outcomes. The theory suggests that similarities exist in terms of neural activity between the state in which an action is simulated and the state of execution and that this similarity results in the benefits seen in mental practice (Jeannerod, 2001).

Multiple lines of evidence in the literature converge to suggest, as proposed by Simulation Theory, that imagined and executed actions share similar processes. For instance, at the behavioral level, several commonalities between the two have been observed. The contextual interference effect, which states that blocked practice facilitates skill acquisition and random practice benefits retention, and Fitts’ Law (Fitts, 1954, as cited in Magill, 2001), which states that movement times increase as target distance increases or target width decreases (i.e., speed–accuracy trade-off), are two robust findings in the motor learning and control literature (Magill, 2001). Interestingly, both findings appear to hold true when movements are imagined (Decety & Jeannerod, 1996; Gabriele, Hall, & Lee, 1989; Sirigu et al., 1996). The notion that healthy people’s physical and mental actions share similar durations is another behavioral observation suggesting that the two may be functionally equivalent (Decety & Jeannerod, 1996; Sirigu et al., 1996). For example, a review of the duration of mental movements found temporal equivalence for reaching; grasping; writing; and cyclical activities, such as walking and running (Guillot & Collet, 2005). Additional evidence for a similarity between the two comes from literature that has shown that physiological correlates for imagined and executed actions are comparable. When people engage in mental practice, changes in vegetative functions (Decety, Jeannerod, Germain, & Pastene, 1991; Livesay, & Samaras, 1998; Roure et al., 1998), muscle activity (Guillot et al., 2007; Livesay & Samaras, 1998), and muscle strength (Fontani et al., 2007; Sidaway & Trzaska, 2005; Yue & Cole, 1992) occur in a fashion comparable to that seen during physical activity. Perhaps the most convincing line of evidence comes from studies investigating the neural correlates of imagined and executed actions in healthy people. Studies using positron emission tomography (Lafleur et al., 2002; Stephan et al., 1995), functional magnetic resonance imaging (Ehrsson, Geyer, & Naito, 2003; Gerardin et al., 2000; Johnson, Rotte, et al., 2002; Lotze et al., 1999; Michelon, Vettel, & Zacks, 2006; Oullier, Jantzen, Steinberg, & Kelso, 2005; Porro et al., 1996), and transcranial magnetic stimulation (Pascual-Leone et al., 1995) have all revealed commonalities in the neural substrate governing imagined and executed actions.

Because overt and covert actions are similar at the behavioral, physiological, and neural levels and because mental practice has been shown to enhance motor performance in healthy people, researchers have speculated about its utility in neurorehabilitation (de Vries & Mulder, 2007; Jackson et al., 2001; Sharma, Pomeroy, & Baron, 2006). In fact, several review articles examining the impact of mental practice have been published. Two reviews (Braun, Beurskens, Borm, Schack, & Wade, 2006; Zimmermann-Schlatter, Schuster, Puhan, Siekierka, & Steurer, 2008) examined stroke outcomes in general and did not limit their review to upper-extremity–focused outcomes. Both articles included studies that were published in 2005 or earlier. Two additional reviews focused on upper-extremity outcomes from studies published in 2003 or earlier (Bell & Murray, 2004) or 2005 or earlier (Sharma et al., 2006); those reviews, however, did not attempt to rate the studies reviewed in terms of the level of evidence they provided. Thus, in this review, we determined whether mental practice is an effective means to fill the practice gap.
intervention strategy to remediate impairments and improve upper-limb function after stroke by examining and rating the current evidence.

**Method**

**Sources**

The first two authors of this paper (Nilsen and Gillen) performed independent searches of electronic databases including Medline, PubMed, the Cochrane Database, PsycINFO, and CINAHL from 1985 to February 2009. In addition, they hand-searched reference lists of obtained articles. Search terms included mental practice, mental imagery, motor imagery, stroke, cerebrovascular accident, limb, arm, and upper extremity. The search was limited to journals published in English.

**Study Selection**

We included published and completed studies in this review if they met the following criteria: The participant’s primary diagnosis was a stroke, mental practice was used as part of the intervention plan either in isolation or in conjunction with other therapies, and mental practice was used to reduce upper-extremity impairment or improve upper-extremity function. All levels of evidence were considered for this review, from Level I (randomized controlled trials, or RCTs) to Level V (case reports).

**Data Extraction**

Nilsen and Gillen reviewed the articles that met the inclusion criteria and extracted the following data: study objectives, level of evidence and design, description of participants (e.g., age, time since stroke, lesion sites), intervention description, outcome measures, and dimension of the outcome measures based on the International Classification of Functioning, Disability and Health (World Health Organization, 2001). For this review, we used the following levels of evidence: Level I (systematic reviews, meta-analyses, RCTs), Level II (nonrandomized controlled trials, case control trials), Level III (pretest–posttest designs, cross-sectional designs), Level IV (single-subject designs, case series), and Level V (case reports, narrative literature reviews). Additionally, Nilsen and Gillen assessed the quality of the included Level I and II studies using the PEDro scale (partitioned; 2003). The PEDro (partitioned) rates a study’s internal validity and statistical reporting using 8-point and 2-point scales, respectively, with higher scores indicating higher quality. This scale has been found to be a reliable instrument for assessing the internal validity and statistical reporting of RCTs (Tooth et al., 2005). Consensus was used if there was disagreement on whether a study met the inclusion criteria, level of evidence, or quality ratings.

**Results**

Nilsen and Gillen originally located 20 articles using the previously mentioned key words and study selection criteria. Of those articles, 2 were excluded because they did not address remediation of upper-limb function directly (Liu, Chan, Lee, & Hui-Chan, 2004a; Liu, Chan, Lee, & Hui-Chan, 2004b), and 3 were excluded because they were not completed studies (Braun et al., 2007; Ietswaart et al., 2006; Verbunt et al., 2008). Therefore, a total of 15 articles were reviewed and classified according to the criteria described earlier. The results are summarized in Table 1.

As can be seen in Table 1, the research designs differed substantially among studies. A critical appraisal of the study designs resulted in 4 studies being categorized as Level I evidence (Page, 2000; Page, Levine, & Leonard, 2005, 2007; Page, Levine, Sisto, & Johnston, 2001b), 2 as Level II (Dijkerman, Ietswaart, Johnston, & MacSweeney, 2004; Müller, Bütfisch, Seitz, & Hömberg, 2007), 1 as Level III (Simmons, Sharma, Baron, & Pomeroiy, 2008), 6 as Level IV (Butler & Page, 2006; Crosbie, McDonough, Gilmore, & Wiggam, 2004; Hewett, Ford, Levine, & Page, 2007; Page, Levine, & Hill, 2007; Stevens & Phillips Stoykov, 2003; Yoo, Park, & Chung, 2001), and 2 as Level V (Gaggioli, Meneghini, Morganti, Alcaniz, & Riva, 2006; Page, Levine, Sisto, & Johnston, 2001a).

The quality assessment of the Level I and II studies are summarized in Table 2. In terms of internal validity, the overall scores ranged from 2 to 5. Four of the 6 studies were rated positively for random allocation of groups (Page, 2000; Page et al., 2001b, 2005; Page, Levine, & Leonard, 2007) and similar groups at baseline (Dijkerman et al., 2004; Müller et al., 2007; Page et al., 2005; Page, Levine, & Leonard, 2007). Three of 6 studies scored positively for blinding of the assessors (Page et al., 2001b, 2005; Page, Levine, & Leonard, 2007), whereas only 2 studies included blinding of the therapists who provided the treatment (Page et al., 2001b; Page, Levine, & Leonard, 2007). All the studies scored positively on obtaining key outcome measures from ≥85% of participants initially allocated to groups. Conversely, all the studies scored negatively on concealment of allocation, blinding of participants, and intention-to-treat analysis. In regard to
### Table 1. Summary of Evidence on Use of Mental Practice to Improve Upper-Limb Recovery After Stroke

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Study Objectives</th>
<th>Level/Design/Participants</th>
<th>Intervention and Outcome Measures</th>
<th>Results</th>
</tr>
</thead>
</table>
| Butler & Page (2006) | To measure the efficacy of a program combining MP and physical practice with the efficacy of a program composed of only CIMT or only MP | Level IV: Case series | Participants  
N = 4 men and women  
Mean age = 62.75  
Mean time since stroke = 9.25 mo (range = 3–16 mo)  
Left cortical and subcortical CVAs | Intervention  
3 hr/day for 2 wk of either CIMT, MP only, or a combination of the two were administered. Two patients received MP and CIMT, 1 received only MP, and 1 received only CIMT.  
Outcome Measures  
a. FMA (Impairment)  
b. Wolf Motor Function Test (Activity Limitation)  
c. MAL (Activity Limitation) | a. The participant receiving MP regressed on this measure. One participant receiving MP plus CIMT increased from 21 to 37, and the other remained stable.  
b. The participant receiving MP only showed a slight but not meaningful improvement (a 0.1-s decrease). One participant receiving MP plus CIMT showed a 1.8-s improvement, and the other patient regressed by 6.2 s.  
c. The participant receiving only MP showed a slight but not meaningful improvement on the MAL scales. One participant receiving MP plus CIMT showed a clinically meaningful improvement on both scales (2.3 and 1.08). |
| Crosbie, McDonough, Gilmore, & Wiggam (2004) | To assess the feasibility and practicalities of using the technique of mental practice as an adjunct in the rehabilitation of the upper limb after stroke | Level IV: Case series | Participants  
N = 10 men and women  
Age range = 45–81 yr  
Time since stroke = 10–176 days  
Both right and left CVAs | Intervention  
2-wk intervention consisted of daily MP sessions of a reach-and-grasp task in addition to usual therapy.  
The participants were shown videotapes to cue the visualization.  
Outcome Measures  
Motricity Index (UE) Impairment | 8 participants demonstrated significant improvement on the basis of a 2-band standard deviation method. |
| Dijkerman, Ietswaart, Johnston, & MacWalter (2004) | To assess the efficacy of motor imagery training for arm function in chronic stroke patients vs. nonmotor imagery vs. no mental rehearsal | Level II: CCT | Participants  
N = 20 men and women  
Experimental group = 10  
Control Group 1 = 5  
Control Group 2 = 5  
Mean age = 64  
Mean time since stroke = 2.0 yr (range = 1–4 yr)  
Both right and left CVAs | Intervention  
A 4-wk home-based program  
Experimental group practiced self-generated daily MP consisting of moving 10 tokens with their affected arm 3× per day. The nonmotor imagery control group visually recalled a previously seen set of pictures. The third group was not involved in mental rehearsal. All patients practiced physically moving the tokens. Patients kept a log that recorded when they performed the tasks.  
Outcome Measures  
a. Motor training task (Impairment)  
b. Modified motor training task (Impairment)  
c. Pegboard test (Impairment)  
d. Dynamometer (Impairment)  
a. 14% increase in experimental group compared with 6% for control group (p < .05).  
b. No differences  
c. No differences  
d. No differences  
e. No differences  
f. No differences  
g. No differences  
h. No differences  
i. No difference |
Gaggioli, Meneghini, Morganti, Alcaniz, & Riva (2006) To investigate the technical and clinical viability of using computer-facilitated MP in the rehabilitation of upper-limb hemiparesis after stroke

**Level V: Case study**

**Participants**

- N = 1 man
- Age = 46
- Time since stroke = 13 mo
- Left hemispheric ischemic stroke

**Intervention**

- 3 computer-enhanced 0.5-hr MP sessions/wk were administered for 4 wk plus usual half-hour sessions of PT. A virtual reality system was used to guide MP, followed by a 3×/wk for 1-mo home program.

**Outcome Measures**

- a. FMA (Impairment)
- b. ARAT (Impairment)

a. Consistently increased during the 4 wk of intervention (21% improvement compared with baseline) with modest increases during the home-based training

b. Consistently increased during the 4 wk of intervention (23% improvement compared with baseline) with modest increases during the home-based training

Hevett, Ford, Levine, & Page (2007) To examine MP efficacy using a kinematics reaching model

**Level IV: Case series**

**Participants**

- N = 5 men and women
- Mean age = 52.6
- Mean time since stroke = 51.2 mo (13–126 mo)
- Both right and left CVAs

**Intervention**

- Outpatient intervention
  - Participants practiced the same set of ADLs, both via physical practice and MP.
  - Therapy occurred 2×/wk in 30-min segments for 6 wk.
  - After therapy, participants participated in the tape-recorded MP intervention.

**Outcome Measures**

- Kinematic analysis of 2 functional reaching tasks consisting of reaching and grasping a plastic cylinder positioned at either elbow height (reach out) or shoulder height (reach up) (Impairment)

- Preintervention, the mean horizontal reaching distance was 8.3 ± 1.7 cm and 10.9 ± 2.2 cm for the reach-up and reach-out tasks, respectively.

- On completion of the intervention, ability to reach up significantly improved to 9.9 ± 1.6 cm (p < .001). Horizontal reach distance also improved, although not significantly, during the reach-out task (11.7 ± 2.2 cm, p = .366). No differences were observed in linear hand velocity.

- Patients also exhibited greater shoulder flexion (M = 8˚) and elbow extension (M = 4˚) during both the posttest reach-up and posttest reach-out tasks.

Müller, Bütefisch, Seltz, & Hömberg (2007) To test the hypothesis that imagery of finger movements is a specific strategy to improve hand function

**Level II: CCT**

**Participants**

- N = 17 men and women
- Experimental group = 6
- Control Group 1 = 6
- Control Group 2 = 5
- Mean age = 62

**Intervention**

- Experimental group received a daily training session of 30 min 5×/wk for 4 wk. Participants were taught a sequence of finger movements that was presented via videotape. The MP group mentally rehearsed the sequence. The motor group physically practiced. The conventional therapy group received standard OT/PT.

a. Subtests reflected a trend of better recovery for the MP group and the physical practice group but not the conventional group. A significant difference was observed for the writing and simulated feeding subtests for the MP group vs. the conventional therapy group (p < .01).

b. Significant differences were found between the MP group and the conventional therapy group (p < .02). No
<table>
<thead>
<tr>
<th>Author/Year</th>
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<th>Intervention and Outcome Measures</th>
<th>Results</th>
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<tbody>
<tr>
<td><strong>Page (2000)</strong></td>
<td>To test the efficacy of an OT plus MP program on reducing chronic UE motor impairment compared with OT only</td>
<td>Level I: RCT</td>
<td><strong>Intervention</strong>&lt;br&gt;A 4-wk program administered 3×/wk in 1-to 2-hr outpatient sessions combining OT and MP&lt;br&gt;The tape-recorded MP intervention lasted 20 min.</td>
<td>a. The experimental group exhibited a 35.98% improvement compared with a 21.15% improvement in control group. The experimental group exhibited a significantly greater improvement (p = .002).&lt;br&gt;Effect size = 1.39</td>
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<td><strong>Participants</strong>&lt;br&gt;N = 16 men</td>
<td><strong>Outcome Measures</strong>&lt;br&gt;a. Jebsen Hand Function Test (Activity Limitation)&lt;br&gt;b. Pinch strength (Impairment)</td>
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<td></td>
<td>Experimental group = 8</td>
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<td>Control group = 8</td>
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<td></td>
<td>Mean age = 63.2</td>
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<td></td>
<td>Mean time since stroke = 1.8 yr</td>
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<td></td>
<td>All left CVAs</td>
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<td><strong>Page, Levine, &amp; Hill (2007)</strong></td>
<td>To determine the efficacy of an MP program that preceded mCIMT in improving more-affected arm function in patients with a stroke</td>
<td>Level IV: case series</td>
<td><strong>Intervention</strong>&lt;br&gt;Outpatient intervention</td>
<td>a. Mean change score = 3.8&lt;br&gt;b. Mean change = 4.9&lt;br&gt;c. After intervention, participants became eligible for mCIMT on the basis of improved motor status.</td>
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<td><strong>Participants</strong>&lt;br&gt;N = 4 men and women</td>
<td><strong>Outcome Measures</strong>&lt;br&gt;a. FMA (Impairment)&lt;br&gt;b. ARAT (Activity Limitation)&lt;br&gt;c. Motor criteria to engage in mCIMT (Impairment)</td>
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<td>Mean age = 62.5</td>
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<td>Mean time since stroke = 32.0 mo (range = 14–63 mo)</td>
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<td>Both right and left CVAs</td>
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<td><strong>Page, Levine, &amp; Leonard (2005)</strong></td>
<td>To determine the efficacy of an MP protocol in increasing the function and use of the more affected limb in patients with chronic stroke</td>
<td>Level I: RCT</td>
<td><strong>Intervention</strong>&lt;br&gt;6-wk program</td>
<td>a. Significantly greater changes for the experimental group (10.7) vs. control group (4.8); p = .004&lt;br&gt;b. Greater changes for the experimental group (+1.6) vs. control group (+0.4)&lt;br&gt;c. Greater changes for the experimental group (+2.2) vs. control group (+0.2)</td>
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<td></td>
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<td><strong>Participants</strong>&lt;br&gt;N = 11 men and women</td>
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<td></td>
<td>Experimental group = 6</td>
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<td></td>
<td>Control group = 5</td>
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<tr>
<td></td>
<td>Mean age = 62.3</td>
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<td></td>
<td>Mean time since stroke = 23.8 mo (range = 15–48 mo)</td>
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<tr>
<td>Study Information</td>
<td>Description</td>
<td>Study Design</td>
<td>Participants</td>
<td>Intervention</td>
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<tr>
<td>Page, Levine, &amp; Leonard (2007)</td>
<td>To compare the efficacy of a rehabilitation program incorporating MP of specific arm movements to a placebo condition</td>
<td>Level I: RCT</td>
<td>32 men and women (N=32)</td>
<td>Participants received 30-min therapy sessions 2 x/wk for 6 wk. Experimental participants also received 30-min MP sessions after therapy. Control participants received the same amount of therapist interaction as the experimental group and a sham intervention directly after therapy, consisting of relaxation.</td>
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<tr>
<td>Page, Levine, Sisto, &amp; Johnston (2001a)</td>
<td>To examine the effect of PT plus MP on both impairment and functional outcomes related to UE motor deficit after stroke</td>
<td>Level V: Case study</td>
<td>1 man (N = 1)</td>
<td>A 6-wk program was administered. The patient received PT 3x/wk for 1 hr/session. In addition, 2x/wk after his PT and 2x/wk at home, he engaged in MP (a taped-recorded intervention lasting approximately 10 min).</td>
</tr>
<tr>
<td>Page, Levine, Sisto, &amp; Johnston (2001b)</td>
<td>To compare the feasibility and efficacy of a program combining MP and OT with a program of OT/PT only to reduce (sub) acute UE motor impairment and improve UE function</td>
<td>Level I: RCT</td>
<td>13 men and women (N=13)</td>
<td>A 6-wk program of 1 hr outpatient sessions of OT/PT administered 3x/wk. Experimental participants received 10-min MP sessions after therapy and at home 2x/wk. Control participants listened to stroke education tapes for 10 min.</td>
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<td>Simmons, Sharma, Baron, &amp; Pomeray (2008)</td>
<td>To examine the effects of motor imagery training on motor recovery</td>
<td>Level II: pretreatment–posttreatment single group</td>
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<td>The intervention consisted of 10 sessions</td>
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<tr>
<td>Author/Year</td>
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<td>Intervention and Outcome Measures</td>
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</table>
| Stevens & Phillips Stoykov (2003) | To examine the effectiveness of using motor imagery training via imagined movements and the use of a mirror box apparatus in the rehabilitation of hemiparesis | Participants  
N = 2 (1 man, 1 woman)  
Mean age = 76 and 63, respectively | Intervention  
1-hr sessions, 3×/wk for 4 consecutive wk including computer-facilitated imagery using movies focused on wrist and forearm movements and mirror box-facilitated imagery were administered. Mirror box imagery training lasted about 30 min. | a. Baseline mean = 72.33 (21.63); outcome mean = 78.83 (17.10); follow-up mean = 76.67 (15.88)  
b. Baseline mean = 0.17 (0.15); outcome mean = 0.17 (0.14); follow-up mean = 0.18 (0.11)  
c. Baseline mean = 0.42 (2.95); outcome mean = 0.46 (0.28); follow-up mean = 0.53 (0.31)  
d. Baseline mean = 1.6 (1.19); outcome mean = 2.28 (1.32); follow-up mean = 2.01 (1.26)  
e. Baseline mean = 39.83 (21.33); outcome mean = 43.17 (19.5); follow-up mean = 46.67 (20.54) |
| Yoo, Park, & Chung (2001) | To investigate the effect of MP on line-tracing accuracy of people with hemiparesis after stroke | Participants  
N = 3  
Ages = 24, 44, and 59 yr | Intervention  
MP was administered using 10-min audiotapes for horizontal line-tracing training in 17 sessions. Immediately after listening to the tape, the participants physically traced a horizontal and a curved line. | a. Consistently increased during intervention and modest increases during the 3 follow-up months  
b. Improved overall  
c. Improved during intervention with minimal decreases at follow-up  
d. 1-point increases during the intervention that diminished during the 1st month postintervention  
e. Decreases in movement time during intervention and generally maintained at follow-up for 3 subtests |
Time since stroke = 16, 2, and 12 mo
All right CVAs

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Shorter tracing times and improved tracing quality were also noted.</th>
</tr>
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<tbody>
<tr>
<td>a. Tracing a 5.9-in. long horizontal line (Impairment)</td>
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<tr>
<td>b. Tracing a 6-in. long curved line (Impairment)</td>
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</tbody>
</table>

Note. Impairments are problems in body function (physiological functions of body systems) or structure (anatomical parts of the body such as organs, limbs, and their components), such as a significant deviation or loss. Activity limitations are difficulties a person may have in executing activities. Participation restrictions are problems a person may experience in involvement in life situations. Level I = systematic reviews, meta-analyses, randomized controlled trials; Level II = nonrandomized controlled trials, case control trials; Level III = pretest-posttest designs, cross-sectional designs; Level IV = single-subject designs, case series; Level V = case reports, narrative literature reviews. ADLs = activities of daily living; ARAT = Action Research Arm Test; CCT = clinical control trial; CIMT = constraint-induced movement therapy; CVA = cerebrovascular accident; FMA = Fugl-Meyer Motor Assessment; MAL = Motor Activity Log; mCIMT = Modified Constraint Induced Movement Therapy; MP = mental practice; OT = occupational therapy; PT = physical therapy; RCT = randomized controlled trial; STREAM = Stroke Rehabilitation Assessment of Movement; UE = upper extremity.

Table 2. Quality Assessment of Internal Validity of the Clinical and Randomized Clinical Trials With the PEDro Scale (Partitioned)

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<tbody>
<tr>
<td>Internal Validity</td>
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<tr>
<td>1. Random allocation of groups</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<td>2. Concealed allocation</td>
<td>-</td>
<td>-</td>
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<tr>
<td>3. Similar groups at baseline</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>4. Blinding of participants</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>5. Blinding of therapists who provided the treatment</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>6. Blinding of assessors who measured at least one key outcome</td>
<td>-</td>
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<td>+</td>
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<td>7. Measures of at least one key outcome obtained from &gt;85% of participants initially allocated to groups</td>
<td>+</td>
<td>+</td>
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<td>8. All participants for whom outcome measures were available received the condition as allocated or intention to treat</td>
<td>-</td>
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<tr>
<td>Internal validity score total (scored out of 8)</td>
<td>2/8</td>
<td>4/8</td>
<td>2/8</td>
<td>4/8</td>
<td>5/8</td>
<td>2/8</td>
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<td>Statistical Reporting</td>
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<tr>
<td>1. Study provides between-group statistical comparison for at least one outcome measure</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>2. Study provides both point measures and measures of variability for at least one key outcome</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Statistical reporting score total (scored out of 2)</td>
<td>2/2</td>
<td>1/2</td>
<td>2/2</td>
<td>2/2</td>
<td>2/2</td>
<td>2/2</td>
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Note. + = 1 point; – = 0 points.
statistical reporting, the overall scores ranged from 1 to 2; all but 1 study (Page et al., 2001b) scored positively on both items.

In addition to differences in study design and methodologic quality, the studies differed with respect to patient characteristics, intervention protocols, and outcome measures. In terms of patient characteristics, all the studies included participants who had sustained a unilateral right or left cerebrovascular accident. However, stroke onset varied considerably within and across studies from the acute phase (i.e., several days after stroke; e.g., Müller et al., 2007) to the chronic phase (i.e., several years after stroke; e.g., Page, Levine, & Leonard, 2007). Additionally, inclusion and exclusion criteria varied from clearly stated inclusion–exclusion criteria (e.g., Müller et al., 2007; Page, Levine, & Leonard, 2007; Page et al., 2001b, 2005) to practically none stated at all (e.g., Dijkerman et al., 2004). Most studies mentioned did not assess individual participants’ ability to engage in imagery. This issue is important because although it has been suggested that after stroke, many patients retain the ability to mentally represent movements of the impaired limb (Johnson, Sprehn, & Saykin, 2002), it appears that certain brain lesions (e.g., parietal lobe) result in an inability to perform motor imagery (Sirigu & Duhamel, 2001; Sirigu et al., 1996). Additionally, data for healthy participants indicate that imagery ability may affect performance gains (Goss, Hall, Buckolz, & Fishburne, 1986).

Concerning the interventions used, most of the studies combined mental and physical practice, although the exact intervention protocols differed substantially among studies. For example, how the mental practice was facilitated (e.g., audiotape, written instruction, pictures), the imagery perspective used (i.e., internal vs. external), the tasks that were practiced, and the duration and intensity of the practice sessions varied among studies. With regard to how the mental practice was facilitated, studies used audiotaped instructions (Hewett et al., 2007; Page, 2000; Page et al., 2001b, 2005; Page, Levine, & Hill, 2007; Page, Levine, & Leonard, 2007), written instructions (Dijkerman et al., 2004), videotaped instructions (Crosbie et al., 2004; Müller et al., 2007), or visual displays of the less affected limb via a mirror box (Stevens & Phillips Stoykov, 2003) or computer-generated image (Gaggioli et al., 2006). Moreover, it appeared some studies had participants use an internal (i.e., first-person) view (e.g., Müller et al., 2007; Page et al., 2005; Page, Levine, & Leonard, 2007; Simmons et al., 2008), and others had participants use an external (i.e., third-person) view (e.g., Page, 2000; Page et al., 2001a, 2001b). In several studies, the perspective used was not clearly articulated (e.g., Crosbie et al., 2004; Dijkerman et al., 2004; Yoo et al., 2001). Additionally, the studies used various tasks during the mental practice sessions. These tasks included selective finger opposition sequences (Müller et al., 2007), simple wrist and forearm movements (Stevens & Phillips Stoykov, 2003), line tracing (Yoo et al., 2001), and functional reaching and grasping tasks (Crosbie et al., 2004; Dijkerman et al., 2004; Page, 2000; Page et al., 2005; Page, Levine, & Hill, 2007; Page, Levine, & Leonard, 2007). With reference to intensity and duration, RCT studies varied considerably regarding the number of trials or minutes engaged in practice, with participants receiving approximately 4–5 hr of mental practice over a 4-wk (Page, 2000) or 6-wk period (Page et al., 2001b), respectively, at a minimum to a maximum of 21 hr over a 6-wk period (Page et al., 2005).

Most studies used the Fugl-Meyer Motor Assessment (i.e., Gaggioli et al., 2006; Page, 2000; Page et al., 2001a, 2001b; Page, Levine, & Hill, 2007; Page, Levine, & Leonard, 2007; Stevens & Phillips Stoykov, 2003), the Motricity Index (i.e., Crosbie et al., 2004; Simmons et al., 2008), the Jebsen Test of Hand Function (i.e., Müller et al., 2007; Stevens & Phillips Stoykov, 2003), or the Action Research Arm Test (i.e., Gaggioli et al., 2006; Page et al., 2001b, 2005; Page, Levine, & Hill, 2007; Page, Levine, & Leonard, 2007) as primary outcome measures. One study (Hewitt et al., 2007) used a kinematic analysis of functional reaching tasks, and another used outcome measures aimed at complex task function (Dijkerman et al., 2004). The results of most of these primary outcome measures suggest that mental practice has a positive effect on upper-limb recovery at both the impairment (as supported by 3 Level I studies, 2 Level II studies, 1 Level III study, 6 Level IV studies, and 2 Level V studies) and activity limitations levels (as supported by 3 Level I studies, 1 Level II study, 1 Level III study, 3 Level IV studies, and 2 Level V studies). In fact, 7 of the studies showed statistically significant differences favoring mental practice on at least one outcome measure (Crosbie et al., 2004; Dijkerman et al., 2004; Hewett et al., 2007; Müller et al., 2007; Page, 2000; Page et al., 2005; Page, Levine, & Leonard, 2007). Moreover, as can be seen by an examination of the Level I and II studies, it appears that mental practice combined with physical practice yields better outcomes than physical practice alone or conventional therapy (Dijkerman et al., 2004; Müller et al., 2007; Page, 2000; Page et al., 2005; Page, Levine, & Leonard, 2007).

In addition, 4 studies contained outcome measures that assessed the participants’ perception of recovery (Butler & Page, 2006; Dijkerman et al., 2004; Page et al.,
Although not explicitly stated, it appears that those measures were treated as secondary measures. One study found no effect on perceived recovery (Dijkerman et al., 2004), and the other 3 suggested that participants perceived they were using their arm more, had better quality of arm movement, or both (Butler & Page, 2006; Page et al., 2005; Simmons et al., 2008). Interestingly, only 2 studies included a measure of retention (Simmons et al., 2008; Stevens & Phillips Stoykov, 2003). Thus, it is unclear whether the improvements seen as a result of mental practice are retained over time.

Discussion and Implications for Practice, Education, and Research

Most studies have shown that mental practice reduces impairments and improves functional recovery of the upper limb. Thus, it appears to be an appropriate intervention strategy to be used during poststroke rehabilitation. As indicated in previous reviews (e.g., Braun et al., 2006; Sharma et al., 2006), however, given the studies’ heterogeneity, generalizations are difficult to make at this time. Further investigations are needed to determine which people are most likely to benefit from the intervention after stroke, whether the benefits of mental practice are retained over time, and how broad the effects are in terms of improving perceived occupational performance. In addition, it remains unclear what the optimal dosing is regarding the amount of mental practice or the ratio of mental to physical practice needed to obtain a positive effect.

Moreover, it would be of interest to determine whether one type of instruction is more beneficial to facilitating imagery than another and to what extent imagery training before engagement in mental practice is beneficial (Hall, Buckoltz, & Fishburne, 1992). Moreover, although not explicitly stated, all of the studies likely used a combination of visual and kinesthetic imagery modalities, but they may have done so from different imagery perspectives. Unfortunately, imagery modality and perspective are often considered one and the same in the literature, making conclusions regarding their benefits difficult to discern (Callow & Hardy, 2004; Glisky & Williams, 1996). For example, neurorehabilitation literature in the area of mental practice has proposed that the first-person perspective and kinesthetic imagery are synonymous, whereas the third-person perspective corresponds to visual imagery (de Vries & Mulder, 2007).

According to Stevens (2005), a motor representation contains both the kinesthetic and the biomechanical constraints associated with the action, as well as the spatial coordinates of the action. Therefore, the visual imagery modality (i.e., “seeing” your hand move) may be used to represent the spatial coordinates (i.e., distance and location), and the kinesthetic imagery modality (i.e., “feeling” your hand move) may be used to represent the biomechanical constraints (Stevens, 2005). Thus, the use of both visual and kinesthetic imagery during mental practice would appear to be valuable. However, one can engage in both imagery modalities from either perspective. For example, one may be able to “see” or “feel” one’s hand moving from either point of view. The assumption that only the internal perspective is suitable for the generation of kinesthetic imagery appears erroneous and has been questioned in the literature (Callow & Hardy, 2004). In addition, behavioral evidence in healthy people suggests that the imagery modality used (Féry, 2003) and the imagery perspective chosen (Hardy & Callow, 1999; Sirigu & Duhamel, 2001; White & Hardy, 1995) during mental practice may affect task performance differently. Thus, although we agree with the conclusions reached by de Vries and Mulder (2007) regarding the need to determine the benefits of internal versus external motor imagery, we suggest that perspective (i.e., internal vs. external), modality (i.e., visual vs. kinesthetic), and the relationship between the two are separate areas needing further investigation in patient populations.

In summary, although the benefits of mental practice in poststroke rehabilitation appear promising, general conclusions are difficult to make at this time. Further investigation is warranted in terms of appropriate dosing, mode of presentation, the effects of visual and kinesthetic motor imagery, and the effects of imagery perspective during mental practice. In addition, it remains to be determined whether the benefits of mental practice are retained over time and to what degree mental practice affects occupational performance. Although several studies have shown support for the notion that mental practice can reduce upper-limb impairments and increase functional use of the affected limb (e.g., Page et al., 2001b, 2005; Page, Levine, & Leonard, 2007; Müller et al., 2007), none of the studies investigated whether mental practice promotes return to occupational performance as perceived by the participants engaged in the treatment.

Limitations to this systematic review that may threaten the validity of findings include limiting the search to journals published in English, the possibility of missing some studies because of combinations of search terms and terminology used in published papers, and, in general, studies with statistically significant or positive findings being more likely to be published than trials with nonsignificant or negative findings. Finally, the levels of evidence that were used for this
systematic review did not differentiate between large and small RCTs, granting Level I evidence to all RCTs. ▲

References


imagery as a function of muscle contraction types. *International Journal of Psychophysiology, 66*, 18–27. doi: 10.1016/j.ijpsycho.2007.05.009


