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

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

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, Born, 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...
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 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, & MacWalter, 2004; Müller, Bütefisch, Seitz, & Hömberg, 2007), 1 as Level III (Simmons, Sharma, Baron, & Pomeroy, 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>
<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     | 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. | 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     | 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. | 8 participants demonstrated significant improvement on the basis of a 2-band standard deviation method. |
| Dijkerman, Ietswaart, Johnston, & Mac-Walter (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             | 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. | 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 differences |
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)


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)

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 1. Summary of Evidence on Use of Mental Practice to Improve Upper-Limb Recovery After Stroke (cont.)

<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>
<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>Intervention</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 ($p = .002$).</td>
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<tr>
<td></td>
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<td>Participants 16 men</td>
<td>Outcome Measures</td>
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<td></td>
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<td>N = 8</td>
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<td></td>
<td>Control group 8</td>
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<td></td>
<td>Mean age = 63.2</td>
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<td>Mean time since stroke = 1.8 yr</td>
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<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>Intervention</td>
<td>a. Mean change score = 3.8</td>
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<td>Participants 4 men and women</td>
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<td>N = 4</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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<tr>
<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>Intervention</td>
<td>a. Significantly greater changes for the experimental group (10.7) vs. control group (4.6); $p = .004$</td>
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<td></td>
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<td>Participants 11 men and women</td>
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<td>N = 11</td>
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<td>Mean age = 62.3</td>
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<td>Mean time since stroke = 23.8 mo (range = 15–48 mo)</td>
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<td>Both right and left CVAs</td>
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</table>
Both right and left CVAs

### Outcome Measures
- **a.** ARAT (Activity Limitation)
- **b.** MAL (amount of use) (Activity Limitation)
- **c.** MAL (quality of movement) (Activity Limitation)

### Page, Levine, & Leonard (2007)
To compare the efficacy of a rehabilitation program incorporating MP of specific arm movements to a placebo condition

<table>
<thead>
<tr>
<th>Level</th>
<th>RCT</th>
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<tbody>
<tr>
<td><strong>Participants</strong></td>
<td></td>
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<tr>
<td><em>N</em></td>
<td>32 men and women</td>
</tr>
<tr>
<td>Experimental group</td>
<td>16</td>
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<tr>
<td>Control group</td>
<td>16</td>
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<tr>
<td>Mean age</td>
<td>59.5</td>
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<tr>
<td>Mean time since stroke</td>
<td>42 mo (range = 12-174 mo)</td>
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</table>

### Intervention
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.

### Outcome Measures
- **a.** FMA (Impairment)
- **b.** ARAT (Activity Limitation)

- a. Experimental group improved a mean 6.72 points, as compared with 1.0-point changes for the control group (*p* = .0001).
- b. Experimental group improved an average of 7.81 points; the control group improved an average of 0.44 points (*p* < .0001)

### Simmons, Sharma, Baron, & Pomeroy (2008)
To examine the effects of motor imagery training on motor recovery

<table>
<thead>
<tr>
<th>Level</th>
<th>pretreatment–posttreatment single group</th>
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<tbody>
<tr>
<td><strong>Intervention</strong></td>
<td>The intervention consisted of 10 sessions</td>
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(Continued)
Table 1. Summary of Evidence on Use of Mental Practice to Improve Upper-Limb Recovery After Stroke (cont.)

<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>
<tbody>
<tr>
<td>Stevens &amp; Phillips Stoykov (2003)</td>
<td>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</td>
<td>Level IV: Case series</td>
<td>Intervention and Outcome Measures</td>
<td>Results</td>
</tr>
<tr>
<td>Participants</td>
<td>N = 2 (1 man, 1 woman)</td>
<td>(two 20-min periods separated by a 10-min break). The MP consisted of imagining isolated movements, combined functional movements focused on the hand, and combined functional movements including the arm and hand. The actions were first physically demonstrated, followed by the participant physically performing the task with the nonparetic limb (2 repetitions), followed by imagined movements of the nonparetic limb (2 repetitions), and imagined movements of the paretic limb (9 repetitions).</td>
<td>a. Baseline mean = 75.0 (16.3); outcome mean = 78.83 (17.10); follow-up mean = 76.67 (15.88)</td>
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<tr>
<td>Age</td>
<td>76 and 63, respectively</td>
<td></td>
<td>b. Baseline mean = 0.17 (0.15); outcome mean = 0.17 (0.14); follow-up mean = 0.18 (0.11)</td>
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<tr>
<td>Time since stroke</td>
<td>14 mo and 6 yr, 2 mo, respectively</td>
<td></td>
<td>c. Baseline mean = 0.42 (2.95); outcome mean = 0.46 (0.28); follow-up mean = 0.53 (0.31)</td>
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<tr>
<td>Right and left CVAs, respectively</td>
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<td>d. Baseline mean = 1.6 (1.19); outcome mean = 2.28 (1.32); follow-up mean = 2.01 (1.26)</td>
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<tr>
<td>Yoo, Park, &amp; Chung (2001)</td>
<td>To investigate the effect of MP on line-tracing accuracy of people with hemiparesis after stroke</td>
<td>Level IV: Single-case, experimental, multiple-baseline design</td>
<td>Intervention</td>
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<tr>
<td>Participants</td>
<td>N = 3</td>
<td>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.</td>
<td>a. Consistently increased during intervention and modest increases during the 3 follow-up months</td>
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<tr>
<td>Ages</td>
<td>24, 44, and 59 yr</td>
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<td>b. Improved overall</td>
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<td>c. Improved during intervention with minimal decreases at follow-up</td>
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<td>d. 1-point increases during the intervention that diminished during the 1st month postintervention</td>
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<td>e. Decreases in movement time during intervention and generally maintained at follow-up for 3 subtests</td>
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</table>

a. Motricity Index (Impairment)
b. Nine-Hole Peg test (Impairment)
c. Finger tapping ratio (paretic to nonparetic; Impairment)
d. MAL (quality of movement scale) (Activity Limitation)
e. ARAT (Activity Limitation)

b. Grip strength (Impairment)
c. Range of motion (Impairment)
d. Chedoke–McMaster Stroke Assessment (Impairment)
e. Jebsen Test of Hand Function (Activity Limitation)
**Table 2. Quality Assessment of Internal Validity of the Clinical and Randomized Clinical Trials With the PEDro Scale (Partitioned)**

<table>
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<tbody>
<tr>
<td>Internal Validity</td>
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<tr>
<td>1. Random allocation of groups</td>
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<td>+</td>
<td>+</td>
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<td>2. Concealed allocation</td>
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<td>3. Similar groups at baseline</td>
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<td>4. Blinding of participants</td>
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<td>5. Blinding of therapists who provided the treatment</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>
<td>+</td>
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<td>+</td>
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<tr>
<td>7. Measures of at least one key outcome obtained from &gt;85% of participants initially allocated to groups</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8. All participants for whom outcome measures were available received the condition as allocated or intention to treat</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<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>
</tr>
<tr>
<td>Statistical Reporting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Study provides between-group statistical comparison for at least one outcome measure</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<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>
</tr>
</tbody>
</table>

**Note.** + = 1 point; − = 0 points.

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**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. Information in parentheses is the disability dimension according to the World Health Organization's (2001) *International Classification of Functioning and Disability (ICF).*
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 (Croibie 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., Croibie 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 (Croibie 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 period (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., Croibie 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 (Croibie et al., 2004; Dijkerman et al., 2004; Hewitt 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., 2005; Page et al., 2001).
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straints associated with the action, as well as the spatial
contains both the kinesthetic and the biomechanical con-
responds to visual imagery (de Vries & Mulder, 2007).
first-person perspective and kinesthetic imagery are syn-
spective. Unfortunately, imagery modality (i.e., visual vs. kinesthetic), and the relationship
between the two are separate areas needing further inves-
tigation 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


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