Stroke, the leading cause of disability in the United States (American Heart Association, 2004), causes motor deficits that compromise quality of life (Bamford, Dennis, Sandercock, Burn, & Warlow, 1990) and lead to considerable care costs (Dobkin, 1995). However, increased use and function of the more-affected arm have been reported after people with chronic stroke (>1 year after stroke) participated in constraint-induced movement therapy (CIMT) (Miltner, Bauder, Sommer, Dettmers, & Taub, 1999; Taub et al., 1993; Van der Lee et al., 1999; Wolf, LeCraw, Barton, & Jann, 1989). The most well-recognized variant of CIMT has emphasized massed practice with the more-affected upper limb in two ways: (a) participants’ less-affected upper limbs are restricted during 90% of waking hours of a 2-week period, and (b) participants engage in 6-hr activity sessions using their more-affected limbs on the 10 weekdays of the same 2-week period. However, CIMT may be difficult to implement clinically because of its demanding contact time and expense and patients’ lack of compliance and interest (Page, Levine, Sisto, Bond, & Johnston, 2002). Consistent with these concerns, a CIMT trial by Van der Lee and colleagues (1999) stated that most participants found CIMT participation strenuous.

Simple shortening of CIMT contact time has proven to be a straightforward, efficacious solution to CIMT limitations (Pierce et al., 2003; Sterr et al., 2002). The most well-studied example has been modified constraint-induced movement therapy (mCIMT), which combines structured, 30-min, functional practice sessions using the more-affected arm, with restriction of the less-affected upper arm 5 days per week for 5 hr per day, both during a 10-week period. Besides its ability...
to be implemented on an outpatient basis, the mCIMT treatment effect is robust in case studies (Page, Sisto, Johnston, & Levine, 2002; Page, Sisto, & Levine, 2002), in randomized controlled pilot studies that enrolled people who had had acute stroke (Page, Levine, & Leonard, 2005) and subacute stroke (Page, Johnston, Levine, & Hughes, 2001, 2002), and in a randomized controlled study that enrolled people with chronic effects from stroke (Page, Sisto, Levine, & McGrath, 2004). Data suggest that cortical reorganizations, brought about by increased arm use during mCIMT, are responsible for these motor changes (Szaflarski, Page, Kissela, Levine, & Lee, 2005). The clinical portion of mCIMT also has been successfully reimbursed using existing CPT™ (Current Procedural Terminology) codes (e.g., ADL training).

Despite some recent deviations (e.g., Bonifer, Anderson, & Arciniegas, 2005), CIMT and mCIMT protocols have typically required that participants exhibit active extension in their more-affected wrists and fingers to be efficacious. Consequently, patients exhibiting active wrist flexion, but no extension in their affected wrists or fingers, are ineligible for mCIMT programs and often are discharged with residual motor deficits. Recently, mental practice has been shown to increase use of the more-affected arm (Page & Levine, 2005) and function (Page, 2000; Page, Levine, Sisto, & Johnston, 2001a, 2001b) in patients who have had a stroke. Importantly, the above mentioned mental practice studies enrolled patients exhibiting some active flexion in their more-affected wrists, but active extension in the more-affected wrist and fingers was not a requirement. On the basis of the positive outcomes reported in previous mental practice studies, we wondered whether mental practice could be an efficacious “gateway” therapy whereby patients could participate in mental practice, regain some motor function, and then participate in mCIMT.

Previously, mCIMT has been combined with surface electromyography—triggered neuromuscular stimulation (Page & Levine, 2006) to produce gains in patients who would otherwise not be eligible for mCIMT. This study reports on a group of patients with chronic effects from stroke who participated in a mental practice program that increased their more-affected wrist and finger extension. These patients were then eligible for mCIMT and, after mCIMT participation, exhibited additional functional gains.

in this article because of the motor changes they gained from participating in the present study, which resulted in subsequent mCIMT participation and additional motor changes. To initially participate in the mental practice trial, participants had to meet the following inclusion criteria: (a) stroke experienced >1 year before study enrollment, (b) 10° of active flexion in the more-affected wrist, and (c) age >18 years. We also applied the following exclusion criteria: (a) excessive pain in the more-affected arm or wrist as measured by a score of ≥5 on a visual analog scale; (b) being administered medication that impairs neuromuscular performance (e.g., botulinum toxin A); (c) cognitive deficits, as evidenced by a score ≤69 points on the Modified Mini-Mental Status Examination (Teng & Chui, 1987); (d) excessive spasticity in the more-affected upper limb, as defined as a score of ≥4 on the Modified Ashworth Spasticity Scale (Bohannon & Smith, 1987); (e) ability to actively extend the affected wrist; (f) current enrollment in any form of physical rehabilitation; and (g) participation in any other experimental studies.

On the basis of these criteria, 4 participants (3 men, 1 woman) were included (mean age of 62.5 years; range 49–73 years; mean time since stroke = 32.0 months, range 14–63 months; and 4 strokes exhibiting hemiparesis on the dominant side; see Table 1).

### Instruments

The Fugl-Meyer Assessment (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) evaluates several dimensions of impairment, including range of motion, pain, sensation, upper extremity, lower extremity, and balance. Data arise from a 3-point ordinal scale (0 = cannot perform; 2 = can perform fully) applied to each item, and the items are summed to provide a maximum score of 226. The upper-extremity motor component, which consists of 66 points, was used in this study. The Fugl-Meyer Assessment has been shown to have impressive test–retest reliability (total = .98–.99; subscores = .87–1.00), interrater reliability, and construct validity (DiFabio & Badke, 1990; Duncan, Propst, & Nelson, 1983). The Fugl-Meyer Assessment has been used extensively in studies measuring functional recovery in patients who have had a stroke and, according to Gladstone, Danells, and Black (2002), is highly recommended for “use in clinical trials designed to

### Table 1. Participant Characteristics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Months Since Stroke</th>
<th>Side Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>66</td>
<td>63</td>
<td>Right</td>
</tr>
<tr>
<td>Male</td>
<td>62</td>
<td>19</td>
<td>Right</td>
</tr>
<tr>
<td>Male</td>
<td>49</td>
<td>32</td>
<td>Left</td>
</tr>
<tr>
<td>Female</td>
<td>73</td>
<td>14</td>
<td>Right</td>
</tr>
</tbody>
</table>

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**Method**

**Participants**

Participants in the present study were enrolled in a larger clinical trial examining mental practice. They are reported
evaluate changes in motor impairment following stroke” (p. 239).

The Action Research Arm Test (ARA) (Lyle, 1981) is a 19-item test divided into four categories (grasp, grip, pinch, and gross movement), with each item graded on a 4-point ordinal scale (0 = can perform no part of the task; 1 = performs test partially; 2 = completes test but takes abnormally long time or has great difficulty; 3 = performs test normally) for a total score of 57. The test is hierarchical in that, if the patient is able to perform the most difficult skill in each category, he or she will be able to perform the other items within the category and, thus, they need not be tested. The ARA has high intrarater (r = .99) and retest (r = .98) reliability and validity (Lyle, 1981; Van der Lee et al., 2001).

**Design, Pretesting, and Intervention**

A single-blinded, pre- and posttest, case series design was applied. After participants had signed approved consent forms, a research team member administered the Fugl-Meyer scale and the ARA.

Combining physical and mental practice of ADLs is more effective than either mental practice or physical practice alone (McBride & Rothstein, 1979). Therefore, 1 week after the final pretesting session, participants practiced the same set of ADLs, both via physical practice (i.e., therapy for the more-affected arm) and mental practice. Specifically, all participants received therapy for their more-affected arms 2 times per week in 30-min segments for 6 weeks. During therapy sessions, emphasis was placed on performing the ADLs listed in Table 2 bimanually through the entire range of motion, with each activity practiced during the week(s) specified in Table 2. This ADL practice dominated the sessions, and stretching and compensatory exercises were provided as needed to assist patients with the ability to perform the ADLs.

After therapy, participants received the appropriate, tape-recorded mental practice intervention corresponding to the week of therapy in which they were currently engaged. For example, during weeks 1 and 2, patients were practicing reaching for and grasping a cup in therapy while mentally practicing the same ADLs at home and in our laboratory. All mental practice interventions were on audiotape, read by a male psychologist with 10 years’ experience in this area. The interventions consisted of relaxation in the opening 5 min: asking patients to imagine themselves in a warm, relaxing place (e.g., a beach), then asking them to contract and relax their muscles (i.e., progressive relaxation). This portion of the tapes was followed by suggestions for internal, cognitive polysensory images (Paivio, 1985) related to using the more-affected arm in functional tasks listed in Table 2. Using such images, the patient would imagine himself or herself performing the tasks from a “first-person” perspective (as opposed to seeing oneself from a third-person perspective as an outside observer might) while engaging as many senses as possible (e.g., what the movement feels like, what it looks like, what sounds one might hear during the movement). The final 3–5 min allowed patients to refocus into the room. The mental practice tapes were administered directly after each therapy session in our laboratory, with each session of mental practice occurring on days of therapy.

All patients received therapy in the same environment, in the same fashion, and from the same therapists from whom they had received outpatient therapy. Patients had been discharged from this therapy because of a perceived performance “plateau” in which they were not responding to this therapy regimen. Thus, any improvements exhibited in this study would be attributable to the mental practice regimen.

**Results**

Before intervention, participants could minimally flex their wrists and were unable to extend their more-affected wrists or functionally use their more-affected wrists and fingers. Indeed, an ARA mean score of 32.9 was observed before intervention (Table 3), which primarily reflected ability to slowly pick up small items (although insufficient extension prevented grasping larger items on the ARA) and to perform gross movements. Similarly, a mean score of 42.5 on the Fugl-Meyer Assessment was observed before intervention (see Table 3), which reflected intact reflexes; shoulder and elbow movements in synergy; selected flexion and extensor synergies; and partial, selected, volitional movements with little synergy dependence, such as shoulder abduction to 90°. All participants’ more-affected arm function had not changed since outpatient occupational therapy discharge, per their medical records and as confirmed by their physicians.

After mental practice, participants exhibited new active extension in the more-affected wrists and fingers. This movement gain manifested in increased ability to perform ARA items, such as stretching the fingers around objects, and resulted in a new mean ARA score of 37.8 (mean

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**Table 2. Sequences on Each Audiotape and Where and When Tape Was Used**

<table>
<thead>
<tr>
<th>Tape Number</th>
<th>Functional Task Described</th>
<th>Where and When Administered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reaching for and grasping a cup or object</td>
<td>Research lab/Weeks 1, 2</td>
</tr>
<tr>
<td>2</td>
<td>Turning a page in a book</td>
<td>Research lab/Weeks 3, 4</td>
</tr>
<tr>
<td>3</td>
<td>Proper use of a writing utensil</td>
<td>Research lab/Weeks 5, 6</td>
</tr>
</tbody>
</table>
change = +4.9). Patients also exhibited new ability to perform items on the Fugl-Meyer Assessment, such as mass extension (mean score = 46.3; change score = +3.8). Patients and their caregivers each reported high compliance with the mental practice protocol. These claims were supported by participants’ home use diaries administered after pretesting and checked weekly during therapy visits and by weekly telephone calls to their households. Among the 4 participants, only two missed therapy visits were reported, which were due to weather, and no missed mental practice sessions were reported, with mental practice performed for the prescribed duration at home (i.e., patients did not turn their tapes off early or skip portions of the home-based mental practice regimen).

**mCIMT Eligibility**

Each participant now exhibited adequate active wrist extension (20° at the wrist), as well as the requisite 10° active extension in fingers of the more-affected hand, such that they were eligible for mCIMT. Thus, 1 week after mental practice posttesting, mCIMT was described and all participants signed approved consent forms for an ongoing mCIMT trial. The Fugl-Meyer Assessment and ARA were next administered by the same rater who did so before and after mental practice. As in previous mCIMT studies, the clinical portion of mCIMT consisted of 30-min sessions of more-affected arm therapy, concentrating on limb use in functional tasks largely chosen by patients and their treating therapists. Shaping techniques were used, with two to three upper-limb activities chosen by the patients. During the same 10-week period, participants’ less-affected arms were restrained every weekday for 5 hr that had been identified as a time of frequent arm use. Their arms were restrained using a cotton hemi-sling, and their hands were placed in mesh, polystyrene-filled mitts with hook-and-loop fastening straps around the wrist. After 10 weeks, all participants returned to the laboratory, where they were again administered the Fugl-Meyer scale and ARA by the same rater who returned to the laboratory, where they were again administered the Fugl-Meyer scale and ARA by the same rater who administered them before and after mental practice.

Participants’ Fugl-Meyer Assessment and ARA scores before mCIMT were nominally different from Fugl-Meyer and ARA scores at mental practice posttesting, which had occurred just 1 week earlier (see Table 3). After mCIMT participation, patients displayed improved ability to perform Fugl-Meyer Assessment wrist items and hand items, such as hook grasp and 1st and 2nd digit pulpa approximation. As a result, after mCIMT testing, participants exhibited a Fugl-Meyer score of 56.1 (change score = +9.9). A new ability to fully or partially execute ARA items—such as picking up and holding small objects between the thumb and third finger—resulted in a mean change of 8.7 points on the ARA, for a post-mCIMT score of 46.7. Functionally, patients reported new ability to perform valued activities, such as grasping a favorite cup and bringing it to their mouths, playing notes on a piano keyboard, and writing. Patients also returned 3 months after completing the mCIMT intervention; these motor changes were sustained when the Fugl-Meyer Assessment and ARA were again administered.

**Discussion**

Even years after a stroke has occurred, mCIMT increases more-affected arm use and function. Patients, however, must exhibit some active wrist and finger extension to participate, meaning that people who are more impaired are not eligible for this therapy. In other medical disciplines (e.g., cancer, AIDS management), singularly efficacious treatment strategies often are combined to realize a greater effect. The current study examines the efficacy of combining two motor therapy strategies and should increase the number of patients recovering from stroke who could potentially be served by mCIMT.

In our study, before mental practice, patients were only able to actively flex their more-affected wrists; they exhibited no active finger or wrist extension. All of the participants had not received therapy for their more-affected arms in months (and, in 2 cases, years), had been discharged owing to a perceived plateau, and had been told that additional motor improvements were not expected. Participants then practiced the ADL listed in Table 2 during therapy and as part of the mental practice regimen described previously. This regimen resulted in new active movement in the more-affected limb, as shown on the ARA (+4.9) and Fugl-Meyer

| Table 3. Participant Scores Before and After Each Intervention and 3 Months After Intervention |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                           | Mental Practice | mCIMT           | 3-Month Follow-up |
|                                           | Before* | After* | Change | Before* | After | Change | |
| FM                                           | 42.5   | 46.3  | +3.8   | 46.2   | 56.1  | +9.9   | 58.0 |
| ARA                                           | 32.9   | 37.8  | +4.9   | 38.0   | 46.7  | +8.7   | 50.2 |

*These testing sessions occurred 1 week apart.

Note. mCIMT = modified constraint-induced movement therapy; FM = Fugl-Meyer Assessment (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglin, 1975); ARA = Action Research Arm Test (Lyle, 1981); Change = mean change scores, which were computed using the following formula: \[ \text{POST mean} - \frac{\text{PRE-1} + \text{PRE-2}}{2} \]
Assessment (+3.8), which qualified patients for mCIMT. After participating in a 10-week mCIMT regimen, participants showed additional motor changes (+9.9 on the Fugl-Meyer Assessment; +8.7 on the ARA), resulting in new ability to perform valued ADLs. These changes were sustained 3 months after mCIMT completion.

On the basis of results of previous studies (Page & Levine, 2005; Szafirski et al., 2005), we hypothesize that participation in mental practice and mCIMT produced increased use patterns in the more-affected limbs, causing cortical reorganizations and subsequent functional changes. Indeed, after intervention, patients reported performing ADLs with their more-affected hands that they had not done in months, such as manipulating eating and writing utensils and completing various grooming activities (e.g., using a toothbrush).

With these changes noted, the present study would have been strengthened by using additional measures of more-affected limb activity, such as activity monitors. Activity monitors provide objective, quantified measurement of affected limb activity and have measured more-affected limb activity with previous stroke interventions (e.g., Page, Sisto, & Levine, 2002). To overcome this shortcoming, we are examining the functional and neural effects of mental practice and mCIMT using functional magnetic resonance imaging, as well as the impact of these interventions on affected limb use.

Although mCIMT appears promising, the optimal duration of the mental practice component needs to be identified in future work. Indeed, it seems reasonable that stroke patients who exhibit less active movement may require a longer mental practice program with more sessions of longer durations than less impaired patients. Also, it is believed that most motor recovery occurs during the first 6–12 months after stroke (Jorgenson et al., 1995; Parker, Wade, & Langton-Hewer, 1986). However, in this and other studies, patients with chronic effects from a stroke have responded favorably to novel interventions, bringing this precept into question. Clinicians should be cognizant of these findings and should consider combining singularly efficacious modalities, as was done in this study, before discharging patients who have had a stroke.

Finally, although outcomes were marked and in accord with those observed in previous studies of mCIMT and mental practice, a small sample and lack of control group are minor limitations. The lack of a control group is less problematic; patients had supposedly "plateaued" and were not undergoing any other regimens. Given the dramatic changes that they exhibited in a relatively short time, the changes are most likely attributable to the interventions described here. However, it would be beneficial to test this combined technique with more people, which would demonstrate more clearly on which individuals the treatment effect occurs, and how generalizable the treatment effect is to various etiologies of people recovering from stroke.

Clinical Application
After they have had a stroke, patients rely on therapists to assist them with recovery of function. Despite the fact that stroke is the leading cause of disability in the United States, there is limited evidence to support that current therapy interventions are, in fact, benefiting patients. As discussed previously, some evidence supports the precept that patients recover function with clinically practical, outpatient protocols, such as mCIMT and mental practice, which accentuates why these treatments need to be implemented into stroke therapy protocols. Therapists can refer to the research for best practice techniques and also support payment for a patient’s continued treatment if using mCIMT and mental practice.

Neither mCIMT nor mental practice is expensive, inconvenient, or absolutely reliant on an occupational therapist for a patient to participate. A patient can use the techniques during treatment as well as at home. Often patients are willing to work longer and harder than facilities or payment providers allow; therefore, these interventions provide the patient the opportunity to do so without these barriers. These interventions can be used at any phase of the recovery process.

Conclusion
Although mCIMT is a reimbursable regimen improving use and function in more-affected arms, patients must exhibit active extension in the more-affected wrist and fingers to participate in the program, rendering many patients ineligible. Data from this study suggest that mental practice can engender active wrist and finger extension in patients who initially exhibit only limited wrist flexion. In doing so, mental practice can provide a pathway whereby patients can participate in mCIMT; realize additional, sustained motor gains; and again perform valued activities. The present study is one of the first to effectively combine two singularly efficacious regimens to realize greater functional effect in impaired patients who are recovering from stroke.

References


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