A Randomized Controlled Trial of Mental Imagery Augment Generalization of Learning in Acute Poststroke Patients

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Background and Purpose—Our previous studies demonstrated that mental imagery intervention enhanced poststroke patients relearning daily task performance. This study aimed to test the efficacy of mental imagery for promoting generalization of the task skills learned in a training environment to trained and untrained tasks carried out in a novel environment.

Methods—Thirty-five acute poststroke patients were randomly assigned to the mental imagery (MI; n = 18) or conventional functional rehabilitation (FR; n = 17) group. The MI intervention was 3-week standardized practices and daily tasks using the chunking-regulation-rehearsal strategies. Outcome measurements were the performances on trained and untrained tasks in the training and novel environments.

Results—The MI patients showed significantly better performances on 4 of 5 trained tasks (P = 0.001 to 0.026) versus only 1 task in the FR patients (P = 0.021). The MI patients also outperformed their FR counterpart on the 3 (of 5) (P = 0.025 to 0.049) trained and 2 (of 3) untrained tasks (P = 0.042 to 0.045) carried out in the novel environment.

Conclusions—The mental imagery intervention was useful for improving patients’ ability on performing the tasks which they did not previously trained on and in places different from the training environments. These involved generalization of the skills learned at the task performance level. Our findings are limited to poststroke patients who share similar characteristics with those in this study. (Stroke. 2009;40:2222-2225.)

Key Words: mental imagery ■ generalization of learning ■ stroke ■ randomized controlled trial

Recent studies have reported the positive effects of using mental imagery intervention on enhancing relearning of functions among poststroke people.1–3 Our prior event-related potential studies revealed the temporal sequence of the neural processes of imagery which cover generation, visualization, manipulation, and maintenance of the images in the working memory.4–5 In a 3-week program developed by Liu and colleagues, the imagery process, further broken down into chunking, self-regulation, and mental rehearsal, was found to be effective for improving performances of daily tasks for poststroke patients.6–7

Generalization to new situations is an important concept in stroke rehabilitation as, after learning and mastering skills in a restricted environment such as a hospital, patients would need to transfer and apply these skills to new situations such as at home or in other social environments. A recent systematic review by Braun and colleagues8 of 5 Class I clinical studies on mental imagery found that researchers have not yet addressed this issue. This study aimed to investigate the efficacy of mental imagery intervention for enhancing patients to generalize the skills learned in a training to a novel environment.

Patients and Methods
First acute poststroke patients (7 days or longer from onset) admitted to a local rehabilitation hospital and had a unilateral infarction within the middle cerebral artery system were recruited. Patients with brain stem or cerebellar lesions, medical comorbidity, dementia and related types, depression (scores < 7 on the Geriatric Depression Scale – Short Form), and signs of cognitive or communication problems (scores > 7 on the Abbreviated Mental Test) were excluded. Barthel Index (BI) was administered within 1 week after the onset – for measuring the severity of the stroke.9 Patients satisfying the selection criteria were randomized by drawing lots to the mental imagery (chunking-regulation-rehearsal, MI) or functional rehabilitation (demonstration-and-practice, FR) group. The randomization and clinical assessments were conducted by occupational therapists who were not involved in delivering the interventions. Ethics
approval was obtained from the local ethics committees, and patients’ informed consent was obtained.

The interventions were 15 1-hour sessions (daily on weekdays, total 3 weeks) administered by 4 trained occupational therapists—2 for each group. Patients learned a total of 15 daily living tasks (5 per wk; Table 1). The tasks learned in 1 week shared similar complexity and difficulty level, and progressed from the easiest to the most difficult across the 3 weeks.1,7 All tasks were learned in the clinic room of the hospital except for the “Go to canteen” and “Go to park” tasks. The clinic room, the canteen, and the park were referred to as the “training environment.” The MI intervention involved patients truncating the task (chunking), self-reflecting on their abilities and deficits in performing it (self-regulation), feedback (using video playback), mentally rehearsing as if performing it (rehearsal), and then actually carrying the task out.7 The FR intervention was conventional occupational therapy involving the therapist to demonstrate the adapted task performance followed by the patients practicing the tasks under supervision.10 Besides the MI and FR, each patient received 1-hour daily physical therapy—mobilization, strengthening, and walking exercises. The main outcomes were gains in task performances in the 3rd week. The performances were on 8 tasks of similar difficulty level11: 5 trained in the “training environment” (called trained tasks), and 3 tasks not previously exposed for training (called untrained tasks). Performances on the trained tasks were assessed at the beginning and end the 3rd week in the “training environment.” The MI patients had significant increases in scores (median diff. = 1.0 to 2.0) on 4 of the 5 tasks tested in the “training environment”—fry vegetable with meat (P = 0.029), tidy table after meal (P = 0.003), sweep floor (P = 0.001), and go to park (P = 0.026). In contrast, the FR patients showed significant increase (median diff. = 1.0) in only 1 task – go to park (P = 0.021; see Figure ). When these 5 tasks were retested in the “novel simulated environment,” the MI patients performed significantly better than the FR patients on fry vegetable with meat (median diff. = 1.0 and 2.0, P = 0.034), tidy table after meal (median diff. = 2.0; P = 0.025), and go to park (median diff. = 2.0; P = 0.049). In the 3 untrained tasks tested in the “novel simulated environ-

### Table 1. Tasks Used in Training and Testing, and Evaluation Criteria of the Trained and Untrained Tasks

<table>
<thead>
<tr>
<th>Week</th>
<th>Tasks for Training (Trained Tasks)</th>
<th>Training Environment</th>
<th>Novel Simulated Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Put clothes on hanger; fold the laundry; prepare a cup of tea; wash the dishes; carry out money transaction</td>
<td>Pre- and posttest of the same trained tasks in Week 3</td>
<td>Posttest only of the same trained tasks in Week 3</td>
</tr>
<tr>
<td>2</td>
<td>Prepare fruit; make the bed; take medication; use the telephone; see the doctor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sweep the floor; tidy the table after a meal; fry vegetables with meat; go to a park / outdoors; go to the canteen</td>
<td>Untrained tasks: cook vegetable soup; clean refrigerator; go to resource centre</td>
<td></td>
</tr>
</tbody>
</table>

**Score Descriptions**

1. Total assistance (unable to perform 25% or more of task)
2. Maximal assistance (perform 25% to 49% or more of task)
3. Moderate assistance (perform 50% to 74% of task)
4. Minimal assistance (perform 75% or more of task)
5. Supervision (perform task under a person’s supervision)
6. Modified independence (perform task independently with use of a device)
7. Complete independence (perform task in a timely and safe manner)

"Training environment" was the clinic room with basic furniture of 1 table, 2 plinths, and 3 chairs; “novel simulated environment” was a simulated living setting made up of the indoor environment—a home-like flat set up in the hospital, and an outdoor environment—a park near to the hospital, and a canteen inside the hospital campus, though not the one used during training.

The interrater reliability of the task items was: r = 0.89–0.98 and κ = 0.54–0.72.

### Results

Thirty-five patients were recruited (MI: n = 18; FR: n = 17). One patient assigned to the MI group dropped out after the screening because of persistent fever and an unstable medical condition, and another patient who completed the MI intervention was excluded from analysis because the identified brain lesion was not located within the middle cerebral artery system. This resulted in 16 and 17 patients in the MI and FR groups, respectively. No significant differences were found in the background factors between the 2 groups (P > 0.050; Table 2). Their BI scores indicated that they required moderate assistance in self-care tasks before commencing the interventions.

At the 3rd week baseline, no significant differences in the task performances between the 2 groups (P = 0.168 to 0.986). By end of the 3rd week, the MI patients had significant increases in scores (median diff. = 1.0 to 2.0) on 4 of the 5 tasks tested in the “training environment”—fry vegetable with meat (P = 0.029), tidy table after meal (P = 0.003), sweep floor (P = 0.001), and go to park (P = 0.026). In contrast, the FR patients showed significant increase (median diff. = 1.0) in only 1 task – go to park (P = 0.021; see Figure ). When these 5 tasks were retested in the “novel simulated environment,” the MI patients performed significantly better than the FR patients on fry vegetable with meat (median diff. = 1.0 and 2.0, P = 0.034), tidy table after meal (median diff. = 2.0; P = 0.025), and go to park (median diff. = 2.0; P = 0.049). In the 3 untrained tasks tested in the “novel simulated environ-

### Statistical Analysis

For gains in the performances on the trained task tested in the “training environment,” Wilcoxon sign-rank test was used. For group differences in the performances tested in the “novel simulated environment,” Mann–Whitney U test was used. Spearman rho correlation was used to explore the relationships between severity of stroke (measured by Barthel Index at admission) and task per-
ment,” the MI patients outperformed the FR patients on clean refrigerator (median diff. 1.5; \(P=0.042\)), and go to resource center (median diff. 1.0; \(P=0.045\)). The task scores were found to mostly correlate with the BI scores in the FR patients (rho=0.76 to 0.89 for the trained tasks and 0.76 to 0.936 for the untrained tasks, \(P<0.001\)). In contrast, the correlations in the MI patients was largely not significant except for the go to canteen task (rho=0.53, \(P=0.036\)).

**Discussion**

The 3-week MI intervention was found to enhance patients’ performances on the trained and untrained tasks, particularly when they tested in the novel environment. Further analysis indicated that the task performances largely did not relate to the severity of the stroke (measured by BI). In contrast, performances of the FR patients related substantially to the severity. These prompted us to take the view that the better performances demonstrated by the MI patients were attributable to the chunking-regulation-rehearsal strategy learned and practiced in the intervention.

The therapeutic effects of MI perhaps can be illustrated by the “go to canteen” and “go to park” tasks. These 2 tasks both required mobility, forming cognitive mapping of route, and commuting between different locations. “Go to park” involved leaving the hospital building to outdoor spaces with which the patients were less familiar. This would demand more planning (chunking-regulation-rehearsal) before actual execution than that of “go to canteen.” The FR patients did not gain significantly after the training on “go to canteen.” The MI patients showed some improvements in performances on this task but not reaching a statistical significance. In “go to park,” the MI patients showed improvements and per-

| Table 2. Characteristics of Patients Completing the FR and MI Interventions |
|-----------------|-----------------|-----------------|
|                 | FR (n=17)       | MI (n=16)       |
| Age, y          | 69.7±7.4        | 70.8±9.3        |
| Gender          |                 |                 |
| M, %            | 12 (70.6)       | 8 (50.0)        |
| F, %            | 5 (29.4)        | 8 (50.0)        |
| Days since stroke at inclusion | 12.3±7.4        | 12.2±5.1        |
| Location of stroke |               |                 |
| Left hemisphere, % | 5 (29.4)        | 4 (25.0)        |
| Right hemisphere, % | 12 (70.6)      | 12 (75.0)       |
| AMT, score      | 8.4±1.4         | 8.4±1.5         |
| GDS, score      | 2.6±2.5         | 2.1±2.4         |
| Barthel Index (at admission), score | 40.41±24.26     | 38.12±14.05     |

Values are means±SDs. FR indicates functional rehabilitation; MI, mental imagery; AMT, abbreviated mental test; GDS, geriatric depression scale–short form.

**Figure.** Within- and between-group comparisons of the 8 daily tasks (median scores). FR indicates functional rehabilitation; MI, mental imagery. All within-group comparisons are between the 3rd week pre- and posttest performances on the trained tasks conducted in the training environment. Between-group comparisons are on the performances of the trained and untrained tasks conducted in the novel simulated environment. *\(P<0.050\).
formed equally well in both the trained and novel environments. In contrast, the improvements gained by the FR patients after training declined substantially (median diff = −2.0) when tested in a new location. These findings support our proposition that the MI intervention can enhance skills generalization, especially in an environment that is unpredictable and continuously changing such as in outdoor and community reintegration.

Generalization can occur at the motor control level such as in synergies of muscle contraction and limb movements\textsuperscript{12–13} or the task performance level. Previous studies on motor control indicated that generalization was commonly observed in the same workspace and limb segments. The generalization studied in this study is at the task performance level of which use of mental strategy for skill transfer is deemed important.

There are several limitations in this study. The results cannot be generalized to patients having brain lesions and levels of cognitive and emotional functions different from those in this study. The relatively small sample size, use of behavioral test which is less sensitive, and lack of follow-up assessments call for cautious interpretation of the findings. The benefits of the MI intervention can be further enhanced by having patients choose their own tasks or including more diverse tasks for training in the program. Telephone follow-ups to reinforce patients using MI at home and in the community can also be useful.

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None.

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