Effects of Constraint-Induced Therapy Combined With Eye Patching on Functional Outcomes and Movement Kinematics in Poststroke Neglect

Ching-Yi Wu, Tien-Ni Wang, Yu-Ting Chen, Keh-Chung Lin, Yi-An Chen, Hsiang-Ting Li, Pei-Luen Tsai

OBJECTIVE. We investigated the effect of constraint-induced therapy (CIT) plus eye patching (EP), CIT alone, and conventional treatment on functional performance, eye movement, and trunk–arm kinematics in stroke patients with neglect syndrome.

METHOD. Twenty-four participants were recruited and randomly allocated to three intervention groups. All participants received intervention 2 hr/day, 5 days/wk, for 3 wk. Outcome measures included the Catherine Bergego Scale, eye movement, and trunk–arm kinematic analysis.

RESULTS. The CIT + EP and CIT groups demonstrated larger improvements in functional performance than the control group. The CIT group showed better performance with left fixation points than the CIT + EP group and shorter reaction time than the control group. The CIT + EP group improved more in preplanned control and leftward trunk shift than the other two groups.

CONCLUSION. CIT + EP and CIT were more effective interventions than conventional treatment of patients with neglect syndrome in daily functional performance.

Stroke is one of the most common causes of long-term disability in adults (Brainin, Teuschl, & Kalra, 2007). Survivors usually present with persistent physical, cognitive, and psychological impairments (Kwakkel, Kolles, Van der Grond, & Prevo, 2003; Nakayama, Jorgensen, Raaschou, & Olsen, 1994). They often face difficulties in performing daily activities and restrictions in participating in life situations and thus have a reduced quality of life (Lai, Studenski, Duncan, & Perera, 2002).

Among impairments after stroke, unilateral neglect, which is recognized as a significant disabling deficit, is clinically defined as a failure to report, respond, or orient to novel stimuli presented on the side opposite to a brain lesion (Heilman & Valenstein, 2003). This symptom heightens the risk and difficulty for patients in executing their activities of daily living (ADLs; Jehkonen, Laihosalo, & Kettunen, 2006) from the perception and motor aspects and further affects movement performance such as eye movement and trunk–arm reaching. Active occupational therapy is important for neglect rehabilitation, and relevant treatment regimens may include constraint-induced therapy (CIT) and eye patching (EP; Freeman, 2001).

CIT has been reported to be the most effective technique for hemiparesis rehabilitation (Taub, Uswatte, & Pidikiti, 1999; Wu, Chen, Tang, Lin, & Huang, 2007). CIT combines restraint of the unaffected upper limb for an extended period with repetition of task-specific intensive training of the affected upper limb (Wolf et al., 2006) and was developed to overcome the nonuse...
phenomenon that results from the difficulty of using the affected limb (Mark & Taub, 2004).

Theoretically, CIT also has some implications for the treatment of neglect (Freeman, 2001). Many people with unilateral neglect may have learned nonuse of the affected extremity because of motor or personal neglect rather than because of the weakness associated with corticospinal damage (Heilman & Valenstein, 2003). CIT sessions force the client to use the affected extremity. Active movement of the affected extremity, especially in the affected hemispace, could reduce the manifestations of neglect (Robertson & North, 1993).

The only practical evidence to date has been reported by van der Lee et al. (1999). Their findings suggested that patients with unilateral neglect who received treatment that forced the use of the affected extremity showed greater improvement on the Motor Activity Log scale (MAL; Taub et al., 1993) than those who received traditional rehabilitation using neurodevelopmental techniques. However, previous research has focused on the effects of CIT on motor and functional outcomes, and the potential benefits of CIT for improving unilateral neglect after stroke remain underinvestigated.

The EP technique, which is inexpensive and practical to use, has been advocated as a treatment for neglect (Beis, André, Baumgarten, & Challier, 1999). EP is based on the use of anatomical, physiological, and psychophysical models (Arai, Ohi, Sasaki, Nobuto, & Tanaka, 1997; Butter & Kirsch, 1992) and can be incorporated into conventional treatment approaches. This technique blocks visual stimuli projected from the ipsilesional (right) visual field into the intact (left) hemisphere; the remaining contralesional (left) visual field induces the superior colliculus in the lesional (right) side to generate saccadic eye movements toward the contralesional, neglected (left) side, which in turn induces the patient to shift eye movements and attention toward the contralesional hemispace (Beis et al., 1999).

Previous studies of EP as an intervention for unilateral neglect have reported varying results. Zeloni, Farnè, and Baccini (2002) and Tsang, Sze, and Fong (2009) found significant improvements in performance on neglect tests after treatment in a half-field EP group compared with a control group. Improvements in daily function after treatment were also obtained by Arai et al. (1997) and Beis et al. (1999). Fong et al. (2007) tried to integrate an EP intervention with motor-intention strategies for neglect syndrome. They conducted a randomized controlled trial to compare the effectiveness of three interventions: experimental training in voluntary trunk rotation (TR), TR with half-field EP, and conventional rehabilitation training.

Their results showed no significant differences among TR, TR and EP, and control participants in functional performance or on neglect measures. A possible explanation was that voluntary TR, as initiated by the ipsilesional (right) hand in the Fong et al. study, might abolish the advantage of left limb activation. To reduce the confounding of ipsilesional limb activation, the CIT approach might be an alternative.

Applying combinations of different neglect treatments may increase therapeutic benefits (Saevarsson, Halsband, & Kristjánsson, 2011). The potential benefits of the combined approach warrant empirical scrutiny. No study to date has integrated CIT and EP to examine their effects on the functional performance of patients with neglect, although these two treatments can easily be combined and applied in a clinical environment. The purpose of this study, therefore, was to investigate the relative effects of the combined CIT–EP treatment versus CIT alone versus a control group receiving conventional training.

The goal was to find out whether significantly larger benefits would be obtained from the combined therapy or CIT alone than from conventional training in enhancing functional performance and reducing neglect-related behaviors, including bias in eye movement and trunk–arm movement.

Method

Research Design

This study had a single-blinded, randomized pretest and posttest control-group design. Eligible participants were randomized into three rehabilitation groups: CIT + EP, CIT alone, and conventional rehabilitation. Institutional review board approval was obtained from all of the clinical settings for this project, and informed consent was obtained from the participants.

Participants

We recruited stroke patients with neglect from eight medical centers and rehabilitation clinics. Participant inclusion criteria were as follows:

- A right-side cerebral stroke
- Neglect syndrome as shown by results on two or more of four tests (double simultaneous stimulation test [Stone, Halligan, Wilson, Greenwood, & Marshall, 1991], line bisection test [Schenkenberg, Bradford, & Ajax, 1980], random shape cancellation test [Weintraub & Mesulam, 1988], and the random Chinese word cancellation test [Chen Sea, Henderson, & Cermak, 1993])
• Ability to reach Brunnstrom’s Stage II or higher for the proximal and distal upper extremity (UE; Brunnstrom, 1970)
• Considerable nonuse of the more affected UE (MAL amount of use score <2.5; Taub et al., 1993)
• No excessive spasticity in the affected arm, including shoulder, elbow, wrist, and fingers (Modified Ashworth Scale score ≤2 in any joint; Bohannon & Smith, 1987)
• No severe cognitive impairment by showing awareness and ability to respond to oral instructions (Folstein, Folstein, & McHugh, 1975)
• No severe impairment of visual acuity after rectification
• No participation in any experimental rehabilitation or drug studies during the study period.

Eligible participants were randomly assigned to CIT + EP, CIT, or conventional intervention in accordance with a random number table. When a new participant was enrolled, the study coordinator gave a sealed opaque envelope identifying the participant’s group to the therapists, and they were informed of the group allocation and delivered therapy accordingly.

Interventions

All participants received 2 hr of therapy, 5 days/wk for 3 wk, with one-to-one supervision. The interventions were provided at the participating hospitals by occupational therapists who were trained in the administration of the three protocols by the investigators and who completed a written competency test before they administered treatment. The treating therapists were not blinded to group allocation. All other routine rehabilitation, such as physical therapy or speech therapy, proceeded as usual.

CIT + EP group. The participants in this group received CIT + EP. CIT addressed forced use of the affected UE and restricted the unaffected UE during training. Shaping skills were delivered while participants were forced to use their affected UE in the mass practice of functional tasks such as drinking water and opening a jar. Participants wore a mitt on their unaffected hand and wrist for 6 hr/day during the 3-wk training and reported their compliance in a daily log. Home skill activities were assigned to promote this training in daily life, and problems were discussed to aid participants in overcoming barriers they encountered. Participants were also asked to wear glasses with a patch on the right lens to block the visual stimuli from the right side and force them to receive the stimuli from the left visual field.

CIT group. The intervention in the CIT group resembled the intervention in the CIT + EP group, except participants did not wear the EP glasses.

Control group. The control group received traditional occupational therapy matched in intensity and duration with that of the other groups. The training program for the affected UE included stretching and weight bearing, improving range of motion, muscle strengthening, and practicing of tasks used for functional training that might involve the unaffected UE assisting the affected UE, for example, stabilizing a bottle while opening its lid or moving pegs into holes on a board.

Primary Outcome Measure: Catherine Bergego Scale

The Catherine Bergego Scale (CBS; Bergego et al., 1995) is a checklist designed to examine the effect of neglect syndrome on a patient’s daily function in 10 real-life situations, such as grooming, dressing, or maneuvering a wheelchair. The scale involves observing and evaluating the patient’s functional performance in daily life. Each item is rated on a 4-point scale (range = 0–3 points). Patients with a total score of 0 are considered as not being affected by neglect syndrome in performing daily activities. Rasch statistical analysis has suggested that the construct of the CBS is homogeneous (Azouvi et al., 2003). The CBS has also been reported to have good interrater reliability (Spearman r = .96, p < .01) and fair to good concurrent validity compared with conventional paper-and-pencil tests (Pearson rs = .54–.76, p < .01; Azouvi et al., 2003; Bergego et al., 1995).

Secondary Outcome Measures

Eye movement analysis and eye movement variables. The ClearView 2.0 eye tracker system (Tobii 1750, with 1024 × 768 resolution and 30-Hz sampling rate; Tobii Technology, Danderyd, Sweden) was used to record the participant’s eye movement by detecting his or her pupil. During the experimental trials, the participant sat in a comfortable position in front of the system with his or her head stabilized on a chin rest. The line bisection test (Schenkenberg et al., 1980) was used during the trials to acquire the eye movement data, and participants were asked to mark the middle of a 24-cm-long and 1-mm-wide line. After a calibrating procedure and a practice trial, the participant performed the line bisection test for three data-collecting trials.

The abnormal eye movement pattern in patients with neglect might be characterized by a rightward initial fixation point, a gradient decrease of fixation points toward the contralesional side, and shorter duration of a single fixation point on the affected side (Behrmann, Watt, Black, & Barton, 1997). To examine the possible improvement in abnormal eye movement after the intervention, the eye movement parameters included the fixation amplitude...
(the distance between the leftmost and the rightmost fixation points), the number of fixation points, and the fixation time in the left area, as assessed by left fixation points and left fixation time. A fixation point is defined as where the gaze point stays in 50 pixels on the screen over 30 ms and can be screened by a fixation filter function in the ClearView 2.0 program. Wider fixation amplitude, larger left fixation points, and longer left fixation time represent the alleviated syndrome of neglect.

Kinematic analysis and kinematic variables. We used kinematic analysis to detect UE and trunk movement. The kinematic task required the participant to use the index finger of his or her unaffected UE to press a task bell as quickly as possible. The bell (3 cm long × 3 cm wide × 0.5 cm high) was placed at the distance of 90% of the arm length (as measured from the acromion to the third fingertip) along the participant’s affected side. The purpose of having the participant use the unaffected UE to press the bell was to decrease the effects of the impairment of the affected UE on the possible benefits of alleviated neglect syndrome resulting from the three interventions. Each participant sat in a height-adjustable chair, with the hand initially positioned on the edge of an adjacent table and the elbow flexed at 90°. After a practice trial, the participant reached to press the bell for three data-producing trials. Only the reaching phase of the movement was analyzed.

A seven-camera motion analysis system (VICON MX; Oxford Metrics Inc., Oxford, England) was linked to a personal computer to capture the movement of markers. Reference markers were placed on the seventh cervical vertebra (C7), the fourth thoracic vertebra (T4), bilateral clavicles, mid-sternum, unaffected side of the acromion, middle of the humerus, lateral epicondyile, styloid process of the ulna and radius, and index nail. Movement onset was defined for each trial using the time at which the tangential index velocity was 5% higher than its peak value. Movement offset was defined as the bell being pressed, indicated by the digital signal connected to the computer. Movements were recorded at 120 Hz and digitally low-pass-filtered at 5 Hz using a second-order Butterworth filter with dual passes.

To demonstrate the possible change after intervention, kinematic variables included reaction time, normalized movement time, normalized total distance, percentage of movement time during which peak velocity (PPV) occurred, and trunk lateral shift.

- **Reaction time**, which indicates the temporal efficiency for generation or planning of the motor action, is the interval from the start signal to movement onset (Brooks & Watts, 1988).
- **Movement time**, representing temporal efficiency, refers to the total duration of the reaching movement (Wu, Lin, Chen, Chen, & Hong, 2007).
- **Total distance**, representing spatial efficiency, refers to the path of the hand in three-dimensional space (Wu et al., 2007). Because of the varied task distance across participants, movement time and total distance were normalized by the direct distance between the hand at the start position and the target for each participant. The smaller normalized total distance shows the more direct movement path.
- **PPV**, reflecting the percentage of movement time used for the acceleration phase, characterizes the control strategy of reaching. A higher PPV value indicates less online error correction and more planned control of the reaching movement (Georgopoulos, 1986).
- **Trunk lateral shift** shows the change in trunk movement in the horizontal plane between the start and the end position. A larger value represents more trunk left shift.

Data Collection

Three certified occupational therapists blind to group allocation were trained to provide the evaluations before and after a 3-wk intervention. The same rater administered all the study measurements to each participant at baseline and after the 3-wk intervention. The training for the clinical assessment tool included careful examination of written instructions and repeated practice. The training for conducting the kinematic analysis was based on standardized procedures, described earlier. Rater competence for performing kinematic and clinical evaluations was assessed by the senior authors of this study (Keh-Chung Lin and Ching-Yi Wu). The intrarater reliability for the clinical measure was high (intraclass correlation coefficient = .92).

Data Analysis

We analyzed the data using SPSS 15.0 software (SPSS Inc., Chicago). To control for differences among groups in baseline performance, we used analysis of covariance (ANCOVA) to examine the relative effects of the treatment groups for each variable. The pretest score was the
covariate, group was the independent variable, and the posttest score was the dependent variable. We conducted post hoc Fisher’s least significant difference tests (Portney & Watkins, 2008). To index the magnitude of group differences in performance, we calculated \( \eta^2 = \frac{SSb}{SStotal} \) (between-group sum of squares/total sum of squares) for each outcome variable (Rosenthal & Rosnow, 1991). A large effect is represented by a \( \eta^2 \) of \( \geq .14 \), a moderate effect by \( \eta^2 = .06 \), and a small effect by \( \eta^2 = .01 \) (Cohen, 1988).

**Results**

We recruited 27 participants. Two participants in the CIT + EP group and 1 in the CIT group dropped out before completing the posttest. Consequently, we analyzed data for 7 participants in the CIT + EP group, 8 in the CIT group, and 9 in the control group. All baseline characteristics were comparable among these three groups, and no preexisting statistically significant differences were found among the three groups for any of the outcome measures. See Figure 1 for a diagram of participant flow through the study.

**Participant Characteristics**

All demographic and clinical characteristics of the participants were comparable and are summarized in Table 1. No preexisting statistically significant differences were found among the three groups on any of the outcome measures.

**Primary Outcome Measure: CBS**

The CBS results achieved statistical significance and a large effect size (Table 2). Poor functional performance was considered to be alleviated in the CIT + EP (\( p < .01 \)) and CIT (\( p = .02 \)) groups after the intervention compared with the control group.

**Secondary Outcome Measures: Eye Movement Analysis and Kinematic Analysis**

The left fixation points represented a significant and large effect among the three groups (Table 2). Post hoc analyses showed that the CIT (\( p = .03 \)) and control groups (\( p = .02 \)) exhibited a greater total number of left fixation points than the CIT + EP group. Differences in the fixation amplitude and left fixation time were not significant.

The ANCOVA results showed significant differences in reaction time, PPV, and trunk lateral shift (Table 2). Post hoc analyses revealed that only the CIT group had more improvements in reaction time than the control group (\( p = .01 \)). However, the CIT + EP participants showed more preplanned control of the reaching movement than the CIT group (\( p = .02 \)) and control group (\( p = .01 \)), as represented by a higher PPV. The CIT + EP group also showed greater trunk lateral shift to left than the CIT group (\( p = .01 \)), but we noted no significant difference between the CIT and control groups.

**Discussion**

This study is the first randomized controlled trial to investigate the effectiveness of CIT + EP in stroke patients with neglect syndrome versus CIT alone and the control intervention. The findings of this study are intriguing: CIT + EP and CIT alone both improved daily function, as measured by the CBS, more than the control intervention. In addition, the CIT intervention was more beneficial in increasing the left fixation points than the
CIT + EP intervention and in shortening the reaction time than the control intervention. In contrast, the CIT + EP treatment demonstrated effectiveness in forming feed-forward motor control strategy and ameliorating rightward trunk leaning in patients with neglect syndrome. These findings indicate that CIT + EP and CIT have differential benefits on different manifestations of the neglect syndrome.

Consistent with our hypothesis, the CIT + EP and CIT participants had significantly larger improvements in daily function than the control participants, as assessed with the CBS. These findings are consistent with those of previous studies that showed that CIT improved functional outcomes, including enhancing function of the affected hand in daily life (Page, Levine, Leonard, Szaflarski, & Kissela, 2008; Taub et al., 2006) and the level of

Table 1. Demographic and Clinical Characteristics of the Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>CIT + EP (n = 7)</th>
<th>CIT (n = 8)</th>
<th>Control (n = 9)</th>
<th>Test statistic&lt;sup&gt;a&lt;/sup&gt;</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean ± SD</td>
<td>56.1 ± 14.5</td>
<td>65.5 ± 9.8</td>
<td>61.33 ± 11.2</td>
<td>1.2</td>
<td>.33</td>
</tr>
<tr>
<td>Gender, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>Handedness, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months since stroke, mean ± SD</td>
<td>13.0 ± 13.9</td>
<td>10.1 ± 10.4</td>
<td>13.7 ± 14.1</td>
<td>.02</td>
<td>.84</td>
</tr>
<tr>
<td>MMSE, mean ± SD</td>
<td>26.4 ± 1.0</td>
<td>24.1 ± 5.5</td>
<td>23.9 ± 4.2</td>
<td>.9</td>
<td>.44</td>
</tr>
<tr>
<td>Line bisection test, LI, mean ± SD</td>
<td>0.07 ± 0.08</td>
<td>0.08 ± 0.04</td>
<td>0.06 ± 0.06</td>
<td>.2</td>
<td>.87</td>
</tr>
<tr>
<td>DSS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.08</td>
</tr>
<tr>
<td>Extinction</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonextinction</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape Cancellation test</td>
<td>0.42 ± 0.10</td>
<td>0.34 ± 0.21</td>
<td>0.44 ± 0.08</td>
<td>1.2</td>
<td>.32</td>
</tr>
<tr>
<td>Word Cancellation test</td>
<td>0.45 ± 0.07</td>
<td>0.46 ± 0.03</td>
<td>0.29 ± 0.24</td>
<td>3.2</td>
<td>.07</td>
</tr>
</tbody>
</table>

Note. CIT = constraint-induced therapy; CIT + EP = CIT with eye patching; DSS = double simultaneous stimulation test; LI = laterality index; M = mean; MMSE = Mini-Mental State Examination; SD = standard deviation.

<sup>a</sup>The ×<sup>2</sup> test was used for categorical variables and analysis of variance for continuous variables.

Table 2. Descriptive and Inferential Statistics for the Eye Movement and Arm–Trunk Movement Tasks

<table>
<thead>
<tr>
<th>Variables</th>
<th>CIT + EP (n = 7), M ± SD</th>
<th>CIT (n = 8), M ± SD</th>
<th>Control (n = 9), M ± SD</th>
<th>ANCOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBS</td>
<td>16.1 ± 3.2</td>
<td>10.4 ± 3.2</td>
<td>13.9 ± 4.8</td>
<td>9.9 ± 4.4</td>
</tr>
<tr>
<td>Secondary outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye movement variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude, cm</td>
<td>15.0 ± 6.5</td>
<td>12.5 ± 4.2</td>
<td>12.6 ± 7.1</td>
<td>17.1 ± 5.4</td>
</tr>
<tr>
<td>Left fixation points, n</td>
<td>9.1 ± 5.6</td>
<td>4.8 ± 2.8</td>
<td>6.5 ± 2.6</td>
<td>8.0 ± 5.0</td>
</tr>
<tr>
<td>Left fixation time, ms</td>
<td>2,537.8 ± 1,794.2</td>
<td>1,437.2 ± 923.3</td>
<td>1,560.7 ± 641.8</td>
<td>2,214.0 ± 1,168.0</td>
</tr>
<tr>
<td>Arm–trunk movement variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction time, s</td>
<td>0.40 ± 0.44</td>
<td>0.38 ± 0.05</td>
<td>0.58 ± 0.44</td>
<td>0.38 ± 0.15</td>
</tr>
<tr>
<td>NMT</td>
<td>0.02 ± 0.01</td>
<td>0.01 ± 0.00</td>
<td>0.03 ± 0.04</td>
<td>0.01 ± 0.00</td>
</tr>
<tr>
<td>NTD,</td>
<td>1.06 ± 0.04</td>
<td>1.06 ± 0.04</td>
<td>1.09 ± 0.03</td>
<td>1.06 ± 0.02</td>
</tr>
<tr>
<td>PPV, %</td>
<td>44.1 ± 6.6</td>
<td>51.7 ± 7.8</td>
<td>43.9 ± 12.8</td>
<td>42.0 ± 5.8</td>
</tr>
<tr>
<td>Trunk lateral shift, mm</td>
<td>0.3 ± 0.8</td>
<td>10.9 ± 14.2</td>
<td>0.8 ± 0.3</td>
<td>3.0 ± 1.0</td>
</tr>
</tbody>
</table>

Note. ANCOVA = analysis of covariance; CBS = Catherine Bergego Scale; CIT = constraint-induced therapy; CIT + EP = CIT with eye patching; df = degrees of freedom; M = mean; NMT = normalized movement time; NTD = normalized total distance; PPV = percentage of movement time during which peak velocity occurs.

<sup>*p < .05.</sup>
independence, as measured by MAL and FIM™ (Hamilton, Granger, Sherwin, Zielezny, & Tashman, 1987; Lin, Wu, Wei, Lee, & Liu, 2007; Wu, Lin, et al., 2007).

Apart from the measurement tools used in previous studies, we used the CBS to examine functional performance in patients with neglect after CIT + EP or CIT. The CBS indicates the degree of neglect syndrome affecting functional performance. Lower CBS scores among CIT + EP and CIT participants suggest that daily function improved, possibly as a result of relief of the neglect syndrome and advanced ability to perform ADLs with more attention to the left side. These positive findings could be explained by the spatiomotor cueing and the hemispheric arousal mechanism.

CIT directs patient attention and effort toward the hemiparetic arm and excludes the use of the unaffected contralateral limb (Freeman, 2001; Taub et al., 1999). Using these principles in the CIT + EP and CIT groups, the movements performed by the affected limb might act as a cue to strengthen the connection between spatial and personal coordination and enhance the body’s representation in the left personal space (Robertson, McMillan, MacLeod, Edgeworth, & Brock, 2002). The movements of the affected hand also activated the motor and associated attentional circuits of the damaged right hemisphere to attend to the left side (Rizzolatti & Gallese, 1988). As the body–spatial integration and leftward attention shifting are improved, the neglect syndrome might be ameliorated. Moreover, the CIT principle emphasizes repetitive and mass practice of functional tasks in accordance with a patient’s ability, and functional performance is promoted as a consequence. These findings also extend the results of studies of EP treatment in which EP reduced neglect syndrome (Beis et al., 1999; Tsang et al., 2009; Zeloni et al., 2002) but did not increase functional independence (Tsang et al., 2009).

Regarding the result of eye movements, CIT group participants showed larger numbers in left fixation points than the CIT + EP participants, indicating that CIT was able to shift attention toward the left side in patients with neglect. A scrutiny of the descriptive data showed that the CIT + EP intervention resulted in deterioration of eye fixation point performance after treatment. We speculate that patients with the subtypes of sensory–attentional or motor–intentional neglect might have had differential responses to EP. EP might worsen neglect syndrome among patients with sensory–attentional neglect but not among those with motor–intentional neglect (Barrett, Crucian, Beversdorff, & Heilman, 2001). Because we did not separate the neglect patients into the neglect subtypes, the possible beneficial effects in a certain type of neglect syndrome might not be revealed. Future research might recruit patients with specific types of neglect to examine the effects of CIT + EP.

In the analysis of the intervention effect on kinematic performance in the reaching task, the CIT group showed a larger improvement in reaction time than the control group, and the CIT + EP group had better performance in PPV and trunk lateral shift than the CIT and control groups. Krakauer, Pine, Ghilardi, and Ghez (2000) suggested that repetitive practice could help reduce the reaction time for preplanning a motor task. The CIT principle emphasizes massive practice of affected limbs, which induces more efficient preplanning of movements and, thus, reduces the reaction time in reaching to press the task target (Desmurget & Grafton, 2000; Wu, Chen, et al., 2007). In the CIT + EP group, however, the EP glasses occluded half of the visual field, and the personal representation during training might not have been completed, thereby hindering the improvement in the efficiency of movement preparation for a motor task.

The CIT + EP group showed a higher PPV than the other groups, implying that once the movement was initiated, the CIT + EP participants could perform better in anticipatory motor control and reduce the time required for online correction. The CIT + EP approach is a compelling intervention because it provides a large amount of visual and somatosensory input to excite the damaged right hemisphere—such as parietofrontal circuits, intraparietal sulcus, and frontal eye fields—that dominates visuospatial attention, proprioceptive processing, and the computation of motor–spatial motor planning (Rizzolatti & Gallese, 1988). Patients in the CIT + EP group would have a better ability to integrate multisensory information with spatial coordination and perform a more planned movement pattern. The effect of CIT + EP in our study supported previous statements that the multisensory-based rehabilitation approach might be able to deal with the multimodal problems of patients with neglect (Kerkhoff & Rossetti, 2006).

Our results showed that only massive use of the affected limb under CIT + EP strategies reversed the right-tilt phenomenon and induced a leftward trunk shift. We speculate that the block of the right hemisphere by EP contributed to the leftward trunk shift because of the intention to track visual stimulations on the left side.

When we compared the results of the CIT and CIT + EP approaches, CIT + EP demonstrated better effects in planned motor control and leftward trunk shift than did the CIT intervention, whereas CIT showed better effects
for left fixation points and reaction time than did CIT + EP. These results might indicate that CIT + EP, which provided an intensive amount of visual and somatosensory input, had benefit for more efficient motor control (better planned movement pattern and leftward trunk shift). However, the combination of double-restraint strategies might disperse the patient’s energy for visuomotor adjustment (Fong et al., 2007), leading to longer reaction time than seen in the CIT intervention. In addition, left-side fixation points improved more after the CIT approach than after the CIT + EP intervention. This finding is reminiscent of the Barrett et al. (2001) study, which reported that EP might worsen neglect syndrome among patients with sensory–attention neglect. Further investigations with specific types of neglect and a larger sample size are required to confirm this finding.

### Conclusion

This study provides evidence to support the effects of CIT + EP and CIT in neglect syndrome compared with the control intervention. CIT + EP and CIT demonstrated similar beneficial effects on functional performance in patients’ everyday lives and differential effects on eye movement and reaching kinematics. CIT might improve eye movement and limb initiation, whereas CIT + EP might facilitate preplanned control and trunk control. Future research with a larger sample and addressing different subtypes of neglect is needed to validate the findings.

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