

Comparison of Constraint-Induced Movement Therapy and Bilateral Treatment of Equal Intensity in People With Chronic Upper-Extremity Dysfunction After Cerebrovascular Accident

Kate Hayner, Ginny Gibson, Gordon Muir Giles

KEY WORDS

- activities of daily living
- immobilization
- motor skills
- restraint, physical
- recovery of function
- stroke

OBJECTIVE. We compared the effectiveness of constraint-induced movement therapy (CIMT) with bilateral treatment of equal intensity for chronic upper-extremity (UE) dysfunction caused by cerebrovascular accident (CVA).

DESIGN. We conducted a 2-group, randomized intervention trial with stratification by severity of UE dysfunction. Twelve community-dwelling adults were provided with 6 hr of occupational therapy for 10 days plus additional home practice. Six participants wore a mitt on the unimpaired UE, and 6 participants were intrusively and repetitively cued to use both UEs. The Wolf Motor Function Test (WMFT) and the Canadian Occupational Performance Measure (COPM) were administered before and after treatment and at 6-month follow-up.

RESULTS. Significant improvements were found in WMFT and COPM scores across time in both groups. No significant between-group differences were found on the WMFT.

CONCLUSION. High-intensity occupational therapy using a CIMT or a bilateral approach can improve UE function in people with chronic UE dysfunction after CVA. Treatment intensity rather than restraint may be the critical therapeutic factor.

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Kate Hayner, EDD, OTR/L, is Associate Professor and Chairperson, Occupational Therapy Department, Samuel Merritt University, Oakland, CA.

Ginny Gibson, MS, OTR/L, CHT, is Assistant Professor, Samuel Merritt University, Oakland, CA, and Senior Occupational Therapist, Children's Hospital and Research Center Oakland, Oakland, CA.

Gordon Muir Giles, PhD, OTR, FAOTA, is Professor, Department of Occupational Therapy, Samuel Merritt University, 450 30th Street, Oakland, CA 94609, and Director of Neurobehavioral Services, Idylwood Care Center, Sunnyvale, CA; ggiles@samuelmerritt.edu

Although clinicians use a range of therapies to address cerebrovascular accident (CVA)-related upper-extremity (UE) dysfunction, the superiority of any one intervention remains unclear (van der Lee et al., 2001; Young & Forster, 2007). Constraint-induced movement therapy (CIMT) significantly improves UE function when applied in both its original and modified forms (Kunkel et al., 1999; Miltner, Bauder, Sommer, Dettmers, & Taub, 1999; Page & Levine, 2006; Page, Sisto, Levine, Johnston, & Hughes, 2001; Page, Sisto, Levine, & McGrath, 2004; Shaw et al., 2005; Wolf et al., 2006).

When somatic sensation is surgically abolished from a monkey's UE by dorsal rhizotomy, the movement of the deafferented extremity is permanently abolished (Knapp, Taub, & Berman, 1958, 1963; Lassek, 1953). However, if the monkey is induced to use the UE by (1) preventing use of the uninvolved UE or (2) extensive training of the involved UE, the return of motor functioning to the involved extremity is permanent (Knapp et al., 1958, 1963; Taub, Ellman, & Berman, 1966). Taub (1980) proposed that unilateral sensory or motor loss induced "learned nonuse" of the affected limb because attention was directed to the unaffected extremity.

CIMT applies the principles of constraint of the uninvolved extremity and extensive training of the involved extremity to human rehabilitation and has been used to treat adults and children and following CVA (Shaw et al., 2005) and traumatic brain injury (Karman, Maryles, Baker, Simpser, & Berger-Gross, 2003; Shaw et al., 2005) and in children with cerebral palsy (Crocker, MacKay-Lyons, & McDonnell, 1997; Taub, Ramey, DeLuca, & Echols, 2004).

Learned nonuse is hypothesized to result from early attempts to use the post-CVA affected UE that are extinguished by failure and from compensatory attempts to use the unaffected extremity that are reinforced by success. Following this line of reasoning, it was found that avoidance or escape conditioning could increase motor functioning in some people after CVA who had chronic UE dysfunction (Halberstam, Zaretsky, Brucker, & Guttman, 1971; Ince, 1969).

Early theories of neural plasticity in CIMT emphasized “latent abilities” and “unmasking” of established connections. Actual regrowth or regeneration of neurons was considered implausible given the rapidity of the changes seen in CIMT (Miltner et al., 1999; Ostendorf & Wolf, 1981; Wolf, Lecraw, Barton, & Jann, 1989). More recent theories have accounted for the effectiveness of CIMT by emphasizing rapid use-dependent cortical restructuring, which is consistent with the contemporary understanding of the rapidity of neural plasticity (Classen, Liepert, Wise, Hallett, & Cohen, 1998; Levy, Nichols, Schmalbrock, Keller, & Chakeres, 2001; Nudo, 2007).

A standard CIMT protocol uses constraint, massed practice, and shaping (Taub, 1999; Wolf et al., 2006) and includes immobilizing the unaffected UE for a minimum of 6 hr per day for 2 wk of active treatment with continuation of the constraint at home (including weekends) for 90% of waking hours (Taub, 1999). Massed practice frequently consists of exercises or drills in pseudofunctional tasks (e.g., picking up pencils, moving beans between containers) rather than real functional tasks (e.g., preparing lunch, eating lunch, cleaning dishes). Shaping attempts to facilitate successive approximations to desired movements (Boake et al., 2007; Taub, Uswatte, & Pidikiti, 1999). Changes in theory, difficulties with protocol tolerability (Page, Levine, Sisto, Bond, & Johnston, 2002), and difficulties with reimbursement have led to modifications in how CIMT is provided (Page et al., 2001, 2004). With few exceptions, constraint is present in CIMT studies (Gillot, Holder-Walls, Kurtz, & Varley, 2003; Naylor & Bower, 2005; Taub et al., 1999), but interventions may include one or more of the following: massed practice, shaping, intensive treatment, functional activities,

a client-centered approach (Roberts, Vegher, Gilewski, Bender, & Riggs, 2005), a home program (Gillot et al., 2003), automated treatment (Lum et al., 2004), and the application of preparatory modalities (Page & Levine, 2006). For example, in modified CIMT (mCIMT) constraint is applied for <6 hr during the day and for longer treatment periods (weeks to months; Page et al., 2001; Ploughman & Corbett, 2004; Sterr et al., 2002).

The restrictive nature of the inclusion and exclusion criteria have led CIMT proponents to estimate that only 20%–30% of patients with a hemiparetic UE caused by CVA qualify for inclusion (Taub et al., 1993). In the EXCITE multicenter study, only 6% of those screened were included. The value of some of the eligibility criteria has been challenged. Fritz, Light, Patterson, Behrman, and Davis (2005) showed that meeting the standard active range of motion criteria was not necessary to benefit from CIMT.

A fundamental concern relating to CIMT is whether constraint provides unique benefits or whether other factors (e.g., therapy intensity) can account for the observed effects. One study compared full, partial, and no restraint and found that all groups demonstrated significant improvement (Uswatte, Taub, Morris, Barman, & Crago, 2006). Few studies have compared CIMT to an intervention of similar intensity (Boake et al., 2007), and most studies have confounded the type of therapy with the frequency and duration of its application. The largest trial of CIMT compared CIMT to “usual and customary care,” which in 51.1% of control participants meant no treatment (Wolf et al., 2006). Three prior studies have attempted to control for frequency and duration of therapy. In two of those studies, participants were in the acute post-CVA period; in one study, a chronic population was examined. These studies showed inconsistent findings indicating no difference, superiority of CIMT only in clients with perceptual difficulties, or superiority of the CIMT condition (Boake et al., 2007; Dromerick, Edwards, & Hahn, 2000; van der Lee et al., 1999).

Both the intensity and the nature of the activities provided have been shown to affect the therapeutic response to treatment. A dose–response relationship is known to exist in rehabilitation for people with CVA such that the improved outcomes from CIMT could result from treatment intensity (Dobkin, 2007). Meta-analyses by Langhorne, Wagenaar, and Partridge (1996) and Kwakkel, Wagenaar, Koelman, Lankhorst, and Koetsier (1997) showed greater improvement in activities of daily living (ADLs) with increasing intensity of therapy. In addition to intensity, use of real functional activities and enriched (real-world) environments are most likely to enhance use-dependent cortical

restructuring (Bayona, Bitensky, Salter, & Teasell, 2005; Davis, 2006; Teasell, Bitensky, Salter, & Bayona, 2005). Given the protocol variability, limitations of published reports, and difficulty in specifying the “active component” of treatment, CIMT remains an experimental treatment (Dahl et al., 2008; Dromerick, 2003; Siegert, Lord, & Porter, 2004; van der Lee, 2003).

Study Rationale and Hypotheses

The current study attempted to contribute to the understanding of CIMT by comparing two treatments for chronic UE dysfunction in people in the post-CVA period. The treatments were (1) a modification of the standard CIMT protocol and (2) bilateral treatment provided with intensity equal to the CIMT condition. The CIMT protocol was changed from the standard CIMT protocol by making the UE movement inclusion criteria less stringent, by using real functional activities and not massed practice of nonfunctional tasks or shaping, and by not requiring 90% protocol compliance outside the clinic. Stringency was lessened to include a broader range of UE dysfunction. Use of real functional activities was incorporated because of the evidence for their superiority over rote activity. The 90% compliance criterion was eliminated to remove a barrier to participation for people who lived either alone or with others who were unwilling to assume the homemaking or child-rearing responsibilities of the participants. Bilateral treatment was selected as a comparison for CIMT because it has been used as a comparison condition in an earlier CIMT study that controlled for frequency and duration of treatment (van der Lee et al., 1999). Bilateral rehabilitative interventions have recently been a focus of experimental (Cunningham, Stoykov, & Walter, 2002) and clinical research (Rose & Winstein, 2004; Whittall, McCombe, Silver, & Macko, 2000) and might be considered the conceptual antithesis of CIMT.

Participants were recruited with the intention that some would meet the standard movement inclusion criteria and some would potentially fail to meet the standard criteria.

This study was based on the following research hypotheses:

1. All participants will demonstrate improved total Wolf Motor Function Test (WMFT; Wolf et al., 2001) scores after CIMT or bilateral treatment of comparable intensity, frequency, duration, and activity selection.
2. Participants in the CIMT group will demonstrate greater improvement in total WMFT scores than participants in the bilateral group after treatment of comparable intensity, frequency, duration, and activity selection.

3. Participants with more impaired UE function, receiving either intervention, will demonstrate greater gains on the WMFT than the participants with less impaired UE function.
4. Participants with more impaired UE function (i.e., those who would typically not be included in a CIMT study) and who are receiving either intervention will demonstrate gains on the WMFT.
5. All participants will demonstrate improved scores on COPM subscales.
6. All participants will maintain gains established at posttesting on the total WMFT scores when tested at follow-up.
7. All participants will maintain gains established at posttesting on the COPM subscales when tested at follow-up.
8. Across both treatment groups, the participants with less impaired UE function will report more time spent in home activities.

Method

Study Design

The study was a stratified, randomized pretest–posttest, 6-month follow-up, two-group comparison design. Participants were stratified as having more or less UE dysfunction—as determined by performance on the WMFT—and then randomly assigned to either the CIMT or the bilateral group. To ensure that intervention was truly of the same intensity and to avoid organizational confounds, all participants were treated simultaneously, in the same location, and by the same therapists. The appropriate institutional review board approved the research protocol.

Setting and Researchers

Intervention took place at Samuel Merritt University, a health sciences training institution in Oakland, California. Facilities included clinic rooms with a kitchen, tables, and typical occupational therapy clinic supplies. Three occupational therapy researchers, seven second-year masters of occupational therapy students, and four first-year masters of occupational therapy students provided the intervention. The ratio of clinicians to participants was approximately 1:1.

Participant Recruitment and Prescreening

Information about the study was disseminated to participants in a free clinic at Samuel Merritt University, clinics in the vicinity, and a local CVA support group.

A two-stage screening process preceded participant enrollment in the study. Potential participants were prescreened by telephone to determine whether they had English-language skills adequate to understand and follow verbal directions, were 18 to 100 yr old, were at least 6 mo after CVA with related UE dysfunction, had sufficient endurance to participate in therapy 6 hr per day for 10 consecutive weekdays, agreed not to smoke, could walk without an ambulatory aid, could eat food that was not mechanically altered, and were available for the study period. People who reported inability to refrain from smoking were excluded from the study because a smoking area was unavailable. People who by self-report were unable to tolerate a regular diet were excluded from the study because making lunch was a part of the therapeutic design and a mechanically altered diet was not feasible. Potential participants who met the telephone prescreening requirements were invited to an in-person screening and study orientation. In-person screening consisted of administration of the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and an author-developed balance assessment consisting of four items (sitting unsupported, sitting while reaching, rising from a chair, and walking 10 ft without a device), each of which had to be passed in order to participate in the study. Additionally, participants needed to successfully place their affected hand on a table surface. There was no minimum criterion for wrist or finger extension, but trace movement in the hand was required.

Pretest, Posttest, and Follow-Up Procedures

Immediately after prescreening, participants were informed that they would be randomly assigned to either the CIMT group or the bilateral group. Participants were informed that both groups would receive the same amount of therapy and that the superiority of one treatment over the other was unknown. Thirteen people met inclusion criteria and were pretested. Risks and benefits of participation were discussed with each participant individually, and informed consent was documented. Participants were stratified into more and less affected UE groups as determined by the WMFT total score and then blindly randomized into the CIMT or bilateral group. Pretesting and posttesting occurred on the weekdays before and after the 10 days of treatment. Follow-up testing occurred 6 mo after the posttest. Raters were not blinded. All assessments were administered or directly supervised by licensed occupational therapists. One participant, randomized to the CIMT group, injured his affected UE at home before posttesting during a non-study-related activity and was dropped from the study.

Instruments and Measures

The WMFT is the most widely used measure of UE motor function in CIMT research (Morris, Uswatte, Crago, Cook, & Taub, 2001; Wolf et al., 2001). The WMFT measures fine and gross motor skills determined by quality of movement and speed of movement on 15 tasks (plus 2 strength tests). Excellent interrater reliability and test-retest reliability of $>.90$ have been established for the WMFT when used with people after CVA with subsequent UE dysfunction (Morris et al., 2001; Wolf et al., 2001).

The Canadian Occupational Performance Measure (COPM; Law et al., 1988) is a structured clinical assessment that allows participants to self-rate goals of therapy in the categories of self-care, productivity, and leisure. Goals are rated on two 10-point scales describing Performance and Satisfaction With Performance. Test-retest reliability for the COPM, when used with people after CVA, was 0.89 for Performance and 0.88 for Satisfaction With Performance (Cup, Scholte op Reimer, Thijssen, & van Kuyk-Minis, 2003). Correlations between scores on the COPM and standardized measures of ADL functioning have been found to be low, suggesting that the COPM provides unique information regarding client function (Dedding, Cardol, Eyssen, Dekker, & Beelen, 2004).

Interventions. The CIMT and the bilateral group interventions differed in the following ways: The CIMT group participants wore a padded mitt (J. T. Posey Co., Arcadia, CA; Model No. 2811) on the unaffected hand and practiced functional activities with only the affected UE. The CIMT group participants were prevented from using the unaffected UE for almost all activities, including stabilizing objects (the mitt was removed only for restroom use). The “bilateral” group participants were provided with repetitive and intrusive cuing to use both hands during all activities (even tasks normally performed unilaterally). Little attempt was made to facilitate “normal” movement in either group.

Tasks were structured to be just within the participants’ ability to perform either individually or with others, or the participant was afforded just as much assistance as was necessary for task performance. Assistive devices were used when required by a participant in the CIMT group to accomplish a task with one hand (e.g., universal cuff for self-feeding; scrub brush with suction cups for hand washing). Many of the tasks involved repetition (e.g., chopping vegetables), and many occurred each day (e.g., hand washing, eating). Tasks requiring repetition, daily performance, or both are likely to improve motor control (Davis, 2006). Treatment activities

were designed to promote function and active range of motion, were routine and purposeful (e.g., setting the table, washing hands, washing dishes), and were intended to be meaningful, but they were not client-selected occupations (i.e., client-preferred meaningful customary activities). Treatment began each day with a morning meeting and ended with an afternoon meeting. On the first day of treatment, the morning meeting was used for introductions and study orientation. On subsequent days, the morning meeting was used to elicit from participants the time that they had spent at home either performing activities with constraint or performing tasks bilaterally. Attempts were made to encourage home activities and to be as neutral as possible regarding reports of non-performance. The morning continued with stretching and warm-up activities (e.g., balloon volleyball). A major focus for the day's routine was lunch. Participants were divided into teams to retrieve equipment and ingredients and worked together on meal subcomponents, cooking, table setting, and serving. After lunch, the afternoon was devoted to clean up, a craft activity, or table games. The daily afternoon meeting was used as a wrap up. The participants were encouraged to devote as much time as possible to the home program and to report the time each day, but there was no minimum requirement for home compliance.

Statistical Analysis. Descriptive statistics for the pretest, posttest, and follow-up (trials), more or less impaired UE functioning (functional level), and CIMT or bilateral treatment (treatment group) are presented. Means (M s), standard deviations, frequencies, minimum scores, maximum scores, and ranges were calculated for the demographic data. Independent t tests and χ^2 tests were used to determine whether the groups (functional level and treatment group) differed on age, MMSE score, balance score, and time after CVA.

Mixed-model (split-plot) analysis of variance (ANOVA) with one within-subject factor (pretest, posttest, and follow-up) and two between-subject factors (functional level and treatment group) were performed to establish whether between-group differences existed. Violations of sphericity were corrected with the Greenhouse–Geisser adjustment coefficient (Williams, 2004).

Significant interactions were followed up with simple effects tests. Significant between-subject main effects did not require follow-up post hoc tests because each factor contained only two groups. Significant within-subject main effects were followed up with Bonferroni post hoc tests (Stevens, 1990). Effect sizes (η^2) and the power observed were calculated for each source of variance. Effect sizes around .01 were considered small; .06, medium; and

.14, large (Stevens, 1990). In addition, independent t tests were performed to ensure that the CIMT and bilateral groups were not significantly different on the pretests. Means, standard deviations, and sample sizes for each trial by functional level and by treatment group are presented.

Descriptive statistics, including mean ranking, were calculated for the number of hours spent practicing at home. A Wilcoxon Mann–Whitney U test (Siegel & Castellan, 1988) was performed to determine whether the bilateral group differed from the CIMT group in the number of home practice hours. The bilateral and CIMT groups were then further analyzed by functional level, resulting in four subgroups. A Kruskal–Wallis one-way analysis (Siegel & Castellan, 1988) was used to determine whether these groups differed for number of home practice hours. Post hoc tests described in Siegel and Castellan (1988) were used. SPSS–PC (SPSS, Inc., Chicago) was used to perform all of the analyses. Level of significance was set at $p = .05$ for all analyses.

Results

Descriptive statistics for age, balance, MMSE, time since CVA, and gender are presented in Table 1. No significant differences were found between the CIMT and the bilateral group or the more impaired versus the less impaired group, with the exception that the bilateral group was significantly longer post-CVA than the CIMT group.

Independent t tests were performed for all of the assessments. The CIMT and bilateral groups did not differ significantly on any of the pretest assessments.

All participants completed the WMFT (see Table 2). In the mixed-model ANOVA, the functional level and trial main effects were found to be significant. The less impaired UE functioning group ($M = 57.94$) scored significantly better than the more impaired UE functioning group ($M = 33.44$) on the WMFT. The WMFT pretest score ($M = 40.83$) was significantly worse than the posttest ($M = 46.83$, $p = .009$) and the follow-up test scores ($M = 49.42$, $p = .008$) across all groups. In addition, the posttest score was significantly worse than the follow-up test score ($p = .022$). The effect sizes for functional level ($\eta = 0.608$), trials ($\eta^2 = 0.689$), and Trial \times Functional Level ($\eta^2 = 0.223$) are considered to be large, indicating significant improvement in function from pretest to posttest and from posttest to follow-up but did not differentiate between the CIMT or bilateral group.

The COPM includes a self-assessed Performance and a Satisfaction With Performance rating, which were analyzed separately. All participants completed the COPM Performance rating (see Table 3). The functional level and trials

Table 1. Participant Demographics

Variable	Data by Condition			Data by Function		
	CIMT Group (<i>n</i> = 6)	Bilateral Group (<i>n</i> = 6)	Comparison	More Impaired Group (<i>n</i> = 6)	Less Impaired Group (<i>n</i> = 6)	Comparison
Age (years)						
Mean	54.00	59.50		51.67	61.83	
<i>SD</i>	11.628	11.777		5.60	14.063	
<i>t</i>			0.814			1.642
Balance (4-point scale)						
Mean	3.83	3.83		3.67	4.00	
<i>SD</i>	0.408	0.408		0.516	0.000	
<i>t</i>			0.000			1.581
Mini-Mental State						
Mean	29.17	29.08		29.08	29.17	
<i>SD</i>	0.983	0.801		0.801	0.983	
<i>t</i>			0.161			0.161
Time since CVA (days)						
Mean	642.33	2039.00		1148.67	1532.67	
<i>SD</i>	421.121	925.328		684.986	1283.094	
<i>t</i>			3.365*			0.647
Gender						
Men (<i>n</i>)	2	3		3	2	
Women (<i>n</i>)	4	3		3	4	
χ^2			0.345			0.345

Note. CIMT = constraint-induced movement therapy; *M* = mean; *SD* = standard deviation. For *t* tests, *df* = 10 for all groups. For χ^2 , *df* = 1 for all groups. *Significant at .01 level.

main effects were significant. The Trial \times Treatment Group \times Functional Level interaction was also significant. Simple effects were calculated by comparing the more and less impaired UE functioning groups for Trial \times Treatment Group. In the bilateral group, the more and less impaired UE functioning groups did not differ significantly for the pretest ($p = .08$) and posttest ($p = .091$) or for the follow-up test ($p = .938$). For the CIMT group, the more and less impaired UE functioning groups were significantly different on the posttest ($p = .026$) and the

follow-up test ($p = .023$). For the functional level main effect, the less impaired UE function group ($M = 6.16$) scored significantly higher than the more impaired UE function group ($M = 4.24$). Bonferroni post hoc tests were used to see where the trials differed across the groups. The pretest score ($M = 3.05$) was significantly lower than the posttest ($M = 6.40$, $p = .000$) and the follow-up test ($M = 6.14$, $p = .000$) scores. The posttest and the follow-up test scores were not significantly different ($p = 1.00$). Large effect sizes were found for functional level, trials,

Table 2. Split-Plot (Mixed-Model ANOVA) for Wolf Motor Function Test

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	Partial η^2 (Effect Size)	Obs. Power*
Between Subjects						
Condition	1.00	66.69	0.15	.706	0.019	0.064
Function	1.00	5402.25	12.39	.008*	0.608	0.868
Condition \times Function	1.00	78.03	0.18	.683	0.022	0.066
Error	8.00	436.00				
Within Subjects						
Trials	1.07	433.52	17.73	.002*	0.689	0.994
Trial \times Condition	1.07	4.71	0.19	.686	0.024	0.068
Trial \times Function	1.07	56.05	2.29	.166	0.223	0.277
Trial \times Condition \times Function	1.07	3.78	0.15	.722	0.019	0.065
Error	8.59	24.45				

Note. ANOVA = analysis of variance; *df* = degree of freedom; *MS* = mean square; Obs. = observed. *df* corrected for sphericity with Greenhouse–Geisser adjustment coefficient.

*Computed using $\alpha = .05$.

Table 3. Split-Plot (Mixed-Model ANOVA) for Canadian Occupational Performance Measure: Performance

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	Partial η^2 (Effect Size)	Obs. Power*
Between Subjects						
Condition	1.00	6.25	0.00	.988	0.000	0.05
Function	1.00	33.16	13.24	.007*	0.623	0.89
Condition \times Function	1.00	2.08	0.83	.389	0.094	0.13
Error	8.00	2.50				
Within Subjects						
Trials	1.83	45.47	40.45	.000*	0.835	1.00
Trial \times Condition	1.83	3.17	2.82	.096	0.261	0.45
Trial \times Function	1.83	0.58	0.52	.590	0.061	0.12
Trial \times Condition \times Function	1.83	6.57	5.85	.015*	0.422	0.77
Error	14.66	1.12				

Note. ANOVA = analysis of variance; *df* = degree of freedom; *MS* = mean square; Obs. = observed. *df* corrected for sphericity with Greenhouse–Geisser adjustment coefficient.

*Computed using $\alpha = .05$.

Trial \times Treatment Group, and Trial \times Treatment Group \times Functional Level.

All participants completed the COPM Satisfaction With Performance rating (see Table 4). The functional level and trials main effects were significant. The Trial \times Functional Level and Trial \times Treatment Group \times Functional Level interactions were significant. Simple effects were used to follow up the Trial \times Treatment Group \times Functional Level interaction. For the bilateral group, the more and less impaired UE functioning groups were not significantly different for any of the trials. However, for the CIMT group, the more and less impaired UE functioning groups were significantly different on the posttest ($p = .031$) and follow-up test ($p = .034$). The functional level main effect was significant. The less impaired UE function group ($M = 6.29$) scored significantly higher than the more impaired UE function group ($M = 4.37$). Bonferroni post hoc tests were con-

ducted to follow up the trials main effect. The pretest score ($M = 3.30$) was significantly lower than the posttest score ($M = 6.52$, $p = .02$) and the follow-up test score ($M = 6.52$, $p = .004$). The posttest and follow-up test scores were not significantly different ($p = 1.00$). The effect sizes were large for all of the sources of variance except treatment group and Treatment Group \times Functional Level.

Both more and less impaired bilateral groups reported significantly more time spent in home practice ($M = 25.96$, $s = 7.94$, mean rank = 9) than either CIMT group ($M = 12.46$, $s = 5.01$, mean rank = 4; Figure 1). The difference between the groups in reported home practice reached significance for all but the bilateral less impaired group ($M = 22.17$) versus the CIMT less impaired ($M = 16.25$) group. The less impaired CIMT group reported significantly more time in home practice than the more impaired CIMT group ($M = 8.67$). The

Table 4. Split-Plot (Mixed-Model ANOVA) for Canadian Occupational Performance Measure: Satisfaction With Performance

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	Partial η^2 (Effect Size)	Obs. Power*
Between Subjects						
Condition	1.00	2.38	0.56	.477	0.065	0.101
Function	1.00	26.10	6.12	.039*	0.433	0.584
Condition \times Function	1.00	0.43	0.10	.758	0.013	0.059
Error	8.00	4.27				
Within Subjects						
Trials	1.77	56.63	45.44	.000*	0.850	1.000
Trial \times Condition	1.77	1.34	1.08	.359	0.119	0.194
Trial \times Function	1.77	5.65	4.55	.033*	0.362	0.646
Trial \times Condition \times Function	1.77	6.10	4.90	.027*	0.380	0.680
Error	14.16	1.24				

Note. ANOVA = analysis of variance; *df* = degree of freedom; *MS* = mean square; Obs. = observed. *df* corrected for sphericity with Greenhouse–Geisser adjustment coefficient.

*Computed using $\alpha = .05$.

bilateral more impaired group ($M = 29.75$) spent the most time practicing at home.

Discussion

This study differed in several ways from most CIMT studies. Criteria for participation were less restrictive (i.e., extended downward) in requirements for active UE range of motion. Both the CIMT and the bilateral groups received the same frequency, duration, and intensity of treatment. There was a focus on engagement in real functional activities.

Some hypotheses were supported by the current study, whereas others were not. Consistent with earlier reports, and supporting the first hypotheses, we found that CIMT is effective in increasing UE movement in people who are post-CVA and have chronic UE dysfunction. The first hypothesis was also supported with respect to the bilateral group. The second hypothesis was not supported because no differences were found between the effects of CIMT and bilateral treatment on total WMFT scores. Both the CIMT and the bilateral groups showed statistically significant improvements over the study period; the effect sizes for both groups were large and comparable to those reported in other CIMT studies (Miltner et al., 1999; Wolf et al., 2006). Similarly, in both the CIMT and bilateral groups, the percentage change—but not the absolute amount of change—was comparable for the more and less impaired UE function groups. This finding does not support the third hypothesis—that participants with more impaired UE function, receiving either intervention, would demonstrate greater gains on the WMFT than the less impaired participants—but it does

support the fourth hypothesis—that participants with more impaired UE function and who were receiving either intervention would demonstrate gains on the WMFT (see Table 2).

For both self-assessed Performance and Satisfaction With Performance on the COPM, all groups improved from pretesting to posttesting, supporting the fifth hypothesis. For both the COPM and the WMFT, the gains made during the treatment period were largely maintained at follow-up. There was a slight increase in score means between posttest and follow-up on the WMFT and a slight decrease between posttest and follow-up on the COPM Satisfaction With Performance. These findings support both the sixth and the seventh hypotheses (see Tables 3 and 4).

The eighth hypothesis was not supported, and the time spent in home practice did not differ significantly between the more and less impaired groups. Interestingly, the bilateral group practiced more at home. It may be that the bilateral group participants were more able to carry out necessary functional activities when adhering to the treatment protocol than were the CIMT group. In the bilateral group, the unaffected hand could assist with any activity so that actual functional performance was not inhibited. In the CIMT group, the unaffected hand was constrained, often preventing unaided functioning (see Figure 1).

CIMT studies typically have small sample sizes, such that the current study falls at approximately the median number of participants for published reports. Most reports fail to include a discussion of power (see Boake et al., 2007, and Wolf et al., 2006, for exceptions). Power is an important concern in the current study: Caution is

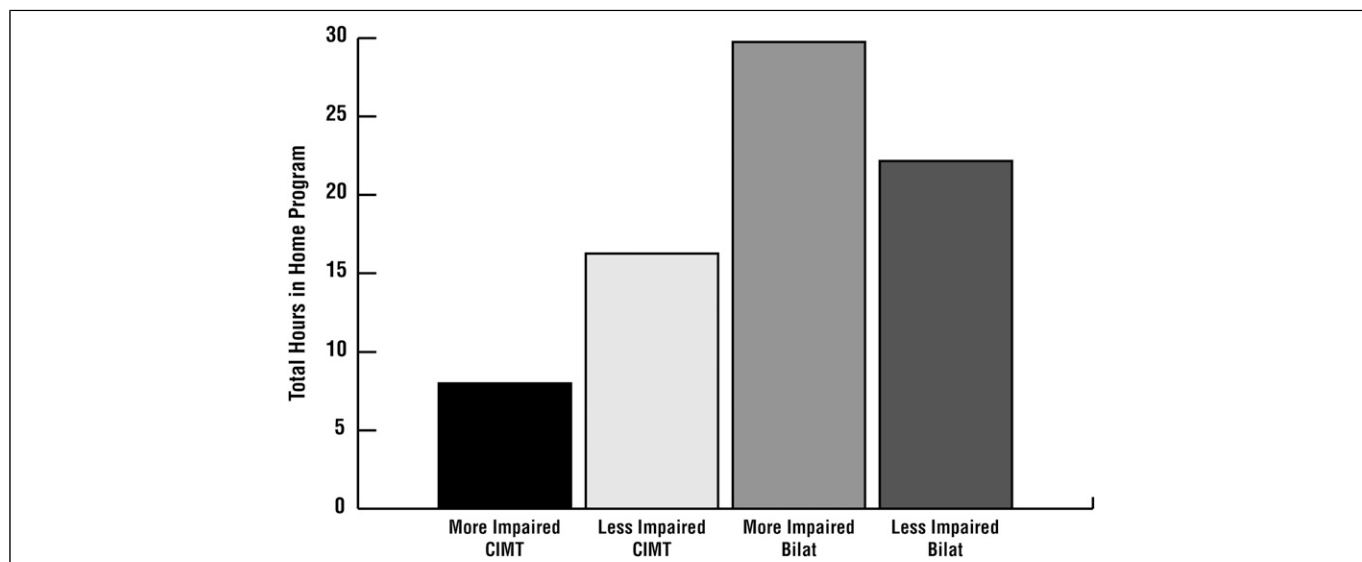


Figure 1. Total time spent in treatment-at-home groups. Bilat = bilateral; CIMT = constraint-induced movement therapy.

necessary in interpreting the results because there is an increased risk of a Type II error when power is low. Nonetheless, the power for the functional level factor (the within-treatment group change) for COPM Satisfaction With Performance was 0.584 and the effect size was .433 for the same analysis (same sample size). Given the robust nature of the obtained differences, we consider it unlikely that the current study failed to find a large difference in treatment effectiveness between the CIMT and bilateral groups if one was present.

This is the fourth published study comparing CIMT with a comparison group receiving treatment of similar duration and frequency. Of these studies, two have found CIMT to be superior to the comparison group (Dromerick et al., 2000; van der Lee et al., 1999). However, there are reasons to be cautious in accepting these findings.

The first study compared mCIMT to customary treatment in patients with acute CVA. Customary treatment was not described but is likely to involve both compensatory treatment and UE retraining so comparable amounts of retraining of the affected UE are unlikely to have occurred. The second study compared CIMT with bimanual neurodevelopmental treatment in 66 people with chronic CVA (van der Lee, 2003). The authors reported that the CIMT group performed significantly better than the bimanual group; however, clinically relevant gains occurred only in participants who had sensory disorder or hemineglect (van der Lee et al., 1999). The third study failed to find significant differences between groups (Boake et al., 2007).

The current study is the first attempt to control for rehabilitation intensity by providing the same staff and the same rehabilitation activities for both groups. Both of the treatments used in the current study resulted in substantial gains in UE functioning for participants. Here we propose that the attentional focusing and intensive practice—shared by both interventions—may be the active components of treatment. Most explanations of CIMT focus on learning theory or neurological repair without a discussion of cognitive mechanisms. Schneider and Shiffrin's (1977) model of automatic and controlled attention allows an understanding of how difficult it is for people with CVA to attempt to use the affected UE. In the Schneider and Shiffrin model, controlled processing (required for new learning) is capacity limited and effortful and requires sustained attention. Automatic processing is fast, is noneffortful, and does not require conscious attention. Different attentional failures are possible; here, however, the focused attentional deficit (FAD) is most relevant. A FAD occurs when an unfamiliar response is required to a stimulus when the stimulus already has an

overlearned response attached to it. The FAD results in the derailment of the planned action and the substitution of the automatic action. CIMT may be effective in interrupting the automatic use of the unaffected extremity, which is a necessary condition for use of the habitually nonused (impaired) extremity. The constraint in combination with high-intensity activity demand is what "forces the use," leading to neurological restructuring. It may be that bilateral retraining maintained by repetitive and intrusive cuing served a similar function.

The current study used purposive activities to maximize participants' on-task performance. The actual behaviors learned by the bilateral group may have been more easily compatible with the participant's routine activities than the activities of the constrained group: This "translation failure" may have been particularly marked in the CIMT more impaired group. This finding may account for the COPM findings that the more impaired CIMT group reported less satisfaction with treatment and less home practice than any of the other groups, including the more impaired bilateral group.

Both the CIMT and bilateral treatments used in this study may not be directly comparable to those described in other reports. Taub et al. (1999) described CIMT as a family of techniques with the actual treatments (both the CIMT and the control conditions) in published reports varying widely. Research in the past 10 years has demonstrated that the standard protocol (i.e., postacute and daily constraint for 2 wk) is not mandatory for positive participant outcomes (Kunkel et al., 1999; Miltner et al., 1999; Page & Levine, 2006; Page et al., 2001, 2004; Shaw et al., 2005; Wolf et al., 2006).

As a result of a design intended to prevent the confounding of type of therapy with duration, frequency, or intensity of intervention, an unusual amount of therapy was provided for the comparison (bilateral) treatment group (i.e., equal to that provided to the CIMT group). It would have been advantageous to have a third comparison group providing bilateral treatment at a reduced (i.e., more customary) intensity; however, a third group was not possible given available resources. The addition of a no-treatment control group could have controlled for spontaneous improvement or the effects of nonspecific factors such as therapists' attention, change in routine, or expectation of improvement as a cause of change. The time from CVA to treatment in participants suggests that spontaneous recovery is not a significant factor in patient improvement. The design of this study prevents the elimination of nonspecific factors from accounting for the observed improvement; however, a study contrasting CIMT with an attentional control group (that did not

involve UE rehabilitation) found no change in the control group and large to very large changes in the CIMT group (Taub et al., 2006).

Intensive occupational therapy provided in either a CIMT or a bilateral format appears to be effective in improving motor function in the UE of people post-CVA with chronic UE dysfunction. The current findings are consistent with treatment intensity rather than physical restraint of the unimpaired UE being the critical therapeutic factor. Arresting use of the unimpaired extremity and forced use of the impaired extremity may both be necessary, but these two goals may be accomplished in ways other than the use of constraint. However, the identification of the active components of treatment requires further research. ▲

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