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Retention of Motor Changes in Chronic Stroke Survivors Who Were Administered Mental Practice

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Abstract

OBJECTIVE—To determine retention of motor changes 3 months after participation in a regimen comprised of mental practice combined with repetitive task specific training (MP + RTP).

DESIGN—Prospective, blinded, cohort, pre-post study

SETTING—Outpatient rehabilitation hospital

PARTICIPANTS—Twenty-one individuals in the chronic stage of stroke (mean age = 66.1 ± 8.1 years; age range = 56 to 76 years; mean time since stroke at study enrollment = 58.7 months; range 13 to 129 months) exhibiting mild to moderate impairments of hand function.

INTERVENTION—All individuals had been randomly assigned to receive a 10-week regimen comprised of MP emphasizing paretic upper extremity use during valued activities. Directly after each of these sessions, subjects were administered audiotaped MP. We assessed this group's paretic upper extremity motor levels before, after, and 3 months after intervention.

MAIN OUTCOME MEASURES—The upper extremity section of the Fugl-Meyer Assessment of Sensorimotor Impairment (FM), the Action Research Arm test (ARAT), the Arm Motor Ability test (AMAT), and Box and Block test (BB).

RESULTS—None of the scores significantly changed from the period directly after intervention to the 3-month post testing period (FM: $t = 0.817$; ARAT: $t = 0.923$; AMAT:$t = 0.898$, $t = 0.818$, and $t = 0.967$ for the functional ability, quality of movement, and time scales, respectively; BB: $t = 0.892$).

CONCLUSIONS—Changes in paretic upper extremity movement realized through MP + RTP participation are retained 3 months after the intervention has concluded. This is the first study examining retention of motor changes after MP + RTP participation, and one of only a few studies

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examining long retention of motor changes following any intervention targeting stroke-induced hemiparesis.

While recent emphasis has been placed on prevention of stroke risk factors and improved acute stroke treatments, only a minority of patients are administered these promising treatments,[1] and there continues to be a steady stroke incidence.[2] These challenges, combined with an aging population and diminishing lengths of rehabilitative stay, are expected to yield a rising number of stroke survivors exhibiting residual impairments.[3]

Upper extremity (UE) hemiparesis is one of the most frequent, disabling, stroke-induced impairments. epetitive task specific practice (RTP) has emerged as a commonly-used,[4] efficacious[5] strategy for UE hemiparesis. Moreover, RTP efficacy is significantly increased when augmented by mental practice (MP),[6,7,8,9] during which the UE movements performed during RTP are cognitively rehearsed. The muscular and neural activations exhibited during MP are similar to those observed during physical performance of the same movement,[10] while cortical plasticity is observed following MP + RTP participation.[11]

MP + RTP efficacy has previously been determined by comparing subjects' paretic UE movement levels before regimen participation to their levels after MP + RTP use.[6–9,11] However, as with many medical treatments, identifying the approaches that confer sustained benefits -even after the intervention has concluded - is desirable in stroke rehabilitation. Thus, the purpose of this study was to determine whether motor changes observed after MP + RTP participation were retained 3 months after the intervention had concluded. It was hypothesized that the current subjects - who had already exhibited significant increases in UE movement from participation in a MP + RTP regimen - would exhibit nonsignificant changes in measures of paretic UE movement from time of posttesting directly after the intervention to 3 months after the intervention had concluded. This would be indicative of retention of the benefits of the intervention.

Despite recent interest in MP, this was the first study to examine retention of motor changes following MP, and one of only a few studies that have measured retention of motor benefits for any approach addressing UE hemiparesis.

Method

Subjects

The subjects described herein had previously consented to participate in a randomized, controlled, MP + RTP trial. All were administered MP + RTP, and, as a group, had been shown to benefit from the intervention when compared to a matched control group. As part of consent for the trial, the subjects were being longitudinally tracked.

They had been made aware of the trial using advertisements placed in local therapy clinics in the Midwestern United States. Upon volunteering for participation in the trial, subjects were screened using following inclusion criteria: (a) 10° of active flexion in the paretic wrist, as well as 2 digits in the paretic hand; (b) stroke experienced > 12 months prior to study enrollment; (c) a score ≥ 70 on the Modified Mini Mental Status Examination;[12] (d) age ≥ 18 ≤ 75; (e) only experienced one stroke; (f) discharged from all forms of physical rehabilitation and/or progressive exercise regimens. (g) Additionally, to be included in the current, longitudinal, analysis, subjects had to have been willing and/or able to return to the laboratory for additional testing 3 months after conclusion of the MP + RTP intervention. Exclusion criteria were: (a) excessive spasticity in the paretic UE, as defined as a score of ≥ 2 in the paretic elbow, wrist, and/or fingers as determined by the Modified Ashworth Spasticity Scale;[13] (b) excessive pain in the paretic UE, as measured by a score ≥ 5 on a 10-

point visual analog scale; (c) participating in any experimental rehabilitation or drug studies; (d) history of a parietal stroke (because some data suggest that ability to estimate manual motor performance through mental practice is disturbed after parietal lobe damage).[14]

Assessments

The UE section of the *Fugl-Meyer Measure of Sensorimotor Impairment (FM)*[15] ascertains UE impairment by requiring the subject to actively attempt isolated proximal movements (e.g., shoulder abduction, internal rotation) followed by successively more distal movements (e.g., mass grasp; pincer grasp) using the paretic UE, as well as testing UE reflexes. The rater evaluates each movement attempt using a 3-point ordinal scale (0=cannot perform; 2=can perform fully), and the items are summed to provide a maximum score of 66. The FM has been shown to have high test-retest reliability (total=.98–.99; subtests=.87–1.00), interrater reliability, and construct validity.[16,17]

To measure paretic UE limitation, the *Action Research Arm Test, (ARAT)*:[18] was administered. The ARAT is a 19-item test divided into four categories (grasp, grip, pinch, and gross movement), with 16 of the nineteen ARAT items measuring distal regions of the arm (e.g., pinching a ball bearing or marble between the thumb and each finger of the affected hand). Given that subjects qualifying for this study exhibited some active distal movement, and that the intervention concentrated on acquisition of additional distal movements, the ARAT was an excellent match for this study. When subjects attempt one of the ARAT items, the rater evaluates the quality of the movement using a 4-point ordinal scale (0=can perform no part of the test; 1=performs test partially; 2=completes test but takes abnormally long time or has great difficulty; 3=performs test normally) for a total possible score of 57. For this test, subjects were seated in a comfortable chair with a straight back, while the ARAT items that they had to grasp were placed on an adjustable table in front of them. Table height was adjusted according to the needs of each subject. The ARAT has high intrarater (r = .99) and retest (r = .98) reliability and validity,[19,20] all in stroke-induced hemiparesis.

The *Arm Motor Activity Test* (AMAT)[21] is a 13-item test in which ADLs are rated according to a Functional Ability scale that examines paretic limb use (0 = does not perform with paretic upper extremity; 5 = does use arm at a level comparable to less affected side) and a Quality of Movement Scale (0=no movement initiated; 5=normal movement). The AMAT movements are also timed, which allows for examination of changes in time taken to perform the movement.

Finally, the *Box and Block test* (BB),[22] was also administered. The BB is a timed grasp and release test, in which subjects are seated in front of a box with a large partition separating the box into two equal squares. Colored blocks are situated on one side of the partition and subjects are asked to move as many blocks from one side to the other with the paretic hand in the course of one minute. Since the MP + RTP intervention partially targets reaching, grasping, and releasing objects, the B&B was thought to be an appropriate instrument in this study.

The above measures were chosen because of their successful use in previous MP studies,[e.g.,6,7,11] and because of their responsivity to motor changes in chronic stroke.[e.g.,23] Subjects were also administered other assessments of paretic UE use and quality of life, which will be reported elsewhere.

Testing and Intervention

Following screening, consenting using approved consent forms, and pretesting, all subjects participated in a 10-week regimen consisting of MP + RTP. While more information is available elsewhere,[6–9,11] the intervention consisted of the following elements: (a) RTP, administered 3 days/week in ½ hour increments. During RTP sessions, subjects engaged in 25–30 minutes of a pre-specified task, with each task practiced in two-week. Tasks were derived from a list of approximately 60 activities that stroke patients commonly wish to relearn, collected by this laboratory over the past decade.

Temporal and spatial parameters of tasks were changed during successive therapy sessions, making the particular task more challenging. Global feedback regarding the patient's performance of the task during the session was usually provided at the end of the RTP session. (b) Mental practice (MP): Immediately after each RTP session, each subject listened to a 20–30 minute audiotape in a secluded room adjacent to the RTP treatment area. The tape first consisted of approximately 5 minutes of progressive relaxation (i.e., tighten and relax successive muscles from inferior to superior), immediately followed by the subject imagining him/herself in a familiar environment that was appropriate for performance of the task to be practiced on that day (e.g., his/her kitchen table, if the task was reaching for a favorite coffee cup). For the next 20–25 minutes, the subject was guided through the feelings (e.g., feelings associated with using the muscles of the paretic UE to perform the task), appearances (i.e., how the subject appeared from first and third person perspectives while performing the task with the paretic UE), and any relevant sounds or smells associated with physical performance of the movement that had just been physically practiced during RTP. The session concluded by refocusing the subject into the room.

Posttesting

One week after MP + RTP completion, the outcome measures were re-administered by the same examiner who had administered them before intervention (POST). The examiner was blinded, with no knowledge of the intervention in which subjects had participated. Subjects also returned three months after the last day of intervention (POST-3) and the same evaluator again administered the tests.

Results

Twenty-one individuals met study criteria, and, thus were included in the current analysis (11 males; mean age = 66.1 ± 8.1 years; age range = 56 to 76 years; mean time since stroke at study enrollment = 58.7 months; range 13 to 129 months). The subjects had already exhibited changes from the pretesting to posttesting periods in response to MP + RTP participation, with many of these changes approaching a level of significance. These changes are detailed elsewhere.

To address the current study purpose, paired samples t-tests were conducted to compare POST versus POST-3 total scores on each of the measures (i.e., FM total scores, ARAT total scores, Functional Ability, Quality of Movement, and Time scale scores of the AMAT; BB total scores). Differences between means (rejection of the null hypothesis) were considered significant when $P < 0.05$. These tests showed that no score on any measure had significantly changed from the period directly after intervention to the 3-month post testing period (FM: $t = 0.817$; ARAT: $t = 0.923$; AMAT:$t = 0.898$, $t = 0.818$, and $t = 0.967$ for the functional ability, quality of movement, and time scales, respectively; BB: $t = 0.892$). (Table 2), thus confirming the study hypothesis, as there were no differences between subject scores between POST and POST-3.

Discussion

Previous data show that MP + RTP participation conveys statistically and clinically meaningful changes in paretic UE use,[24] movement,[6–9,11,23] and movement patterns.[6]

However, the long term retention of these changes had not been determined. The current study adds to the literature by showing that score changes exhibited on several stroke-specific, movement outcome measures are uniformly retained several months after MP + RTP has concluded.

While measuring duration of treatment response is common in other medical disciplines, this study provides the first data showing a sustained motor response associated with participation in MP + RTP – or any mind-body intervention – targeting UE hemiparesis. Specifcally, this study showed that MP + RTP effects are retained, which was corroborated by several different outcome measures. For example, reductions in both UE impairment and UE functional limitation were retained 3 months after the intervention had concluded. This finding is important because: (a) rather than impacting only one domain of movement (e.g., isolated movement in some joints), this intervention produces changes in movement initiation, the quality of movement, ability to use the UE in functionally-relevant tasks, and the time taken to perform the movement. Such widespread changes make the intervention more likely to impact daily UE use and increase patient independence (which, after all, is the primary goal o most rehabilitative services); (b) corroborating information from several data sources means that the findings reported herein are likely valid and not due to chance.

A handful of other studies have similarly shown retention of paretic UE motor changes associated with participation in constraint-induced movement therapy (CIT).[25,26] For example, Brogardh and colleagues[25] reported retention of hand function on the Sollerman hand function test 4 years after CIT. Likewise, van der Lee and colleagues[26] reported retained hand function increases one year after CIT participation. The CIT family of therapies differs from MP + RTP in that it: (a) requires participation in many more hours/ day of practice than MP + RTP; and (b) necessitates that subjects exhibit more active distal movement than the MP + RTP intervention requires. Nonetheless, the finding that motor changes rendered by these approaches are retained months after the intervention period has concluded is an exciting one, likely to affect future practice and reimbursement patterns, as well as conceptions regarding the long-term potency of stroke behavioral interventions.

Study Limitations and Future Directions

Per the study criteria, subjects described herein did not participate in any rehabilitative or exercise intervention during the period between MP + RTP completion and POST-3 evaluation. There was also a high degree of agreement among the various outcome measures that were administered, which further strengthens the validity of our findings. Given these factors, it is likely that the changes herein described are attributable to a sustained benefit from the MP + RTP intervention, and not due to chance. Nonetheless, the unlikely possibility exists that an unreported level of sustained motor activity or exercise may have affected the sustained motor benefits exhibited by some subjects in this study. This constitutes a minor study design limitation. To overcome this shortfall, our current MP + RTP studies are including monitoring of a placebo group to compare longitudinal changes in MP + RTP subjects versus those who are not administered MP + RTP. The use of a time-matched comparison group is expected to further strengthen the validity of the findings reported herein.

An additional study limitation was no longitudinal collection of paretic UE use and neurobiological data (e.g., neuroimaging). To overcome this limitation, future studies may also wish to monitor paretic UE use and cortical plasticity patterns, since the former constitutes a mediating factor – and the latter a correlative factor – in motor function changes.[27] Consistent with this suggestion, longitudinal MP + RTP efforts in this laboratory are measuring paretic UE use, neuroimaging, and movement patterns using qualitative and quantitative methodologies. While motor changes are of primary interest to patients and payers, diminished paretic extremity use can cause more disability to be manifest than actually exists, and constitutes an especially important variable that we will report elsewhere. We are also monitoring ongoing, long-term MP in some subjects after the intervention period has concluded. The collection of these data overcomes a final, minor limitation, which is a paucity of data examining the actual adoption of MP as a long term home exercise strategy among our participants. Continued MP use could partially explain retention of motor benefits reported herein. However, we are also curious whether subjects are continuing to use MP to augment their physical practice regiments, improve existing skills or learn new skills. While not examined in the current cohort, future efforts are examining this possibility.

Given the preponderance of evidence that now supports MP + RTP efficacy[6–9,23] and its mechanisms of action, future authors may also consider turning their attention to questions regarding how to optimize MP + RTP delivery. Some of these questions may include the following: (a) strategies to facilitate straightforward MP delivery in more naturalistic settings. In most MP efficacy studies heretofore performed, the intervention has been delivered in a laboratory setting, largely to maintain internal validity and control subject compliance. Given that efficacy has been shown in the days and months following MP use, researchers may now wish to contemplate more naturalistic MP delivery settings in which to measure MP effectiveness. Concurrently, researchers should also contemplate methods whereby MP can be more easily accessed and/or consumed by larger patient groups. Examples of the former could include the use of MP in wards or therapy gyms, while examples of the latter may be the innovative use of MP via Internet-based strategies, as was recently suggested in a promising pilot study.[28] Collectively, the use of innovative MP delivery strategies to clinical populations is expected to accelerate MP clinical implementation and, we believe, improve outcomes while reducing costs. (b) strategies to improve/enhance MP compliance. We have experienced no difficulties with MP compliance. Nonetheless, the recent application of behavioral strategies to enhance compliance with neurorehabilitation regimens deserves consideration for MP. For example, some[29] have discussed the utility of having patients and/or their care-partners sign behavioral contracts prior to initiating their therapy regimens. Such agreements are thought to provide greater assurance that the patients fully understand the procedures involved, promote patient/carepartner “buy-in,” and increase compliance. We have found such contracts to be especially beneficial when there is a significant home-based component associated with participation in a particular protocol, as might be the case in future iterations of MP. (c) optimal window of MP delivery. A final question is at what point(s) after ictus may MP + RTP be most efficaciously administered? For example, authors have long argued that motor response to rehabilitative interventions should not be expected > 6 months after injury;[30] yet, studies of MP[6–11] and other interventions strongly suggest response can occur years after ictus. Similarly, in the weeks after stroke, there is considerable spontaneous plasticity and, thus, potential responses to motor rehabilitative interventions are thought to be high. However, the acute period is also a time of great adaptation for the patient and his/her family, and a period during which a number of therapeutic approaches may be co-administered. These factors may dampen the efficacy of a cognitively-based intervention that requires concentration and sustained attention, including MP. Future researchers must tease out the additive effect of MP - as well as its disadvantages and potential burden - in this fragile phase of stroke recovery.

Conclusion

There appears to be a long-term retention of motor benefits associated with MP + RTP participation in multiple domains. Indeed, not only were reductions in motor impairment and functional limitation retained, but improved ability to perform valued activities – as well as the time taken to perform these activities – remained several months after the intervention had concluded. Since interest in MP + RTP has increased in the last decade, yet no studies have heretofore examined its long-term benefits associated with its use, additional studies on its long term impact are encouraged to further guide its effective use.

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ABBREVIATIONS

MP	Mental Practice
UE	Upper extremity
RTP	Repetitive, task-specific practice
FM	Fugl-Meyer Assessment of Sensorimotor Impairment
ARAT	Action Research Arm Test
BB	Box and Block Test
AMAT	Arm Motor Ability Test
CIT	Constraint-induced movement therapy

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Table 1

Tasks that were Physically/Mentally Practiced, and Weeks During Which They Were Practiced

Functional Task that Was Physically/Mentally Practiced	When Administered
Reaching for and grasping a cup or object	Weeks 1,2
Turning a page in a book	Weeks 3,4
Proper use of a writing utensil	Weeks 5,6
Proper use of an eating utensil	Weeks 7,8
Using a hairbrush or comb	Weeks 9,10

Table 2

Mean MP + RTP Group Scores on Outcome Measures After and 3 Months After Administration

Measure	POST	POST-3	Change*	T*
FM	32.95 (10.6)	32.11 (12.2)	−0.84	0.817
ARAT	24.48 (16.2)	24.42 (17.3)	−0.06	0.923
AMAT Functional	2.33 (1.2)	2.45 (1.3)	+0.12	0.898
AMAT Quality	2.23 (1.2)	2.40 (1.3)	+0.17	0.819
AMAT Time	15.85 (18.8)	16.86 (20.4)	+1.01	0.967
BB	13.19 (12.9)	12.79 (12.2)	−0.40	0.892

Note. Numbers in parentheses are standard deviations; “AMAT Functional” denotes AMAT Functional Ability Scale; “AMAT Quality” denotes AMAT Quality of Movement Scale; “AMAT Time” denotes time taken to perform AMAT movements;

* denotes that computation was based on change from POST to POST-3, per the purpose of the current study.