

Computer-Based Rhythm and Timing Training in Severe, Stroke-Induced Arm Hemiparesis

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KEY WORDS

- motor skills
- paresis
- stroke
- therapy, computer-assisted
- upper extremity

OBJECTIVE. We pilot tested the efficacy of computer-based training implementing rhythm and timing in chronic, severe, stroke-induced hemiparesis.

METHOD. Two chronic stroke patients were administered the upper-extremity section of the Fugl-Meyer Impairment Scale (FM), the Arm Motor Ability Test (AMAT), Stroke Impact Scale (SIS), and Canadian Occupational Performance Measure (COPM). We then administered the computer-based intervention for 60 min, 3 days/wk for 4 wk. One week after intervention, we administered the FM, AMAT, COPM, and SIS.

RESULTS. After intervention, participants exhibited reduced arm impairment (indicated by FM scores of +2.0 and +4.0) and increases in average functional ability (+0.85 and +1.1 points on the AMAT), perceived quality of life (+2.0 and +32.0 points on the SIS), and perception of overall recovery (+10.0 points for each participant on the SIS).

CONCLUSION. This study provides preliminary evidence suggesting efficacy of computer-based rhythm and timing in chronic stroke.

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Stroke remains the leading cause of disability in the United States (Rosamond et al., 2008) and the most common diagnosis seen by occupational therapists (National Board for Certification in Occupational Therapy, 2004). Stroke-induced arm hemiparesis is a problem because of its devastating impact on the ability to perform valued activities of daily living (ADLs). Many promising approaches targeting arm hemiparesis require active, distal movement to be efficacious—an ability not exhibited by most stroke survivors.

Because motor performance is mediated by an internal timing mechanism (Buhusi & Meck, 2005; Lewis & Miall, 2006; Mauk & Buonomano, 2004), researchers have reduced impairments using rhythmic auditory signals (Getchell, 2007). One modality using this approach is the Interactive Metronome (IM; Interactive Metronome, Inc., Sunrise, FL), a computer-based version of a traditional

metronome, which purports to target motor planning and sequencing by incorporating rhythm and timing during repetitive movements. Using the IM, several authors (e.g., Bartscherer & Dole, 2005) have shown cognitive, attentional, language, and motor changes in children with attention and motor coordination difficulties, including attention deficit hyperactivity disorder and Landau-Kleffner syndrome.

To date, only one study has examined IM effects on functional arm motor skills (Bartscherer & Dole, 2005), and no studies have examined IM efficacy in stroke-induced hemiparesis. Given the need for treatments for severe arm hemiparesis and the relation between affected arm functional use and neuroplasticity, we hypothesized that IM use during occupation-based activities would reduce impairment and increase ADL performance in adults with chronic stroke. This pilot study examined efficacy

of the IM approach in 2 participants exhibiting severe, stable arm hemiparesis after stroke.

Method

Participants

Volunteers were recruited using advertisements placed in rehabilitative clinics in the midwestern United States. A research team member screened volunteers using the following inclusion criteria: (1) severe affected arm impairment indicated by an upper-extremity Fugl-Meyer Scale (FM; Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) score of 10–19; (2) stroke experienced <12 mo before study enrollment; (3) a score ≥ 25 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975), (4) age ≥ 21 and <75; (5) had experienced one stroke; and (6) discharged from all forms of physical rehabilitation.

Exclusion criteria were (1) age <21; (2) excessive pain in the affected hand, arm, or shoulder, as measured by a score ≥ 5 on a 10-point visual analog scale; (3) excessive spasticity in the affected elbow, wrist, or fingers, defined as a score of ≥ 3 on the Modified Ashworth Spasticity Scale (MAS; Bohannon & Smith, 1987); (4) currently participating in any experimental rehabilitation or drug studies; (5) received botulinum toxin injection to any portion of the affected arm within the past 4 mo or phenol injections <12 mo before study participation; (6) visual neglect or visual field deficit; and (7) absent bilateral or unilateral hearing.

Using these criteria, 2 volunteers were recruited. Before screening and participation, they signed informed consent forms approved by the local institutional review board. Participant 1 was a 68-yr-old African-American man who experienced an ischemic stroke affecting his right side 23 yr before study enrollment. He was left hand dominant. Participant 1 received inpatient physical and occupational therapy for 1 mo, followed by outpatient physical and occupational therapies for an additional 6 mo. At the time of study enrollment, his medications included diltiazem HCl (240 mg), amlodipine (5 mg), atacand (16 mg), atorvastatin (10 mg/day),

metformin (500 mg), and fexafenodine (60 mg). His MAS scores were 1 at all affected upper-extremity joints. He lived with his wife at home, where his only other exercise consisted of riding a bicycle ergometer 2–3 days/wk.

Participant 2 was also an African-American man, age 75, who experienced an ischemic stroke affecting his left, non-dominant side 2 yr 2 mo, before study enrollment. His medications included azithromycin (250 mg/day), rosuvastatin (10 mg/day), clopidogrel (75 mg/day), montelukast (10 mg/day), and fluticasone and salmeterol oral inhalation (100/50, twice/day). Participant 2 was a community ambulator with an ankle-foot orthosis and walker; he exhibited mild spasticity in his affected arm, as evidenced by MAS scores of 2 in the affected elbow and 1+ in the affected wrist and fingers. He had received approximately 7 wk of inpatient and outpatient therapies and had done nothing more since time of discharge, either at home or in the community.

Apparatus

The PC-based IM System includes the IM control unit, two hand cuffs, a foot trigger, a hand trigger, and headphones (Figure 1). According to IM specifications, the master control unit produces sounds, registers

movement, and counts repetitions. The hand trigger is attached to the cuff with a hook-and-loop strap, and the hand trigger transmits data to the control unit. The foot trigger is a mat with transmitters that sends data to the control unit, and the headphones allow the user to hear the auditory output from the control unit (IM). The foot trigger requires considerable force for activation and precise foot placement to make contact with the sensor. Approximate setup for the IM is 10 min.

Outcome Measures

The primary outcome measure was the upper-extremity section of the FM, which assessed changes in arm impairment. Data arise from a 3-point ordinal scale, ranging from 0 = *cannot perform* to 2 = *can perform fully*, that is applied to each item.

Demonstration of changes in motor impairment alone is not sufficient to warrant clinical implementation of a new rehabilitation intervention. Thus, the Arm Motor Activity Test (AMAT; Kopp et al., 1997) was used to determine whether changes occurred in activity limitation. The AMAT is a 13-item test in which ADLs are rated according to a functional ability scale that examines affected limb use (0 = *does not perform with affected arm*; 5 = *does use arm at a level comparable to*



Figure 1. The Interactive Metronome.

unaffected side) and a Quality of Movement Scale (0 = *no movement initiated*; 5 = *normal movement*).

In addition to the participant's ability to actively perform isolated movements and ADLs, we administered the Canadian Occupational Performance Measure (COPM; Law et al., 2000), an interview used to identify occupational performance problems and to measure satisfaction and importance of tasks according to the patient. After questions are asked, clients identify on a scale ranging from 0 to 10 the importance of the task to them, their perception of their performance with skills, and their satisfaction with their performance. Once the top five tasks are determined, they are used to guide the treatment. The test is usually administered at baseline and discharge to determine change in performance and satisfaction. If the number is positive, then there was change for the better. If the number is negative, the person's perception of the skills have declined.

Finally, to determine whether the previously mentioned changes altered quality of life, we administered the Stroke Impact Scale 3.0 (SIS; Duncan, Bode, Min Lai, & Perera, 2003). The instrument is a 59-item self-report measure with items further broken down into eight domains (Strength, Hand Function, ADL, Mobility, Communication, Emotion, Memory, and Social Participation).

Pretesting and Intervention

This study used a pretest–posttest case study design. Specifically, after consent and screening, each participant was individually administered the FM, AMAT, COPM, and SIS by a research team member who was blinded to the intervention to be administered. It took approximately 90 min to administer all measures to each participant.

One week after pretesting concluded, the intervention phase began. Treatment sessions occurred 3 times/wk for 4 wk. Each treatment session lasted 60 min and consisted of approximately 5 min of preparatory stretching exercises, 30 min of IM use, and a combination of purposeful and occupation-based activities for the final 25 min. Purposeful and occupation-based activities

Table 1. Arm Motor Fugl-Meyer (FM) and Arm Motor Ability Test (AMAT) Average Functional Ability Pretest and Posttest Scores

Test and Participant No.	Pretest Score	Posttest Score	Change
Arm Motor FM			
1	18	22	4.0
2	13	15	2.0
AMAT average functional ability			
1	1.05	2.15	1.1
2	0.8	1.65	0.85

focused on participant-determined tasks established by the COPM. The number and duration of activities varied in each session, depending on participant tolerance. Activities included tying shoes bimanually, opening jars, and signing receipts. Each participant was continuously teamed with Sarah C. Beckelheimer, Ann E. Dalton, or Charissa A. Richter in the same lab environment throughout the duration of the study.

IM protocol specifies six phases of treatment, during which participants engage in activities such as clapping hands or tapping feet while trying to synchronize movement with a reference tone. In Phase 1, participants learn the reference tone; in Phase 2, the guide sounds; in Phase 3, timing skills; in Phase 4, advanced timing skills; in Phase 5, focus skills; and in Phase 6, prolonged focus and timing (Interactive Metronome, 2007). Participants in this study advanced through three to five phases within the short duration of the study. They progressed through the phases of IM on the basis of phase transition guidelines provided by Interactive Metronome, such as understanding of the guide and reference tones or improved task average.

Posttesting

One week after the final treatment session, each participant returned to the room at which pretesting had occurred. The same measures administered at pretesting were again administered by the same rater. The examiner was blinded as to whether the

participant had been administered any intervention.

Results

During the course of the intervention, the participants expressed no complaints or limitations. Compliance was 100%; they attended all clinical sessions.

Before intervention, the participants exhibited minimal active movement in their paretic arms, indicated with FM scores of 18 and 13 before intervention (Table 1). This score reflected normal reflexes, ability to partially or fully complete all FM shoulder items, and ability to actively move the affected elbow to varying degrees. After intervention, both participants showed improvement in FM total scores, specifically in grasping, pronation, and supination.

Both participants also demonstrated increased ability to perform laboratory-based ADLs using the affected arm, as measured by the AMAT. Specifically, at posttesting, participants showed increases in average functional ability scores (see Table 1). The most notable changes occurred for test items such as “placing paretic arm in shirt sleeve” and “inserting arms in t-shirt.”

We used the SIS to measure participants' perceived quality of life after stroke. Both participants' domain scores increased; Participant 2's domain score increased by 32.0 points (Table 2). Changes in recovery scores were +10.0 points for both participants.

Table 2. Stroke Impact Scale Domain and Recovery Pretest and Posttest Scores

Participant	Domain Score			Recovery Score		
	Pretest	Posttest	Change	Pretest	Posttest	Change
1	258	260	2.0	40	50	10.0
2	197	229	32.0	30	40	10.0

Table 3. Canadian Occupational Performance Measure Pretest and Posttest Performance and Satisfaction Scores

Participant	Performance			Satisfaction		
	Pretest	Posttest	Change	Pretest	Posttest	Change
1	2.5	5.5	3.0	3.5	5.5	2.0
2	3.8	7.2	3.4	3.8	8.2	4.4

The COPM assessed participants' perceived performance ability and satisfaction with meaningful occupations. Perceived performance and satisfaction scores increased (Table 3). Participant 1 was able to identify only two COPM objectives. His initial performance scores were 2 for bimanually tying shoes and 3 for reaching objects; those scores increased to 5 and 6 at posttesting. In addition, his satisfaction scores for these tasks were 3 and 4 and increased to 5 and 6 at posttesting.

Participant 2's initial performance scores were 1 for taking off jar lids, 5 for stair mobility, 4 for making the bed, 3 for bimanually tying shoes, and 6 for standing in the shower. He exhibited performance score increases of from 2 to 6 points. His satisfaction with his ability to perform these tasks ranged from 1 to 6 points initially and increased to 7 to 9 points at posttesting.

Discussion

Despite its increasing pervasiveness and disabling impact, few treatments reduce stroke-induced hemiparesis. Moreover, most regimens require some active movement at the affected wrists and fingers—a prerequisite that excludes most stroke patients. In response to those shortfalls, the current study piloted the IM to examine its impact on active affected arm movement and quality of life in stroke patients exhibiting severe hemiparesis.

The participants demonstrated minimal isolated movement in their affected arms at pretesting, and they substantially increased movement after intervention, reflected in their FM scores. FM increases were comparable to isolated movement changes observed in a 2005 case study using the IM (Bartscherer & Dole, 2005), in which a child with motor and attention deficits made significant improvements in visual–motor control and upper-limb

strength and dexterity, as measured by a pediatric motor skills test (Bruininks–Oseretsky Test of Motor Proficiency; Bruininks & Bruininks, 2005). Although the Bruininks–Oseretsky Test is used to measure motor skills in pediatric populations, certain items that showed change on that measure are comparable to FM items that showed change in the current study.

Other devices targeting the stroke-affected arm have included the IMT InMotion2 and InMotion3 (Interactive Motion Technologies, Boston, MA), and Motorika Reo Go (Motorika, Birmingham, AL). Although some of them have evidence supporting their promise in severely impaired stroke, all are large-platform systems and incorporate force transducers and visual feedback by means of therapycentric videogames to provide the patient with full to partial upper-extremity assistance. Moreover, the devices do not provide patients with the ability to practice ADLs when they are working with a therapist—a prerequisite for Medicare reimbursement. FM changes in this study were comparable to those shown in previous work involving robotics in severe stroke (Housman, Scott, & Reinkesmeyer, 2009). Unlike the previous studies, however, the current study required little specialized machinery, low expense, and minimal therapist interaction. Thus, our data suggest that IM may be an equally efficacious, lower cost solution to platform-based robotics in treating affected arm impairment in severe stroke.

Both participants demonstrated increased AMAT scores, and Participant 2 showed a 32-point score increase on total domain score (Table 2), demonstrating clinically meaningful change (Duncan et al., 1999). However, those changes did not translate to clinically meaningful change on the SIS for Participant 1 (defined as a ≥ 10 -point change on the do-

main score). Although SIS scores did not indicate clinically significant change for both participants, subjective reports given by participants during the SIS posttesting session indicated improved perception of function. For example, Participant 1 noted change by saying, "This is the first time I've tied my shoes in 27 years." Participants 1 and 2 also reported increased attentiveness during daily tasks, and Participant 1 noted, "I feel sharper for sure."

Participants 1 and 2 exhibited marked improvement in their overall recovery, as shown by the SIS overall score. Results of this assessment were consistent with an 8-wk study on rhythmic auditory stimulation for chronic stroke by Jeong and Kim (2007). As in the current study, the authors reported that a small sample size may have prevented the results from being significant.

Both participants also demonstrated clinically significant COPM score improvement, which is typically defined as a ≥ 2 point increase from pretest to posttest (Law et al., 1998). Participants identified initial difficulties in the areas of home management and self-care, similar to a study by Phipps and Richardson (2007), which found that stroke patients receiving outpatient occupational therapy after right-hemisphere stroke were most likely to identify self-care and home management goals on the COPM. After intervention, both participants reported increased performance in and satisfaction with daily tasks. Changes observed were comparable to changes in the Phipps and Richardson study and those in a case study by Hill Hermann et al. (2008).

Study Limitations

The change in COPM scores represents a significant increase in participants' perceived performance and satisfaction with performance for meaningful activities. Holliday, Ballinger, and Playford (2007) noted that use of client-driven goals in neurological rehabilitation led to increased understanding and greater commitment to the treatment protocol. Because participants set their own objectives for treatment, it is possible that they became more invested in their recovery as a part of this study. The

primary study limitation was a small sample size, although this was understandable, given that the goal was to examine IM feasibility in the stroke population.

Conclusion

Given our promising findings, future research not only should attempt to replicate the effects herein described with a larger sample but also should use qualitative measures to better understand whether Holliday and colleagues (2007) were accurate in their assertion. Given the magnitude of treatment effects observed and the variety of domains in which motor changes were observed, it is unlikely that treatment effects were simply caused by the attention that participants received from study participation. Nonetheless, controlled methods in future work would allow for adequate monitoring of this effect. ▲

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