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Effect of using TheraBracelet on grasping vs. reaching in post-stroke rehabilitation

Allison Pennington, OTD[1], **Viswanathan Ramakrishnan, PhD**[2], **Gabrielle Scronce, PT, DPT, PhD**[3], **Kristen Coupland, MS, OTR/L, CSRS, CDRS**[3], **Amanda A. Vatinno, PhD OTR/L**[3], **Na Jin Seo, PhD**[1,3,4]

[1.]Division of Occupational Therapy, Department of Rehabilitation Sciences, College of Health Professions, Medical University of South Carolina, Charleston, SC

[2.]Department of Public Health Sciences, College of Medicine, Medical University of South Carolina, Charleston, SC

[3.]Department of Health Sciences and Research, College of Health Professions, Medical University of South Carolina, Charleston, SC

[4.]Ralph H. Johnson VA Medical Center, Charleston, SC

Abstract

Background: A peripheral sensory stimulation named TheraBracelet has recently been shown to have a potential to improve gross manual dexterity following stroke. Upper limb function requires both reach and grasp. It is unknown whether TheraBracelet affects one more than other.

Objective: Determine whether TheraBracelet improves reaching vs. grasping.

Methods: Secondary analysis of a pilot randomized controlled trial. Persons with stroke received TheraBracelet (treatment) or no stimulation (control) during task practice therapy (n=6/group). Effects of TheraBracelet on reaching vs. grasping were determined using breakdown of movement times in the Box and Block Test video recordings.

Results: Improvements in movement times for the treatment compared to control group were more pronounced for grasping than for reaching at both post and follow-up time points.

Conclusions: TheraBracelet may be beneficial for persons with grasping deficits. This knowledge can guide clinicians for targeted use of TheraBracelet, resulting in effective implementation of the new treatment.

Keywords

stroke; rehabilitation; upper extremity; subliminal stimulation; wearable electronic devices

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[*]Corresponding author: Na Jin Seo, PhD, 77 President St, MSC 700, Charleston SC 20425, seon@musc.edu, 843-792-0084.

Declaration of Interest: N.J. Seo is an inventor of a patent regarding the investigated sensory stimulation. The other authors report no conflicts of interest.

Ethics Approval: The study protocol was approved by the Institutional Review Board at the Medical University of South Carolina (approval id: Pro42759).

Clinical trial registration number: NCT02675764

Introduction

Complete functional recovery of the upper limb occurs in only 11.6% of people 6 months post-stroke, with many persons with stroke requiring ongoing rehabilitative services to continue the recovery process (Kwakkel et al., 2003). A meta-analysis shows that upper extremity motor function improves more when therapy is augmented by peripheral sensory stimulation, compared with therapy alone (Conforto et al., 2018). The scientific rationale is that afferent input is a powerful driver of change in the motor cortex (Baker, 2007; Schabrun et al., 2012).

TheraBracelet is one such peripheral sensory stimulation modality that has recently been developed to improve upper extremity function after stroke (Seo, Woodbury, et al., 2019). TheraBracelet is subthreshold (i.e., imperceptible) random-frequency vibratory stimulation applied to the paretic wrist to enhance sensorimotor cortical activity for paretic upper extremity tasks (Schranz et al., 2022; Seo et al., 2015; Seo, Lakshminarayanan, et al., 2019). Subsequently, it has shown to improve upper extremity sensorimotor function (Enders et al., 2013; Hur et al., 2014; Lakshminarayanan et al., 2015; Seo et al., 2014; Wang et al., 2015) and recovery (Seo, Woodbury, et al., 2019; Vatinno et al., 2022).

Specifically, a recent pilot randomized controlled trial investigated if the use of TheraBracelet during task-practice therapy yielded significantly greater improvements in upper extremity motor outcome compared to task-practice therapy alone (Seo, Woodbury, et al., 2019). Upper extremity motor outcome was assessed by the Box and Block Test (BBT) followed by the Wolf Motor Function Test (WMFT). The pilot trial found large effect sizes on upper extremity outcome measures of the BBT and WMFT time. BBT quantifies the number of blocks that a person can move from one box to the other across a barrier in a minute (Mathiowetz et al., 1985; Platz et al., 2005). The WMFT time is the average movement time to complete 15 functional tasks such as lifting a pencil (Wolf et al., 2001). The pilot trial also found significant improvement in BBT for the treatment group that received TheraBracelet during therapy compared to the control group that received sham (no) TheraBracelet during therapy, but not for the WMFT possibly due to a small sample size and short therapy duration. However, it is currently unknown whether TheraBracelet is more effective in improving reaching or grasping because clinical assessments of upper extremity function typically include both reaching and grasping movements.

The rationale for dissociating the reaching and grasping movements is as follows. Grasping requires control of the distal finger muscles that are predominantly innervated by monosynaptic corticospinal fibers, while reaching requires control of the proximal arm muscles influenced by other resources such as brainstem pathways (Buccolieri et al., 2003; McPherson et al., 2018; Turton & Lemon, 1999). Thus, these movements are differentially impacted by stroke depending on lesion characteristics (Cunningham et al., 2016; Weiller et al., 1993). Furthermore, it has been observed that persons with stroke regain reaching earlier than grasping (Lang et al., 2006).

Therefore, rehabilitation treatments should target the specific reach vs. grasp deficit of a person depending on their stage of recovery and impairment characteristics. Likewise, development of new rehabilitation technologies should have a clear indication of the specific benefits they intend to have. Rehabilitation therapists report that they are more likely to adopt a new rehabilitation technology if they know that the new intervention targets the client's specific need (Chen & Bode, 2011; Morrow et al., 2021).

Consequently, the objective of this study was to determine whether use of TheraBracelet results in greater improvement in reaching vs. grasping. TheraBracelet stimulation has been shown to affect the sensorimotor cortex activity (Schranz et al., 2022; Seo et al., 2015; Seo, Lakshminarayanan, et al., 2019), which has greater influence over the distal hand muscles used for grasping than proximal arm muscles used for reaching (Buccolieri et al., 2003). In addition, previous evidence shows TheraBracelet's effect on dexterous hand function (Seo et al., 2014). Based on this, we hypothesized that TheraBracelet would result in greater improvement in grasping than reaching. The knowledge obtained in the present study could improve effective use of the TheraBracelet treatment by providing clinicians with a more targeted approach to rehabilitation of the upper limb following stroke.

Materials and methods

Study design

This study is a secondary analysis of a triple-blind pilot randomized controlled trial that showed use of TheraBracelet during therapy can improve gross manual dexterity in persons with stroke compared to therapy alone (Seo, Woodbury, et al., 2019). In this trial, participants were randomly assigned to either a treatment group or control group (n=6/group). Participants, therapists administering task-practice therapy, and assessors were blinded to group allocation. The treatment group received a 2-week task-practice therapy while a vibrator applied TheraBracelet subthreshold random-frequency vibratory stimulation to the paretic wrist (Figure 1). The control group received the same 2-week task-practice therapy but no stimulation from the vibrator.

The therapy involved repetitive practice of tasks requiring primarily unilateral dexterous hand and finger motions in sitting. The therapy was manualized following the EXCITE trial manual (Wolf et al., 2006) and task-specific training manual (Lang & Birkenmeier, 2014). Participants and therapists collaboratively chose meaningful tasks from the task menu to facilitate applicability of learned skills to the participants' real-world tasks and goals. Task difficulty was graded to achieve optimal challenge for the participant, as described by Lang & Birkenmeier (2014).

For assessment, a trained study personnel administered BBT. BBT was completed by participants using the paretic hand prior to the intervention (pre), on average 6 days after the completion of the 2-week intervention (post), and on average 19 days after the intervention completion (follow-up). All BBT assessments were videotaped from the top/sagittal view at 30 frames per second.

Participants

A total of 12 adults who were at least 6 months post stroke were recruited, to control for the confounding effects of time since stroke and spontaneous recovery (Colombo et al., 2013).

Participants had mild to moderate upper limb impairment based on the well-established upper limb impairment scale of Fugl-Meyer Assessment Upper Extremity, with scores 30-60 out of 66 (Fugl-Meyer et al., 1975; Woodbury et al., 2013) . All participants had cognitive abilities to follow instructions and participate in the task-practice therapy. No participants had botulinum toxin injection in the paretic upper limb within 3 months of or during enrollment. Participants were 7 males and 5 females, on average 63 years old (SD=8), and on average 5 years post stroke (SD=5). Their average Fugl-Meyer Assessment Upper Extremity score was 48 (SD=8). The demographic and clinical characteristics were comparable between the two groups (Table 1) (Seo, Woodbury, et al., 2019). This study was approved by the Institutional Review Board. Informed consent was obtained from all participants.

Movement time analysis

To determine relative effects of TheraBracelet on reaching vs. grasping, change in reaching and grasping time during BBT from pre- to post-intervention was compared between the two groups. BBT was used because the movement time analysis for BBT has been established in the literature (Seo & Enders, 2012; Slota et al., 2014). In addition, BBT involves repeated measurements for one task of moving one block at a time, thus providing more accurate estimate of measurement variability. Following the established movement time analysis method (Seo & Enders, 2012; Slota et al., 2014), video recordings of BBT were analyzed in the following way. The motions of BBT were broken down into 6 movement components required to complete BBT (Figure 2, adapted from Seo & Enders, 2012 and Slota et al., 2014). The start of each movement component was defined as follows. (1) Reach to Grasp: starts when the hand crosses the barrier toward the next block. (2) Contact to Lift: starts when the fingers have contacted the block. (3) Transport: starts when the block has been lifted off the floor of the box. (4) Release: starts when the block crosses the barrier. (5) Free Fall: starts when the block has left contact with the fingers. (6) Return: starts when the hand begins moving toward the barrier. For each block moved for BBT, one examiner who was blind to the group assignment determined the movement component times by counting the number of frames used for each movement component using QuickTime (Apple Inc., Cupertino, CA) and multiplying it by 1000/30 to compute time in milliseconds. These 6 movement components were further classified as either reaching or grasping (Figure 2).

Statistical analysis

Linear mixed model analysis was performed using SAS (SAS Institute Inc., Cary, NC) to determine the effect of TheraBracelet on the movement component times. Factors included in the model were group (treatment and control), time (pre, post, and follow-up), and BBT movement component. To account for within-participant correlations, a random intercept was included in the model. An autoregressive (AR(1)) structure was used for the correlations over time. Diagnostics were performed to verify assumptions and to choose the appropriate structure for the within-subject correlations over time. A log transformed led to adequacy of assumptions such as normality. P-values smaller than 0.05 were deemed statistically significant. When interactions were significant, linear contrasts with Tukey adjustment were used to make post-hoc pairwise comparisons.

Results

Movement time changed differently over time by group and movement component (group x time x movement component interaction p<.0001, Figure 3). For the treatment group, movement became significantly faster from pre to post for the two grasp movement components of Contact to Lift (p=0.0003) and Release (p<.0001). Contact to Lift time improved by 45% and Release time improved by 26% from pre to post. Release time also improved from pre to follow-up by 21% (p<.0001). Return time also significantly improved from pre to post for the treatment group (p=0.0039). However, the mean difference was only 15 milliseconds, less than our measurement increment. Movement time for other components did not significantly change with the time (p>0.05).

In the control group, movement became significantly slower for Release (p=0.0025) and Return (p=0.0329) from pre to post. Release time became slower by two folds. Return time became slower by 45%. All other movement component time comparisons were not significant including the between-group movement time comparison at pre (p>0.05). Individual participants' changes in the movement component time across the three time points are presented in Figure 4.

Discussion

This study examined how the use of TheraBracelet affected reaching vs. grasping time. For the treatment group, movement became significantly faster in the grasping components of BBT (Contact to Lift and Release) rather than the reaching components. These changes in the movement time corresponded to improvement in the BBT score exceeding the minimum detectable change (Chen et al., 2009) in the previous trial (Seo, Woodbury, et al., 2019). For the control group, neither reach nor grasp movements became faster. These results suggest that TheraBracelet may be more beneficial in targeting grasping deficits than reaching. This study provides in-depth understanding of how TheraBracelet was able to improve gross manual dexterity in persons with chronic hemiparesis after stroke.

These results support the hypothesis and its rationale that the TheraBracelet stimulation may affect the neural activity in the sensorimotor cortex (Schranz et al., 2022; Seo et al., 2015; Seo, Lakshminarayanan, et al., 2019) which has a greater influence over the distal hand muscles used for grasping than proximal arm muscles used for reaching (Buccolieri et al., 2003; McPherson et al., 2018; Turton & Lemon, 1999). We speculate that this rationale may explain why movement became faster only for the grasping components and not for the reaching components in the treatment group. It is interesting to note that this finding was obtained even though the TheraBracelet stimulation was applied to the wrist, not to the hand.

Another potential explanation for the finding is that TheraBracelet enhanced grasping more than reaching because the task-practice therapy in this study focused on dexterous manipulation of objects with the hand and finger. Peripheral sensory stimulation along with other stimulation modalities is utilized as a tool to prime the brain and nervous system and enhance the effect of the subsequent behavioral therapy (Carrico, Chelette, Westgate, Powell, et al., 2016; Carrico, Chelette, Westgate, Salmon-Powell, et al., 2016; Cassidy et al., 2014; Celnik et al., 2007; Conforto et al., 2007). However, all practiced therapy tasks involved activities of daily living which inherently involve some reaching in addition to grasping (Lang & Birkenmeier, 2013). Reaching during therapy tasks did not involve full shoulder flexion and elbow extension, but neither does BBT.

Clinically, the results of this study offer an important insight into the benefits of TheraBracelet use. Specifically, the results of this study can be used to assist clinicians in improving outcomes by providing a guide for the persons TheraBracelet can be best used for. Occupational therapy is a discipline founded on activity analysis, in which each activity is broken down into the small individual components needed to complete the activity. Similarly, treatment modalities need to specify what components they target to improve overall upper extremity function (Chen & Bode, 2011; Morrow et al., 2021). The results of this study demonstrate that TheraBracelet not only improves overall upper limb function (Seo, Woodbury, et al., 2019), but it can also be used as a targeted treatment approach for persons with stroke who are experiencing challenges in completing daily activities specifically because of grasping deficits. Thus, TheraBracelet as an addition to task specific therapy targeting grasping deficits may benefit upper limb recovery post stroke.

Strengths of this study include the blinding of all parties. In addition to participants, therapist providing the therapy, and the study personnel administering BBT, the examiner who determined the movement component times was blind to the group assignment of individual participants. Furthermore, an established movement time analysis method was applied to tease out the effect of an intervention on reach vs. grasp separately. These movement components are typically lumped in clinical assessments in intervention trials and the dissociation in the present study provides in-depth understanding of how the new intervention may improve the upper extremity function.

Limitations of this study include the limited sample size. Although the vibrator's wire did not appear to impede participants' ability to complete the tabletop therapy activities in this study, a wireless vibrator (Seo et al., 2020) is expected to improve usability. In addition, outcome measures of the previous trial were based on movement time, not quality. In subsequent research, we plan to use other standardized assessments or 3-dimentional kinetic and kinematic analysis to investigate not only the speed but also quality of reaching and grasping components in more functional tasks. Moreover, a larger trial for TheraBracelet will use therapy balanced for both in-hand manipulation and reaching (Seo et al., 2022). Thus, the finding will be re-examined with the future trial data with therapy balanced for reaching and grasping and a larger sample size. Future work will also examine clinical meaningfulness of the intervention associated with faster movement time by assessing participants' perceived meaningfulness (Seo et al., 2022).

Conclusion

Functional upper limb recovery requires recovery of both reach and grasp. This study shows that TheraBracelet may be a beneficial treatment tool to use in adjunct with task practice therapy for persons with deficits in grasping in particular. This knowledge can guide clinicians for targeted use of TheraBracelet, resulting in effective implementation of the new treatment.

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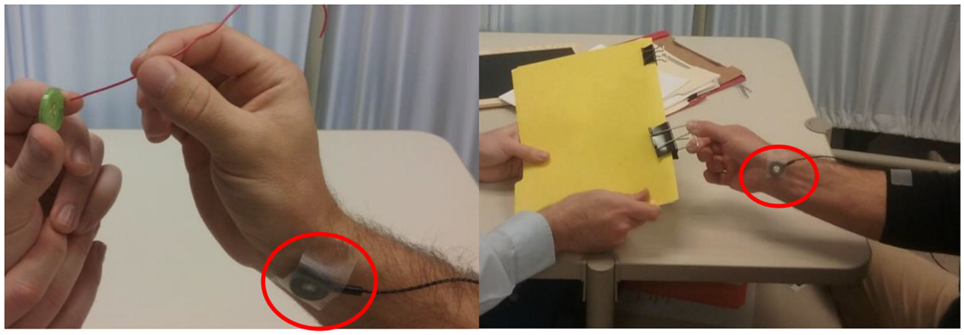


Figure 1.
A vibrator was placed on the paretic wrist for both groups. The vibrator delivered subthreshold vibratory TheraBracelet stimulation for the treatment group and no stimulation for the control group during therapy.

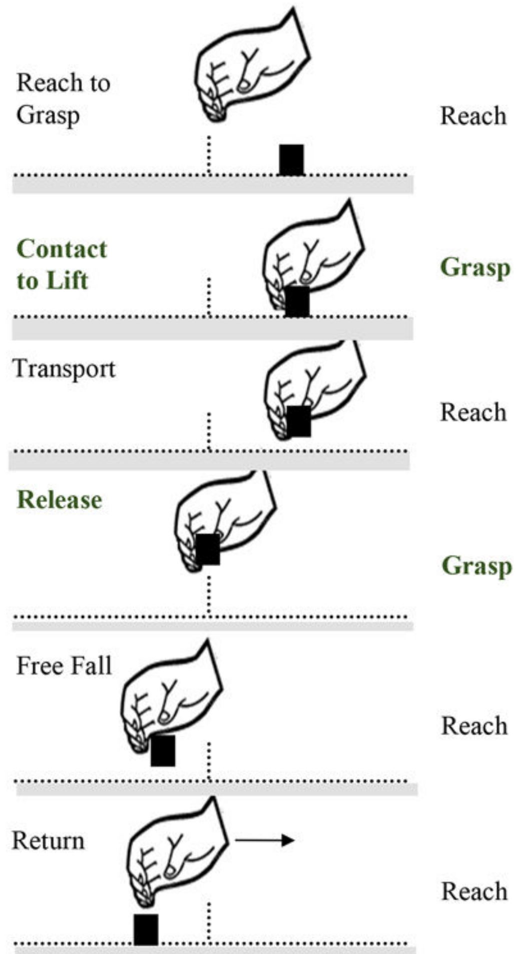
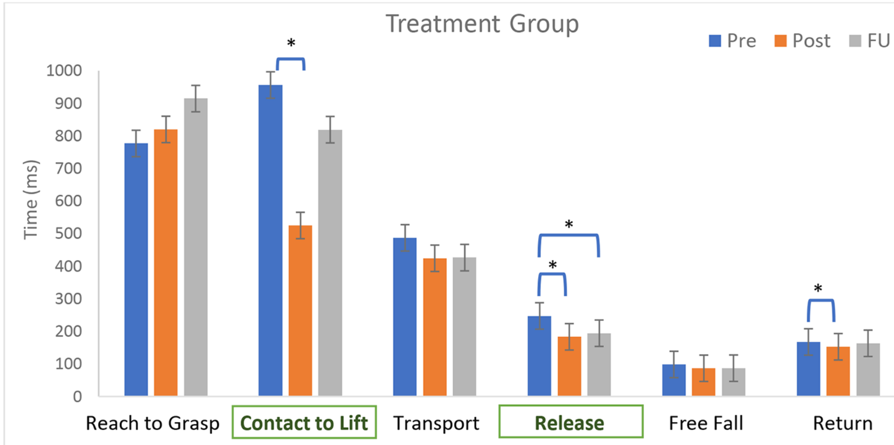
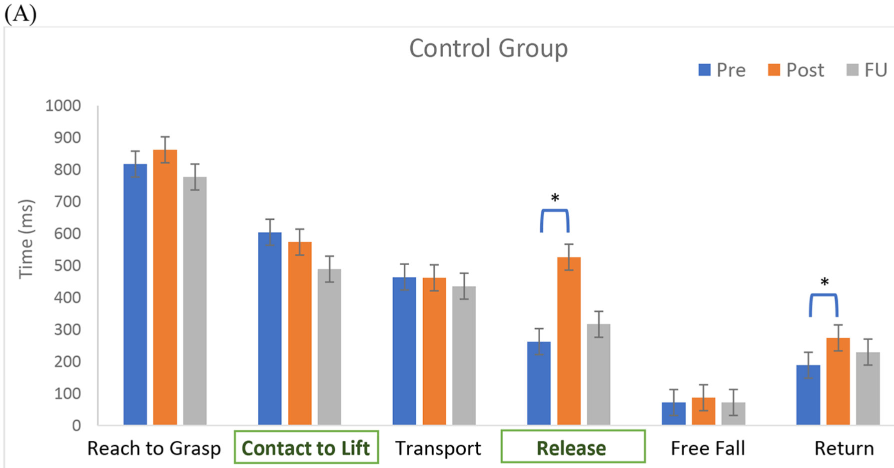


Figure 2.

Illustration of six movement components that are required to grasp and move each block (black square) across the barrier (vertical line in the middle) in the Box and Block Test (adapted from Seo & Enders 2012). The designation of each of the six movement components to the reaching vs. grasping class (in bold) is also noted.



(A)



(B)

Figure 3.
Movement time for each component at 3 timepoints (pre, post, and follow-up) for the treatment group (A) and control group (B). Error bars show standard errors. Asterisks denote significant changes based on pairwise comparisons with Tukey post hoc adjustment. Movement components for grasp are in bold in rectangles (Contact to Lift and Release), while those for reach are not.

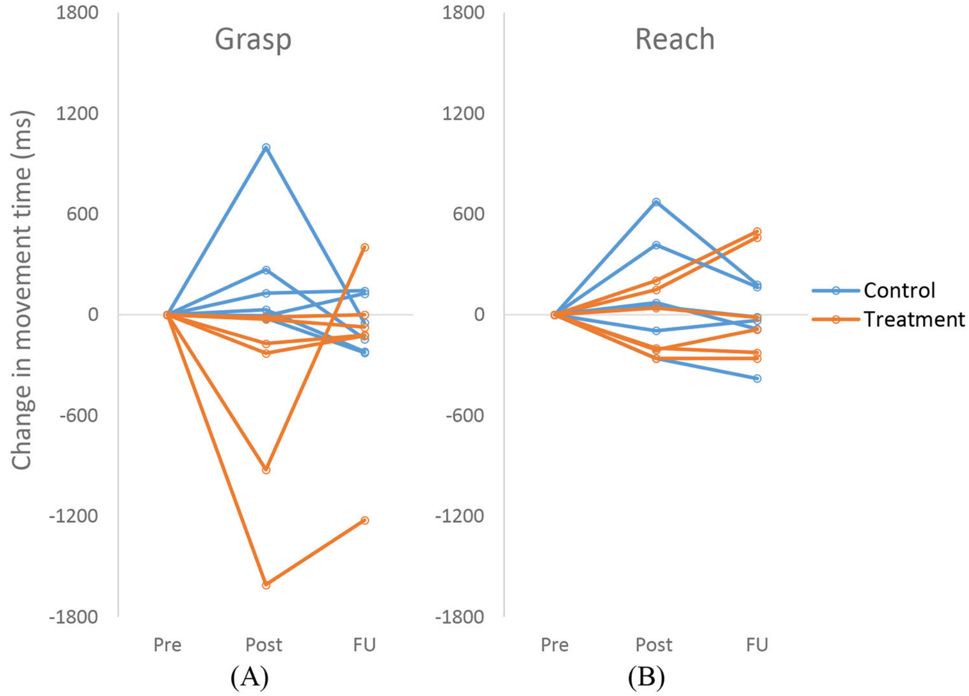


Figure 4.
Change in the movement time for the grasp (A) vs. reach (B) for individual participants in the treatment and control group.

Table 1.

Participant characteristics

	Treatment group (n=6)	Control group (n=6)	p
Age mean (SD) in years	61 (10)	64 (8)	0.73
Male/female	5/1	2/4	0.24
Ischemic/hemorrhagic stroke	5/1	6/0	1.00
Time since stroke range in years	1-16	1-6	0.24
Fugl-Meyer Assessment Upper Extremity Score mean (SD)	45 (9)	51 (7)	0.59