Effects of Occupational Therapy Task-Oriented Approach in Upper Extremity Post-Stroke Rehabilitation

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Dedication

This work is dedicated to my amazing father, family, and to the soul of my mother. It is also dedicated to the study participants who showed unique kindness and collaboration and for all individuals who have had stroke... improving your quality of life is my passion.

Abstract

There is a need for effective Upper Extremity (UE) post-stroke rehabilitation approaches. The Occupational Therapy Task-Oriented (TO) approach was described early in the nineties of the past century. Many of the TO principles were supported in the literature. However, the TO as a whole was only evaluated in case studies. This study aimed to evaluate the functional and the impairment effects of this approach and to refine its treatment protocol. Twenty participants with stroke of three months or more fulfilled the minimal affected UE active movements of at least 10° of shoulder flexion and abduction and elbow flexion-extension and volunteered for this study. Participants were randomized into two order groups. The immediate group got 3 hours of TO treatment per week for six weeks and then got six weeks of no treatment control while the delayed intervention group underwent the reversed order. Participants were evaluated before the first phase, at the cross over, and after the second phase by trained, blinded evaluators. The treatment change scores from both groups were compared with those of the control. The results supported the TO functional superiority as indicated by significant and clinically meaningful changes in the Canadian Occupational Performance Measure (COPM), the Motor Activity Log (MAL), and the time scale of the Wolf Motor Function Test (WMFT). The result failed to support hypothesis of the impairment effects superiority of the TO. We conclude that the TO approach is an effective UE post-stroke rehabilitation approach in improving the UE functional abilities. More studies are needed to provide more evidence for this approach and to illuminate more of its therapeutic abilities with different stroke severity and chronicity levels.

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Cerebrovascular accident (CVA) or stroke is the leading cause of long term disability in the United States. Each year about 700,000 Americans experience a stroke. Two-thirds of those individuals need rehabilitation (National Institute of Neurological Disorders and Stroke, 2007). Stroke is a major cause of disablement in many western countries; approximately 80% of stroke patients survive the acute phase, and although most patients regain their walking ability, 30% to 66% of the survivors are no longer able to use the affected arm (Kwakkel, Kollen, & Wagenaar, 1990). The recovery process of upper extremity function is often slower than the recovery process of lower extremity function (Kwakkel, Wagenaar, Kollen, & Lankhorst, 1996). There is a need to have more research to establish best practice methods for patients who are not able to regain their hemiplegic upper extremity (UE) functional abilities (Barreca, Wolf, Fasoli, & Bohannon, 2003).

The Occupational Therapy Task-Oriented approach (TO) is a relatively new therapeutic approach. This approach is based on systems models of motor control, and recent motor development and motor learning literature (Mathiowetz & Bass-Haugen, 1994). Many of the TO approach principles (Wu, Trombly, Lin, and Tickle-Degnen, 2000; Wu, Wong, Lin, & Chen, 2001; Kwakkel, Wagenaar, Twisk, Lankhorst, and Koetsier, 1999) and variations (Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998; Finley, Fasoli, Dipietro, Ohlhoff, Macclellan, Meister, et al. 2005; Housman, Scott, and Reinkensmeyer, 2009) of the TO approach are supported in the literature. Thus, studying this approach as a whole seems warranted.

In neurorehabilitation, the Occupational Therapy TO approach as a whole was only supported by case studies. These case studies emphasized the use of meaningful functional activities as therapeutic activities while focusing on the sensorimotor control parameters such as strength, endurance, range of motion (ROM), degrees of freedom, and postural control. These case studies treatment protocols acknowledged and utilized other systems that may affect motor behavior including psychosocial and cognitive personal systems, and environment-related systems such as cultural, socioeconomic, and physical environment systems (Flinn, 1995; Gillen, 2000; Gillen, 2002; Preissner, 2010). The Occupational Therapy TO approach as a whole has not been studied in a randomized clinical trial. This approach needs more research to evaluate its clinical effectiveness. Specifically, we evaluated the effects of TO approach in post-stroke rehabilitation for improving motor impairment and functional use of the more affected UE.

Review of literature

Cerebral vascular accident

The US health care system faces serious challenges in serving persons with stroke. As the major cause of disability, stroke leads to a huge financial cost in addition to its impact on the patients' health and quality of life. On average, a person with stroke hemiparesis costs the Medicare about \$77,143 over a 4-years period. During the first year, most rehabilitation occurs in inpatient settings. However, the rehabilitation services shift into skilled nursing facilities and home health agencies in the following years (Zorowitz, Chen, Tong, & Laouri, 2009).

Cerebrovascular accident (CVA), commonly referred to as stroke, is a complex medical condition, which includes various disorders that occur following sudden neurological impairments. CVA happens when the blood flow to the brain is interrupted. Following stroke the brain cells in the affected area begin to die because they stop getting the oxygen and nutrients necessary to function (Bartels, 2004). The world health organization (WHO) defines stroke as a neurological dysfunction of vascular origin with symptoms and signs corresponding to the severity and the involved damaged area of the brain (WHO, 2007). Stroke ranges from being an unnoticeable and reversible incident called transient ischemic attack (TIA), to complete stroke in which the symptoms may never completely disappear (Gillen, 2001).

There are two major types of CVA; ischemic and the hemorrhagic. The ischemic stroke is caused by a blood clot, which may be due to a thrombosis or an emboli. CVA occurs when a clot blocks or constrains a blood vessel in the brain for an adequate time. About 80% of CVA incidents are of this type. Hemorrhagic stroke is caused by a rupture of a blood vessel in the brain leading to an intracerebral bleeding or a subarachnoid bleeding. Additionally, there are a small percentage of stoke incidents with unknown causes (Gillen, 2001).

Although stroke is a disease of the brain, it can affect the entire body. Generally the outcomes depend on the area of the brain affected. The outcomes range from mild to severe including death. The loss of UE control is common after stroke. Stroke might lead to UE dysfunctions due to several factors including: pain, contracture and deformity, loss

of selective motor control, weakness, shoulder subluxation, tone abnormalities, sensory abnormalities, loss of postural control to support UE control, learned nonuse, loss of biomechanical alignment, and inefficient and ineffective movement patterns. Many patients do not regain enough control to integrate the affected UE into activities of daily living and mobility. Deformities and body image problems are more common in those individuals (Gillen, 2001; Bartels, 2004; Woodson, 2002).

Gravity Eliminating Approaches to Remediate Motor Control Problems

Task oriented treadmill training with partial weight support. This is a task-specific repetitive training technique that utilizes walking on a treadmill while the patient is secured within a harness. The harness provides various amounts of body weight support (usually decreased as the patient improves) or might be used just to enhance safety during ambulation (Danielsson, & Sunnerhagen, 2000).

As compared with on floor gait training, treadmill training with partial weight support showed more typical gait utilizing more gait symmetry, less plantar flexor spasticity, more typical muscular activation pattern, and longer weight bearing period on the affected limb (Hesse, Konrad, & Uhlenbrock, 1999). Treadmill training with body weight support provided evidence of efficacy in improving gait ability and standing balance (Hesse, Bertelt, Schaffrin, Malezic, & Mauritz, 1994). Additionally it showed better gait velocity and cadence when compared with traditional gait training using Bobath approach (Hesse, Bertelt, Jahnke, Schaffrin, Baake, Malezic, et al. 1995; Sullivan, Knowlton, & Dobkin, 2002). When combined with functional electrical

stimulation, treadmill training with partial weight support had significant advantages over the regular Bobath-based physiotherapy in terms of gait restoration and walking velocity (Hesse, Malezic, Schifrin, & Mauritz, 1995). However, none of these studies was a randomized clinical trial (all lacked a control group), nor did any have a large enough sample (N ranged between 9 and 24).

In two randomized clinical trials with larger sample sizes, the results were mixed. Post- stroke gait training with partial body weight support showed positive evidence when compared with treadmill training without body weight support (Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998). The partial body weight support group showed more significant functional balance, motor recovery, over ground walking speed, and over ground walking endurance. The over ground walking speed and motor recovery remained significantly higher in the body weight support group at a three-month follow up. This represents a strong evidence of post-stroke gait training using treadmill with partial body weight support. The study had 100 participants and was a randomized controlled clinical trials. However in another randomized controlled clinical study (N=60), the researchers did not find a significant difference between post-stroke gait training using treadmill with partial body weight support and on ground motor relearning gait training (Nilsson, Carlsson, Danielsson, Fugl-Meyer, Hellstrom, Kristensen, et al., 2001). Both groups were significantly improved on Functional Independence Measure (FIM), walking velocity, Functional Ambulation Classification (FAC) and Berg's Balance Scale. However, Nilsson et al., recruited acute stroke patients which adds a confounder to their study in

comparison with Visintin et al., who used subacute patients with less possibility of undergoing spontaneous recovery. Nilsson et al., used different outcome measures than Visintin et al., except for balance (using Berg balance scale), in addition, both studies differed in the type of control used and in the stage of stroke. Regardless of these differences, the TO gait training showed significant gait and balance improvements in both of the well designed studies.

Overall, gait training following stroke with partial body weight support showed efficacy in terms of improving walking velocity, balance, and gait characteristics. A good point in this treatment approach is that it was studied using clinical outcome measures of a functional value, which were seen in gait-related measurements. However, most of the supporting studies lacked sufficient number of participants and many lacked control groups, consequently, the generalizability of the results was limited. In addition that partial weight support gait training fulfills the TO concepts and assumptions, this treatment approach was introduced to justify the idea of using gravity elimination or reduction effect in post stroke rehabilitation. Through using the elevating mobile arm support (MAS), we hope to utilize the gradually decreased body weight support principle in the UE rehabilitation post-stroke.

The Armeo® system. Sanchez, Liu, Rao, Shah, Smith, Rahman, et al. (2006) studied a system that enables persons with moderate-severe motor impairments following stroke to practice UE functional training. The system is called Therapy WREX, and commercially called Armeo® (Hocoma, 2008). This system includes a passive orthosis

that provides elevation assist to the arm and the forearm, a hand grip pressure sensor, and virtual reality software, which simulates functional activities. The orthosis has five degrees of freedom mechanism which passively reduces the arm weight using elastic bands. Sanchez et al., 2006 reported the results of two pilot studies they conducted on the WREX. The results of these studies indicated that patients with severe chronic stroke could perform reaching and drawing movements while using the system. Additionally, exercising for eight weeks using this system improved unassisted UE motor abilities. The researchers claimed that the used system was an effective UE rehabilitation therapy for people with severe stroke. However, these studies were pilot; did not have control groups, and had a small number of participants (N = 5 and N = 4).

Housman, Scott, and Reinkensmeyer (2009) compared the Armeo system (also known as T-WREX) with conventional training for UE stroke rehabilitation. They randomly assigned twenty eight moderate to severe stroke participants into Armeo training or tabletop training for gravity support. Control activities targeting the affected UE consisted of self ROM stretching exercises, active ROM exercises, and functional ADL exercises utilizing the help of the more affected arm. Gravity elimination assistance for the more affected UE was provided through the less affected UE or a tabletop. The treatment consisted of a twenty four one-hour sessions and the assessment took place before and after the treatment as well as at a 6-months follow-up. All subjects significantly improved (p < .05) UE motor control (Fugl-Meyer), active reaching ROM, and self-reported quality and amount of arm use (Motor Activity LOG, MAL).

Improvements were sustained at 6 months; however, the Armeo group sustained more significant improvement on Fugl-Meyer at the six-month follow-up. Participants also reported a stronger preference for T-WREX training. This project added to the evidence of gravity-supported arm exercise. Interestingly, the concept of UE weight reduction could be applied without using the sophisticated robotic-aided devices such as the Armeo as seen in the tabletop control. This anit-gravity support was provided by using the help of the less affected UE or the table surface. However, the Armeo were more preferred by participants.

The Armeo® can be perceived as a supporting modality that can assist the UE in active functional exercises in moderate to severe stroke patients. Unlike MAS, the Armeo® potentials in UE stroke rehabilitation were examined; it includes virtual reality games that can simulate functional exercises for moderate and severe stroke clients (Housman, et. al., 2009; Sanchez, et. al., 2006). However, Armeo® studies mainly showed some superiority using impairment outcome measures (such as Fugl-Meyer or ROM) but no superiority using functional outcome measures. Lastly, the Armeo® is much more expensive than the MAS. In 2008, the Armeo® cost was about \$60,000 while the MAS cost was about a thousand of dollars.

The mobile arm support. The mobile arm support (MAS) is a device developed in the 1930's and improved in 1950's and again recently through the development of MAS with elevation assistance (Belkin & Yasuda, 2001; Jaeco orthopedic, 2007). This device can be used to support the weak UE in patients with various conditions. The elevating

MAS assists the shoulder movements against gravity and makes elbow movements easier. This device can be attached to participants' wheelchairs or their tables in order to enhance functional engagement in desired activities. However, using a MAS is challenged by wheelchairs mounting difficulties, learning adjustment strategies, and patients compliance issues (Belkin & Yasuda, 2001).

Deshaies (2002) indicated that MAS works through using gravity to support the arm and decrease the required load on the weak muscles during an activity. It also reduces the frictional energy loss utilizing its ball joints. This device might be used with patient having cervical spinal cord injuries and other neurological conditions (such as muscular dystrophy and amyotrophic lateral sclerosis). Deshaies also mentioned that in order to use this device, the patient need to have a specific functional need as well as enough residual power provided from the neck, trunk, shoulder or elbow. Other important requirements include enough motor control abilities and ROM. The passive ROM needed is 0-90 degrees of shoulder flexion, 0-30 degrees of external rotation, and full shoulder internal rotation and elbow flexion. Finally, 0-80 degrees of pronation is desired.

Deshaies mentioned motivation as another requirement of successful utilization of the MAS.

The literature about the MAS is limited and deals with compliance issues or patient's preferences and performance while using the MAS as a compensatory device (Haworth, Dunscombe, & Nichols, 1978; Yasuda, Bownman, & Hsu, 1986). However, the purpose of this study was to investigate the potential remedial benefits of body weight

support in the hemiplegic UE rehabilitation following stroke, which has never been investigated using the MAS. A new MAS device called the multilink MAS has been developed by Jaeco (Jaeco orthopedic, 2007). According to Jaeco this MAS is built of light aluminum with the advantage of elevation assistance through rubber bands that stores the energy and work against gravity to assist a person with weak elbow and shoulder muscles.

In this research project, the MAS was introduced as therapeutic activity rather than compensatory device. It was suitable for moderately involved stroke patients because it simplified the reaching tasks for them. This simplification was gradually decreased by decreasing the amount of gravity elimination offered by the rubber bands to grade up the offered challenge hoping to get a better functional performance out of the MAS. This made this piece of equipment compatible with the TO approach and simulating the partial weight relief gait training as used in the lower extremity for stroke and spinal cord patients which is considered an application of the TO approach (Rao, 2004). In this UE post-stroke project, we were trying to simulate gait training with partial weight support which showed some effectiveness evidence in improving gait following stroke (Hesse, Bertelt, Schaffrin, Malezic, & Mauritz, 1994; Hesse, Konrad, & Uhlenbrock, 1999; Visintin, Barbeau, Korner-Bitensky, Mayo, 1998).

Occupational Therapy Task-Oriented (TO) Approach

The TO approach for stroke was proposed by Mathiowetz and Bass-Haugen (1994). It was based on systems models of motor control, and recent motor development

and motor learning literature. Under this approach, motor skills for the stroke patient are taught by selecting functional tasks that are contextually suitable for the specific patient. Based on motor control and learning principles, the chosen therapeutic activities should vary to enhance learning transferability. The schedule and the structure of the practice should enhance the patient's active participation and should consider motor control and learning principles. The setup of the environment should include all factors that might regulate a specific task practice. Finally, appropriate feedback (in terms of timing and amount) should be available to enhance the motor learning or relearning processes. The application of these principles requires knowledge and skills of task analysis of the targeted activities needed to be performed (Mathiowetz and Bass-Haugen, 1994; Mathiowetz, 2011; Mathiowetz & Bass-Haugen, 2008).

This approach assumes that there is a heterarchial organization of the individual's and the environmental systems. Other assumptions include: functional tasks help organize functional behavior; occupational performance results from the interaction between the individual and their environment; motor experiences using different strategies help the person to determine optimal (effective and efficient) patterns or solutions for the motor problems; recovery following CNS injuries varies among patients due to the uniqueness of the patient's factors and the environmental contexts; and the behavioral changes are the individual's attempt for compensation and achieving task performance (Mathiowetz, 2011; Mathiowetz & Bass-Haugen, 2008; Bass-Haugen, Mathiowetz, & Flinn, 2008).

The occupational therapy TO approach as a whole has not been studied in a randomized clinical trial. However, many of the TO approach principles and variations of the TO approach are supported in the literature. For example, the task-oriented poststroke gait training with partial body weight support was supported in the literature (Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998; Nilsson, Carlsson, Danielsson, Fugl-Meyer, Hellstrom, Kristensen, et al., 2001; Hesse, Konrad, & Uhlenbrock, 1999; Hesse, Bertelt, Schaffrin, Malezic, & Mauritz, 1994). These studies showed a beneficial effect of their protocol for improving gait and balance. The following are TO principles fulfilled in these studies. The body weight support provided to patients was adjusted to provide the right challenge for each and was decreased as the patient's gait ability improved. Therapists provided various types of feedback and hands-on assistance. The used therapeutic task (gait) and their natural environment were important and meaningful for their patients. The protocol manipulated several factors affecting the clients' motor behavior and provided the patient with motor experience through real interaction with the environment and with many repetitions. This helped patients to find the optimal solutions to their gait motor problems.

In the upper extremity post-stroke rehabilitation, robotic-aided therapy (Finley, Fasoli, Dipietro, Ohlhoff, Macclellan, Meister, et al. 2005; Stein, Krebs, Frontera, Fasoli, Hughes, & Hogan, 2004; Fasoli, Krebs, Stein, Frontera & Hogan, 2003; Lum, Burgar, Shor, Majmundar, & Van der Loos, 2002; Masiero, Celia, Rosati, & Armani, 2007) and special orthotics integrated with virtual reality such as the Armeo® (Sanchez, Liu, Rao,

Shah, Smith, Rahman, et al., 2006; Housman, Scott, and Reinkensmeyer, 2009) also fulfill some of the TO principles such as simplifying the task (treatment) requirements and gradually providing more challenge, mass practice for reaching tasks suitable for the individual patient, and providing feedback. However, in addition to the high cost, the active participation of the patient in selecting meaningful tasks and the use of natural task environments is still limited with these UE neurorehabilitation technologies.

Stroke task oriented training showed evidence supporting using functional meaningful activities to improve the stroke patient's functional performance. Studying 101 participants, Kwakkel, Wagenaar, Twisk, Lankhorst, and Koetsier, (1999) found that as compared with the control group (immobilization of the paretic arm and leg by an inflatable pressure splint) focusing on arm rehabilitation using occupational-based activities (functional exercises such as punching a ball or grasping and moving objects) resulted in dexterity improvements as measured by the Action Research Arm test. All of the participants received 15 min per day leg rehabilitation, 15 min per day arm rehabilitation, and 1.5 hour/week of ADL training by an occupational therapist. The researchers concluded that functional performance can be enhanced by using intensive functional activities and the treatment had training-specific effects (i.e. UE dexterity was improved in the UE training group).

The use of real, functional objects was an effective method to enhance efficient, smooth, and coordinated movement with the impaired arm in persons post-stroke. Wu, Trombly, Lin, and Tickle-Degnen (2000) evaluated kinematically (i.e., movement time,

total displacement, peak velocity, percentage of reach where peak velocity occurs, and movement units) the effect of using a real object in a reaching task in stroke and healthy participants. They found better performance in the presence of the real object indicated by shorter movement time, less total displacement, higher peak velocity, greater percentage of reach where peak velocity occurs, and fewer movement units.

Furthermore, providing occupational therapy for stroke population using the patient's natural environment and preference was also supported. Wu, Wong, Lin, & Chen, (2001) identified high functional (taking a drink from a can of beverage) and low functional goals (bringing the can to the mouth without drinking) and then crossed these two levels of functional goals with personal preference of the participant to get four experimental conditions. They found large significant effects of the personal preference and the functional goals level on the movement variables (movement time and reaction time). The researchers suggested that enabling personal choice and using high functional goals within the treatment activities might enhance the stroke patients' movement efficiency and response rate.

Flinn (1995) studied the occupational therapy TO efficacy in post-stroke rehabilitation. The researcher conducted a case-report on a 34-year old person with hemiparesis. The researcher considered that the sensorimotor system was the critical system which played the fundamental role in limiting the participant's occupational performance. Consequently the treatment activities were emphasizing improving the sensorimotor system components (including strength, ROM, endurance, coordination,

postural control, sensory awareness, and perceptual skills). Working under the TO approach concepts (the motor behavior emerges from the interaction of many systems); the researcher also considered other systems that may affect the motor behavior (psychosocial and cognitive personal systems, and environment-related systems such as cultural, socioeconomic, and physical environment systems). The participant received a one-hour occupational therapy sessions over a period of six months. The frequency of the treatment session decreased from three sessions/week to one session/month at the end of the study. The focus of treatment was meeting the participant's functional goals including child care, homemaking activities, and work-related activities. Throughout the treatment, the therapists tried to continuously revise the treatment plan by identifying the critical control parameters and working on them under the purpose of evoking functional performance improvements. The treatment was directed toward the client's affected UE strength and incorporation in daily use under controlled degrees of freedom (simplifying the tasks' requirements by reducing the variables needed to be controlled). As the participants' motor abilities were improved, she was getting more challenging functional and strengthening exercises that required more degrees of freedom. The therapists tried to give as many repetitions of functional tasks with contextual variability to simulate real world contextual variability. After having a total of 33 therapy sessions, the client was independent in all self-care tasks and, able to perform her housekeeping and family care tasks, and was able to ambulate independently. The patients' affected UE was improved substantially. Her various UE muscles' strength (as measured by the manual muscle test)

increased from 2+ at max to 4 at least, and her ability to use the affected UE in functional tasks was improved. The researcher concluded that the use of TO approach principles (such controlling the degrees of freedom, using control parameters, and strengthening exercises for clients with high tone) have potential benefits in post-stroke rehabilitation. However, this was a case study only and utilized a relatively long therapy time (Flinn, 1995).

In another case study, Gillen, (2000) evaluated the efficacy of the occupational therapy TO approach for improving the activities of daily living (ADL) performance in a person with multiple sclerosis(MS). The participant's limited occupational performance was due to the MS related ataxia syndrome which led to motor control deficits, visual dysfunction, and gait disturbance. The therapy aimed to improve the participant's occupational performance through engaging him in functional activities meaningful to him. In those therapeutic activities, researcher tried to simplify the tasks' required postural stability and degrees of freedom. Using environmental control parameters, the task-specific ADL training incorporated orthotics, environmental adaptation, adaptive equipment prescription, and movement retraining. Those task-specific training included areas of feeding, oral care, shaving, bathing, bladder management, sexual activities, and instrumental activities of daily living (IADL). The patient received ten-day intensive rehabilitation program included a 90-minute daily occupational therapy sessions. Upon discharge, the patient had substantial improvements in scores on standardized ADL evaluations (as measured by the Functional Independence Measure and Barthel index),

was satisfied with his ADL improvements, returned to his previous living environment, and was able to work part time in his same job. The researcher concluded that using meaningful activities utilizing the occupational TO approach concepts (focusing on control parameters such as postural control and degrees of freedom) was beneficial in improving the client's functional performance. However, this is a case study implemented with a condition that differs from stroke. Additionally, the result might be confounded by other interventions the participant got in addition to the occupational therapy (i.e. physical therapy and pharmacology).

Gillen (2002) also conducted another case study to evaluate the TO approach efficacy on MS. The objective of the occupational therapy TO intervention was to improve the participant's powered mobility regardless of his ataxia. The intervention focused mainly in controlling the degrees of freedom required in the therapeutic tasks to improve the postural stability and consequently enhancing the occupational performance of the patient during using the powered wheelchair. The therapist implemented task-specific training of wheelchair mobility with the help of assistive technology, positioning, orthotics, and adapted movement patterns. The wheelchair training (consisted of ten 1.5-hour sessions) was implemented in various contexts and environments. The patient Functional Independence Measure score for power wheelchair mobility improved (from 4 to 6 for indoor and from 1 to 5 for outdoor). These results were sustained at a one-year follow-up. The study had conclusions and limitations similar to Gillen, (2000) discussed above.

Preissner (2010) implemented the TO approach on a person who had CVA with significant cognitive limitation due to dementia. The researcher applied the approach in the acute phase of the stroke rehabilitation in an attempt to improve the client's ADL skills. After observing the client implementing few ADL activities, the therapist identified the client's motor behavior control parameters which were related to her motor ability (such as balance) and cognitive abilities (such as attention). The therapist decided that a compensatory approach is more suitable than a remedial approach for this client due to her impairment and functional limitations levels. After receiving six 90-minute OT sessions per week for four weeks, the client achieved most of her long term ADL goals except for bathing. The researcher concluded that the TO approach was effective in helping the client in achieving her long-term goals, improving her participation in meaningful activities, and enabling her to leave the hospital to her daughter's home.

The TO approach uses a wide variety of principles and concepts that enhance stroke rehabilitation strategies. It is client centered, occupation-based, and considers more factors both within the person and their environment than other approaches. When indicated, it tries to improve the motor behavior by remediating performance components to meet individual patients' needs and then grades the activity to provide the 'right challenge'. Many of the TO approach assumptions and principles are obtained from theories and disciplines outside of the occupational science philosophy. This increases the demands on occupational therapy researchers to provide further evidence for this approach. This approach needs more research to clearly define it and to refine its

treatment protocol. Many issues in TO stroke rehabilitation need to be investigated including the best intervention time relative to the stroke onset, the duration of each session, total duration of intervention, the type of the used treatment activities, and the best clinical use of these activities. This project is focused on evaluating the TO approach and to refine its treatment protocol. Specifically, we will evaluate the effects of the TO approach in post-stroke rehabilitation for improving motor impairment and functional use of the affected upper extremity.

Conclusion

It is concluded that there is no evidence of a superior treatment approach for moderate stroke rehabilitation in general. There are several suggested techniques to deal with various specific problems following stroke, or various comprehensive approaches with advantages and disadvantages. There is a need for a more effective UE treatment for stroke patients. Treatment efficacy studies need to be more rigorous using clinical trial designs. Efficacy studies should focus more on the functional outcomes or the clinical significance rather than on impairment outcomes only.

It could be that many persons post-stroke might not be improving enough in response to various stroke rehabilitation interventions because they lack enough initial motor abilities. However, using the TO approach, we utilized meaningful functional activities (encouraging the use of the affected hand) that provided just the right challenge suitable for each individual patient. In this project, these TO UE activities were applied in a gravity-eliminated or reduced gravity environment as needed. This anti-gravity

assistance was provided through an elevating MAS. We incorporated the Wii (Nintendo Wii, 2009) in this project as a leisure activity option which represents an innovative and affordable virtual reality treatment. Other self care, leisure, and work related activities were also provided. These activities were individualized based on the participant's roles, interests, functional needs, and the concepts of the TO approach. We considered the personal and the environmental factors that could have affected the patient's motor behavior. The proposed protocol manipulated these factors enabling the participants to have as much contextually variable practice of functional activities as possible. Proper feedback schedules and types were provided to enhance the motor learning and relearning processes. Our project aimed to introduce a flexible and contextually variable training protocol that uses functional activities which hold value and meaning for persons with stroke. We hoped to refine the TO treatment protocol which might help to improve persons with stroke UE motor impairment level and functional abilities.

Purpose

The ultimate goal for rehabilitation in general and occupational therapy particularly is to enhance functional performance in various essential real life activities. With stroke population, this goal might be more achievable following improving the motor abilities and other critical factors affecting the paretic UE motor behavior. This study evaluated the efficacy of the Occupational Therapy TO approach to improve functional and impairment level outcomes of stroke survivors. This study also described the clinical application of the TO approach in UE post-stroke rehabilitation.

Hypotheses

- 1. All participants post-stroke who receive the TO approach for six weeks will show significant improvement in UE function as measured by the Canadian Occupational Performance Measure (COPM), Motor Activity Log (MAL), and Wolf Motor Function Test (WMFT) as compared to the control period. The assignment order will have no significant effects on the conditions change scores.
- 2. All participants post-stroke who receive the TO approach for six weeks will demonstrate significant improvements in their affected UE motor components including: shoulder flexion, shoulder abduction, elbow extension and wrist extension strength as measured by the handheld dynamometer; shoulder flexion, shoulder abduction, elbow flexion-extension, and wrist extension active ROM measured by a goniometer; and grip strength measured by a Jamar dynamometer as compared to the control period. The assignment order will have no significant effects on the conditions change scores.

Methods

Design

This randomized clinical trial used a cross over design (see Table 1 below). Participants were randomized (withdrawal of a card out of 4 without substitution) into two different orders. Half of the participants (n = 10) were assigned to the immediate intervention group (I) and got the TO treatment first and the control (C) of no therapy second. The other half (n = 10) were assigned to the delayed intervention group (D) and got a reversed order. Each phase of the study consisted of a 6-week period.

Table 1

Repeated Measures, Crossover Design Used in the Study

Assessment during Weeks:	1		6		12
Immediate Intervention Group (I)	О	X	О	С	О
Delayed Control Group (D)	О	C	О	X	0

Note: O = Observation/assessment times; X = Experimental OT Task-Oriented Approach intervention; C = Control (no treatment).

The outcome measures were administered within four days interval before the first treatment phase (pretest), between the two phases (posttest1), and after finishing the second phase (posttest2). The study used single blinded design where the evaluators were masked of the groups' assignments. The screening and the majority of the treatment were done by the principal investigator (KAM). An occupational therapist (MW) helped in delivering some of the study-related therapy as well. The evaluations were done by two other occupational therapists (JS & YC-H) who were blinded to the participants' assignments. Both of the evaluators received the same training on conducting the outcome measures by the principal investigator (KAM) and his advisor (VM). Each evaluator collected the complete set of data (pretest, posttest1 and posttest2) from each participant (16 participants for JS and 4 participants for YC-H) in an attempt to reduce any potential inter-rater variability within each participant's outcome measures. The data

from the COPM performance and satisfaction were collected by principal investigator (KAM), who was not blinded. The COPM was collected by the PI since he was the primary therapist. This was critical to enable him to design and deliver client-centered, functional treatment.

Participants

A convenience sample of 20 participants with stroke was recruited through local medical facilities and local community organizations in the Twin Cities metropolitan area. Inclusion criteria included being a person at least three months post-stroke with UE motor deficits (functional limitation, weakness, and/or ROM limitation). The participants also needed to be able to demonstrate at least 10° of shoulder abduction and flexion as well as 10° of elbow flexion-extension in the more-affected UE. These movements were required to be isolated and performed against gravity. Participants also needed to demonstrate sufficient visual-perceptual abilities to perform the treatment tasks. Exclusion criteria included persons with unstable medical conditions, moderate to severe cognitive impairments (i.e., score of 24 or less on the Mini-Mental Status Test) (Folstein, Folstein, & McHugh, 1975), neurological disorders other than stroke affecting UE function, severe spasticity [i.e., score of 4 at any joint of the UE on the modified Ashworth scale (Bohannon & Smith, 1987)], or severe pain in affected upper extremity (i.e., > 7/10 on 0-10 pain scale where 0 = no pain, and 10 = extreme pain). The participants could not be concurrently enrolled in any professional occupational or physical therapy treatment for the UE. Each screening session took 1.5 to 2 hours on

average.

Independent Variables

The first independent variable was a between group variable of the order the participant had in getting the two treatment conditions. The first level of the order was the Immediate group (I) where the participant started with TO treatment first and then got the control. The Delayed group (D) was the second order level and this was where the participant started with the control and then got the treatment.

The second independent variable was a within group variable consisting of the treatment used (conditions) and had two levels. Condition A was the TO treatment and condition B was the no treatment control (C) and each condition lasted for 6 weeks. During the TO condition, the participants were trained to improve their affected UE physical abilities and their overall functional ability. This TO training was customized to fit each individual's need and motor ability (see TO approach section of the literature review and the TO treatment protocol and the case study in the Appendices F & G). TO treatment was provided in two 1.5-hour sessions/week for six weeks (i.e., total of 18 hours of clinical treatment) conducted at Sister Kenny Research Center (SKRC) in Minneapolis. In addition, the treatment phase included a homework set of individualized functional and impairment exercises (1-1.5 hours/day on average). During the control condition, participants had a six-week period of no treatment. In both phases, the participants were not allowed to get any other professional rehabilitation for their upper extremities. Regular meetings (between the therapists and the original author of the TO

approach VM, who also observed several treatment sessions), written protocol instructions, and detailed therapy notes were used to enhance treatment fidelity.

Dependent Variables and Outcome Measures

The primary outcome measures included three functional tests emphasizing the affected UE functional use; COPM, MAL, and WMFT. Our secondary outcome measures included participants' motor impairment level of the affected UE including nine measures of UE strength and active ROM.

The self-perceived functional performance and satisfaction. The COPM is a client-centered semi-structured interview that evaluates the patient's self-perceived level of occupational performance. This measure helps the clients in identifying specific problem areas for functional ability in self-care, productivity, and leisure. The top 5 functional problems are identified based on their importance score (10-point scale). Each of the top 5 identified problems is then rated by the individual for performance on a scale from 1(unable to perform) to 10 (able to perform) and for satisfaction from 1 (not satisfied) to 10 (satisfied) (Law, Babtiste, Carswell, McColl, Polatajko, & Pollock, 1994). The COPM showed high test-retest reliability (*ICC* of .80 for its performance scores and an *ICC* of .89 for its satisfaction scores) (Bosch, 1995). When it was tested on participants with stroke, the COPM showed higher test-retest reliability for performance (*rho* = .89) and satisfaction scales (*rho* = .88). (Cup, Scholte op Reimer, Thijssen, & van Kuyk-Minis, 2003). The COPM was responsive to functional abilities changes following functional training for persons with stroke (Roberts, Vegher, Gilewski, Bender, & Riggs,

2005; Birkenmeier, Prager & Lang, 2010). In a systematic review of literature yielded in reviewing 88 papers, a research group concluded that the COPM was valid, reliable, clinically useful and responsive outcome measure acceptable for occupational therapy practice and research (Carswell, McColl, Baptiste, Law, Polatajko, Pollock, 2004). Our TO study used the form and the instruction manual of the COPM (Law et al., 1991). Participants' previous COPM performance and satisfaction scores were not shared with them during their reassessments.

that assesses the persons' post-stroke insight of how much they use the affected UE to perform common functional activities. This test has two subscales: Amount of Use scale (AoU) and How Well scale (HW), where the average of 0-5 scale scores are computed for 30 common UE daily life tasks. MAL showed a high (r = .91) concurrent validity with an objective accelerometer-based measure of arm movement, good internal consistency ($\alpha > .81$), and high test-retest reliability (r > .91) (Uswatte, Taub, Morris, Vignolo, & McCulloch, 2005). MAL also showed convergent validity (r = .68) with the hand function domain of the Stroke Impact Scale (SIS) (Uswatte, Taub, Morris, Light, & Thompson, 2006). The MAL is sensitive to upper extremity real world use for persons post-stroke, showing significant improvement in scores following constraint induced movement therapy (Kunkel, Kopp, Mller, Villringer, Villringer, & Taub et al., 1999; Wolf, Winstein, Miller, Taub, Uswatte, Morris, et al. 2006).

UE functional use ability and speed. WMFT measures person's post-stroke

affected UE performance of timed reaching and manipulative tasks. The test has a time scale (average time needed to perform 15 UE functional tasks) and a functional scale (average functional ability scores of 15 UE functional tasks). WMFT has shown discriminative validity between normal persons and those with stroke, high inter-rater reliability (r = .95-0.99, $ICC \ge .93$), high test retest reliability (r = .90-.95), and high internal consistency (Chronbach's $\alpha = .86-.96$) (Wolf, Catlin, Ellis, Archer, Morgan, & Piacentino, 2001; Morris, Uswatte, Crago, Cook, & Taub, 2001). The WMFT was sensitive to upper extremity functional improvement for persons with stroke following constraint induced movement therapy (Kunkel, Kopp, Mller, Villringer, Villringer, & Taub et al., 1999; Wolf, Winstein, Miller, Taub, Uswatte, Morris, et al. 2006). Figure 1 below shows one of the WMFT tasks. The grip strength part of WMFT was collected separately according to the standards published by Mathiowetz et al., 1984. The WMFT *Weight to Box* task was removed since it has its own scale and because this study included many other more accurate UE dynamometry strength measures.



Figure 1. Task # 15 in the Wolf Motor Function Test (WMFT): Lifting a basket loaded

with a weight of 3 pounds.

UE active ROM. Goniometry is valid for measuring upper extremity joints active and passive ROM and is recognized as the gold standard for this purpose (Flinn, Trombly-Latham, & Podolski, 2008). It is economical, portable, and has a clear clinical value and meaning for most therapists (Lea & Gerhardt, 1995). Mayerson and Milano (1984) found that intra-rater reliability for flexion and extension of elbow joints was high (r = .91 to .99). The Inter-rater reliability was also high (r = .88 to .97). The shoulder flexion, abduction, and lateral rotation inter-rater reliability were also high (*ICC*s ranged from .84 to .90) (Riddle, Rothstein, & Lamb, 1987).

For this study, with the exception of elbow extension, the affected UE AROM segments positioning and goniometer placements followed the standards recommended by Flinn, Trombly-Latham, and Podolski (2008). We were more interested in the elbow extension rather than the elbow flexion-extension motion described by Flinn et al. (2008). For elbow extension (demonstrated in Figure 2), the participants were sitting erect on a chair starting with 60°-80° of shoulder flexion, with the forearm pronated and supported on a table, and the elbow at 90° flexion. Additionally, the wrist extension ROM was done with mid-position between pronation and supination of the forearm instead of fully supination as demonstrated by Flinn et al., 2008. The required ROM movements were demonstrated before asking the participants to go as far as they could. The evaluators verbal instructions were standardized to generate maximum encouragement: "go as far as you can... can you go any further?"



Figure 2. Elbow extension range of motion (ROM) testing.

WE strength. The hand-held dynamometry is a direct measure of strength in kilograms or pounds (Flinn et al., 2008). It has excellent inter-rater and intra-rater reliability, ICC = .79-.96 and .87-.98 respectively (Ottenbacher, Branch, Ray, Gonzales, Peek & Hinman, 2002). Using 200 healthy participants, Phillips (2000) found that for both the intrasession and intersession of the hand-held dynamometry using the "break" test produced ICC > .85. The "break" test is what was used in our TO study where the examiners held the dynamometer against the limb segment being tested and participants were instructed to exert a maximum force against it. Evaluators exerted just sufficient resistance to overcome the force produced by the participant. Evaluators were instructed to meet the participants' force, block their attempts to push the dynamometer and then break their tested segment position. The evaluators followed similar procedures as those used by Phillips, 2000. However, for this study, participants were sitting erect with their backs supported on a chair whereas Philips used a supine position eliminating gravity for all testing situations. A MicroFET2® hand-held dynamometer was used for all of the UE

strength measurements except for grip strength (Hoggan Health Industries, 2011).

The affected UE strength measures in this study were performed as the follows: shoulder flexion (sitting erect on chair, back supported, starting position: 0° of shoulder flexion and abduction, externally rotated arm, 0° of elbow extension, the dynamometer placed at the center of the anterior aspect of the distal end of the humerus); shoulder abduction (sitting erect on chair, back supported, starting position: 0° of shoulder flexion 20-30° of shoulder abduction, internally rotated arm, 0° of elbow extension, the dynamometer placed immediately proximal to the lateral epicondyle of the humerus); elbow extension (sitting erect on chair, back supported, starting position: 60°-80° of shoulder flexion, the forearm pronated and supported on a table, the elbow is at 90° flexion, the dynamometer placed just proximal to lateral styloid process of the forearm); and wrist extension (sitting erect on chair, back supported, starting position: 60°-80° of shoulder flexion, the forearm pronated and supported on a table, the elbow was at about 15° flexion, the wrist was over the table edge and at 20° extension, the dynamometer placed at the center of the hand dorsum just proximal to metacarpophalangeal joints). The shoulder flexion hand-held dynamometer strength testing is demonstrated in Figure 3 below. The evaluators' verbal reinforcements were standardized to elicit the maximal effort by the participants. After instructing the participants and demonstrating the required movement (pushing against the dynamometer), the evaluators said: "Are you ready? Push as hard as you can, Harder! Do not let me break you! Relax". The mean scores of three trials (maximum generated force in pounds) implemented with about 30

seconds of rest between each trial were entered into the data analysis table.



Figure 3. Shoulder flexion hand-held dynamometer strength testing.

Grip strength. Hand-grip dynamometry is a valid test for grip strength and is recommended by the American Society of Hand Therapy (Fess, 1992; Bohannon, 1998). The test-retest reliability of the Jamar dynamometer was reported as r = .88 and the interrater reliability as r = .99 (Mathiowetz, Weber, Volland & Kashman, 1984). A Jamar dynamometer was used to test the hand grip strength following Mathiowetz et. al. (1984) recommended positioning and verbal instructions. The mean score of three trials (in pounds) implemented with about 15 seconds of rest between trials was used for the grip strength variable. Grip strength testing is demonstrated in Figure 4.



Figure 4. Grip strength testing using a Jamar dynamometer.

Participants Post-treatment Survey. The principal investigator has conducted a likert scale survey after getting done with each participant. This brief survey was conducted at the end of the study to get participants feedback about strengths and weaknesses of the TO approach as applied in the study. The survey included 8 statements graded on a Likert scale (strongly disagree: 1, disagree: 2, neutral: 3, agree: 4, strongly agree: 5). The survey also included three structured questions to list 3 strengths, 3 weaknesses, and to list suggestions for future designs. The survey is attached in Appendix H.

Procedures

Recruitment flyers were distributed. Interested persons contacted the PI by phone.

During the initial phone screening, the PI made sure that the potential participants could meet the study criteria and that they got a clear idea about the nature of the study.

Interested participants were then scheduled for a clinic screening which they were given a detailed explanation of the study procedures, requirements, commitments, and potential risks and benefits. Participants who agreed to proceed were then asked to sign the

approved University of Minnesota and Allina Health System institutional review boards consent forms and HIPPA authorization forms. Then, participants were screened to determine eligibility for the study and to determine their baseline measurements: evaluating the general cognitive ability using Mini-Mental Status test, evaluating the extent of motor impairment using the UE section of the Fugl-Meyer test (UEFM), evaluating the muscle tone in the affected upper extremity using the Modified Ashworth Scale, measuring the active and the passive ROM (goniometrical measurements) and strength (using manual muscle testing) of the shoulder, elbow, and the wrist of the more affected upper extremity. The eligible participants were those who met the inclusion/exclusion criteria (listed in the participant section) and were willing to comply with the study procedures and requirements. Screening/consent sessions took about 2 hours/participant on average and were conducted in the same order for all participants by the study PI.

All participants received the Occupational Therapy TO approach targeting their UE motor ability. Additionally, all of the participants also went through a control period (Randomly assigned into one of two different orders combinations). The study had 3 data collection points where each evaluation session took 1.5 to 2 hours of evaluating the more affected UE. At the end of the TO treatment, the participants were asked to complete a brief survey (see Appendix H) evaluating the intervention, which took 5-10 minutes.

Statistical Analyses

Baseline characteristics and pretest scores. The researchers statistically compared between the two order groups to double check the randomization efficacy in guaranteeing the baseline characteristics homogeneity. For this purpose, the researchers used a multivariate analysis of variance (MANOVA) with order as a between groups' variable and the standardized scores of age (in years), chronicity (in months), and stroke motor impairment severity at screening (measured by UEFM). The Two groups were also compared for gender and whether the affected hand was the dominant prior to the stroke using Fisher's exact test (GraphPad Software, 2011). Fisher's test was used because these variables did not qualify for parametric statistical testing and there were cells with counts less than 5 in the contingency tables.

The researchers also statistically compared between the two order groups to double check the randomization efficacy in guaranteeing the pretest measures (functional and impairment) homogeneity. Two analyses were used for this purpose; a MANOVA analysis was used to check the homogeneity of the two order groups' functional pretest scores. This analysis used the order as between groups' variable and the dependent variables of standardized pretest functional scores of COPM performance, COPM satisfaction, MAL AoU, MAL HW, WMFT time, and WMFT functional ability scales. In the second analysis, another MANOVA was used to check the homogeneity of pretest impairment scores between the two order groups. For this latter purpose, the order was used as the between groups' variable and the standardized impairment pretest motor

impairments scores (ROM and strength of shoulder flexion and abduction, elbow extension and wrist extension as well as grip strength) as dependent variables. Each of these pretest scores (functional and impairment) MANOVA analysis was conducted against p < .025.

Primary statistical analyses. The change scores were computed for each of the functional and impairment dependent variables. The change scores were calculated for the TO treatment (Functional or impairment change scores of the treatment: posttest1 - pretest scores for I group combined with posttest2 - posttest1 for group D). The change scores for the control were also calculated (Functional or impairment change scores: posttest2 - posttest1 scores for I group combined with posttest1 - pretest for group D).

Then, two multivariate analyses (each conducted against p < .025) were used to compare the outcome measures change scores using the order as the between groups' variable and condition as the within groups' variable. For each of these outcome measures change score multivariate analysis, the researchers kept the baseline characteristics and/or the pretest outcome measures that appeared to have significant effects as covariates in their corresponding multivariate statistical model. The functional MANOVA included the primary functional outcome measures standardized change scores as dependent variables (6 levels including: COPM performance, COPM satisfaction, MAL AoU, MAL HW, WMFT time, and WMFT functional ability) and no covariates (none appeared to have significant effects as covariates). The dependent variables in the impairment multivariate analysis of covariance (MANCOVA) included the impairment outcome measures change

scores (9 levels included handheld strength and active ROM for shoulder flexion, shoulder abduction, elbow flexion-extension, and wrist extension, as well as grip strength) and 5 impairments pretest scores as covariates that appeared to have significant effects in the MANCOVA.

Working with p < .025, achieving a significant main effect for condition variable with no significant main effect for order were the criteria to proceed for the univariate analyses for each functional or impairment outcome measure. For each of the two outcome measures multivariate analyses, the univariate analyses were conducted for one outcome measure only as the within groups' condition variable (treatment change scores compared with control change score for that particular outcome measure) using the same set of the covariates (if used in the multivariate) and order as between groups' variable against p < .025. All of the multivariate and the univariate analyses were conducted using SPSS (version 16.0) using the repeated measures feature of the general linear model.

Sample Size

Based on our pilot experimental sample of the immediate group (n=2), we got the following effect sizes: COPM satisfaction d = 0.47, COPM performance d = 0.26, MAL AOU d = 1.55, MAL HW d = 0.66. Based on GPower 3.1 software (Institute for Experimental Psychology, 2010), assuming getting moderate effect size of 0.5 (using the MANOVA global effect as the statistical model, and the post hoc power analysis with p < .025) a sample size of 40 participants was estimated in order to get a power of 0.80. Due to several resources and recruiting issues, the study goal was set at 30 participants.

Funding was crucial to keep the blinded evaluator setup and to enhance recruitment (i.e. compensating participants for parking and transportation). Furthermore, recruiting cooperative persons with stroke is another challenge, not speaking about the efforts of working with each participant (about 28 hours of actual work with each participant). However, the study stopped at 20 participants after seeing the large effect sizes of most of the functional outcome measures and due to time limitations. The observed power for the condition multivariate effect was 1.0 for the functional analysis and 0.91 for the impairment analysis.

Results

Baseline Characteristics of Participants

Data were collected from May 2010 to May 2011. Many persons post-stroke responded to the recruitment flyers. However, only 25 participants were actually screened in person. Out of those 25, three did not meet the inclusion criteria, one had difficulties in transportation, and one dropped out after random assignment and before the first treatment session. The study ended up with 21 participants randomly assigned into the two order groups; the immediate intervention group (n = 11) and the delayed intervention group (n = 10). The flow of the participants through the study is illustrated in Figure 5 below.

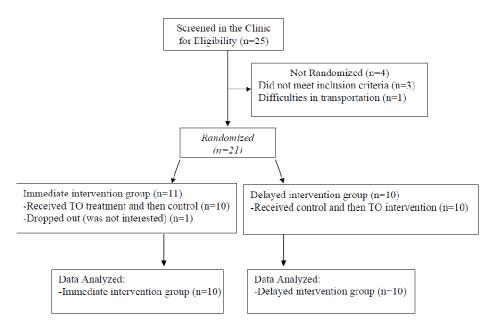


Figure 5. Flow of the participants through the trial.

Baseline characteristics and the pretest functional and impairment scores of the two groups were compared. There were no statistical differences between the two groups in baseline characteristics (tested at p < .05) or pretest functional and impairment outcome measure scores (tested at p < .025 for each).

For the baseline characteristics (age, chronicity, and motor impairment severity), the order variable was not statistically significant [*Wilks' Lambda* = 0.99, F(3, 16) = 0.04, p = .99]. The Fisher's exact test for the variable of gender was not significant (p = 1.00). The Fisher's exact test for the variable of hand dominace was not significant (p = 1.00). Therefore, there were no significant difference in any baseline characteristics relative to order variable.

For the pretest functional measures, the order variable was not significantly

different between the two order groups [Wilks' Lambda = 0.74, F(6, 13) = 0.76, p = .614]. For pretest impairment outcome measures, the order variable was also not statistically different between the two order groups [Wilks' Lambda = 0.65, F(9, 10) = 0.60, p = .773].

These results (the comparisons between the two groups' baseline characteristics and pretest scores) support that the study two order groups were statistically similar. The baseline characteristics for our participants are presented in Table 2 below.

Table 2

Participants' Baseline Characteristics

Variable	All participants	Immediate intervention group (I)	Delayed intervention group (D)
Sample size	20	10	10
# Males	13	6	7
# Females	7	4	3
# Right hemisphere affected	5	3	2
# Left hemisphere affected	15	7	8
# Dominant side affected	6	3	3
# Non-dominant side affected	14	7	7
Age $M \pm SD$ (range in years)	62.3 ± 8.85 $(48-82)$	61.1 ± 9.56 $(48-81)$	62.5 ± 8.54 (51-82)
Chronicity: $M \pm SD$ (range in months)	62.1 ± 46.11 $(9.7-153)$	62.3 ± 45.24 $(9.7-138)$	61.9 ± 49.42 (14.97-153)
Motor impairment severity (UEFM): $M \pm SD$ (range)	34.4 ± 13.87 (15-58)	35.1 ± 13.78 (17-58)	33.7 ± 14.67 (15-58)

Note. UEFM = upper extremity subtest of Fugl-Meyer test; SD = standard deviation.

Functional Outcome Measures

Hypothesis. The functional hypothesis stated that all participants post-stroke who receive the TO approach for six weeks will show significant improvement in the affected UE functional abilities as compared to the control period. The order will have no between

group's significant main effects.

Overall MANOVA for functional outcomes. This analysis included within groups (condition) and between groups (order) variables tested at p < .025. This overall model did not include any covariate because there was no significant between groups' pretest scores effects in the multivariate functional model. The within groups (condition) variable was statistically significant [Wilks' Lambda = 0.12, F(1, 18) = 133.88, p < .001]. The between groups (order) variable did not have significant main effect [F(1, 18) = 0.27, p = .61]. The significant main effect for condition allowed testing each univariate functional outcome measure using repeated measures MANOVAs (six statistical tests tested at p < .025 for each) with condition as within groups' variable and order as between groups' variable.

Canadian Occupational Performance Measure (COPM). The treatment change score was significantly greater than the control period change score on both of the COPM performance and satisfaction scales. COPM performance mean change score was 2.83 units greater the control mean change score (p < .001). COPM satisfaction mean change score was 3.46 units greater than that following the control (p < .001) (see Table 3 and Figure 6 below). These results support the functional hypothesis.

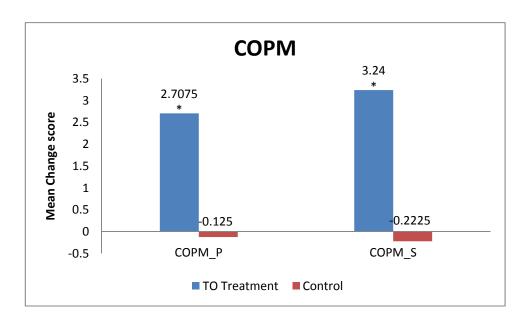


Figure 6. Mean change scores of Canadian Occupational Performance Measure: Performance (COPM_P) and Satisfaction (COPM_S) scales.

Motor Activity Log (MAL). The treatment change scores were significantly greater than the control period change scores on both of the MAL: AoU and HW scales. MAL: AoU mean treatment change score was 1.11 units greater the control mean change score (p < .001). MAL: HW treatment mean change scores was 0.87 units greater the change score mean following the control (p < .001). These results support the functional hypothesis. Differences in the mean change scores between the MAL: AoU and HW scales and their effect sizes are listed in Table 3 and demonstrated in Figure 7 below.

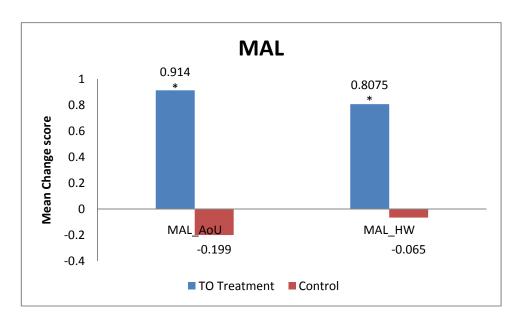


Figure 7. Mean change scores of Motor Activity Log: Amount of Use (MAL_AoU) and How Well (MAL_HW) scales.

Wolf Motor Function Test (WMFT). The treatment change score was bigger than the control period change score on both of the WMFT time and functional ability scales. WMFT time mean change score was 8.35 second less (participants were faster) than the control mean change score. This difference was statistically significant (p = .009) which supports the functional hypothesis. WMFT functional ability mean treatment change score was 0.20 units greater than the control one. However, this latter difference was not statistically significant (p = .106). Differences in change scores means for WMFT time and functional abilities scales and their effect sizes are listed in Table 3 and demonstrated in Figure 8 and 9 below.

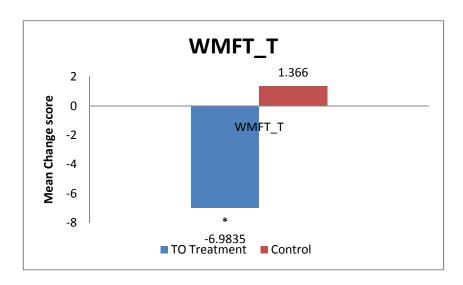


Figure 8. Mean change scores of Wolf Motor Function Test Time scale in Seconds (WMFT_T). A negative change score reflects the functional improvement of getting faster.

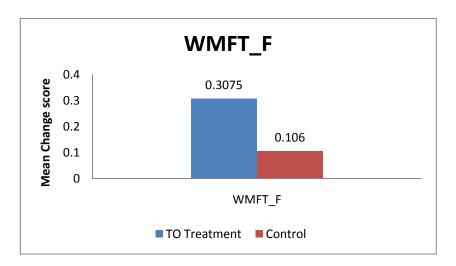


Figure 9. Mean change scores of Wolf Motor Function Test: Functional Ability scale (WMFT_F)

Table 3

Change Scores, Overall and Univariate MANOVAs, and Effect Sizes for Functional
Outcome Measures

Dependent Variable	Change Score Differences: M (SD)	Wilks' Lambda:	F(1,18)	р	Effect size: Cohen's <i>d</i>	
Overall MANOVA for Functional Outcomes						
Condition	NA	0.12	133.88	< .001*	NA	
Order	NA	NA	0.27	.61	NA	
Univariate MA	Univariate MANOVAs for Each Functional Outcome					
COPM:						
	2.83 (1.70)	0.25	52.68	< .001*	1.66	
Performance Satisfaction	3.46 (2.17)	0.27	48.61	< .001*	1.59	
MAL:						
AoU	1.11 (0.79)	0.30	42.43	< .001*	1.41	
HW	0.87 (0.65)	0.32	37.96	< .001*	1.34	
WMFT:						
Time a	-8.35 (12.46)	0.68	8.52	.009*	-0.67	
Function	0.20 (0.52)	0.86	2.89	.106	0.39	

Note. * Significant (p < .025 for each analysis). Change Scores Difference = the mean treatment change score – mean control change score), COPM = Canadian Occupational Performance Measure, WMFT: Wolf Motor Function, MAL: Motor Activity Log, AoU: amount of use scale, HW: how well scale, SD: Standard Deviation.

Figure 10 below is an example of the three data points functional scores patterns

^a A negative time change score reflects the functional improvement of getting faster.

for each of the order groups. All of the functional outcome measures demonstrated similar patterns.

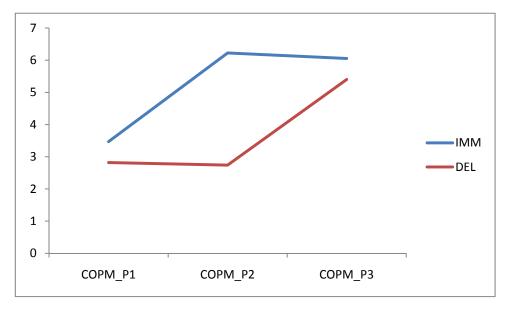


Figure 10. An illustration of functional outcomes score patterns between groups using the COPM: Performance test scores across time as an example. IMM: immediate intervention group, DEL: delayed intervention group.

Impairment Outcome Measures

Hypothesis. The impairment hypothesis stated that all participants post-stroke who receive the TO approach for six weeks will demonstrate significant improvements in their affected UE motor abilities as compared to the control period. The order will have no between group's significant main effects.

Overall MANCOVA for impairment outcomes. This analysis included within groups (condition) and between groups (order) variables tested at p < .025. This overall model also included five covariates (pretest scores of elbow extension strength, shoulder

flexion and abduction ROM, wrist extension ROM, and grip strength). These pretest impairment scores had significant between groups' effects in the impairment MANCOVA. The within groups (condition) variable was statistically significant [*Wilks' Lambda* = 0.51, F(1, 13) = 12.31, p = .004]. The between groups (order) variable did not have significant main effect [F(1, 13) = 0.38, p = .55]. The significant main effect for condition allowed testing each univariate impairment outcome measure using repeated measures MANCOVAs (nine statistical tests tested at p < .025 for each) with condition as within groups' variable, order as between groups' variable, and the same multivariate covariates.

Affected upper extremity (UE) strength. Strength data were collected for the following affected UE movements: shoulder flexion, shoulder abduction, elbow extension, wrist extension, and grip strength. Except for shoulder flexion, the affected UE strength means change scores were greater than the control means change scores. However, none of these differences between the treatment and the control means change scores were statistically significant (see Table 4 for specific data). Differences between the treatment and control affected UE strength mean change scores are demonstrated in Figure 11. These results do not support the impairment hypothesis.

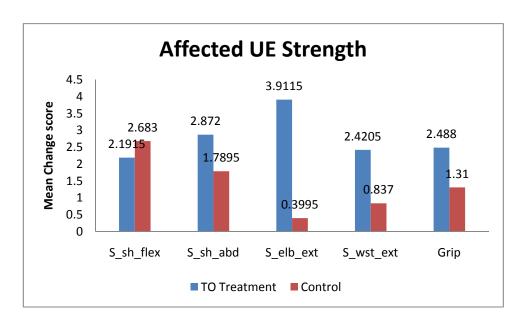


Figure 11. The affected upper extremity (UE) hand-held dynamometry strength and hand Jamar grip strength means of change scores (lbs). S_sh_flex: shoulder flexion strength, S_sh_abd: shoulder abduction strength, S_elb_ext: elbow extension strength, S_wst_ext: wrist extension strength.

Affected upper extremity (UE) active ROM. Active ROM data were collected for the following affected UE movements: shoulder flexion, shoulder abduction, elbow extension, and wrist extension. The affected UE ROM treatment means change scores were greater than those of the control. However, none of these differences was statistically significant as demonstrated in Table 4 which includes the exact statistics, p values, and effect sizes as well. The differences between the treatment and control affected UE ROM change score are demonstrated in Figure 12. These results do not support the impairment hypothesis.

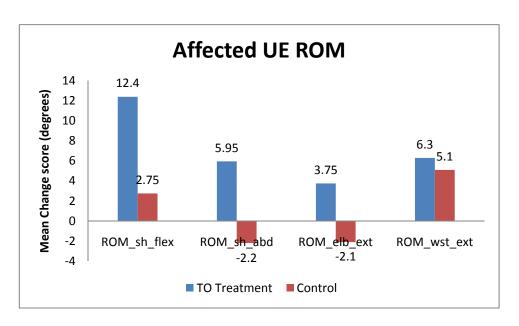


Figure 12. The affected upper extremity (UE) active range of motion (ROM) mean change scores (degrees). ROM_sh_flex: shoulder flexion ROM, ROM_sh_abd: shoulder abduction ROM, ROM_elb_ext: elbow extension ROM, ROM_wst_ext: wrist extension ROM.

Table 4

Change Scores, Overall and Univariate MANCOVAs, and Effect Sizes for Impairment

Outcome Measures

Dependent Variable	Change Score Differences: M (SD)	Wilks' Lambda:	F(1,13)	п	Effect size: Cohen's d
v arrabic	Difficiences. M (SD)	Lambua.	1'(1,13)	Р	Concils a
Overall MANCOVA for Impairment Outcomes Model					
Condition	NA	0.51	12.31	.004*	NA
Order	NA	NA	0.38	.55	NA
Univariate MANCOVAs for Each Impairment Outcome Strength Shoulder Flex0.49 (9.63) 0.99 0.001 .97 -0.05					
Shoulder Al	` '	0.13	1.95	.19	0.12
Elbow Ext.	3.51 (9.32)	0.69	5.92	.03	0.38
Wrist Ext.	1.58 (9.09)	0.82	2.81	.12	0.17
Grip	1.18 (11.59)	0.98	0.29	.60	0.10
ROM					
Shoulder Flo	ex. 9.65 (26.27)	0.81	3.03	.11	0.37
Shoulder Ab	od. 8.15 (21.95)	0.77	3.81	.07	0.37
Elbow Ext.	5.85 (17.92)	0.94	0.85	.37	0.33
Wrist Ext.	1.20 (17.67)	0.99	0.02	.89	0.07

Note. * Significant (p < .025 for each analysis). Change Scores Difference = the mean treatment change score – mean control change score), SD: Standard Deviation.

Flex: flexion, Abd: abduction strength, Ext: extension strength.

Impairment outcome measures did not demonstrate consistent change patterns. Impairment outcome measures patterns of change by group graphs are attached in Appendix E.

Post-treatment Participants' Survey

Participants were surveyed at the end of their treatment period to get their

feedback about the strengths and the weaknesses of the TO approach as applied in the study. Table 5 below lists the participants' average response for each statement and Table 6 shows a summary for their responses for the structured questions.

Table 5

Participants Average Response on the Post-treatment Survey Statements

Statement	M (SD)
The treatment I received was unique:	4.4 (0.50)
It was easy to follow up with the homework assignments	3.5 (1.24)
The treatment was customized to fit my functional needs:	4.7 (0.47)
I was interested in all of the treatment activities used in the study:	4.5 (0.51)
The treatment was challenging:	4.7 (0.49)
The treatment used in the study was better than what I experienced	4.5 (0.69)
in the past:	
I would have paid \$2500 out of my health insurance money for this	4.2 (0.75)
study:	
I would refer someone else for this study:	4.9 (0.32)

Note: M = Mean; SD = Standard Deviation.

Table 6
Summary of Participants' Responses on the Post-treatment Survey Open-ended
Questions

Question	Responses Summary	
What are the 3 things you liked most about the treatment program?	Challenging, individualized, effective, encouraging, incorporating my affected arm, daily-life based, educating, intensive, confidence builder, interesting, easy to comprehend, variety of the activities, schedule flexibility, the therapist,	
WI - 4 2 4 11 11 1	stretching.	
What are the 3 things you did not	Frustrating when I fail, transportation, the	
like most about the treatment program?	homework is time consuming, some fatigue, treatment days were too close, the random assignment, difficult research testing, did not like some of the activities	
Do you have any suggestions?	Written feedback about the improvements, being able to change my goals after the initial evaluation, more sessions, more time on certain activities I like more, using more natural setups, getting more variety of activities, using repetitions instead of time for exercises, more evaluations throughout the therapy.	

Discussion

Key Findings

The order variable. In all of the outcome measures analyses, the order between groups variable had no significant multivariate or univariate effects, which confirmed that the two groups changes patterns did not differ significantly between the two orders' groups under each condition. This validated combining the two groups' change scores for each condition (TO or control) and the used statistical comparisons. These findings

suggest that for each condition (TO or control), the functional or impairment change scores appeared to be statistically similar regardless of the participants order assignment, which is consistent with our hypotheses.

The functional outcome measures. The results supported the functional hypotheses stated that the TO is better than the no treatment control in improving the functional abilities of the participants post-stroke. Study participants reported significantly greater increase in their top-priority functional tasks' self-perceived performance and satisfaction levels as measured by the COPM favoring the TO treatment. Furthermore, the TO approach was better as the participants showed a significantly greater increase in self perceived ratings of their affected UE amount and quality of use in daily life functional activities as measured by the MAL. Finally as they were using their affected UE functionally, the participants were significantly faster following the TO as indicated by the WMFT time scale and were a little bit better functionally as indicated by the WMFT functional ability scale. However, the difference between the two treatment conditions change scores at the WMFT functional ability was not statistically significant. Most of these advantageous differences of the TO treatment had large effect sizes (as demonstrated in Table 3), which support the TO functional superiority hypothesis and suggest that the TO approach is an effective client-centered approach in improving the functional abilities for clients who have had stroke.

The responsiveness of WMFT functional ability scale. WMFT functional ability difference was not statistically significant and had a small effect size (p = 0.106, d =

0.39). This small difference might be related to the responsiveness of the WMFT which was designed to test clients with mild to moderate strokes while our sample included many participants with severe stroke. Even with more homogenous samples, inducing large changes in the WMFT functional ability did not appear easy as can be noticed with the 0.30 points change (for the CIMT group) seen following CIMT in the EXCITE trial (Wolf et al., 2006), 0.34 points, and 0.20 points (for the CIMT groups) seen in another two CIMT studies (Dahl, Askim, Stock, Langørgen, Lydersen, Indredavik, 2008; Taub, Uswatte, King, Morris, Crago, Chatterjee, 2006). This study TO mean change score was 0.31 which is comparable to these cited CIMT studies. The EXCITE trial WMFT functional ability change following CIMT was statistically significant while our study was not. This might be understood by looking at the EXCITE larger sample size and better homogeneity in addition to using all of the 0.3 points difference (post-CIMT – pre-CIMT for the within group analysis) as opposed to what was done in this study of using the difference in the two groups' change scores.

The impairment outcome measures. Study results failed to support the impairment hypotheses that the TO is better than the no treatment control in improving impairments of persons post-stroke. The multivariate analysis condition within group's variable was statistically significant (p = .004), which indicates that there was a significant difference between the two conditions' effects on impairment measure as a whole. However, the univariate analysis failed to capture any statistically significant condition's effect. It should be noted that 8 out of the 9 differences in the impairment

change scores were in the favor of the TO approach, which might suggest a trend of superiority of the TO treatment over the control relative to impairment measures.

There were many raw scores changes with small effect sizes in favor of the TO approach. As demonstrated in Table 4 these included elbow extension strength (which had a trend of being significant), shoulder flexion ROM, shoulder abduction ROM, and elbow extension ROM. The relatively broad inclusion criteria (including mild, moderate, and severe severity of stroke) resulted in less homogeneity across participants than other stroke studies (e.g., CIMT studies, who included mild to moderate strokes only). Stricter inclusion and exclusion criteria would elicit a more homogenous sample. It can be noted that this study's impairment univariate change scores differences ranged between - 0.49 to 9.65 while the *SD* of the differences ranged between 8.94 and 26.27. Probably a larger and more homogenous sample could have improved the homogeneity of the participants impairment change differences and consequently improved the statistical power to detect any true potential impairment improvements supporting TO superiority

Possible Interpretation

Strength and range of motion limitations effects. Muscle weakness was identified as one of the consequences following stroke (Landau, 1974). Bohannon, 1989 stated that the muscle strength measurements in persons post-stroke are correlated with functional performance and can predict future impairment and functional improvements. Early hand grip strength recovery following stroke was associated with useful hand function at three months post-stroke. (Heller, Wade, Wood, Sunderland, Hewer & Ward,

1987). The abilities to demonstrate active movement initiation of elbow, wrist and fingers extension were identified as the primary predictors of the independent use of the affected UE following stroke (Wolf, 1983). In another study, persons with chronic stroke who had greater active range of motion at all major affected UE joints gained maximal functional benefits following rehabilitation (Wolf & MacLeod, 1983). Baseline fingers extension demonstrated in releasing a mass flexion was the primary predictor of UE functional abilities as measured by WMFT scores following CIMT therapy (Fritz, S L, Light, Patterson, Behrman, & Davis, 2005). These studies suggest that persons post-stroke starting with relatively limited UE ROM and strength (as seen in our study) would have limited post-rehabilitation recovery potentials.

Chronicity effects. In a one-year post-stroke longitudinal study interested in the affected UE functional recovery as measured by the Action Research Arm Test (ARAT), Kwakkel and Kollen, 2007 found that progressing in time (chronicity) was negatively associated with the improvement on ARAT. Spontaneous neural recovery can occur in the first few months after stroke (Carmichael, 2006). It is documented that the motor recovery slows after the first 3 to 6 months following the stroke (Dobkin, 2004; Kreisel, Hennerici, & Bzner, 2007; Nakayama, Jrgensen, Raaschou, & Olsen, 1994). These studies suggest starting at more stroke chronicity point (like our participants) would limit the recovery potentials.

Functional limitations severity. Functional improvements in response to subacute and chronic stroke rehabilitation have been well demonstrated in the literature (Richards,

Stewart, Woodbury, Senesac & Cauraugh, 2008; Wolf, Winstein, Miller, Taub, Uswatte, Morris, et al., 2006; Birkenmeier, Prager & Lang, 2010). However, it is thought that with traditional stroke rehabilitation methods, those persons with low functioning tend not to benefit as much as high functioning ones from treatment (Hendricks, van Limbeek, Geurts, & Zwarts, 2002; Jorgensen, Kammersgaard, Houth, Nakayama, Raaschou, Larsen, et al., 2000; Sanchez-Blanco, Ochoa-Sangrador, Lopez-Munaín, Izquierdo-Sanchez, & Fermoso-Garcia, 1999). In CIMT studies, it was found that clinically meaningful functional improvements (defined as achieving MAL HW score > 3 following CIMT) was significantly associated with pretest MAL HW, WMFT, and UEFM scores (Park, Wolf, , Blanton, Winstein, Nichols-Larsen, 2008). These studies suggest that persons post-stroke starting with more UE functional limitations (as seen in our study) would tend to demonstrate less functional improvements following rehabilitation.

The TO approach study population and treatment effects. Our study inclusion and exclusion criteria were much broader than the CIMT studies ones. Many of our participants lacked active movement in their affected hands comparable to CIMT studies participants. Adding the 62 months mean of post-stroke chronicity (which is more than Wolf et al., 2006 of 6 months, Dahl et al., 2008 of 21 months, and Taube et al., 2008 of 43 months), it seems that the TO approach applied in our study was disadvantaged as compared with the CIMT studies in terms of chronicity and motor impairment severity. However, with less treatment intensity, the TO therapy was able to demonstrate

comparable functional improvements as those seen in the CIMT studies. The severity of the motor impairment seen in our study combined with the high stroke chronicity might explain the lack of the motor impairment improvements. At this point, it is unknown if the TO approach might do a better job in improving the motor impairment of less stroke severities and chronicities.

At any rate, the impairment level can explain portions of the functional performance only and can help in predicting parts of the potentials of functional recovery. Two recent studies (Wolf et al., 2006; Birkenmeier, Prager & Lang, 2010) reported that functional improvements were much more possible to achieve than impairment improvements following functional training. Clinical treatments delivered in both studies were of the same or more intensity than our study. Participants in our study were of more chronicity and had more severe motor impairment severity when compared with these two cited studies. However, the TO approach used in this study produced comparable or better treatment functional change score as these of Wolf et al, 2006 (compared with MAL, WMFT) and Birkenmeier et al, 2010 (compared with COPM). Both of these two cited studies and ours failed to demonstrate significant impairment improvements measured by grip strength as can be seen in Table 7 below.

Table 7

A Comparison Between the TO Study, A CIMT Study, and Intensive Task-Specific

Training Study

Comparison	Wolf et al.	Birkenmeier	TO study		
	(CIMT group data only)	et al.			
Approach	CIMT	Task specific	ТО		
Sample size	105	13	20		
Clinical treatment	Up to 6 hours each week	3 hours/week	3 hours/week		
intensity	days for two weeks	for 6 weeks ^a	for 6 weeks		
Baseline comparisons					
Impairment severity	42.5	NA	33.7		
(UEFM)					
WMFT Time	19.3	NA	38.9		
WMFT function	2.39	NA	2.8		
Chronicity (months)	6.0	40.0	61.9		
Treatment change scores comparisons					
WMFT Time ^b	- 8.50	NA	- 6.98		
WMFT Function	0.30	NA	0.31		
MAL AoU	1.03	NA	0.91		
MAL How Well	0.92	NA	0.81		
COPM Performance	NA	2.2	2.71		
COPM Satisfaction	NA	2.50	3.24		
Grip strength	1.98	2.50	2.49		

CIMT: constraint induced movement therapy, TO: occupational therapy task-oriented,
UEFM: upper extremity division of Fugl-Meyer test (the larger the better). WMFT: Wolf
Motor Function Test), MAL: Motor Activity Log, COPM: the Canadian Occupational
Performance Measure.

 $^{^{\}alpha}$ Aimed to get 300 functional reaching and manipulation repetitions per hour b The more negative the better

These observations of the negative effects of chronicity and motor impairment severity on stroke recovery and the failure of other studies (conducted on participants with less severity and chronicities) to produce impairment improvements, might explain the lack of motor impairment improvements in our study. In this TO study, the functional improvements were emphasized more during treatment than the impairment improvements, which might be a valid decision given the chronicity and the severity of our participants' strokes.

The TO approach therapy. The nature of TO treatment used in this study should also be considered when interpreting the impairment outcome measures results. As the TO treatment was being applied in this study, we were not specifically strengthening all of the tested muscles or trying to increase the ROM for all the tested joints. Impairment training for a specific set of joint was done for each client based on that client's specific control parameters identified for the indvidualized functional performance. Additionally, this study had a wide variety of client-centered goals obtained from the COPM, which varied across participants relative to the physical (dexterity, ROM, and strength) demands.

Overall interpretation. The bottom line is that the study participants got functional improvements. Bohannon (1989) stated that the muscle strength alone can not explain the variance in the persons with stroke performance. It would be a challenge to analyze or describe the mechanism of this improvement. According to Almli and Finger (1988), recovery is achieving functional goals with a similar performance way as that

used before the injury. However, a more lenient definition of recovery describes it as a process of achieving tasks goals using efficient and effective techniques or methods of performance not necessarily matching the ones used before (Slavin, Held, Basso, et al, 1988). Motor learning is viewed as a set of practice dependent processes that can lead to relatively permanent changes in the ability to generate skilled movements. However this learning can only be measured indirectly through the behavior (Schmidt & Lee 2005). Shummway-Cook & Woollacott (2012), broaden this definition (stating that motor learning emerges from complex perception, cognition and action processes) which makes it harder to capture all of the motor learning underlining mechanisms in a single research study. The TO approach recommends utilizing motor learning principles in the treatment process. However, this TO research study does not have the setup of a specific motor learning experiment that can check for the motor learning components. Given that this study did not have any brain activity or neuroplastic reorganization (such as transcranial magnetic stimulation or functional magnetic resonance imaging), muscles electrical activity (electromyography), or Kinematical motion analysis of the UE motions patters, it would be a huge and probably invalid assumption to say that the functional improvements seen in this study are driven by compensation rather than remediation due to the lack of impairment outcome measures improvement only. We also did not use many other possible motor impairment measures such passive ROM and muscle tone. Additionally, although this is a motor study, based on the TO approach assumptions (obtained from motor learning and systems model) other personal factors (which we did

not monitor) such as sensory and cognitive abilities play important roles in the motor behavior. Furthermore, analyzing whether the participants were using their pre-stroke performance patterns or new ones in response to the TO is not possible within this study design. However, based on the lack of significant impairment improvements following our TO treatment, it is possible that the compensatory portion of the TO approach played more important roles in producing the noticed functional improvements. At this stage, this study provides evidence that the TO approach (as a combination of remediation and compensation) is effective in improving the functional performance post-stroke. Different designs are needed to characterize the specific contribution for each of remediation and compensation in the recovery process. Further studies would be needed to illuminate how does the TO work and what are the effective components of it.

Several components of stroke rehabilitation (such as functional meaningful activities, repetitive training, training intensity, and patient's active participation) are considered crucial for improving arm and hand function (Woldag & Hummelsheim, 2002; Barreca, Wolf, Fasoli, & Bohannon, 2003; de Kroon, jzerman, Chae, Lankhorst & Zilvold, 2005; Kwakkel, Wagenaar, Twisk, Lankhorst, and Koetsier, 1999; Richards & Pohl 1999). These therapeutic principles in addition to other contemporary principles of motor control and learning (such as practice variability) are incorporated in the TO approach. In addition to the clinical therapy by the occupational therapists, this study included home work functional exercises (1 - 1.5 hours a day) to enhance the training intensity, meaningfulness, and the transferability to real life situations. At the beginning

of each treatment session, the therapist reviewed and recorded what was done at home and suggested new uses or tricks for better functional use of the affected UE. This home work could have possibly helped in reducing the effects of the learned non-use (Morris & Taub, 2001). The home work may have helped in gaining the functional improvements seen in the study through the therapists' support, encouragement, and close follow-up of the use of the more affected UE out of the clinic.

Clinical Implications

CIMT is one of the most widely investigated post-stroke rehabilitation approaches. CIMT refers to a group of intervention techniques designed to overcome the learned non-use that develops in the early stages following a stroke. This approach involves restricting the movements of the less affected UE with a sling or a mitt for 90% of the patient waking hours through a two weeks period, while training use of the more affected UE intensively (Taub, Miller, Novack, Cook, Fleming, Nepomuceno, et al., 1993). CIMT has shown evidence in improving functional ability (as measured by WMFT) and the actual amount and quality of arm use (as measured by MAL). CIMT demonstrates results that transfer into daily activities (Dromerick, Edwards, & Hahn, 2000; Miltner, Bauder, Sommer, Dettmers, & Taub, 1999; Wolf, Winstein, Miller, Taub, Uswatte, Morris, et al. 2006). However, CIMT excluded about 75% of the stroke survivors due to its high functioning inclusion criteria (i.e., at least 10 degrees of wrist extension and 10 degrees of finger extension) (Morris & Taub, 2001; Hakkennes & Keating 2005). Although the CIMT may be an effective treatment approach following

stroke, it has been suggested to add more meaningful individualized training activities (i.e., making it more client-centered) to its efficacy studies (Bjorklund & Fecht, 2006; Roberts, Vegher, Gilewski, Bender, & Riggs, 2005).

This study of TO treatment has produced functional improvements comparable to that of the well-known CIMT clinical trial implemented by Wolf et al., 2006.

Unfortunately, Wolf et al. (2006) study did not use the COPM as an outcome measure, therefore a direct comparison of functional outcomes is not possible. In a smaller study of individualized occupation-based CIMT that used the COPM as an outcome measure (Roberts, Vegher, Gilewski, Bender, & Riggs, 2005), the COPM Performance score increased by 2.07 points while the COPM Satisfaction score increased 3.01points, which is less than the changes (i.e., 2.71 & 3.24 respectively) seen in our study. This study TO approach COPM changes were greater than those of another example of intensive functional therapy seen in the study of Birkenmeier et al. (2010) as demonstrated in Table 7.

According to Law et al, 1991, a change of 2 points or more in the COPM performance or satisfaction is considered to be clinically meaningful. Other researchers stated that the optimal cut-off of meaningful values for the MAL performance and satisfaction change scores ranged from 0.9 to 1.9 (Eyssen, Steultjens, Oud, Bolt, Maasdam, & Dekker, 2011). Therefore, our study COPM performance and satisfaction changes following the TO treatment (2.71 and 3.24 respectively) are considered clinically meaningful. The minimal clinically important differences (MCID) in several measures

early after the stroke were estimated by Lang Edwards, Birkenmeier, and Dromerick, 2008. The researchers stated MCID values early after stroke for the affected dominant and nondominant sides. MCID for grip strength were 5.0 and 6.2 kg, for WMFT functional ability MCID were 1.0 and 1.2 points, and for the MAL quality of movement score were 1.0 and 1.1 points. The researchers were not able to detect the MCID values the WMFT time score (Lang et al., 2008). These values are based on measurements taken during the first month post-stroke and expected to be higher than what we see in subacute and chronic stroke stages. Based on these studies, it is legitimate to state that the functional changes induced by this study TO therapy on MAL and COPM were clinically meaningful (see Table 7).

The theoretical basis of occupational therapy emphasizes that by using meaningful and purposeful activities, we can enhance the rehabilitation of the whole person (Law, 1998; Townsend, 1997). The TO therapeutic approach emphasizes using meaningful activities that have functional value and appear interesting for the patients. The TO approach also views clients as partners in setting therapy goals throughout the therapeutic process. The training activities are encouraged to be in their natural setting and with tools used by the patient (Mathiowetz and Bass-Haugen, 1994; Mathiowetz, 2011). In this study, these concepts were applied by individually identifying the occupational performance needs of each participant. The COPM was used for this purpose (Law et al., 1994) as a research outcome measure and treatment goals tool. The role checklist was also used (Oakely, Kielhofner, Barris, & Riechler, 1986) as one of the

therapy related assessments to evaluate each participant's roles and integration into the community. Finally, the interest checklist was used (Rogers, Weinstein, & Figone, 1978) to customize individual therapeutic activities to hold meaning, value, and of interest for each specific individual. The unique characteristics of the TO approach as applied in this study were confirmed through the participants' post-treatment survey demonstrated in Tables 5 and 6. The participants agreed that the treatment they received was unique, customized to fit their functional needs, of interesting activities, challenging, and better than other treatments they received in the past. The participants said that they would have authorized their health insurance to pay for this treatment cost and they would refer other persons with stroke to our study. These observations confirm that the occupational therapy is a well-perceived client centered approach with its own identity.

Deterioration of the UE functional ability following stroke is one of the critical challenges facing the field of rehabilitation (Luke, Dodd, & Brock, 2004). The use of the affected UE is not possible in 30% to 60% of stroke survivors. There is a need for more effective rehabilitation approaches that can serve acute and chronic stroke patients.

(Barreca, Wolf, Fasoli, & Bohannon, 2003; Kwakkel, Kollen, & Wagenaar, 1990; Lucca, Castelli, & Sannita, 2009). The TO approach proved to be effective post-stroke rehabilitation serving broader degree of motor impairment severity than what is available through CIMT. With much simpler resources, participants with stroke of more motor impairment severity and chronicty, and much less amount of therapy, the TO approach provided comparable functional improvements like these seen following the CIMT.

Based on the post-treatment survey, the effective TO approach was delivered in a well-perceived client-centered therapeutic protocol.

This study is the first clinical trial describing the clinical application of the occupational therapy TO approach and to test its functional and impairment efficacy. This study followed the International Classification of Functioning, Disability, and Health (WHO, 2001) in evaluating the therapeutic efficacy of the occupational therapy TO approach. The body function (impairment) was evaluated through the strength and ROM measures, activities limitation (functional abilities) was evaluated through the WMFT and the activities participation was evaluated by the MAL and the COPM. This study provided a valuable framework could be used for future research studies and for clinical rehabilitation post stroke.

Potential Limitations

This study was the first clinical trial evaluating the efficacy of the occupational therapy TO approach. It was reasonable at this stage to start with comparing the TO approach against no treatment control condition before taking it one step further and do a more challenging comparison against another post-stroke treatment approach. Although this study is limited by having no comparison alternative treatment, this design was necessary at this stage to confirm the uniqueness of this approach and to improve its clinical application protocol. Furthermore, the COPM data collection evaluator was not blinded since we thought that the main therapist (who was also the PI) needed to know

the participants very well in order to customize their treatment.

The proposed TO protocol is a combination of remediation and compensatory strategies delivered at the rehabilitation clinic and coupled with a set of homework exercises. Another limitation of the study related to the nature of the TO approach is not being able to determine which of the TO components is the most effective and accounts for the majority of the functional improvements seen in this study.

The third limitation is that the functional improvements seen in this study can not be explained from a motor learning prospective since this study does not have the setup of motor learning experiment and lacked brain activity and motion analysis outcome measures.

The study is limited regarding its ability to detect the impairment changes. While we used impairment measures from many of the affected UE joints, within the current design, it was not possible to train all of the tested joints for strength and ROM, which could have limited the overall impairment changes across participants. At the same time what was actually done in terms of impairment level remediation is not traceable for statistical analysis purposes (i.e. what was the actual level of strength and ROM training for each tested joint for each participant's) and the study sample size was not sufficient to produce adequate statistical power for this type of analysis. The sampling and the inclusion criteria did not account for this type of analysis in the first place.

The sample size is small due to limited financial recourses and time. A larger sample size could have provided better statistical power to detect any potential

improvements in the insignificant outcome measures (the WMFT functional ability and the impairment outcome measures). Finally, the inclusion criteria could have been stricter to test the efficacy on a more homogenous stroke severity and degree of chronicity.

Future Directions

Future studies evaluating the TO approach can build on the results of our study by using the therapeutic protocol developed for this study. Larger sample sizes and a stronger randomized clinical trial design (with two independent groups, without cross over, and with blinded evaluators for all outcome measures) with comparisons against other treatment approaches (such as traditional OT or CIMT) would improve the quality of future studies. It is needed to confirm the results of this study and to determine which persons post-stroke will benefit the most from this approach. Studies are needed to test the TO approach in various levels of chronicity and severity to see if the approach is delivered differently with different stroke population with various impairment level. Studying the effects of various components of the TO approach would be extremely helpful to illuminate what would be the most helpful part (i.e. remediation or compensation, clinical based therapy or home-based therapy). More attention should be paid while evaluating the impairment outcomes effects of the TO approach. This can be done by having participants with more homogenous functional goals which would improve the odds of getting more homogenous impairment level remedial needs (for example, clients who need training on writing would mostly need wrist and fingers ROM and strength training) without affecting the client-centered nature of the approach. Other

outcome measures modalities (such as brain activity and UE motion analysis) might help in explaining the functional improvements seen following the TO therapy.

Conclusions

The occupational therapy TO approach appeared to be an innovative and wellperceived client centered UE post-stroke rehabilitation approach. Following a six-week
three hours per week clinical UE functional training based on this approach, the study
participants demonstrated significant and clinically meaningful functional improvements
at their activity participation level measured by the MAL and the COPM. The
participants showed significant improvements at their activity limitation level indicated
by significant improvement on their WMFT time scale. The TO approach failed to
demonstrate significant improvements at the WMFT functional ability scale or at the
impairment level monitored by the affected UE ROM and strength measures. At this time
it is not possible to explain the mechanisms of the TO approach functional improvements
due to the design limitations. More studies are required to confirm our results and to
enhance the clinical applicability of the TO approach.

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Appendices

Please note:

A- The researchers obtained written consent from the research participant, who appeared in these thesis pictures. He authorized the use of his picture for teaching, research conferences, and publications purposes.

B- The cited literature in the appendices (mainly in the treatment protocol appendix) is listed in the thesis main reference list, complying with the University of Minnesota Graduate School thesis format.

UNIVERSITY OF MINNESOTA

Department of Rehabilitation Science

In collaboration with Sister Kenny Rehabilitation Institute and Research Center

Seeking Persons Post-Stroke with Limited Use of their Affected Arm

Effects of Occupational Therapy Task-Oriented Approach in Upper Extremity Post-Stroke Rehabilitation

You are invited to participate in a study to evaluate the effects Occupational Therapy Task-Oriented approach of upper extremity rehabilitation following stroke.

This approach uses self-care, leisure, and work-related activities while using a device that reduces the effects of gravity on your arm (Mobile Arm Support). All participants will experience the full treatment approach. These therapy sessions will be provided at no cost to participants. The participants will be reimbursed for mileage and parking costs.

The training and evaluation will take place at Sister Kenny Rehabilitation Institute (800 E. 28th St. Minneapolis, MN 55407) in Minneapolis for 6 weeks. The study will include another 6 weeks of no treatment where you don't need to come to the clinic.

To be eligible for this study you must have a stroke of at least 3 months onset and you are not receiving current rehabilitation for your affected arm. Your affected arm should have strength and range of motion limitation, which limits your ability to perform your daily life functional tasks.

If you have questions or want to sign up for a screening session, please contact Khader Al Mhdawi at the University of Minnesota,

Telephone: office: (612) 626-2443, Cell: (612) 655-6713 Email: almhd001@umn.edu.

3038-31

CONSENT FORM

Protocol Title: "Effects of Occupational Therapy Task-Oriented Approach in Upper Extremity Post-Stroke Rehabilitation"

Investigators: This study is being conducted by Khader Al Mhdawi, OT, MS, Rehabilitation Science PhD student and his advisor Virgil Mathiowetz, PhD, OTR/L, Associate Professor of Occupational Therapy at University of Minnesota in collaboration with Matthew White, OTR, and Jennifer Smith, MS, OTR, from Sister Kenny Rehabilitation Institute. The training will be implemented at Sister Kenny Rehabilitation institute in Minneapolis.

Conflict of Interest Statement: This study is partially funded through a local foundation. Neither the principal investigator, nor any of the research team have any conflicts of interest that might affect the integrity of the study procedures and/or its results.

Research Subject's Bill of Rights:

People who volunteer to participate in an experiment (also called a research study or clinical trial) need to understand what is expected of them and why the research is being done. As you think about whether or not to volunteer, it is important that you know you have rights in place to help protect you. These rights, listed below, will be further explained as you read this informed consent document. If you are asked to participate in a research study, you have the right to:

- · be told the purpose and details of the research study,
- have the drugs or devices (tools or pieces of equipment) used in the research study described,
- · have the procedures of the research study and what is expected of you explained,
- have the risks, dangers and discomforts of the research study described,
- · have the benefits and advantages of the research study described,
- be told of other drugs, devices or procedures (and their risks and benefits) that may be helpful to you,
- be told of medical treatment available to you should you be injured because of the research study,
- · have a chance to ask questions about the research study.
- · quit the research study at any time without it affecting your future treatment,
- have enough time to decide whether or not to take part in this research study and to make that
 decision without feeling forced or required to participate, and
- · be given a copy of this signed and dated informed consent form.

Participants' Selection: You have been selected to participate because you experienced a stroke at least three months ago and are not receiving current rehabilitation for your affected arm. Your affected arm has strength and range of motion limitations, which reduce your ability to perform your daily life functional tasks.

Study Purpose: The purpose of the study is to evaluate the effects of the Occupational Therapy Task-Oriented Approach (i.e., individualized self-care, leisure, and work-related activities) on improving weak arm movements and daily arm use for persons who have had a stroke.

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Size of Study: 30-40 participants will be enrolled in the study.

Study Procedures and Duration: If you agree to participate in this 12-week study, you will be asked to do the following:

Screening: (1.5-2 hours)

- Evaluating your general cognitive ability using Mini-Mental Status test.
- Evaluating your arm movements using Fugl-Meyer test.
- Evaluating your affected arm muscle tone using the Modified Ashworth Scale.
- Measuring your affected arm ranges of motion using a goniometer.
- Evaluating your affected arm strength using the manual muscle testing of the shoulder and the elbow.

If you meet the study criteria, you will be randomly assigned (like the flip of a coin) into either an immediate or delayed treatment group. If you are assigned to the immediate group, you will begin the treatment within a few days after the initial evaluation. If you are assigned to the delayed group, you will begin treatment six weeks after your initial evaluation. Both groups will get the same treatment.

Assessment #1: (1.5 to 2 hours)

We will do the following tests:

- · Motor Activity Log, by which you rate your use of your affected arm in common daily activities.
- Canadian Occupational Performance Measure, where you identify your top functional task in which you want to improve your performance.
- Wolf Motor Function Test, by which we evaluate your arm movements in reaching and hand
 manipulative tasks. This test will be videotaped for evaluation purposes; no one other than the
 researchers will have access to those videos.
- Assessing your upper extremity range of motion using a goniometer and your strength using strength measurement devices.

The Task-Oriented Treatment period will last six weeks for both groups. During this period, we will use everyday functional activities matching your interests. You will have the option to use video game systems (such as Wii or Interactive Rehabilitation Exercise). You will use the mobile arm supports (MAS) as needed to enhance your ability to use your involved arm for things that are most important to you. MAS is an adaptive device designed to assist persons with arm weakness to perform everyday self-care and leisure tasks. The occupational therapy task oriented approach will consist of three hours of treatment per week (i.e., either 3 one-hour sessions/week or two 1.5 hours sessions/week) for a period of six weeks.

The No-Treatment Control period will also last six weeks. During this period, you will be at your home, and you will not get any professional physical or occupational therapy for your affected arm.

Assessment #2 will be at the end of week 6 and will involve the same tests as the first assessment.

<u>Assessments #3</u> will be at the end of week 12 and will involve the same tests as previous assessments. Complete a brief survey evaluating the intervention, which will take 5-10 minutes.

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Wee	ek	Start of W1	W1-W6	End of W6	W7-W12	End of W12
Proced	Immediate Group	Assessment #1 1.5-2 hours at the clinic	Task Oriented Treatment 3 hours/week at the clinic	Assessment # 2 1.5-2 hours At the clinic	No Treatment Control At your home	Assessment #3 1.5-2 hours At the clinic
dures	Delayed Group	Assessment #1 1.5-2 hours at the clinic		Assessment #2 1.5-2 hours At the clinic	Task Oriented Treatment 3 hours/week at the clinic	Assessment #3 1.5-2 hours At the clinic

Video/Audio Recording:

We will record (video + audio) the Wolf motor function test to compare the quality of your arm movements before and after the study treatment. We will record your performance three times in a total up to 90 minutes at Sister Kenny research center. The videos will be secured and encrypted in an external hard drive kept in a secured closet. The principal investigator (Khader Almhdawi) and his academic advisor (Dr. Virgil Mathiowetz) are the only individuals who will have access to the videos. Upon your approval, we might use part of your recordings for scientific presentations.

You may ask that the recorder be turned off at any point during the study if there is something that you do not want recorded.

Initial ei	ther 1 or 2:
1	I do not want to be audio/ video recorded in this study. I understand I still can participate is other parts of the study.
2	I agree to be audio/ video recorded in this study.
Initial ei	ther 1 or 2:
1	I do not authorize the researchers to use my recordings for any scientific presentation. I understand I still can participate in other parts of the study.
2	I authorize the researchers to use my recordings for scientific presentations at conferences and for teaching purposes.

Risks and Discomforts: This study has minimal risks:

- There is a possibility that you might experience some discomfort, pain, or fatigue while performing the study therapeutic tasks.
- These potential risks will not exceed those experienced in traditional rehabilitation commonly
 provided for individuals with a stroke similar to yours.
- Your therapeutic program will be modified to reduce these symptoms if you experience them.
- If those issues cannot be resolved, you will have the opportunity to discontinue your participation.

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Benefits of Study Participation: Possible benefits you may experience include.

- Your ability to move your arm may improve.
- Your participation may contribute to the knowledge base in the field of stroke rehabilitation.

Alternatives to Study Participation: If you do not want to participate in this study, you do not have to. You may still receive rehabilitation through a health care provider, however, some treatment strategies used in this study might not be available to you.

Costs: There is no cost to you to participate in this research study.

Billing Error Information: If you believe you have received a bill in error during the research study, contact Khader Almhdawi at (612) 626-2443

Compensation: You will be reimbursed for your parking and mileage costs (\$12/therapy session).

Compensation for Research-Related Injury: If your participation in this research study results in an injury, treatment will be available, including first aid, emergency treatment, and follow-up care, as needed. Care for such injuries will be billed in the ordinary manner to you or your insurance company. No funds have been set aside to pay for care for injuries resulting from your participation in this study. If you believe you have suffered a research-related injury, notify the primary investigator immediately.

Confidentiality: The records of this study will be kept strictly confidential. However, confidentiality cannot be absolutely guaranteed. Due to the nature of clinical trial oversight, some funding and regulatory agencies may have the right to review the records of this study. These agencies include the University of Minnesota Institutional Review Board and Allina Institutional Review Board. In the case of publication or presentation, we will not disclose your name or any other personal information that could identify you as a participant. Every attempt will be made to disguise identifying features in assessment video recordings and pictures. Otherwise, your personal information will be kept confidential.

Protected Health Information (PHI):

Your PHI created or received for the purpose of this study is protected under the federal regulation known as HIPPA. Refer to the attached HIPAA authorization for details.

Voluntary Participation:

Your participation in this study is strictly voluntary. Your decision whether or not to participate in this study will in no way reflect your relationship with the researchers or Allina clinics.

Right to Withdraw: You may withdraw from the study at any time. Your decision not to take part in or to withdraw from this study will not involve any penalty or lost benefits to which you are entitled. Your withdrawal will not affect your access to health care at Allina clinics.

If you do decide to withdraw, we ask that you contact Khader Almhdawi at Program in Occupational Therapy, UMN, MMC 368, 420 Delaware St. SE, Minneapolis, MN 55455 to let him know that you are withdrawing from the study

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Termination: The investigator or other regulatory or governmental agencies may discontinue your participation in the study without your consent if they feel that it is in your best interest or if you fail to comply with the study procedures or experience a study-related injury or unacceptable side effects. They may also remove you for administrative reasons.

New Findings: If we find out new information during the course of the study that may change your willingness to continue (for example, a new, serious side effect), we will contact you.

Contacts and Questions

The principal investigator conducting this study is Khader Al Mhdawi. Please ask any questions you have at this time, or if you have questions later, you may contact Khader at the Program in Occupational Therapy, University of Minnesota, MMC 368, 420 Delaware St. SE, Minneapolis, MN 55455 or by telephone: office: (612) 626-2443, Cell (612) 655-6713 or by email: almhd001@umm.edu.

If you have any questions or concerns about this study and would like to talk to someone other than the researchers, contact:

- The Fairview Research Helpline at (612)-672-7629 or toll free at 866-508-6961. You may also contact this office in writing or in person at University of Minnesota Medical Center, Fairview-Riverside Campus, #815 Professional Building, 2200 Riverside Avenue, Minneapolis, MN 55454.
- You can also direct your questions to the Allina Institutional Review Board Administrative Office at 612-262-4920.

You will be given a copy of this form to keep for your records.

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Statement of Consent

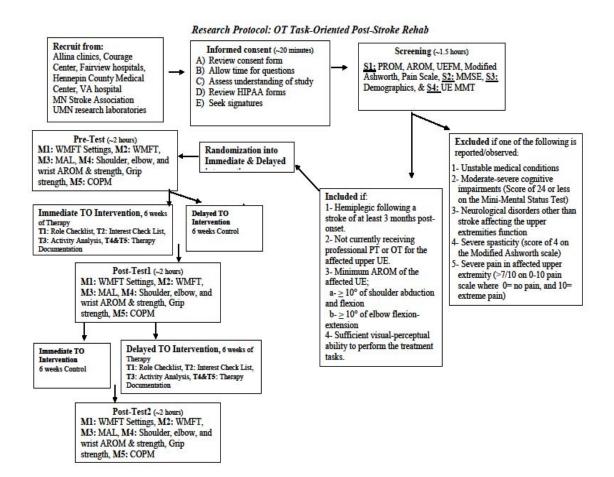
I have read and understand the information above. I have asked questions and received answers regarding this study. I have been given enough time to consider participating. I consent to participate in this study.

Printed name of participant	_	
Signature of participant	Date	
Printed name of person obtaining consent	Role in study	
Signature of person obtaining consent	 Date	



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Appendix C: Procedures Flowchart



Appendix D: Participants Post-Treatment Survey

OT Task-Oriented Post-Stroke Rehab. Outcome Measures, M6 Test: Participants" Post-Study Survey Participant's ID code: Investigator: Tested UE: _R Use the following scale to respond to the following statments. We will really appreciate your honest feedback. We are building a therapeutic approached to be recommended for rehabilitation setting. Strongly Disagree Disagree Neutral Agree Strongly Agree 1- The treatment I received was unique: Strongly Disagree Disagree Neutral Agree Strongly Agree 2- It was easy to follow up with the homework assignments: Strongly Disagree Disagree Neutral Agree Strongly Agree 1 3 3- The treatment was customized to fit my functional needs: Strongly Disagree Disagree Neutral Agree Strongly Agree 4- I was interested in all of the treatment activities used in the study: Strongly Disagree Neutral Disagree Agree Strongly Agree 5- The treatment was challenging: Strongly Disagree Neutral Disagree Agree

Comments:		

6- The treatment of the	study was be	tter than wh	at I experien	ced in the past:							
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree							
1	2	3	4	5							
7- I would have paid \$2500 out of my health insurance money for this study:											
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree							
1	2	3	4	5							
8- What are the 3 thing 1- 2- 3-	,s you need iii	osi aooui ille	. acament p	rveram.							
9- What are the 3 thing 1- 2- 3-	s you did not	like most ab	out the treat	ment program:							
10- Do you have any suggestions?											
11 - I would refer someone else for this study:											
Strongly Disagree	Disagree	Neutral 3	Agree	Strongly Agree							
1	2	3	+	3							

Comments:

2

Appendix E: SPSS Outputs

Baseline Characteristics MANIOVA Multivariate Tests⁴

	Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ⁵
Intercept	Pilal's Trace:	.000	.000°	3.000	16.000	1.000	.000	.000	.050
ı	Wilks' Lambdia	1.000	.000*	3.000	16.000	1.000	.000	.000	.050
l	Hotelling's Trace	.000	.000*	3.000	16.000	1.000	.000	.000	.050
	Roy's Largest Root	.000	.000°	3.000	16.000	1.000	.000	.000	.050
order	Pillal's Trace:	.008	.043 ^a	3.000	16.000	.988	.008	.129	.056
l	Wilks' Lambda	.992	.043ª	3.000	16.000	.988	.008	.129	.056
l	Hotelling's Trace	.008	.043ª	3.000	16.000	.988	.008	.129	.056
	Roy's Largest Root	.008	.043*	3.000	16.000	.988	.008	.129	.056

a. Exact statistic

Pretest Functional MANOVA Multivariate Tectob

	Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillal's Trace	.665	4.306*	6.000	13.000	.013
	Wiks' Lambda	.335	4.306*	6.000	13.000	.013
	Hotelling's Trace	1.988	4.306*	6.000	13.000	.013
	Roy's Largest Root	1.988	4.306"	6.000	13.000	.013
order	Pillal's Trace	.259	.759*	6.000	13.000	.614
	Wiks' Lambda	.741	.759*	6.000	13.000	.614
	Hotelling's Trace	.350	.759*	6.000	13.000	.614
	Roy's Largest Root	.350	.759*	6.000	13.000	.614

a. Exact statistic

Pretest: Impairment MANOVA Multivariate Tecto^b

	Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillal's Trace	.399	.737*	9.000	10.000	.672
l	Wilks' Lambda	.601	.737ª	9.000	10.000	.672
l	Hotelling's Trace	.663	.737ª	9.000	10.000	.672
	Roy's Largest Root	.663	.737"	9.000	10.000	.672
order	Pillal's Trace	.351	.600*	9.000	10.000	.773
l	Wilks' Lambda	.649	.600*	9.000	10.000	.773
l	Hotelling's Trace	.540	.600*	9.000	10.000	.773
	Roy's Largest Root	.540	.600°	9.000	10.000	.773

a. Exact statistic

Figure E1. Baseline characteristics and pretest between groups analyses.

b. Computed using alpha = .05

c. Design: Intercept + order

b. Design: Intercept + order

Functional MANOVA. Multivariate Tects

Effec	t	Value	F	Hypothesis df	Emor df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ⁵
Functional_tests	Pillal's Trace	.841	14.833*	5.000	14.000	.000	.841	74.164	1.000
	Wilks' Lambda	.159	14.833*	5.000	14.000	.000	.841	74.164	1.000
	Hoteling's Trace	5.297	14.833	5.000	14.000	.000	.841	74.164	1.000
	Roy's Largest Root	5.297	14.833	5.000	14.000	.000	.841	74.164	1.000
Functional_tests *	Pilial's Trace	.115	.365*	5.000	14.000	.864	.115	1.824	.114
order	Wilks' Lambda	.885	.365*	5.000	14.000	.864	.115	1.824	.114
	Hoteling's Trace	.130	.365ª	5.000	14.000	.864	.115	1.824	.114
	Roy's Largest Root	.130	.365°	5.000	14.000	.864	.115	1.824	.114
Condition	Pillal's Trace	.881	1.339E2 ⁸	1.000	18.000	.000	.881	133.883	1.000
l	Wilks' Lambda	.119	1.339E2*	1.000	18.000	.000	.881	133.883	1.000
	Hoteling's Trace	7.438	1.339E2*	1.000	18.000	.000	.881	133.883	1.000
	Roy's Largest Root	7.438	1.339E2 [*]	1.000	18.000	.000	.881	133.883	1.000
Condition " order	Pilial's Trace	.065	1.251*	1.000	18.000	.278	.065	1.251	.185
l	Wilks' Lambda	.935	1.251*	1.000	18.000	.278	.065	1.251	.185
	Hoteling's Trace	.070	1.251	1.000	18.000	.278	.065	1.251	.185
	Roy's Largest Root	.070	1.251*	1.000	18.000	.278	.065	1.251	.185
Functional_tests *	Pillal's Trace	.785	10.233 ^a	5.000	14.000	.000	.785	51.163	.998
Condition	Wilks' Lambda	.215	10.233 ^a	5.000	14.000	.000	.785	51.163	.998
	Hoteling's Trace	3.654	10.233ª	5.000	14.000	.000	.785	51.163	.998
	Roy's Largest Root	3.654	10.233ª	5.000	14.000	.000	.785	51.163	.998
Functional_tests *	Pilial's Trace	.106	.332ª	5.000	14.000	.885	.106	1.660	.108
Condition " order	Wilks' Lambda	.894	.332"	5.000	14.000	.885	.106	1.660	.108
	Hoteling's Trace	.119	.332*	5.000	14.000	.885	.106	1.660	.108
	Roy's Largest Root	.119	.332*	5.000	14.000	.885	.106	1.660	.108

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept + order Within Subjects Design: Functional_tests + Condition + Functional_tests * Condition

Tests of Between-Subjects Effects

Measure:MEASURE_1 Transformed Varable:Average

Source	Type III Burn of Squares	ď	Mean Square	F	Sig.	Portiol Cto Squared	Noncont. Parameter	Observed Power ^a
Intercept	34.700	1	34.700	127.300	.000	.876	127.300	1.000
order	.073	1	.073	.267	.612	.015	.267	.078
Error	4.907	18	.273					

a. Computed using alpha = .05

Figure E2. Overall functional MANOVA.

Functional Univariate MANOVA of COPM Performance Multivariate Tests*

E	flect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
Condition	Pillal's Trace	.745	52,677*	1,000	18_000	.000	.745	52,677	1.000
	Wilks' Lambda	.255	52.677*	1.000	18000	.000	.745	52,677	1.000
	Hotelling's Trace	2.927	52.677*	1.000	18000	.000	.745	52,677	1.000
	Roy's Largest Root	2.927	52.677*	1.000	18000	.000	.745	52,677	1.000
Condition *	Pillal's Trace	.003	.056*	1.000	18_000	.815	.003	.056	.056
order	Wilks' Lambda	.997	.056*	1.000	18_000	.815	.003	.056	.056
	Hotelling's Trace	.003	.056*	1.000	18.000	.815	.003	.056	.056
	Roy's Largest Root	.003	.056*	1.000	18000	.815	.003	.056	.056

a. Exact statistic

b. Computed using alpha =.05

c. Design: Intercept + order Within Subjects Design: Condition

Functional Univariate MANOVA of COPM Satisfaction Multivariate Texts⁴

MUIUVAITAD TOGG											
ш	flect	Value	F	Hypothesis df	Emor df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ³		
Condition	Pillal's Trace	.730	48.607*	1.000	18,000	.000	.730	48.607	1.000		
	Wilks' Lambda	.270	48.607*	1.000	18,000	.000	.730	48.607	1.000		
	Hotelling's Trace	2.700	48.607*	1.000	18.000	.000	.730	48.607	1.000		
	Roy's Largest Root	2.700	48.607*	1.000	18.000	.000	.730	48.607	1.000		
Condition "	Pillal's Trace	.011	.201*	1.000	18,000	.659	.011	.201	.071		
order	Wilks' Lambda	.989	.201*	1.000	18,000	.659	.011	.201	.071		
	Hotelling's Trace	.011	.2018	1.000	18,000	.659	.011	.201	.071		
	Rioy's Largest Root	.011	.201 ⁸	1.000	18.000	.659	.011	.201	.071		

a. Exact statistic

b. Computed using alpha =.05

c. Design: Intercept + order Within Subjects Design: Condition

Figure E3. Canadian Occupational Measure (COPM) univariate MANOVA.

Functional Univariate MANOVA of MAL HW Multivariate Tests⁴

Effect		Value	F	Hypothesis df	Emor of	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ⁵
Condition	Pillars Trace	.578	37.963*	1.000	18,000	.000	.678	37.963	1.000
	Wilks' Lambda	.322	37.963*	1.000	18.000	.000	.678	37.963	1.000
	Hotelling's Trace	2.109	37.963*	1.000	18.000	.000	.678	37.963	1.000
	Roy's Largest Root	2.109	37.963*	1.000	18.000	.000	.678	37.963	1.000
Condition *	Pillars Trace	.109	2.210*	1.000	18.000	.154	.109	2.210	.291
order	Wilks' Lambda	.891	2.210*	1.000	18,000	.154	.109	2.210	.291
	Hiotelling's Trace	.123	2.210*	1.000	18.000	.154	.109	2.210	.291
	Roy's Largest Root	.123	2.210*	1.000	18.000	.154	.109	2.210	.291

- a. Exact statistic
- b. Computed using alpha = .05
- c. Design: Intercept + order Within Subjects Design: Condition

Functional Univariate MANOVA of MALAOU Multivariate Tects⁴

Effect		Value	F	Hypothesis df	Error of	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillars Trace	.702	42,428*	1.000	18,000	.000	.702	42,428	1.000
	Wilks' Lambda	.298	42.428"	1.000	18.000	.000	.702	42,428	1.000
	Hotelling's Trace	2.357	42,428*	1.000	18.000	.000	.702	42.428	1.000
	Roy's Largest Root	2.357	42,428*	1.000	18.000	.000	.702	42,428	1.000
Condition *	Pillal's Trace	.111	2.245*	1.000	18.000	.151	.111	2.245	.295
order	Wilks' Lambda	.889	2.245*	1.000	18.000	.151	.111	2.245	.295
	Hotelling's Trace	.125	2.245*	1.000	18.000	.151	.111	2.245	.295
	Roy's Largest Root	.125	2.245*	1.000	18.000	.151	.111	2.245	.295

- a. Exact statistic
- b. Computed using alpha -
- .05
- c. Design: Intercept + order
- Within Subjects Design: Condition

Figure E4. Motor Activity Log (MAL) univariate MANOVA.

Functional Univariate M.ANOVA of WMFT Time Multivariate Tests*

Effect		Value	F	Hypothesis df	Error of	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
Condition	Pillars Trace	.321	8.516*	1.000	18.000	.009	.321	8.516	.788
	Wilks' Lambda	.679	8.516"	1.000	18.000	.009	.321	8.516	.788
	Hiotelling's Trace	.473	8.516*	1.000	18.000	.009	.321	8.516	.788
	Roy's Largest Root	.473	8.516*	1.000	18.000	.009	.321	8.516	.788
Condition *	Pillars Trace	.002	.027*	1.000	18.000	.871	.002	.027	.053
order	Wilks' Lambda	.998	.027*	1.000	18.000	.871	.002	.027	.053
	Hiotelling's Trace	.002	.027*	1.000	18.000	.871	.002	.027	.053
	Roy's Largest Root	.002	.027 ⁸	1.000	18.000	.871	.002	.027	.053

a. Exact statistic

b. Computed using alpha -

.05

c. Design: Intercept + order Within Subjects Design: Condition

Functional Univariate MANOVA of WMFT Functional Ability Multivariate Tests⁴

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillal's Trace	.138	2.891*	1.000	18,000	.106	.138	2.891	.363
	Wilks' Lambda	.862	2.891"	1.000	18.000	.105	.138	2.891	.363
	Hiotelling's Trace	.161	2.891*	1.000	18.000	.106	.138	2.891	.363
	Roy's Largest Root	.161	2.891	1.000	18.000	.106	.138	2.891	.363
Condition *	Pillal's Trace	.016	.287*	1.000	18,000	.599	.016	.287	.080.
order	Wilks' Lambda	.984	.287	1.000	18,000	.599	.646	.287	.080
	Hiotelling's Trace	.016	.287*	1.000	18.000	.599	.016	.287	.080
	Roy's Largest Root	.016	.287*	1.000	18.000	.599	.016	.287	.080

a. Exact statistic

b. Computed using alpha = ns

c. Design: Intercept + order Within Subjects Design: Condition

Figure E5. Wolf Motor Function Test (WMFT) univariate MANOVA.

Impairment MANOVA Multivariate Tests^c

			Mul	tivariate Te	ests				
Effec	at .	Value	F	Hypothesis df	Error df	Sg.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
impairment_tests	Pillai's Trace	.678	1.580"	3.000	6.000	.297	.678	12.639	.291
	Wilks' Lambda	.322	1.580"	3.000	6.000	.297	.678	12.639	.291
	Hotelling's Trace	2.106	1.580°	3.000	6.000	.297	.678	12.639	.291
	Roy's Largest Root	2.106	1.580°	3.000	6.000	.297	.678	12.639	.291
impairment tests *	Pillai's Trace	.638	1.320°	3.000	6.000	.378	.638	10.556	.246
S_ELB_EXT_1	Wilks' Lambda	.362	1.320°	3.000	6.000	.378	.638	10.556	.246
	Hotelling's Trace	1.759	1.320°	3.000	6.000	.378	.638	10.556	.246
	Roy's Largest Root	1.759	1.320°	3.000	6.000	.378	.638	10.556	.246
impairment_tests *	Pillai's Trace	.854	4.378°	3.000	6.000	.044	.854	35.025	.703
R_SH_F_1	Wilks' Lambda	.146	4.378"	3.000	6.000	.044	.854	35.025	.703
	Hotelling's Trace	6.837	4.378ª	3.000	6.000	.014	.851	35.026	.703
	Roy's Largest Root	5.837	4.378°	3.000	6.000	.044	.854	35.025	.703
impairment tests *	Pillai's Trace	.797	2.936°	3.000	6.000	.103	.797	23.489	.515
R_SH_AB_1	Wilks' Lambda	.203	2.936°	3.000	6.000	.103	.797	23.489	.515
	Hotelling's Trace	3.915	2.936°	3.000	6.000	.103	.797	23.489	.515
	Roy's Largest Root	3.915	2.936*	3.000	6.000	.103	.797	23.489	.515
impairment_tests *	Pillai's Trace	.403	.506°	3.000	6.000	.816	.403	4.052	.115
R_WST_EXT_1	Wilks' Lambda	.597	.506*	3.000	6.000	.816	.403	4.052	.115
	Hotelling's Trace	.675	.506°	3.000	6.000	.816	.403	4.052	.115
	Roy's Largest Root	.675	.506*	3.000	6.000	.816	.403	4.052	.115
impairment tests *		.731	2.036"	3.000	6.000	.201	.731	18.287	.369
GRIP_1	Wilks' Lambda	.269	2.036°	3.000	6.000	.201	.731	13.287	.369
	Hotelling's Trace	2.714	2.036ª	3.000	6.000	.201	.731	18.287	.369
	Roy's Largest Root	2.714	2.036"	3.000	6.000	.201	.731	18.287	.369
impairment_tests *	Pillai's Trace	.416	.534°	3.000	6.000	.798	.416	4.269	.119
order	Wilks' Lambda	.584	.534"	8.000	6.000	.798	.416	4.269	.119
	Hotelling's Trace	.711	.534°	3.000	6.000	.798	.416	4.269	.119
	Roy's Largest Root	.711	.534°	8.000	6.000	.798	.416	4.269	.119
Condition	Pillai's Trace	.486	12.309°	1.000	13.000	.004	.486	12.309	.900
	Wilks' Lambda	.514	12.309°	1.000	13.000	.004	.486	12.309	.900

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	Hotelling's Trace	.947	12.309*	1.000	13.000	.004	.486	12.309	.900
	Roy's Largest Root	.947	12.309°	1.000	13.000	.004	.486	12.309	.900
Condition *	Pillai's Trace	.464	11.259°	1.000	13.000	.005	.464	11.259	.873
S_ELB_EXT_1	Wilks' Lambda	.536	11.259°	1.000	13.000	.005	.464	11.259	.873
	Hotelling's Trace	.800	11.259°	1.000	13.000	.005	.404	11.259	.873
	Roy's Largest Root	.866	11.259°	1.000	13.000	.005	.464	11.259	.873
Condition *	Pillai's Trace	.291	5.343*	1.000	13.000	.038	.291	5.343	.571
R_SH_F_1	Wilks' Lambda	.709	5.343"	1.000	13.000	.038	.291	5.343	.571
	Hotelling's Trace	.411	5.343*	1.000	13.000	.038	.291	5.343	.571
	Roy's Largest Root	.411	5.343°	1.000	13.000	.038	.291	5.343	.571
Condition *	Pillai's Trace	.024	.317ª	1.000	13.000	.583	.024	.317	.082
R_SH_AB_1	Wilks' Lambda	.976	.317ª	1.000	13.000	.583	.024	.317	.082
	Hotelling's Trace	.024	.317*	1.000	13.000	.583	.024	.317	.082
	Roy's Largest Root	.024	.317ª	1.000	13.000	.583	.024	.317	.082
Condition *	Pillai's Trace	.295	5.447°	1.000	13.000	.036	.295	5.447	.579
R_WST_EXT_1	Wilks' Lambda	.705	5.447"	1.000	13.000	.036	.295	5.447	.579
	Hotelling's Trace	.419	5.447"	1.000	13.000	.036	.295	5.447	.579
	Roy's Largest Root	.419	5.447*	1.000	13.000	.036	.295	5.447	.579
Condition *	Pillai's Trace	.121	1.796"	1.000	13.000	.203	.121	1.796	.237
GRIP_1	Wilks' Lambda	.879	1.796"	1.000	13.000	.203	.121	1.798	.237
	Hotelling's Trace	.138	1.796*	1.000	13.000	.203	.121	1.798	.237
	Roy's Largest Root	.138	1.796°	1.000	13.000	.203	.121	1.796	.237
Condition * order	Pillai's Trace	.064	.894°	1.000	13.000	.362	.064	.894	.142
	Wilks' Lambda	.936	.894"	1.000	13.000	.362	.064	.804	.142
	Hotelling's Trace	.069	.894*	1.000	13.000	.362	.064	.894	.142
	Roy's Largest Root	.069	.894°	1.000	13.000	.362	.064	.894	.142
impairment tests *	Pillai's Trace	.662	1.469"	8.000	6.000	.329	.662	11.755	.272
Condition	Wilks' Lambda	.338	1.469"	8.000	6.000	.329	.662	11.755	.272
	Hotelling's Trace	1.959	1.469°	8.000	6.000	.329	.662	11.755	.272
	Roy's Largest Root	1.959	1.469*	8.000	6.000	.329	.662	11.755	.272
impairment_tests *	Pillai's Trace	.685	1.632°	8.000	6.000	.284	.685	13.057	.300
Condition *	Wilks' Lambda	.315	1.632"	8.000	6.000	.284	.685	13.057	.300

\$_ELB_EXT_1	Hotelling's Trace	2.178	1.632ª	8.000	6.000	.284	.685	13.057	.300
	Roy's Largest Root	2.178	1.632°	8.000	6.000	.284	.685	13.057	.300
impairment tests *	Pillai's Trace	.443	.598°	8.000	6.000	.756	.443	4.771	.129
Condition * R SH F 1	Wilks' Lambda	.557	.596°	8.000	6.000	.756	.443	4.771	.129
K_SH_F_1	Hotelling's Trace	.795	.596*	8.000	6.000	.756	.443	4.771	.129
	Roy's Largest Root	.795	.596°	8.000	6.000	.756	.443	4.771	.129
impairment_tests *	Pillai's Trace	.252	.252*	8.000	6.000	.962	.252	2.017	.080
Condition * R SH AB 1	Wilks' Lambda	.748	.252*	8.000	6.000	.962	.252	2.017	.080
N_SIT_NS_I	Hotelling's Trace	.336	.252*	8.000	6.000	.962	.252	2.017	.080
	Roy's Largest Root	.336	.252*	8.000	6.000	.962	.252	2.017	.080
impairment tests *	Pillai's Trace	.554	.933°	8.000	6.000	.550	.554	7.465	.181
Condition * R WST EXT 1	Wilks' Lambda	.446	.933*	8.000	6.000	.550	.554	7.465	.181
K_WSI_EXI_I	Hotelling's Trace	1.244	.933°	8.000	6.000	.550	.554	7.465	.181
	Roy's Largest Root	1.244	.933°	8.000	6.000	.550	.554	7.485	.181
impairment_tests *	Pillai's Trace	.355	.413°	8.000	6.000	.877	.355	3.306	.102
Condition * GRIP 1	Wilks' Lambda	.645	.413*	8.000	6.000	.877	.355	3.308	.102
Oldi _i	Hotelling's Trace	.551	.413°	8.000	6.000	.877	.355	3.306	.102
	Roy's Largest Root	.551	.413 ⁸	8.000	6.000	.877	.355	3.306	.102
impairment tests *	Pillai's Trace	.319	.351*	8.000	6.000	.914	.319	2.809	.094
Condition * order	Wilks' Lambda	.681	.351*	8.000	6.000	.914	.319	2.809	.094
	Hotelling's Trace	.468	.351*	8.000	6.000	.914	.319	2.809	.094
a. Exact statistic	Roy's Largest Root	.468	.351 ^a	8.000	6.000	.914	.319	2.809	.094

a. Exact statistic

Tests of Between-Subjects Effects

Measure:MEASURE_1 Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
Intercept	4.453	1	4.453	73.932	.000	.850	73.932	1.000
S_ELB_EXT_1	.449	1	.449	7.463	.017	.365	7.463	.714
R SH F 1	.708	1	.708	11.754	.004	.475	11.754	.886
R_SH_AB_1	.751	1	.751	12.468	.004	.490	12.468	.903
R_WST_EXT_1	2.073	1	2.073	34.420	.000	.726	34.420	1.000
GRIP_1	1.872	1	1.872	31.085	.000	.705	31.085	.999
order	.023	1	.023	.375	.551	.028	.375	.088
Error	.783	13	.080					

a. Computed using alpha = .05

Figure E6. Impairment overall MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S_ELB_EXT_1 + R_SH_F_1 + R_SH_AB_1 + R_WST_EXT_1 + GRIP_1 + order Within Subjects Design: impairment tests + Condition + impairment tests * Condition

Impairment Univariate MACNOVA of Shoulder Flexion Strength Multivariate Tests^c

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Effec	t	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillai's Trace	.000	.001*	1.000	13.000	.973	.000	.001	.050
	Wilks' Lambda	1.000	.001*	1.000	13.000	.973	.000	.001	.050
	Hotelling's Trace	.000	.001*	1.000	13.000	.973	.000	.001	.050
	Roy's Largest Root	.000	.001*	1.000	13.000	.973	.000	.001	.050
Condition *	Pillai's Trace	.225	3.778*	1.000	13.000	.074	.22:5	3.778	.437
S_ELB_EXT_1	Wilks' Lambda	.775	3.778*	1.000	13.000	.074	.22:5	3.778	.437
	Hotelling's Trace	.291	3.778*	1.000	13.000	.074	.22:5	3.778	.437
	Roy's Largest Root	.291	3.778*	1.000	13.000	.074	.225	3.778	.437
Condition *	Pillai's Trace	.243	4.181*	1.000	13.000	.062	.243	4.181	.473
R_SH_F_1	Wilks' Lambda	.757	4.181**	1.000	13.000	.062	.243	4.181	.473
	Hotelling's Trace	.322	4.181*	1.000	13.000	.062	.243	4.181	.473
	Roy's Largest Root	.322	4.181*	1.000	13.000	.062	.243	4.181	.473
Condition *	Pillai's Trace	.148	2.261*	1.000	13.000	.157	.148	2.261	.286
R_SH_AB_1	Wilks' Lambda	.852	2.261**	1.000	13.000	.157	.148	2.261	.286
	Hotelling's Trace	.174	2.261*	1.000	13.000	.157	.148	2.261	.286
	Roy's Largest Root	.174	2.261*	1.000	13.000	.157	.148	2.261	.286
Condition *	Pillai's Trace	.123	1.826**	1.000	13.000	.200	.123	1.826	.240
R_WST_EXT_1	Wilks' Lambda	.877	1.826 ^m	1.000	13.000	.200	.123	1.828	.240
	Hotelling's Trace	.140	1.826*	1.000	13.000	.200	.123	1.826	.240
	Roy's Largest Root	.140	1.826*	1.000	13.000	.200	.123	1.826	.240
Condition * GRIP_1	Pillai's Trace	.205	3.345**	1.000	13.000	.090	.205	3.345	.395
	Wilks' Lambda	.795	3.345*	1.000	13.000	.090	.20-5	3.345	.395
	Hotelling's Trace	.257	3.345*	1.000	13.000	.090	.205	3.345	.395
	Roy's Largest Root	.257	3.345*	1.000	13.000	.090	.20:5	3.345	.395
Condition * order	Pillai's Trace	.003	.044*	1.000	13.000	.836	.003	.044	.054
	Wilks' Lambda	.997	.044*	1.000	13.000	.836	.00:3	.044	.054
	Hotelling's Trace	.003	.044*	1.000	13.000	.836	.00:3	.044	.054
	Roy's Largest Root	.003	.044*	1.000	13.000	.836	.00:3	.044	.054

a. Exact statistic

Figure E7. Shoulder flexion strength univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1 + R SH F 1 + R SH AB 1 + R WST EXT 1 + GRIP 1 + order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Shoulder Abduction Strength Multivariate Tests^c

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Effec	t	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillai's Trace	.130	1.950*	1.000	13.000	.186	.130	1.950	.253
	Wilks' Lambda	.870	1.950*	1.000	13.000	.186	.130	1.950	.253
	Hotelling's Trace	.150	1.050*	1.000	13.000	.186	.130	1.060	.253
	Roy's Largest Root	.150	1.950*	1.000	13.000	.186	.130	1.950	.253
Condition *	Pillai's Trace	.352	7.070*	1.000	13.000	.020	.352	7.070	.691
S_ELB_EXT_1	Wilks' Lambda	.648	7.070*	1.000	13.000	.020	.352	7.070	.691
	Hotelling's Trace	.544	7.070*	1.000	13.000	.020	.352	7.070	.691
	Roy's Largest Root	.544	7.070*	1.000	13.000	.020	.352	7.070	.691
Condition *	Pillai's Trace	.088	1.258*	1.000	13.000	.282	.088	1.258	.180
R_SH_F_1	Wilks' Lambda	.912	1.258"	1.000	13.000	.282	.088	1.258	.180
	Hotelling's Trace	.097	1.258*	1.000	13.000	.282	.088	1.258	.180
	Roy's Largest Root	.097	1.258*	1.000	13.000	282	.088	1.258	.180
Condition *	Pillai's Trace	.003	.045*	1.000	13.000	.835	.003	.045	.054
R_SH_AB_1	Wilks' Lambda	.997	.045*	1.000	13.000	.835	.003	.045	.054
	Hotelling's Trace	.003	.045*	1.000	13.000	.835	.003	.045	.054
	Roy's Largest Root	.003	.045*	1.000	13.000	.835	.003	.045	.054
Condition *	Pillai's Trace	.065	.903*	1.000	13.000	.359	.065	.903	.143
R_WST_EXT_1	Wilks' Lambda	.935	.903*	1.000	13.000	.359	.065	.903	.143
	Hotelling's Trace	.069	.903*	1.000	13.000	.359	.065	.903	.143
	Roy's Largest Root	.069	.903*	1.000	13.000	.359	.065	.903	.143
Condition * GRIP_1	Pillai's Trace	.017	.228*	1.000	13.000	.641	.017	.228	.073
	Wilks' Lambda	.983	.228*	1.000	13.000	.641	.017	.228	.073
	Hotelling's Trace	.018	.228*	1.000	13.000	.641	.017	.228	.073
	Roy's Largest Root	.018	.228*	1.000	13.000	.641	.017	.228	.073
Condition * order	Pillai's Trace	.000	.000*	1.000	13.000	.997	.000	.000	.050
	Wilks' Lambda	1.000	.000*	1.000	13.000	.997	.000	.000	.050
	Hotelling's Trace	.000	.000*	1.000	13.000	.997	.000	.000	.050
	Roy's Largest Root	.000	.000*	1.000	13.000	.997	.000	.000	.050

a. Exact statistic

Figure E8. Shoulder abduction strength univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1+R SH F 1+R SH AB 1+R WST EXT 1+ GRIP_1+ order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Elbow Extension Strength Multivariate Tests^e

			mulc	variate Tests	-				
Effe	ct	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncert. Parameter	Cbserved Power
Condition	Pillai's Trace	.313	5.922	1.000	13.000	.030	.313	5.922	.615
	Wilks' Lambda	.687	5.922	1.000	13.000	.030	.313	5.922	.615
	Hotelling's Trace	.456	5.922*	1.000	13.000	.030	.313	5.922	.615
	Roy's Largest Roct	.458	5.922	1.000	13.000	.030	.313	5.922	.615
Condition *	Pillai's Trace	.249	4.317*	1.000	13.000	.058	.249	4.317	.486
S_ELB_EXT_1	Wilks' Lambda	.751	4.317*	1.000	13.000	.058	.249	4.317	.486
	Hotelling's Trace	.332	4.317*	1.000	13.000	.058	.249	4.317	.486
	Roy's Largest Roct	.332	4.317	1.000	13.000	.058	.249	4.317	.488
Condition *	Pillai's Trace	.078	1.105*	1.000	13.000	.312	.078	1.105	.164
R_SH_F_1	Wilks' Lambda	.922	1.105*	1.000	13.000	.312	.078	1.105	.164
	Hotelling's Trace	.085	1.105	1.000	13.000	.312	.078	1.105	.164
	Roy's Largest Roct	.085	1.105	1.000	13.000	.312	.078	1.105	.164
Condition *	Pillai's Trace	.000	.002*	1.000	13.000	.962	.000	.002	.050
R_SH_AB_1	Wilks' Lambda	1.000	.002*	1.000	13.000	.962	.000	.002	.050
	Hotelling's Trace	.000	.002*	1.000	13.000	.962	.000	.002	.050
	Roy's Largest Roct	.000	.002*	1.000	13.000	.962	.000	.002	.050
Condition *	Pillai's Trace	.304	5.683*	1.000	13.000	.033	.304	5.683	.597
R_WST_EXT_1	Wilks' Lambda	.696	5.683*	1.000	13.000	.033	.304	5.683	.597
	Hotelling's Trace	.437	5.683*	1.000	13.000	.033	.304	5.683	.597
	Roy's Largest Roct	.437	5.683*	1.000	13.000	.033	.304	5.683	.597
Condition * GRIP_1	Pillai's Trace	.174	2.736*	1.000	13.000	.122	.174	2.736	.335
	Wilks' Lambda	.826	2.736*	1.000	13.000	.122	.174	2.736	.335
	Hotelling's Trace	.210	2.736*	1.000	13.000	.122	.174	2.736	.335
	Roy's Largest Roct	.210	2.736*	1.000	13.000	.122	.174	2.736	.335
Condition * order	Pillai's Trace	.006	.072*	1.000	13.000	.792	.006	.072	.057
	Wilks' Lambda	.994	.072*	1.000	13.000	.792	.006	.072	.057
	Hotelling's Trace	.006	.072*	1.000	13.000	.792	.006	.072	.057
	Roy's Largest Roct	.006	.072*	1.000	13.000	.792	.006	.072	.057

a. Exact statistic

Figure E9. Elbow extension strength univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S_ELB_EXT_1 + R_SH_F_1 + R_SH_AB_1 + R_WST_EXT_1 + GRIP_1 + order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Wrist Strength Multivariate Tests^c

				mulci	variate i esi	_				_
Wilks' Lambda 8.822 2.800° 1.000 13.000 .118 .178 2.809 .342	Effe	ect	Value	F			Sig.			Observed Power ^b
Hotelling's Trace 216 2.809" 1.000 13.000 .118 .178 2.809 .342	Condition	Pillai's Trace	.178	2.809"	1000	13.000	.118	.178	2.809	.342
Roy's Largest Root		Wilks' Lambda	.822	2.809°	1000	13.000	.118	.178	2.809	.342
Condition Pillai's Trace .204 .2646* 1.000 13.000 .084 .239 4.090 .465		Hotelling's Trace	.216	2.809°	1.000	13.000	.118	.178	2.809	.342
S_ELB_EXT_1 Wilks' Lambda .761 4.090" 1.000 13.000 .084 239 4.090 .465 Hotelling's Trace .315 4.090" 1.000 13.000 .064 239 4.090 .465 Condition * Pillai's Trace .169 2.646" 1.000 13.000 .128 .169 2.646 .326 R_SH_F_1 Wilks' Lambda .831 2.646" 1.000 13.000 .128 .169 2.646 .326 Hotelling's Trace .204 2.646" 1.000 13.000 .128 .169 2.646 .326 Roy's Largest Root .204 2.646" 1.000 13.000 .128 .169 2.646 .326 Condition * Pillai's Trace .025 .338" 1.000 13.000 .571 .025 .338 .084 Hotelling's Trace .026 .338" 1.000 13.000 .571 .025 .338 .084 RWST_EXT_1 Wilks' Lambda			.216	2.809°	1.000	13.000	.118	.178	2.809	.342
Hotelling's Trace		Pillai's Trace	.239	4.090"	1000	13.000	.064	.239	4.090	.465
Roy's Largest Root	S_ELB_EXT_1	Wilks' Lambda	.761	4.090"	1000	13.000	.064	.239	4.090	.465
Condition Pillai's Trace .169 2.646" 1.000 13.000 .128 .169 2.646 .326		Hotelling's Trace	.315	4.090°	1.000	13.000	.064	.239	4.090	.465
R_SH_F_1 Wilks' Lambda .831 2.646* 1.000 13.000 .128 .169 2.646 .326 Roy's Largest Root .204 2.646* 1.000 13.000 .128 .169 2.646 .326 Condition * R_SH_AB_1 Pillai's Trace .025 .338* 1.000 13.000 .571 .025 .338 .084 Hotelling's Trace .026 .338* 1.000 13.000 .571 .025 .338 .084 Hotelling's Trace .026 .338* 1.000 13.000 .571 .025 .338 .084 Roy's Largest Root .026 .338* 1.000 13.000 .571 .025 .338 .084 Condition * R_WST_EXT_1 Pillai's Trace .201 3.261* 1.000 13.000 .094 .201 3.261 .387 Hotelling's Trace .251 3.261* 1.000 13.000 .094 .201 3.261 .387 Roy's Largest Root .251			.315	4.090°	1000	13.000	.064	.239	4.090	.465
Hotelling's Trace		Pillai's Trace	.169	2.646"	1000	13.000	.128	.169	2.646	.326
Roy's Largest Root 2.04 2.646* 1.000 13.000 .128 .169 2.646 .326	R_SH_F_1	Wilks' Lambda	.831	2.646*	1000	13.000	.128	.169	2.646	.326
Condition Pillai's Trace .025 .338" 1.000 13.000 .571 .025 .338 .084		Hotelling's Trace	.204	2.646°	1000	13.000	.128	.169	2.646	.326
R_SH_AB_1			.204	2.646ª	1000	13.000	.128	.169	2.646	.326
Hotelling's Trace		Pillai's Trace	.025	.338"	1000	13.000	.571	.025	.338	.084
Roy's Largest Root .026 .338" 1.000 13.000 .571 .025 .338 .084	R_SH_AB_1	Wilks' Lambda	.975	.338"	1000	13.000	.571	.025	.338	.084
Condition Pillai's Trace .201 3.261" 1.000 13.000 .094 .201 3.261 .387 .387 .387 .251 3.261" 1.000 13.000 .094 .201 3.261 .387 .387 .387 .251 3.261" 1.000 13.000 .094 .201 3.261 .387 .387 .387 .251 3.261" 1.000 13.000 .094 .201 3.261 .387 .387 .387 .251 3.261" 1.000 13.000 .094 .201 3.261 .387		Hotelling's Trace	.026	.338ª	1.000	13.000	.571	.025	.338	.084
R_WST_EXT_1 Wilks' Lambda .799 3.261* 1.000 13.000 .094 .201 3.261 .387 Hotelling's Trace .251 3.261* 1.000 13.000 .094 .201 3.261 .387 Condition * Root Pillai's Trace .001 .010* 1.000 13.000 .921 .001 .010 .051 GRIP_1 Wilks' Lambda .999 .010* 1.000 13.000 .921 .001 .010 .051 Hotelling's Trace .001 .010* 1.000 13.000 .921 .001 .010 .051 Root .001 .010* 1.000 13.000 .921 .001 .010 .051 Condition * order Pillai's Trace .001 .010* 1.000 13.000 .921 .001 .010 .051			.026	.338°	1000	13.000	.571	.025	.338	.084
Hotelling's Trace		Pillai's Trace	.201	3.261"	1.000	13.000	.094	.201	3.261	.387
Roy's Largest Root .251 3.261* 1.000 13.000 .094 .201 3.261 .387	R_WST_EXT_1	Wilks' Lambda	.799	3.261"	1000	13.000	.094	.201	3.261	.387
Condition * Pillai's Trace .001 .010" 1.000 13.000 .921 .001 .010 .051		Hotelling's Trace	.251	3.261*	1000	13.000	.094	.201	3.261	.387
GRIP_1 Wilks' Lambda			.251	3.261°	1000	13.000	.094	.201	3.261	.387
Hotelling's Trace		Pillai's Trace	.001	.010"	1000	13.000	.921	.001	.010	.051
Rtoy's Largest Root	GRIP_1	Wilks' Lambda	.999	.010"	1000	13.000	.921	.001	.010	.051
Root .001 .010 1.000 13.000 .921 .001 .010 .051 Condition * order Pillai's Trace .006 .082* 1.000 13.000 .779 .006 .082 .058		Hotelling's Trace	.001	.010ª	1000	13.000	.921	.001	.010	.051
			.001	.010ª	1000	13.000	.921	.001	.010	.051
Wilks' Lambda .994 .082" 1.000 13.000 .779 .006 .082 .058	Condition * order	Pillai's Trace	.006	.082"	1000	13.000	.779	.006	.082	.058
		Wilks' Lambda	.994	.082"	1.000	13.000	.779	.006	.082	.058
Hotelling's Trace .006 .082* 1.000 13.000 .779 .006 .082 .058		Hotelling's Trace	.006	.082ª	1.000	13.000	.779	.006	.082	.058
Roy's Largest Root .006 .082* 1.000 13.000 .779 .006 .082 .058			.006	.082ª	1.000	13.000	.779	.006	.082	.058

a. Exact statistic

Figure E10. Wrist extension strength univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1 + R SH F 1 + R SH AB 1 + R WST EXT 1 + $GRIP_1$ + order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Grip Strength

Multivariate Tests^c

_				litivariate re					
				Hypothesis			Partial Eta	Noncent.	Observed
Effec	t	Value	F	df	Error df	Sig.	Squared	Parameter	Power ^b
Condition	Pillai's Trace	.022	.289*	1.000	13.000	.600	.022	.289	.079
	Wilks' Lambda	.978	.289*	1.000	13.000	.600	.022	.289	.079
	Hotelling's Trace	.022	.289*	1.000	13.000	.600	.022	.289	.079
	Roy's Largest Root	.022	.289*	1.000	13.000	.600	.022	.289	.079
Condition *	Pillai's Trace	.023	.308*	1.000	13.000	.588	.023	.308	.081
S_ELB_EXT_1	Wilks' Lambda	.977	.308*	1.000	13.000	.588	.023	.308	.081
	Hotelling's Trace	.024	.308*	1.000	13.000	.588	.023	.308	.081
	Roy's Largest Root	.024	.308*	1.000	13.000	.588	.023	.308	.081
Condition *	Pillai's Trace	.016	.216*	1.000	13.000	.650	.016	.216	.072
R_SH_F_1	Wilks' Lambda	.984	.216*	1.000	13.000	.650	.016	.216	.072
	Hotelling's Trace	.017	.216*	1.000	13.000	.650	.016	.216	.072
	Roy's Largest Root	.017	.216*	1.000	13.000	.650	.016	.216	.072
Condition *	Pillai's Trace	.038	.511*	1.000	13.000	.487	.038	.511	.102
R_SH_AB_1	Wilks' Lambda	.962	.511*	1.000	13.000	.487	.038	.511	.102
	Hotelling's Trace	.039	.511*	1.000	13.000	.487	.038	.511	.102
	Roy's Largest Root	.039	.511*	1.000	13.000	.487	.038	.511	.102
Condition *	Pillai's Trace	.055	.751*	1.000	13.000	.402	.055	.751	.127
R_WST_EXT_1	Wilks' Lambda	.945	.751*	1.000	13.000	.402	.055	.751	.127
	Hotelling's Trace	.058	.751*	1.000	13.000	.402	.055	.751	.127
	Roy's Largest Root	.058	.751*	1.000	13.000	.402	.055	.751	.127
Condition * GRIP_1	Pillai's Trace	.001	.009*	1.000	13.000	.925	.001	.009	.051
	Wilks' Lambda	.999	.009*	1.000	13.000	.925	.001	.009	.051
	Hotelling's Trace	.001	.009*	1.000	13.000	.925	.001	.009	.051
	Roy's Largest Root	.001	.009*	1.000	13.000	.925	.001	.009	.051
Condition * order	Pillai's Trace	.026	.347*	1.000	13.000	.566	.026	.347	.085
	Wilks' Lambda	.974	.347*	1.000	13.000	.566	.026	.347	.085
	Hotelling's Trace	.027	.347*	1.000	13.000	.566	.026	.347	.085
	Roy's Largest Root	.027	.347*	1.000	13.000	.566	.026	.347	.085
a. Exact statistic									

a. Exact statistic

Figure E11. Hand grip strength univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1 + R SH F 1+ R SH AB 1 + R WST EXT 1+ GRIP_1 + order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Shoulder Flexion ROM Multivariate Tests^e

			MU	ıltivariate Te	SIS				
Effec	t	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent Parameter	Observed Power ^b
Condition	Pillai's Trace	.189	3.027*	1.000	13.000	.106	.189	3.027	.364
	Wilks' Lambda	.811	3.027*	1.000	13.000	.106	.189	3.027	.364
	Hotelling's Trace	.233	3.027*	1.000	13.000	.106	.189	3.027	.364
	Roy's Largest Root	.233	3.027*	1.000	13.000	.106	.189	3.027	.364
Condition *	Pillai's Trace	.110	1.509*	1.000	13.000	.227	.110	1.609	.21/
S_ELB_EXT_1	Wilks' Lambda	.890	1.609*	1.000	13.000	.227	.110	1.609	.217
	Hotelling's Trace	.124	1.809*	1.000	13.000	.227	.110	1.609	.217
	Roy's Largest Root	.124	1.809*	1.000	13.000	.227	.110	1.609	.217
Condition *	Pillai's Trace	.167	2.598*	1.000	13.000	.131	.167	2.598	.321
R_SH_F_1	Wilks' Lambda	.833	2.598*	1.000	13.000	.131	.167	2.598	.321
	Hotelling's Trace	.200	2.598*	1.000	13.000	.131	.167	2.598	.321
	Roy's Largest Root	.200	2.598*	1.000	13.000	.131	.167	2.598	.321
Condition *	Pillai's Trace	.013	.166*	1.000	13.000	.690	.013	.166	.067
R_SH_AB_1	Wilks' Lambda	.987	.166*	1.000	13.000	.690	.013	.166	.067
	Hotelling's Trace	.013	.166*	1.000	13.000	.690	.013	.166	.067
	Roy's Largest Root	.013	.166*	1.000	13.000	.690	.013	.166	.067
Condition *	Pillai's Trace	.017	.230*	1.000	13.000	.640	.017	.230	.073
R_WST_EXT_1	Wilks' Lambda	.983	.230*	1.000	13.000	.640	.017	.230	.073
	Hotelling's Trace	.018	.230*	1.000	13.000	.640	.017	.230	.073
	Roy's Largest Root	.018	.230*	1.000	13.000	.640	.017	.230	.073
Condition * GRIP_1	Pillai's Trace	.014	.178*	1.000	13.000	.680	.014	.178	.068
	Wilks' Lambda	.986	.178*	1.000	13.000	.680	.014	.178	.068
	Hotelling's Trace	.014	.178*	1.000	13.000	.680	.014	.178	.068
	Roy's Largest Root	.014	.178*	1.000	13.000	.680	.014	.178	.068
Condition * order	Pillai's Trace	.081	1.149*	1.000	13.000	.303	.081	1.149	.169
	Wilks' Lambda	.919	1.149*	1.000	13.000	.303	.081	1.149	.169
	Hotelling's Trace	.088	1.149*	1.000	13.000	.303	.081	1.149	.169
	Roy's Largest Root	.088	1.149*	1.000	13.000	.303	.081	1.149	.169
a. Exact statistic									

a. Exact statistic

Figure E12. Shoulder Flexion range of motion (ROM) univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S EL8 EXT 1+R SH F 1+R SH AB 1+R WST EXT 1+ GRIP_1+ order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Shoulder Abduction ROM Multivariate Tests

		_			_				
Effect	t	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillai's Trace	.227	3.814*	1.000	13.000	.073	.227	3.814	.440
	Wilks' Lambda	.773	3.814*	1.000	13.000	.073	.227	3.814	.440
	Hotelling's Trace	.293	3.814*	1.000	13.000	.073	.227	3.814	.440
	Roy's Largest Root	.293	3.814*	1.000	13.000	.073	.227	3.814	.440
Condition *	Pillai's Trace	.188	3.003*	1.000	13.000	.107	.188	3.003	.362
S_ELB_EXT_1	Wilks' Lambda	.812	3.003*	1.000	13.000	.107	.188	3.003	.362
	Hotelling's Trace	.231	3.003*	1.000	13.000	.107	.188	3.003	.362
	Roy's Largest Root	.231	3.003*	1.000	13.000	.107	.188	3.003	.362
Condition *	Pillai's Trace	.021	.279*	1.000	13.000	.606	.021	.279	.078
R_SH_F_1	Wilks' Lambda	.979	.279ª	1.000	13.000	.608	.021	.279	.078
	Hotelling's Trace	.021	.279*	1.000	13.000	.606	.021	.279	.078
	Roy's Largest Root	.021	.279*	1.000	13.000	.606	.021	.279	.078
Condition *	Pillai's Trace	.005	.068*	1.000	13.000	.799	.005	.068	.057
R_SH_AB_1	Wilks' Lambda	.995	.068*	1.000	13.000	.799	.005	.068	.057
	Hotelling's Trace	.005	.088*	1.000	13.000	.799	.005	.068	.057
	Roy's Largest Root	.005	.068*	1.000	13.000	.799	.005	.068	.057
Condition *	Pillai's Trace	.080	1.124*	1.000	13.000	.308	.080	1.124	.166
R_WST_EXT_1	Wilks' Lambda	.920	1.124*	1.000	13.000	.308	.080	1.124	.166
	Hotelling's Trace	.086	1.124*	1.000	13.000	.308	.080	1.124	.166
	Roy's Largest Root	.086	1.124*	1.000	13.000	.308	.080	1.124	.166
Condition * GRIP_1	Pillai's Trace	.135	2.036*	1.000	13.000	.177	.135	2.036	.262
	Wilks' Lambda	.865	2.036*	1.000	13.000	.177	.135	2.036	.262
	Hotelling's Trace	.157	2.036*	1.000	13.000	.177	.135	2.036	.262
	Roy's Largest Root	.157	2.036*	1.000	13.000	.177	.135	2.036	.262
Condition * order	Pillai's Trace	.001	.015*	1.000	13.000	.903	.001	.015	.052
	Wilks' Lambda	.999	.015*	1.000	13.000	.903	.001	.015	.052
	Hotelling's Trace	.001	.015*	1.000	13.000	.903	.001	.015	.052
	Roy's Largest Root	.001	.015*	1.000	13.000	.903	.001	.015	.052
a Evant statistic									

a. Exact statistic

Figure E13. Shoulder abduction range of motion (ROM) univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1+R SH F 1+R SH AB 1+R WST EXT 1+ GRIP_1 + order Within Subjects Design: Condition

Impairment Univariate MACNOVA of Elbow Extension ROM Multivariate Tests^e

Effec	ot	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition	Pillai's Trace	.061	.849*	1.000	13.000	.374	.061	.849	.137
	Wilks' Lambda	.939	.849ª	1.000	13.000	.374	.061	.849	.137
	Hotelling's Trace	.065	.849*	1.000	13.000	.374	.061	.849	.137
	Roy's Largest Root	.065	.849*	1.000	13.000	.374	.061	.849	.137
Condition *	Pillai's Trace	.037	.503*	1.000	13.000	.491	.037	.503	.101
S_ELB_EXT_1	Wilks' Lambda	.963	.503*	1.000	13.000	.491	.037	.503	.101
	Hotelling's Trace	.03/9	.503"	1.000	13.000	.491	.037	.503	.101
	Roy's Largest Root	.039	.503*	1.000	13.000	.491	.037	.503	.101
Condition *	Pillai's Trace	.001	.014*	1.000	13.000	.908	.001	.014	.051
R_SH_F_1	Wilks' Lambda	.999	.014*	1.000	13.000	.908	.001	.014	.051
	Hotelling's Trace	.001	.014*	1.000	13.000	.908	.001	.014	.051
	Roy's Largest Root	.001	.014*	1.000	13.000	.908	.001	.014	.051
Condition *	Pillai's Trace	.015	.203*	1.000	13.000	.660	.015	.203	.070
R_SH_AB_1	Wilks' Lambda	.985	.203*	1.000	13.000	.660	.015	.203	.070
	Hotelling's Trace	.016	.203*	1.000	13.000	.660	.015	.203	.070
	Roy's Largest Root	.016	.203*	1.000	13.000	.660	.015	.203	.070
Condition *	Pillai's Trace	.055	.757*	1.000	13.000	.400	.055	.757	.127
R_WST_EXT_1	Wilks' Lambda	.945	.757*	1.000	13.000	.400	.055	.757	.127
	Hotelling's Trace	.058	.757"	1.000	13.000	.400	.055	.757	.127
	Roy's Largest Root	.058	.757*	1.000	13.000	.400	.055	.757	.127
Condition * GRIP_1	Pillai's Trace	.070	.980*	1.000	13.000	.340	.070	.980	.151
	Wilks' Lambda	.930	.980°	1.000	13.000	.340	.070	.980	.151
	Hotelling's Trace	.075	.980*	1.000	13.000	.340	.070	.980	.151
	Roy's Largest Root	.075	.980*	1.000	13.000	.340	.070	.980	.151
Condition * order	Pillai's Trace	.059	.810*	1.000	13.000	.384	.059	.810	.133
	Wilks' Lambda	.941	.810*	1.000	13.000	.384	.059	.810	.133
	Hotelling's Trace	.082	.810*	1.000	13.000	.384	.059	.810	.133
a Evant statistic	Roy's Largest Root	.062	.810*	1.000	13.000	.384	.059	.810	.133

a. Exact statistic

Figure E14. Elbow extension range of motion (ROM) univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S_ELB_EXT_1 + R_SH_F_1 + R_SH_AB_1 + R_WST_EXT_1 + GRIP_1 + order
Within Subjects Design: Condition

Impairment Univariate MACNOVA of Wrist Extension ROM Multivariate Tests^c

							D (115)		
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^b
Condition Condition * S_ELB_EXT_1	Pillai's Trace	.002	.021*	1.000	13.000	.886	.002	.021	.052
	Wilks' Lambda	.998	.021*	1.000	13.000	.886	.002	.021	.052
	Hotelling's Trace	.002	.021*	1.000	13.000	.886	.002	.021	.052
	Roy's Largest Root	.002	.021*	1.000	13.000	.886	.002	.021	.052
	Pillai's Trace	.000	.000*	1.000	13.000	1.000	.000	.000	.050
	Wilks' Lambda	1.000	.000*	1.000	13.000	1.000	.000	.000	.050
	Hotelling's Trace	.000	.000*	1.000	13.000	1.000	.000	.000	.050
	Roy's Largest Root	.000	.000*	1.000	13.000	1.000	.000	.000	.050
Condition * R_SH_F_1	Pillai's Trace	.004	.058*	1.000	13.000	.813	.004	.058	.056
	Wilks' Lambda	.996	.058*	1.000	13.000	.813	.004	.058	.056
	Hotelling's Trace	.004	.058*	1.000	13.000	.813	.004	.058	.056
	Roy's Largest Root	.004	.058*	1.000	13.000	.813	.004	.058	.056
Condition * R_SH_AB_1	Pillai's Trace	.008	.107*	1.000	13.000	.748	.008	.107	.061
	Wilks' Lambda	.992	.107*	1.000	13.000	.748	.008	.107	.061
	Hotelling's Trace	.008	.107*	1.000	13.000	.748	.008	.107	.061
	Roy's Largest Root	.008	.107*	1.000	13.000	.748	.008	.107	.061
Condition * R_WST_EXT_1	Pillai's Trace	.044	.593*	1.000	13.000	.455	.044	.593	.110
	Wilks' Lambda	.956	.593*	1.000	13.000	.455	.044	.593	.110
	Hotelling's Trace	.046	.593*	1.000	13.000	.455	.044	.593	.110
	Roy's Largest Root	.046	.593*	1.000	13.000	.455	.044	.593	.110
Condition * GRIP_1	Pillai's Trace	.000	.002*	1.000	13.000	.963	.000	.002	.050
	Wilks' Lambda	1.000	.002*	1.000	13.000	.963	.000	.002	.050
	Hotelling's Trace	.000	.002*	1.000	13.000	.963	.000	.002	.050
	Roy's Largest Root	.000	.002*	1.000	13.000	.963	.000	.002	.050
Condition * order	Pillai's Trace	.046	.633"	1.000	13.000	.441	.046	.633	.114
	Wilks' Lambda	.954	.633*	1.000	13.000	.441	.046	.633	.114
	Hotelling's Trace	.049	.633*	1.000	13.000	.441	.046	.633	.114
	Roy's Largest Root	.049	.633*	1.000	13.000	.441	.046	.633	.114

a. Exact statistic

Figure E15. Wrist extension range of motion (ROM) univariate MANCOVA.

b. Computed using alpha = .05

c. Design: Intercept + S ELB EXT 1+R SH F 1+R SH AB 1+R WST EXT 1+ GRIP_1+ order
Within Subjects Design: Condition

Occupational Therapy Task-Oriented Approach in Upper Extremity Post-Stroke Rehabilitation Treatment Protocol

Cerebrovascular accident (CVA) or stroke is the leading cause of long-term disability in the United States. Each year about 700,000 Americans experience a stroke. Two-thirds of those individuals need rehabilitation (National Institute of Neurological Disorders and Stroke, 2007). Stroke is a major cause of disablement in many western countries; approximately 80% of persons with stroke survive the acute phase, and although most persons with stroke regain their walking ability, 30% to 66% of the survivors are no longer able to use the affected arm (Kwakkel, Kollen, & Wagenaar, 1990). There is a need to have more research establishing the best practice methods for individuals with stroke who are not able to regain their hemiplegic upper extremity (UE) functional abilities (Barreca, Wolf, Fasoli, & Bohannon, 2003).

The Occupational Therapy Task-Oriented (TO) approach is a relatively new therapeutic approach (Mathiowetz & Bass-Haugen, 1994). Utilizing the TO approach principles as they are applied on a variety of self-care, leisure, and work-related activities in post-stroke UE rehabilitation appears to be promising area of study. Many of the TO approach principles and variations of the TO approach are supported in the literature (Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998; Finley, Fasoli, Dipietro, Ohlhoff, Macclellan, Meister, et al. 2005; Housman, Scott, and Reinkensmeyer, 2009; Kwakkel, Wagenaar, Twisk, Lankhorst, and Koetsier, 1999; Flinn, 1995; Gillen, 2000; Gillen, 2002). However, the TO approach as a whole has not been studied in a randomized clinical trial evaluating its clinical effectiveness.

The ultimate goal for rehabilitation in general and occupational therapy in particular is to enhance functional performance in various essential real life activities. With the stroke population, this goal might be more achievable after improving the motor abilities and other critical factors affecting the paretic UE motor behavior. We have evaluated the efficacy (at the functional and impairment levels) of the Occupational Therapy TO approach to improve motor abilities of the post-stroke paretic UE. In this article, we will describe the therapeutic protocol with the specific strategies and recommendations we used for upper extremity post-stroke rehabilitation based on this approach.

Description of the OT Task-Oriented Approach

The Theoretical Frame of Reference

Description. This approach for stroke was proposed by Mathiowetz and Bass-Haugen (1994). It was based on systems models of motor control and recent motor development and motor learning literature. Under this approach, the motor skills for individuals with stroke are taught by selecting functional tasks that are contextually suitable for the specific client. Based on motor control and learning principles, the chosen therapeutic activities should vary to enhance learning transferability. The schedule and

the structure of the practice should enhance the client's active participation and should consider motor control and learning principles. The setup of the environment should include all factors that might enhance a specific task practice. Finally, appropriate feedback (in terms of timing and amount) should be available to enhance the motor learning or relearning processes. The application of these principles requires knowledge and skills of task analysis of the targeted activities needed to be performed (Mathiowetz and Bass-Haugen, 1994; Mathiowetz, 2011; Mathiowetz & Bass-Haugen, 2008).

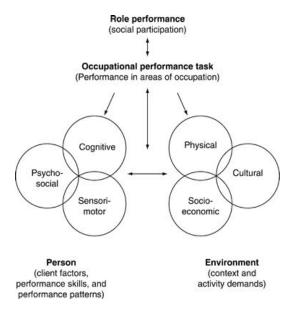


Figure F1. A schematic of the systems model of motor behavior. The occupational performance tasks and role performance emerge from an interaction of individuals and their environment. At the same time, occupational performance tasks affect the individuals and their specific environments. An ongoing interaction occurs between role performance and occupational performance tasks. Adapted from: Mathiowetz, V., & Bass-Haugen, J. (2008). Assessing abilities and capacities: Motor behavior. In M. V. Radomski & C.A. Trombly-Latham (Ed.), Occupational therapy for physical dysfunction (6th ed., pp.186-211). Baltimore: Williams & Wilkins.

Assumptions. This approach assumes that there is a heterarchical organization of the person and the environmental systems. It neither gives the CNS a superior consideration, nor does it give that exclusive importance to the musculoskeletal system or the environment. Other assumptions include: functional tasks help organize functional behavior; occupational performance results from the interaction between the individual and the environment; experimentation with different strategies help the person discover optimal (effective and efficient) patterns or solutions for the motor problems; recovery following CNS injuries varies among clients due to the uniqueness of the client's factors

and the environmental contexts; and the behavioral changes are the individual's attempt for compensation and achieving task performance (Mathiowetz, 2011; Mathiowetz & Bass-Haugen, 2008; Bass-Haugen, Mathiowetz, & Flinn, 2008).

Evidence of efficacy. Many of the TO approach principles and variations of the TO approach are supported in the literature. The TO post-stroke gait training with partial body weight support, for example, was supported in the literature (Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998; Hesse, Konrad, & Uhlenbrock, 1999). In the upper extremity post-stroke rehabilitation, robotic-aided therapy (Finley, Fasoli, Dipietro, Ohlhoff, Macclellan, Meister, et al. 2005; Fasoli, Krebs, Stein, Frontera & Hogan, 2003) and special orthotics integrated with virtual reality such as the Armeo® (Housman, Scott, and Reinkensmeyer, 2009) showed evidence in improving UE motor abilities post-stroke. As they were used, these rehabilitation technologies and techniques fulfilled many of the TO principles (such as manipulating the effects of gravity on the UE to provide the right training challenge and intensity). Stroke TO training showed evidence supporting using functional meaningful activities to improve functional performance (Kwakkel, Wagenaar, Twisk, Lankhorst, and Koetsier, 1999). The use of real, functional objects also showed evidence as an effective method to enhance efficient, smooth, and coordinated poststroke UE movement (Wu, Trombly, Lin, & Tickle-Degnen, 2000). Furthermore, providing occupational therapy for individuals with stroke using their natural environment and preference was also supported (Wu, Wong, Lin, & Chen, 2001).

However, in neurorehabilitation, the TO approach as a whole was only supported by case studies (Flinn, 1995; Gillen, 2000; Gillen, 2002, Preissner, 2010). These case studies emphasized the use of meaningful functional activities as therapeutic activities while focusing on the sensorimotor control parameters such as strength, endurance, range of motion, degrees of freedom, and postural control. These case studies utilized other systems that may affect motor behavior including psychosocial and cognitive personal systems, and environment-related systems such as cultural, socioeconomic, and physical environment systems (Flinn, 1995; Gillen, 2000; Gillen, 2002; Preissner, 2010). We studied the Occupational Therapy TO approach as a whole in a randomized clinical trial. Specifically, we evaluated the effects of TO approach in post-stroke rehabilitation for improving motor impairment level and functional use of the more affected UE. Our results indicated that the Occupational Therapy TO is an effective client-centered approach in improving the clients with stroke UE functional abilities as indicated by significant and clinically meaningful improvements in the Canadian Occupational Performance Measure (COPM) and the Motor Activity Log (MAL) and significant increase in the UE speed in functional activities indicated by Wolf Motor Function Test (WMFT) time scale.

Applying the Approach

This treatment approach is based on the principles, assessments, and treatment strategies described in the literature (Flinn, 1995; Gillen, 2001; Mathiowetz & Bass Haugen, 1994; Bass-Haugen, Mathiowetz, & Flinn, 2008; Preissner, 2010; Mathiowetz, 2011). However, we will be expanding on these previous editions to get more specificity

and to ease the application of this approach in therapeutic facilities.

Definition

This approach can be defined as a highly individualized, client-centered, occupational therapy, functional-based intervention compatible with motor learning and motor control principles such as intensive motor training, variable practice, and intermittent feedback. The intensive practice of functional activities (self care, work, and leisure) aims to enable the client with opportunities to discover the most optimal strategies (i.e., the most efficient and effective) to enable optimal functional performance. During this functional training, the therapist and the client identify the motor control parameters. These are components of the motor tasks that can enhance or inhibit the functional performance. The control parameters are elements of the motor task that could be related to the individual (e.g., strength, range of motion, skill level, and psychosocial considerations), to the environment (e.g., light, space, and context), and/or to the task itself (e.g., difficulty level, time allowed, and tools).

Evaluation and Goals Setting

The evaluation (Figure F2) and treatment (Figure F3) have to focus on a client's functional priorities and goals. A semi-structured interview or the *Role Checklist* can be used to identify the roles that are most important to each client. The Role Checklist helps in understanding the functional expectations specific to that client. The COPM is ideal to elicit client-determined functional problems and priorities and can be used to identify up to five individualized therapeutic goals. Technically, nothing prevents using the COPM to determine more than five goals. However, this is not recommended so that clients' efforts are more focused.

Observation of selected task(s) enables the therapist to identify critical control parameters (i.e., performance components and/or performance contexts), which influence the functional performance. Specific performance components and/or performance context, which appear to interfere with functional performance, must also be evaluated in more detail. ROM using goniometers, muscle strength using the manual muscle test (MMT), grasp strength using a Jamar dynamometer, muscle tone using the modified Ashworth scale, sensory screening, and cognitive and perceptual screening are the most important additional evaluations needed to determine the appropriate treatment program for a client post stroke. These component measurements are only done when they appear to be interfering with function. The therapist must be selective about which subtests of component measurements to use.

Using the information from the tests mentioned above and other assessment data, the therapists and the client can identify three to five functional goals of high functional importance. Next, evaluate the stability of the motor behaviors in these tasks (fixed or intransition), determine the focus of the intervention (compensatory and/or remedial), and determine the client-individualized TO functional activities (purposeful, meaningful. and consistent with interests) to be used in treatment.

Evaluating the Stability of Motor Behaviors

Changing the motor behavior is an active process that needs significant effort by the client. A client will be less likely to change a motor behavior unless there is a functional need. After the client identifies the functional priorities, the therapist needs to evaluate the stability of the motor behaviors during these functional tasks. The appropriate time of implementing remediation for a specific behavior is when the motor behavior is responsive to change or "in transition". The more established the movement patterns are and the closer the functional performance is to the targeted/ideal performance, the more "fixed" the motor behaviors are and the harder they will be to change them without using compensatory strategies. The motor behaviors could also be fixed when the motor impairments are so severe that it limits the potential for motor behavior change. To evaluate the stability of a motor behavior the therapist needs to determine whether there is a lag between the motor performance and the functional needs, consider the severity and the chronicity of the stroke, and observe the motor behavior in action to evaluate its quality and potential for change. The outcome of this process is a decision whether to attempt changing a specific motor behavior using remediation and/or compensation.

Client-Centered Therapy

The customization process of this approach must account for client factors such as interests, functional needs, socio-economical status, resources, cultural values, and level of education. The client has the right to approve or disapprove the selected goals and treatment activities used. However, the therapist and the client need to be realistic in this customization by accounting for the level of motor impairment; this factor plays an important role in the customization process. Providing the participant with "just the right challenge" is the rule of thumb here. Too difficult functional tasks might lead to failure and frustration while too easy activities will not be sufficient to generate changes in the motor behavior and could diminish the client's interest in the therapy. Furthermore, this challenge should be dynamically graded up or down as the quality of the motor behavior changes (i.e., decreasing or increasing challenge). To treatment is a partnership. While the therapist plays the role of the motor behavior coach, the client is encouraged to suggest activities, specify the functional needs, explain available resources, and comply with the clinic and the home-based treatment assignments.

Operationally this client-centered therapy can be implemented by using COPM (Law et al., 1991) to setup the treatment goals and priorities, the Interest Checklist (Rogers et al., 1978) to broaden the appropriate functional activities selection, Role Checklist (Oakely et al., 1986) to understand the client's unique real-life functional expectations.

Functional Training

The chosen therapeutic activities need to be functional based and reflect daily use applications for the specific client. All of these functional activities should be revolving around the generated therapeutic goals. This can be achieved by either practicing the COPM activities directly or practicing other activities consistent with the client interests

and roles. About 70% of the used therapeutic activities should be at the functional performance level (i.e., practicing functional activities: ADL, IADL, work, and leisure). About 30% of the activities should focus directly on performance components or motor impairments (i.e., specific strengthening, ROM, endurance, etc. exercises). However, this is just a general guideline and subject to variation depending on the client's level of impairment and specific functional needs. In most cases, less time should be dedicated for remediating motor impairment for clients with more severe motor impairments and with greater time post stroke.

Ideally, the therapist would treat a motor impairment by practicing the individualized functional activities obtained from the COPM. For example, with a client who wants to play the piano again, most of the time should be spent on practicing piano to enable the client to be a better pianist. Much of the piano practice can be done as homework assignments with treatment time spent experimenting with strategies to enhance performance. For example, some client's performance will be enhanced by supporting of the affected UE on an armrest or with an elevating mobile arm support. At the same time, the therapist can treat the motor impairment by using more challenging musical pieces (requires greater coordination), playing the piano keys (challenging fingers ROM), increasing the practice time (to challenge strength and endurance) and/or applying weighted cuffs on the more affected forearm (to increase strength). In all cases, the functional performance (being a better pianist) should be the ultimate goal of the practice with as much simulation of the client natural environment, tools, and functional needs using the least compensatory strategies as possible.

Determining the Intervention Focus: Compensation and/or Remediation.

In post-stroke rehabilitation, remediation focuses on improving the functional performance mainly by improving the client's performance components such as physical ability (such as strength, ROM, endurance, and prehension patterns). On the other hand, the compensatory approach to treatment aims to simplify the tasks requirements by giving assistance (against gravity for example), removing part of the tasks, changing the way to perform tasks, and/or using additional, easier, or adapted tools in order to improve the functional performance.

Remediation approach to treatment is indicated if the motor behavior appears to be responsive to improvements. This can happen when the stroke is not too chronic (<5 years post stroke), not too severe (when the client is able to grasp and release using the more affected hand), and when the client is motivated (i.e., showing compliance and expressing interest in the therapy). The compensatory strategies are recommended when the motor behavior is more fixed at a poor quality. This can be the case if the stroke is more chronic, more severe, and when the client is less motivated.

Working with the same client, the therapy might include both remediation and compensation depending on the client's specific functional needs and stroke motor impairment severity. Keeping realistic allocation of resources, time and effort in mind, the best is to achieve motor behavior quality level that approaches the normal population performance and matches that specific client expectation with as little modification

(assistive devices or tricks) as possible. Compensatory strategies are advised to be faded out if the motor behavior of the client started to improve. Furthermore, compensatory strategies could be used toward remediation, as in the case of using an elevating mobile arm support (MAS) at the first few therapy sessions to improve grasp patterns and overall functional performance. An elevating MAS is a mechanical device that reduces the effects of gravity on the UE, primarily of shoulder movements. This assistance could simplify grasp-release functional training. By reducing client effort to control proximally, it enhances distal function.

Hands-on Techniques

Passive techniques such as passive range of motion (PROM), blocking certain movement patterns, joint manipulation, and soft tissues stretching) should be kept to a minimum enabling the client maximal practice time for functional tasks. The therapist may use more of hands-on techniques during the first few therapy sessions (i.e., the first 2-4 sessions) and then fading these out as the client's physical abilities (especially strength and ROM) and functional performance improves. As the client is seeking the optimal pattern for motor behavior, the therapist must sit back and observe allowing maximum independent practice for the client.

Practice Intensity

A certain treatment intensity is required to enable permanent and stable changes in the motor behavior. This is believed to be driven by adaptive brain plasticity that organizes motor learning that appears as functional performance improvements (Karni, Meyer, Jezzard, Adams, Turner, & Ungerleider 1995; Nudo, Milliken, Jenkins, & Merzenich, 1996; Nudo, Plautz, & Frost, 2001; Kleim & Jones, 2008). This intensity can be provided by setting up the therapeutic sessions efficiently without wasting time. Session efficiency can be enhanced by planning the tasks ahead for smooth transitions between different tasks and having all the needed tools organized. Breaks are offered only when the client appears tired, confused, or asked for a break. The therapist should try to use about 70% or more of the session time in actual functional training. The frequency of the motor tasks practicing within this time should be as high as possible as well. Additionally, homework assignments can also be used to intensify the training of the more affected UE.

Home-Based Activities and Exercises

Homework is important under the TO approach for many reasons. The home program is essential to enhance the training intensity. Furthermore, the potential improvements must be transferred to real life situations; otherwise, the treatment possible benefits might not be sustained. The therapist needs to assign the client to do activities and exercises that are clearly demonstrated, meaningful to the client, and consistent with his or her interests. These exercises can be at the functional or the impairment level but should enhance functional performance of the client.

One important part of home-based exercises is to ask the client to use the more affected UE as much as possible in daily life situations. This is important to fight the learned non-use (i.e., associating the more affected UE with failure and consequently not

using it). Learned non-use of the stroke-affected UE is a key factor contributing to the reduced level of motor ability in persons post-stroke (Lundy-Ekman, 1998; Morris & Taube, 2001; Taube, Uswatte, & Pidikiti, 1999). Immediately following the onset of a stroke, cortical motor and sensory neurons experience decreased excitation for 3-6 months (Hallett, 2001; Traversa, Cicinelli, Bassi, Rossini, & Bernardi, 1997). This results in an inability or limited ability to use the more-affected arm. Typically, a mild to severe loss of UE motor functioning is demonstrated after a stroke in the more affected side of the body, creating problems in performing activities of daily living (ADL). Repeated failed attempts to use the more affected UE leads to learned non-use, which causes the individual to rely heavily on the less affected UE. Some motor ability naturally returns during the period of spontaneous recovery (usually 3 to 6 months post-stroke) in the more affected UE; however, the individual continues to neglect his/her more affected UE because of the learned non-use (Lundy-Ekman, 1998; Morris & Taube, 2001; Taube, Uswatte, & Pidikiti, 1999; Traversa, Cicinelli, Bassi, Rossini, & Bernardi, 1997). The therapist should encourage all possible functional use of the affected UE. Doing a functional task entirely with the affected UE, doing a bilateral task, or using the affected UE as a helper or stabilizer are the three possible levels of engaging the affected UE in daily life activities. In doing this, the therapist can suggest several functional tasks consistent with the client abilities and needs and encourage the client to come out with new uses for the affected UE. "Come to the clinic with new uses for your affected UE and let me know what did or did not work" is a suggested homework assignment to encourage reestablishing a spontaneous use of the affected UE. Ideally, more encouragement to use the affected UE should be provided to enhance practicing the selected functional tasks. This practice time of the individualized functional priorities should enhance functional performance by allowing the client to determine the optimal performance patterns. The therapist can start each session in the clinic by reviewing the home program (i.e., impairment level and functional level exercises) as the client is bearing weight on the affected UE to elongate the tightened UE flexors.

Stretching is an important exercise to emphasize at home, where the client can apply self stretching for the flexors of the fingers, wrist, and elbow joints and the shoulder adductors. These stretches could be applied by standing and putting weight on the fully extended elbow, wrist, and fingers. The client can do weight shifting during this weight bearing exercise (slight rocking motion to alternate weight bearing between the trunk and the UE being stretched). Bilateral wiping of a table is an active exercise that can stretch the elbow flexors, wrist flexors, and shoulder adductors and mobilize the scapula (upward-downward rotation, protraction and retraction). This later exercise needs to be practiced slowly and the client needs to hold the wash cloth at his maximum reaching point for a prolonged stretch. The third suggested method for stretching is stretching the hand and the elbow flexors of the affected arm using the less affected one. Here the client is instructed to hold his affected hand with the other hand and slowly apply pressure on the affected palm to extend the wrist and the elbow and hold for 15 seconds at least. This is advised to be done in supination and to be repeated till the hand

becomes more relaxed. Stretching can be provided also by positioning (i.e., pronated forearm with neutral wrist and extended fingers by putting the forearm on the table or chair arm rest), or by splints (functional rest splint during sleeping or inactivity). However, splints must be used selectively since they might decrease the use of the affected UE. The client should be instructed to use splints only in preparation for functional activities or during times of inactivity. Stretching is an important exercise to elongate UE soft tissues secondary to high tone and prolonged maladaptive positioning in order to prepare for functional training.

Home exercises should include strengthening where the client is instructed to lift different weighted items bilaterally or unilaterally using the affected hand as much as possible. Grasp-release exercises ranging from tennis balls to paper clips are suggested for the home-based program as well. Variability of training should be applied here, where the client can use many different objects like coins, cloth towels, pencils, screws, golf balls, and any object that provide functional application and proper challenge for the client.

The home program consists of two parts; a structured part where the client has specific method and fixed time to perform a set of exercises (typically 3 times a day), and a non-structured part to engage the affected UE in daily life activities. The client's activity in these two types of home exercises should be recorded (time spent, activities practiced, and quality) and should be graded up throughout the treatment program (e.g., increase time or repetition, and variety of tasks). The duration and the difficulty of the home-based exercises would depend on the stroke severity factors (such as motor impairment level and chronicity) and the client's factor (life roles, motivation, compliance, and targeted functional level). In our study, an average of 1.5 hours/day of structured exercises (weight bearing, stretching, grasping, and COPM functional tasks) appeared feasible for most of our participants. For the non-structured exercises, the therapist can encourage practicing individualized functional activities obtained from the Interest Checklist and functional needs. The therapist should emphasize engaging the affected UE whenever there is a daily life activity to be done. The motor activity log (MAL) could be used as a frame to suggest more daily life UE functional activities. In all cases of non-structured functional exercises, maximum possible use of the affected UE should be encouraged.

A persistent effort should be exerted to overcome the learned non-use by building a new attitude of attempting daily life functional tasks with the affected UE whenever possible. The client should be encouraged to view failure as a normal side product in this motor relearning hoping to decrease the associated frustration. "Your weaker arm is still useful, as you can see" is an example of emotional support that could be provided by the therapist. This home-based program aims to convert the client's natural daily life situations in and out of his home (out of the clinic) to an adaptive therapeutic environment. "Therapy should not be sophisticated; you can turn your life to a smooth continuous therapy" is an example of phrases used in our study.

Educating the Client

Education is important to enhance compliance during the treatment program and adherence to recommendations after discharge. The TO therapy might include activities out of the client's interests and immediate functional needs such as stretching and weight bearing. However, the clients' interests and active participation can be enhanced by explaining the rationale for the exercises and their relationship to their functional performance. Additionally, the clients should have basic skills in analyzing tasks, so they can identify reasons they are having difficulty with a specific task. The bottom line is that a client, who does not understand an exercise rationale, will not appreciate it and will not engage in it actively and efficiently and might not do it on his own.

Practice

For better learning outcomes, the intensive functional tasks training should not be redundant (Hanlon, 1996; Schmidt, 1991). Real life functional tasks requirements are variable. Different tools, environments, and quality demands are examples of factors that can contribute to this variability. Specific examples include varying tools (sizes, weights, manual vs. electrical, and fabrication materials), activity setups (i.e., the placement of the task's tools) and the client's position (sitting or standing and distances between the client and the task's tools). This practice variability is important to enhance motor learning that can lead to permanent changes in the motor behavior (generalized and transferred to different contexts of real life situations) as opposed to temporary changes in the performance when using a fixed context. At all times, the therapist should provide "just the right challenge" where the client can be trained under a simple task setup until getting satisfactory performance before switching into a more complex setup. Ideally, the first setup of the task training needs to match the most used setup of that specific client's natural environment. Random practice (i.e., has contextual and order variability) showed better motor learning adaptive changes than blocked (i.e., performing the task with the same setup and order) practice (Hanlon, 1996; Schmidt, 1991). At the beginning of the functional training, the therapist might need to use blocked practice, especially if there are cognitive deficits. As soon as the client masters the task practiced in blocked series, an upgrade to random practice is advised for better motor learning (generalizablity and retention of the motor performance). Practicing the whole task is better than parts of it (Ma &Trombly, 2001; Winstein, 1991). However, backward or forward chaining might be used in order to get the client into an independent practice of the entire functional task.

Feedback

Knowledge of results (awareness of the outcome of movement in relation to a goal) is believed to enhance motor learning more than knowledge of performance (feedback about the performance itself). Internal feedback (through an individual's sensory systems) is better than external feedback (therapist's verbal or hands-on feedback). Intermittent feedback (irregular or faded) is better than consistent feedback (Lee, Swanson, & Hall et al., 1991; Schmidt; 1991; Winstein; 1991). The idea here is to enable the client to practice the needed tasks and achieve the targeted performance level independent from external feedback. However, during skills acquisition stage the

therapist might need to simplify the task practice. This simplification is required to enhance motor learning by providing more consistent external feedback of performance at the beginning of the training. This external feedback then should be faded out allowing the client to depend on internal feedback, intermittent feedback, and feedback of result. The goal is to have clients learn to self-evaluate their own performance so they can achieve their functional goals with no external feedback by the time they are discharged. *Discontinuing Therapy*

The therapist needs to discharge the client upon achieving therapy goals or when it appears that there is no further progress being achieved. Recent post-stroke rehabilitation evidence suggests that functional improvement can be achieved even with individuals with chronic stroke. However, TO therapy is not exempt from health insurance and hospital policies related to reimbursement. This approach tries to enable the client with sufficient abilities to analyze motor tasks in order to identify the critical control parameters and solving motor problems independently. The hope is to change the client's attitude related to the affected hand use. By encouraging the client to use the affected UE more in daily life situations, the client's natural environment might turn into a continuous cost-free therapy. This attitude coupled with the knowledge related to task analysis and exercise rationale might supplement the expensive and time consuming treatment in the clinic.

TO Therapy Process

A suggested frame to apply the TO approach is demonstrated in Figures F2 and F3 (evaluation) and 14 (treatment) below.

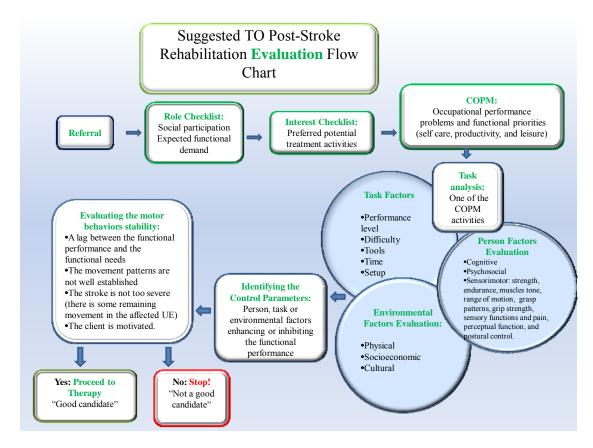


Figure F2. The Occupational Therapy Task-Oriented approach suggested evaluation flowchart.

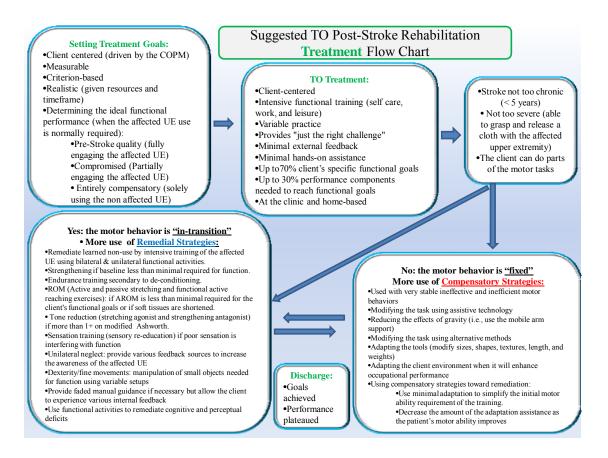


Figure F3. The Occupational Therapy Task-Oriented approach suggested treatment flowchart.

Appendix G:

Occupational Therapy Task-Oriented Approach in Upper Extremity Post-Stroke Rehabilitation Case Study

Client Information

Mr. J., 60 years old, had an ischemic right cerebral vascular accident with resultant left hemiparesis 12 years ago. He also was diagnosed with a slight carpal tunnel syndrome in his left hand two years ago. At this time, he had no pain related to that diagnosis. He fractured his left little finger four years ago but it has fully recovered. As a participant in a research study, MAL and upper extremity Fugl-Meyer (UEFM) tests were conducted on Mr. J left arm. He had scores of 0.26/5 on MAL amount of use scale (MAL AoU) and 0.21/5 on MAL how well scale (MAL HW). His UEFM score at baseline was 23/66. Consequently, Mr. J was characterized as an individual with severe chronic stroke accompanied with significant learned non-use.

Evaluation

Role performance

Mr J identified his important roles in life using the Role Checklist. His valuable roles included being a family member. He said that he spent a significant chunk of his time with his wife, sons, daughters, grandkids, and in-laws. Being a friend, a religious participant, a hobbyist (cards, hunting, fishing, camping, and sailing), and home maintenance worker (inside the house and in the yard mostly using electrically powered tools) were also identified as current and future very valuable roles for him as well. Taking care of his boat and his swimming pool in the yard were of particular interest for him. He was on disability status from his job as a purchasing agent for a company and did not have current or future plans of paid employment. However, Mr. J volunteered as an elementary school literacy tutor. This was a part-time, volunteer job of less than 20 hours a week that he was planning to keep in the future. He was also a care-giver for his mother in-law who lived a few blocks away from his house. Mr. J stated that being a volunteer and a care-giver were somewhat valuable roles in his life. It appeared that Mr. J did not have obligatory commitments except for home maintenance. Mr. J stated that having his more affected hand engaged in his daily life activities would really enhance his life roles especially these of home maintenance and hobbies. Mr. J was not interested in changing the nature of his life roles or switching to do something else.

Occupational Performance Tasks (Areas of Occupations)

Using an interest checklist, the therapist identified Mr. J hobbies and activities of most interest. The therapist checked for Mr. J level of interest before the stroke and after the stroke (casual, strong, and no interest) for about 80 possible activities. For each activity Mr. J expressed interest in, the therapist checked the current and future levels of participation (i.e., Do you currently participate in this activity? Are you planning on pursuing this activity in the future?). Mr. J expressed strong interest in home repairs, cooking, fishing, and hunting. He said that he was still participating in these activities and

was planning on pursuing them in the future. During the last year before starting this therapy, Mr. J was casually interested and occasionally participating in reading, woodworking, driving, camping, and family video games (Wii). Mr. J also had casual interest in car repair, golf, shuffleboard, model building, baseball, volleyball, billiards, tennis, ping pong, leatherwork, and photography. However, he stated that he was not practicing the later group of activities at the time he was evaluated but expressed an interest to do so in the future. The client wanted to improve in his hobbies of strong interest and agreed to try using some activities of his casual interest as treatment activities

COPM was used by the therapist to identify the top five functional priorities of Mr. J. These were washing the right side of the body during bathing, minor repairs at home, cutting vegetables during meals preparation, playing cards, and dressing (specifically buttoning). After identifying the treatment priorities, Mr. J rated his performance as 3.6/10 and satisfaction as 3.2/10. Engaging the left UE in daily life functional tasks was a priority, consequently, learned non-use was listed as an important problem to be addressed during treatment.

Task Selection and Analysis

Playing cards was one of the COPM problems so it was selected to be observed and analyzed. The therapist asked Mr. J how he would usually play cards to have as much simulation of his natural environment as possible. Activity demands and performance analysis was conducted.

Shuffling with two hands was poorly done and the client compensated by supporting his left forearm on the table. Dealing cards with his right hand while holding the cards in left hand was poorly done and the client compensated by supporting his forearm on his belly. Holding cards with his left hand and playing with his right hand went fairly well but sometimes Mr. J cards were visible to the competitor. The client compensated for his limitations by supporting his left forearm on his belly and by using a stronger left hand grasp's force than required.

The following were identified as motor impairments that limited functional performance: left UE weakness, limited active and passive range of motion, increased muscles tone, impaired left UE coordination and dexterity, and learned non-use. Mr. J motor behavior during playing cards seemed "in-transition" and might be responsive to change due to his motivation, and fair shoulder flexors control and active ROM.

Suggested remedial strategies to be used included left hand grasp-release training, left UE stretching (elbow, wrist, and fingers flexors), and left UE strengthening including grip strengthening. Suggested compensatory strategies included supporting the left forearm on the belly or hiding the cards under the table for energy conservation. The therapist suggested that Mr. J consider not using the card holder he used at home to decrease learned non-use.

Evaluating person-related factors (client factors; performance skills and patterns)

Cognitive evaluation. During the first meeting with the client, he was oriented and attended to instructions and treatment description and was asking good clarification

questions. Orientation, attention span, memory, problem solving, sequencing, calculations, learning, and generalization, appeared to be fine. As a part of a research study, Mr. J scored 30/30 on the mini-mental state examination test (MMSE) which confirmed the therapist clinical observation of intact cognitive abilities. The therapist concluded that cognitive abilities were not limiting functional performance.

Psychosocial evaluation. The therapist saw no evidence that coping skills, self-concept, interpersonal skills, self-expression, time management, and emotional regulation and self-control were problems. However, the therapist decided to monitor time management and emotional regulation throughout the treatment program.

Sensorimotor evaluation. The therapist evaluated Mr. J physical components at baseline based on the results of the task analysis that identified control parameters, which appeared to interfere with functional performance. The left affected UE was the focus of the evaluation. Evaluation data on the affected UE active ROM, strength, grasp, and muscle tone at baseline and at the end of the therapy are listed in Table G2. These components were listed as potential control parameters, which limited his functional performance.

The therapist screened the client's left UE for sensations. Pain recognition (pinprick test), light touch/pressure except at the finger tips, proprioception, kinesthesia and stereognosis (with some help in manipulation) were intact. Two-point discrimination and temperature sensation were not tested because they were not suspected as possible control parameters necessary for the targeted functional performance. The therapist concluded that sensory abilities were unlikely to be critical control parameter limiting functional performance.

Dexterity and coordination were evaluated using functional assessment during tasks. This was evaluated during the task analysis of playing cards. Left hand grasp was significantly limited due to spasticity, limited wrist and hand ROM, weakness, and lack of hand voluntary movement control. Consequently dexterity and coordination of the left UE was poor. Finger to nose test was used as part of UEFM yielded in 3.94 seconds with the right hand and in 12.53 second with the left hand. Since the difference is more than 6 seconds, Mr. J got a score of 0/2 for his speed. During this test he had a marked tremor (0/2), slight dysmetria (1/2). Left UE dexterity and coordination were considered critical control parameters limiting functional performance.

The therapist did not formally evaluate the client endurance. Mr. J reported that he was able to drive his car independently and was walking independently with an acceptable speed. He also described being active at home and in the community. Fatigue was not listed as a possible control parameter of this specific client's functional performance.

Environment Factors (Context and Activity Demands)

Physical environment. Information about Mr. J natural environment (2-story home with a basement, yard, swimming pool, & garage, and volunteer environment at the school & community) was gathered. Mr. J had to maintain home, boat, swimming pool and yard. Objects, tools, devices used included hammers, wrenches, screw drivers,

electrical sanding machine, wheelbarrow (occasionally), a push lawn mower, regular car and an SUV, shopping bags, laundry basket, electrical shaver, regular eating utensil, and many other regular tools. For hunting, he adapted his rifle by using a tripod to hold it steady. He also adapted his fishing technique using bigger equipment (e.g., larger lure and hooks). The client was using regular tools in his natural settings, but failed to engage the left UE to the extent he wanted. Mr. J natural environment setup and tools, especially electrically powered ones, seemed to help him perform his functional tasks and were considered as control parameters that enhanced his functional performance.

Socioeconomic factors. Mr. J seemed to have enough social supports and interactions through his family, friends, and community. He reported that they had sufficient financial resources since he was on disability retirement and his wife was still employed. Mr. J completed two years of college and had a successful career as a purchasing agent. At the time of this evaluation, he had a part time volunteer job as a literacy tutor in an elementary school. Mr. J socioeconomic factors did not seem in need of intervention.

Cultural factors. Mr. J customs, beliefs, activity patterns, behavior standards, and societal expectations did not seem to limit his functional task performance and were not identified as critical control parameters.

The Stability of Motor Behaviors

Mr. J has a chronic severe stroke, left hemiparesis, and learned non-use of his left UE. He has very limited left hand grasps and high tone in the hand, wrist, and elbow. These facts indicates that many of his motor behavior especially those related to fine hand manipulation (using left hand) are relatively fixed and might have limited responsiveness to remediation and might respond better to compensation. The therapist advised Mr. J to use his right UE for fine motor activity (such as buttoning or picking fine objects like paper clips or coins). However, Mr. J was motivated and had remaining good ability to move his shoulder and had partial mass flexion and hook grasps but lacked other grasp patterns such as tripod and lateral pinch ones. Consequently, Mr. J motor behavior in gross functional activity could be responsive for changing attempts "in transition". The therapist decided to attempt changing the client motor behavior for better functional performance engaging the left UE in gross motor activities. The therapist decided to use both remediation (mainly reducing the learned non-use) and compensation strategies.

Treatment Goals

- a. By the end of the six-week treatment program, Mr. J will independently use his left hand for washing his right UE for 5 minutes standing in the shower without any assistive devices.
- b. By the end of the six-week treatment program, Mr. J will independently play and shuffle cards for half hour using his left hand for holding cards without any assistive devices.
- c. By the end of the six-week treatment program, Mr. J will independently peel and chop vegetables in less than 3 minutes using his left hand for holding the

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- vegetable.
- d. By the end of the six-week treatment program, Mr. J will independently drive a screw in a piece of wood in less than a minute using his left hand for holding without any assistive devices.
- e. By the end of the six-week treatment program, Mr. J will independently button his shirt using his right hand to button and his left hand to assist in less than 2 minutes while standing and without any assistive devices.

Intervention

The therapist provided "the just right challenge" throughout the treatment program. This challenge was just a little bit beyond Mr. J abilities and was continuously graded up. The treatment activities were consistent with Mr. J COPM goals, interest, and roles. Each exercise was explained with a clear rationale to maintain Mr. J active participation. The client had the option to decline any suggested treatment exercises and was encouraged to suggest activities. He was encouraged to problem solve with the therapist new strategies for performing functional tasks. The treatment was intensive in the clinic (two 1.5 hours sessions/week for six weeks with high repetitions and minimal breaks during the sessions) and coupled with a home-based treatment program of about an hour and half a day. However, this client tended to do only about one hour of the home-based exercises saying that he always got busy with other life issues. The practice of functional tasks was variable and for a whole task when possible with minimal external feedback and hands on techniques. The treatment consisted of functional training (activities of self care, work, and leisure) emphasizing the COPM tasks (about 70% of the time on functional performance). There were also some strengthening, ROM, and muscle tone related exercises (about 30% of the time on critical control parameters performance components).

Applying the OT Task-Oriented Intervention Strategies

- I. Accommodating role and task performance limitations: the client was doing fine with his life roles and was not interested in roles adaptation or switching.
- II. Considering the client as active partner: A client centered approach was used, where Mr. J was given opportunities to prioritize his treatment goals, the treatment activities (meaningful and purposeful consistent with COPM goals, interests, and roles), and the treatment schedule. The therapist was open to trying the client's own solution for the motor behavior problems whenever they appeared efficient and effective.
- III. Whenever possible, the therapist created situations that utilized Mr. J specific daily life challenges to enhance his task performance: For example, the therapist encouraged the client to have as much independent functional practice as possible in different environments/situations. Examples of tasks encouraged included: engaging the left arm in eating, dressing, carrying objects, grooming, and functional mobility. Also the therapist instructed the client to set the environment up to match his level of performance and to enhance engaging the left UE in functional activities (e.g., putting the remote control to the left side of the client).

- IV. Practicing functional tasks as a focus for the treatment:
 - a. Meaningful functional tasks were used more than rote exercises.
 - b. Key ADLs and IADLs tasks that the client needed were incorporated in the treatment plan (e.g., cutting foods).
 - c. The therapist considered the client's needs, preference, roles, and functional priorities in selecting the tasks
 - d. Client's natural (home-based exercises) or close to natural (simulation at clinic) environment was used for the functional task practice.
 - e. Real objects and tools were used instead of less meaningful training tools (i.e., the client was encouraged to bring his own tools such as his electric sander, knife, and tennis racket).
 - f. The therapist offered intensive functional tasks training enabling the client to find his unique optimal strategy (stable, effective, and efficient movement pattern) for tasks performance.
- V. Providing additional functional task practice outside of the clinic (home-based exercises):
 - a. The client was encouraged to engage the affected arm in his daily life activities. Starting with limited use of the left hand in daily life (marked learn non-use) at the first session, the therapist was asking the client to come to the clinic sharing new use(s) of the affected UE in daily life situation. At the beginning of each session as the client was stretching his left UE (weight bearing), the therapist asked him what he had used his left arm for and how that went. The therapist suggested functional activities (harmonized with Mr. J abilities, interests, and needs) to engage the left hand in daily life functional use. By the final session, Mr. J was using his left UE (entirely or partially) in bathing, pushing the lawn mower, holding groceries bags, opening doors with knobs, opening the refrigerator and the freezer, opening drawers and taking clothes out of them, dressing (putting trousers and socks on and off), moving chairs around the table, washing and drying hands, wiping the kitchen table after meals, shaving (electrical razor), holding the laundry basket, recycling, pushing the wheelbarrow, putting weight on the left hand when standing from a chair, holding the remote control, eating snacks and sandwiches, cutting vegetables and fruits, turning the light switches on and off, opening food containers, carrying objects while maintaining his home (such as wood, wires, and fertilizer bags), and using a rake in his yard. Most of these activities were practiced more than once and many of them became a habit (i.e., Mr. J would use his left arm each time he would do the activity). The client gradually built an attitude to attempt using his left arm first when he needed to do something and he developed more tolerance for failure at the beginning of each new functional use.
 - b. The therapist encouraged Mr. J to decrease his dependence on his right arm and to trust his left UE again, dealing with failure as a normal step toward succeed.
 - c. A structured home-based treatment program was built for Mr. J that was believed to be doable given his interests, functional needs, and time availability. This

structured program consisted of exercises at the functional and the impairment levels. At the first few sessions, the home-based exercise program was short (about half hour a day) and emphasized impairment exercises. During the first three sessions, Mr. J was instructed to do weight bearing and shifting on his left hand while standing by a table (elbow, wrist, and fingers were extended) three times a day for five minutes each time. Mr. J demonstrated how to do self stretches for his elbow, wrist and finger and was instructed to do this before engaging the left hand in any functional activity. These two stretching exercises were explained for the client as important preparatory techniques helping to elongate the tightened soft tissues and muscles and to reduce the effects of the high tone. Mr. J was also assigned to do grasp-squeeze-release exercise for the left hand using a tennis ball for two times a day five minutes each time. Additionally, the client was asked to grasp and release a small cloth towel for five minutes each day. The grasp-release exercises were introduced to Mr. J as an attempt to retrain the functional grasp patterns. Mr. J was asked to do bilateral towel ROM exercises where he was reaching as far as he could with a towel over a table (targeting strengthening, active use, and ROM). A nonstructured exercise of finding a new functional uses for the left UE was also assigned to the client during the first 3 sessions. The benefits of using the left hand in daily life activities were emphasized: overcoming disuse effects (weakness and limited ROM) and learned non-use (cortical excitability, cortical maps, and behavioral reinforcement principles). Starting at session 4, the therapist started to incorporate the COPM functional tasks in the home-based structured program. Maintaining the home-based activities from the first 3 sessions, the therapist added cutting and eating an apple or a cucumber a day while using the left hand to stabilize the cut object. Cutting was added when the client demonstrated enough abilities in the clinic guaranteeing safety. In session 4 as well, the therapist added wiping the kitchen table after meals using the left hand. In session 5, the therapist added scrubbing the right side of the body with a dry towel using the left hand for 15 minutes a day. Furthermore, the client was asked to alternate between golf balls and tennis balls in his grasp exercise. The therapist added shuffling cards with two hands for 10 minutes a day in session five as well. By having all of these daily exercises, Mr. J seemed to be at his limit and was not likely to incorporate more home exercises. The therapist kept the same home-based program until session 9 where buttoning and unbuttoning a shirt while standing for 10 minutes a day (he was not able to do this before) were added. The therapist did not make any changes on Mr. J home program after session 9. Mr. J had a moderate compliance with most exercises (about 60% of the assigned exercises were done daily). Mr. J cooperated very well with the nonstructured home training (i.e., finding and practicing new uses for the left UE) but did not comply well with cards shuffling and the buttoning exercises. The client said that buttoning and card shuffling were too frustrating and less important to him than his other COPM activities, so he preferred to focus less on them. At this point, the therapist advised the client to implement more of compensatory strategies (including

- stabilizing the affected arm and more use of the less affected arm) as performing shuffling and buttoning.
- d. The therapist educated the client about the importance of each home-based exercise and suggested ways to make it more practical and less frustrating. This was done to enhance the client's active engagement and compliance.
- VI. The therapist used contemporary motor learning principles in training or retraining functional skills:
 - a. The therapist used blocked practice (Practicing many repetitions of the same functional task in the same order and way) only at the beginning of motor task learning. As soon as the task requirements were understood, random and variable practice strategies (order, tools, setup, and contextual variation) were used. Random practice strategies included practicing more than one task each session with different orders, using different tools/objects with different locations/orientations, using different setups for the environment (by manipulating the support surfaces, the client's position, and the tools orientations, and distances), and manipulating the task's demand (such as time/temporal characteristics, accuracy, physical load, attentional demands, and difficulty).
 - b. The functional practice took place in various natural settings (the task's and the client's natural environment) as much as feasible.
 - c. The functional training was performed for the whole task when task had interrelated parts. However, part learning was used when the task was complicated for the client (e.g., forward or backward chaining were utilized).
 - d.The therapist considered motor learning stages (discovery, mastery, and generalization) and facilitated the transition toward a better performance stage when possible.
 - e. The therapist utilized most efficient feedback strategies (i.e., faded, intermittent, knowledge of results, and more of internal feedback).
 - f. In preparation for all possible motor behavior problems, the therapist developed basic task analysis and problem solving skills of the client to help him in finding solutions to occupational performance problems as they arose in different situations, tasks, and environment out of the clinic.
- VII. The therapist disrupted ineffective and inefficient movement patterns by manipulating critical personal or environmental control parameters of the motor performance:
 - a. The therapist started to remediate a performance component of the critical control parameters that limited the occupational performance. The physical components training started with "just the right challenge" and then the therapist was grading-up the training as the physical component improved.
 - 1. Strength: The therapist used functional and meaningful exercises to improve strength: Increased resistance by adding weights (e.g., weighted cuffs) to task components, utilized biomechanical concepts (decrease the length of levers for example), worked against gravity, increased exercises repetitions, and changed

the orientation of the person and the tools to require more effort.

- 2. Endurance: Although endurance was not a major challenge for this particular client, the therapist gradually increased exercises duration or number of repetitions, and kept changing the orientation of the client and the tools to require more effort over time in an attempt to enhance functional performance endurance.
- 3. ROM/Tone: the therapist attempted to increase PROM in muscles with soft tissue tightening secondary to high tone by reducing soft tissue shortening using active, bilateral activities and passive stretching by the therapist or self-stretching. The therapist also used weight bearing to elongate the tightened soft tissues in Mr. J affected UE especially the elbow, wrist, and finger flexors. Additionally, the therapist mobilized the scapula (using functional activities and/or using hands-on techniques) to maximize AROM during overhead reaching. The therapist used active exercises (i.e., active elongating of the tightened muscles/soft tissues, voluntary control training, and strengthening of antagonist). The therapist used functional training (training the client left UE using weight lifting, grasp-release, wiping counters, COPM tasks, and unstructured home-based functional use).
- 4. Neglect of the affected UE: The client did not seem to be neglecting his left side. His appearance (shaving and dressing) did not indicate that. Mr. J major problem was the learned non-use due to his stroke chronicity (about 12 years). However, this learned non-use affecting his left UE did not appear to be caused by sensory or perceptual problems, it appear to be behavioral suppression due to repeated failure of left hand use.
- 5. Dexterity and coordination: The therapist engaged the client's left UE in fine movement exercises; manipulation of small objects in different contexts and setups, and gradually was increasing the speed requirement of the functional training.
- 6. The therapist attempted strengthening selected weak muscles critical to functional performance. These included shoulder flexors and abductors, elbow extensors, hand flexors and extensors, and grip strength. Meaningful functional activates were used to improve critical movements such as supination and wrist and fingers extension (card shuffling and dealing, tennis balls grasp and release, cloth grasp and release, playing tennis with the affected arm, sanding, weight lifting, cutting vegetables, throwing balls over head, and unilateral Wii playing).
- 7. The therapist provided faded manual guidance when necessary but allowed the client to experience internal feedback related to the functional performance.
- b. The therapist used a compensatory approach with very fixed ineffective and inefficient motor behaviors: mainly those activities requiring fine motor abilities, having safety issues, or requiring a significant level of strength:

The therapist encouraged the client to simplify his functional tasks, using simple devices and utilizing technology (e.g., electrical powered tools such as electrical

sander and electrical razor). The therapist simplified the functional training at the clinic at the beginning of the treatment program, for example he reduced the effects of gravity at the beginning of the training (i.e., use the elevating mobile arm support or supporting the affected UE on the table as using it) and used lighter tools and materials for functional training (lighter balls, lighter weights, and bigger ball that bounces slower as playing tennis). The therapist mainly targeted gross movement during training Mr. J left hand. The therapist also modified the task using alternative methods (i.e., simplify activities that required accuracy, speed, complexity, timing, and abstractness). The therapist adapted some of the tools used in the functional training (modified sizes, shapes, textures, length, and weights, used larger handles, used non-skid mats, and lighter or heavier tools). The client was encouraged to perform his activities with minimum compensatory strategies when possible. The therapist did not recommend any adaptation to the home environment because the client's balance, safety, and endurance did not appear to be critical control parameters for his functional performance. The therapist did not visit the client home since he seemed well adapted given that he had the stroke 12 years ago.

- c. The therapist was dynamic and flexible in switching between and/or combining the remedial and the compensatory strategies throughout therapy giving the priority to functional performance. The therapist tried to remediate as many impairments as possible to get as normal occupational performance as possible.
- VIII. The therapist constrained the affected UE degrees of freedom to enhance functional performance. This was done by decreasing the number of joints needed to be moved during an activity. These less necessary joints were fixed by asking the client to support them (e.g., adducting the arm during left hand manipulation), adapting the task or the environment components (e.g., using non-skid surfaces), and/or adapted positioning of the client to support the less needed joints (e.g., sitting instead of standing, stabilizing the forearm on a table, or stabilizing the left arm with the right arm).
- IX. Constraint-induced therapy principles (encouraging client to intensively use his left UE as much as possible and to reduce the dependency on the right UE) to reverse the learned non-use status affecting the left UE.

Treatment Program Activities Used at the Clinic

The treatment activities in the clinic are summarized in Table G1 and demonstrated in Figures G1-G7. The Table includes most of the practiced exercises; however, not all of the exercises were practiced each session.

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Table G1
Summary of most of the treatment activities used with Mr. J

Activity ^a	Brief Description	Main goal(s)				
Activity	Differ Description	wiam goal(s)	learning principles			
Weight	Standing by a table and	Stretching	Increasing weight			
bearing and	putting weight on the	PROM	bearing time to			
reviewing	affected left hand while the	Intensifying	enhance			
the home	elbow and the hand are	the functional	effectiveness of the			
program	fully extended. While	use of the left	stretch. Efficient			
1 0	discussing the structured	hand out of	use of the session			
	and the non-structured	the clinic	time. Enhancing			
	home program.		compliance in			
	About 10 minutes.		decreasing learned			
			non-use.			
Towel ROM	Reaching as far as possible	Active	Gradual increase			
with both	using both hand on a towel	stretching	the use of the left			
hands	over a table. Holding at the	Strength	arm & hand,			
	end of the range to stretch	AROM	increase speed of			
	soft tissues. About 10		movement, and			
Green and	minutes Grashing transporting and	Improve grasp	AROM Used MAS at the			
Grasp and release	Grasping, transporting, and releasing golf or tennis	and release	first few sessions to			
Telease	balls. Grasping & releasing	ability,	reduce effects of			
	a small towel.	dexterity, &	gravity, decreasing			
	About 10 minutes.	AROM and	the size of the			
		increase grasp	object, using			
		strength	weighted cuffs,			
		C	increasing the			
			heights/distances,			
			increasing the			
			repetitions and the			
			variability.			
Wiping a	Wiping foam from a table	Active	Changing the table			
table	using a cloth towel for	stretching,	height, increasing			
	about 10 minutes.	AROM,	the distance,			
		active use of	increasing the			
		left UE,	amount of foam, using a different			
		strengthening	surface such as a			
			counter top.			
			counter top.			

Throwing with two hands	The therapist mobilized the joints (especially for the scapula) as required. Throwing a basket or a big therapy ball to the therapist or into a hoop. Practiced for about 10 minutes each time.	Active stretching of left UE soft tissues, AROM, strengthening, over head reaching, scapula mobilization, coordination	Increasing the distance, hoop height, increasing repetitions and frequency, varying the throwing style (i.e., overhead, underhand, or overhand), varying the size of the ball.
Playing	Playing indoor tennis	AROM,	Increasing the
tennis with	without a net using a foam	Obtained	distances (height of
the left arm	ball and regular rackets. The therapist served and	from interests, strengthening,	the thrown balls, distance from the
	the client hit the balls with	grasping,	therapist, distance
	his racket. Practice for 15	engaging the	to the sides),
	minutes.	left UE in functional	varying the angle
		use,	and the speed of the serves, increasing
		coordination	the time and the
			frequency.
Weight	Moving a weight from a	Elbow, wrist	Increasing the
lifting	stool to an adjustable table using the left UE for 10	and fingers extension-	weight (2 lbs or 5 lbs) increasing the
	minutes	flexion,	height of the table,
		strengthening,	and more
		AROM,	repetitions.
Nintendo	Playing speed slicing game	grasping, Obtained	The therapist
Wii	on the Wii resort CD. 10	from interests,	increased the
	minutes of the game played	strengthening,	challenge by time,
	with the therapist	dexterity,	alternating between
		coordination, AROM	sitting and standing, increasing
			repetitions & time.

Left UE Stretching	The therapist applied persisted stretching for shoulder internal rotators & adductors, and elbow, wrist, & finger flexors. 10 minutes as needed throughout the treatment session.	Elongate soft tissue tightness, increase PROM	Stretching during breaks for efficient time use. Fading out hands-on techniques as the client progressed and was able to do self-stretching.
Cutting and	Cutting an apple or a	Improving	Non-skid mat,
eating	cucumber using the right hand. The left hand was	functional performance	using different objects to cut,
	used for holding during	in cutting	decreasing the size
	cutting (safety was	(COPM	of the product
	emphasized) and eating the cut items. Practiced for 15	activity) AROM	pieces, increasing the speed, and
	minutes at the clinic and	Strength	increasing the
	assigned for home	Coordination	amount of objects
	program.	Dexterity	to be cut.
Driving	Holding a piece of wood with the left hand and	COPM minor	Increasing the
screws	driving screws into the	repairs functional	repetitions, changing the angle
	wood using the right hand.	performance	of the wood piece
	Practiced for 10 minutes.	AROM	
		Strength	
		Coordination Dexterity	
Sanding	Using two hands for	COPM minor	Increasing the
	sanding a piece of wood	repairs	repetitions & time,
	for 10 minutes.	functional	alternating between electric sander and
		performance AROM	hand sanding,
		Strength	increasing the
		Coordination	resistance (fine to
			rough, changing the table heights &
			location

Scrubbing the right side of the body using left hand	Bathing simulation where the client held a cloth with his left hand and simulated washing of his right UE. Done in standing for 15 minutes at the clinic and assigned for home program.	COPM washing the right side of the body functional performance AROM Strength Coordination	Sitting or standing, different cloths, increasing the time and repetitions, asking the client to actually do it during bathing at home.
Playing cards	Using the left hand to hold cards during shuffling and playing with the right hand. Practiced for 15 minutes at the clinic and assigned for the home program.	COPM playing cards functional performance AROM Strength Coordination dexterity	Changing the deck type (plastic or paper), increasing the number of cards held or shuffled, increasing the speed of the game, increasing the time and the repetitions, changing the distances (table height and location)
Buttoning a shirt	Putting on a shirt and buttoning/unbuttoning it using the right hand, the left hand used to assist. Practiced for 15 minutes at the clinic and assigned for the home program.	COPM buttoning functional performance AROM Strength Coordination dexterity	Changing the shirt style, buttons sizes, sitting or standing, increased time, speed and repetitions, using a mirror for more speed.

Note. COPM: The Canadian occupational performance measure, AROM: active range of motion, PROM: passive range of motion.

^a The activities listed were not necessarily used each session. The order of the activities varied each session.







Figure G1. Different stretching techniques applied on Mr. J left hand. Left: the therapist applying stretch, center: the client applying self stretching, right: weight bearing stretching.







Figure G2. Mr. J performing incorporating his left UE in functional tasks consistent with his interests. Left: overhead bilateral throwing, center: left hand tennis playing, right: left hand Wii playing.







Figure G3. Mr. J being trained on left hand grasping with and without the mobile arm support (MAS) help and strengthening. Left: grasping/releasing golf balls with the assistance of the MAS, center: grasping/releasing tennis balls without the MAS, right: weight lifting.





Figure G4. Mr. J incorporating his left UE while performing COPM functional task of cutting (right) and eating after cutting (left).







Figure G5. Mr. J incorporating his left UE during COPM functional tasks training of playing cards (left), buttoning (center), and washing the right side of the body (right).







Figure G6. Mr. J incorporating his left UE during COPM functional task of minor repairs training. Left: driving a screw, center: tightening a bolt, left: using electric sander.

Mr. J pre-treatment and post-treatment evaluation measures are listed in Table G2 bellow and demonstrated in Figure G7.

Table G2 Summary of Mr. J pre-treatment and post-treatment evaluations scores

Test	Pre-Treatment	Post-Treatment
Left UE WMFT ^a	Time: 54.53	Time: 49.9
	Functional score: 2.2	Functional score: 2.27
Left UE MALa	Amount of use scale: 0.26/5	Amount of use scale: 2.36/5
	How well scale: 0.21/5	How well scale: 1.6/5
COPM	Performance: 3.6/10	Performance: 5.4/10
	Satisfaction: 3.2/10	Satisfaction: 5.4/10
Left hand Grip	30.67	45 lbs
Strength		
Left hand grasp	Hand mass flexion $= 2$, mass	Hand mass flexion $= 2$,
patterns (Fugl-	extension = 0 , hook grasp = 1 ,	mass extension = 1, hook
Meyer test) b	spherical grasp = 1 , cylindrical	grasp = 1, spherical grasp =
	grasp =1, lateral pinch = 1, tripod	1, cylindrical grasp = 1,
	grasp = 0.	lateral pinch = 1, tripod
		grasp = 0.
Left UE Joints	Shoulder flexion: 3-, Shoulder	Shoulder flexion: 4-,
strength (manual	abduction: 3-, Elbow extension:	Shoulder abduction: 4,
muscle test	3-, and Wrist extension: 3	Elbow extension: 3, and
grades)		Wrist extension 3+.
Left UE AROM	Shoulder flexion: 0-115°,	Shoulder flexion: 0-130°,
	Shoulder abduction 0-100°,	Shoulder abduction: 0-90°,
	Elbow extension: 90-80°, and	Elbow extension: 90-15°,
	Wrist extension: 0-45°.	and Wrist extension 0-40°
Left UE PROM	Shoulder flexion: 0-130°,	Shoulder flexion: 0-140°,
	Shoulder abduction: 0-105°,	Shoulder abduction: 0-105°,
	Elbow extension: 90-0°, and	Elbow extension: 90-0°, and
	Wrist extension 0-50°	Wrist extension 0-60°
Left UE tone	Shoulder flexion: 1+, Shoulder	Shoulder flexion: 1,
(Ashworth scale?)	abduction: 2, Elbow extension: 2,	Shoulder abduction: 1+,
	and Wrist extension: 3	Elbow extension: 1, and
		Wrist extension: 2

Note. UE: upper extremity, WMFT: Wolf Motor Function Test, MAL: Motor Activity Log, COPM: The Canadian Occupational Performance Measure, AROM: active range of motion, PROM: passive range of motion.

^a WMFT and MAL tests were conducted for Mr. J as a part of a research study data collection; the therapists at clinic do not have to conduct these tests as part of the OT task-oriented approach.

^b Fugl-Meyer test (UEFM) categories (as 2 = normal, 1 = compromised, or 0 = absent).

[°] Elbow extension testing range: 90° flexion - 0° flexion.







Figure G7. Evaluating Mr. J elbow extension range of motion (ROM) (left), shoulder flexion strength (center), and grip strength (right).

Discharge.

After receiving twelve 1.5-hour sessions over six weeks, the client met all of his treatment goals successfully. MR J. showed significant and clinically meaningful functional improvements (around two points improvement on COPM and more than one point improvement on MAL) and got good improvements at most of his impairment measures as well as demonstrated in Table G2.

Responding to an evaluation survey, Mr. J was pleased with the treatment results and indicated that the quality of this treatment program was better than all other stroke rehabilitation programs he received before. He said that he got more improvements than any other treatment he received and that our treatment program exceeded his expectations. Mr. J stated that he liked the customization of this treatment program where it met his functional needs and matched his interests. He also liked the challenge in the program and appreciated the education received. He most valued how he started to use his left hand spontaneously in daily life activities more than any time since he had the stroke. He indicated that his treatment program was unique and he would have authorized his insurance to pay the cost of this therapy where he would have paid his copayment. He said that he would definitely refer someone else for our research study. Mr. J suggested adding more sessions to the program and more variability to the used treatment activities. Mr. J said also it would have been helpful if he knew the tools needed for the entire program (for home program and some of the clinic treatment) when he first started the therapy.

The therapist encouraged Mr. J to continue using his left arm in daily life activities and to maintain at least some of the home-based exercises in order to maintain the gained improvements and possibly getting more improvements. The therapist's final advice for Mr. J was to never assume that his left hand is useless and to continue trying to use it in his daily life activities.

Appendix H: Treatment Protocol Evaluation and Therapy Documentation Forms

OT Task-Oriented Post-Stroke Rehab.

	грант з сос	le:	Date:	Investigator:				
*Exclu	ısion cutof	fs:						
Pain≥	7							
	d < 10°							
	xion ≤ 10° flex-ext ra	ngo = 100						
		th score of 4						
***The	e ROM min	nimums shoul	d be isolated a	nd against grav	ity.			
Musc	cle group	PROM	AROM	MMT	Modified Ashw			
Sh Fle	ex.							
Sh Ab	od.							
E1b. E	xt.							
E1b. F								
Wrist	Ext.							
Elbow								
			_		if applicable):			
Rate	2 3		ılder at pro 6 7		10			
Rate 1 No pain	2 3		_		10 (Worst pain I			
Rate 1 No pain	2 3		_		10			
Rate	2 3		_		10 (Worst pain I			

Past Present Future Not at all valuable Student Worker Volunteer Care Giver Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other: Other: Please add any further details/comments related to your roles in life:	Role	R	Cole Ident	itv	Va	ue Designati	on
Student Worker Volunteer Care Giver Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other:					Not at all	Somewhat	va
Worker Volunteer Care Giver Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other: Other:	Student						
Volunteer Care Giver Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other:							Т
Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other:							T
Home Maintainer Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other:							T
Friend Family member Religious participant Hobbyist/Amateur Participant in organizations Other: Other:							
Family member Religious participant Hobbyist/Amateur Participant in organizations Other: Other:							T
Religious participant Hobbyist/Amateur Participant in organizations Other: Other:							T
participant Hobbyist/Amateur Participant in organizations Other: Other:							T
Hobbyist/Amateur Participant in organizations Other: Other:							
Participant in organizations Other: Other:							Γ
Other: Other:							Г
Other: Other:	organizations						
	Other:						Γ
	Please add any furth	her deta	ils/comm	ents rela	ted to your	roles in life:	

							1 hera	ру Бос	umentat	10n, 12
Test: Interes	t Check	List								
Participant's	code: _		Date:]	Investiga	tor:		
Please chec	k each	item be	elow ac	cordin	g to you	ır inte	rest			
Activity	Level of Interest Within the past year			Within years	el of Inter the past	ten	Do you current particip this act	ly oate in ivity?	Do you want to pursue this activity in the future?	
1 C	Casual	Strong	No	Casual	Strong	No	Yes	No	Yes	NO
1 Gardening										
2 Sewing								_		
3 Poker										
4 Foreign										
languages										
5 Social clubs										
6 Radio										
7 Bridge										
8 Car repair										
9 Writing										
10 Dancing										
11										
Needlework										
12 Golf										
13 Football										
14 Popular										
music										
15 Puzzles 16 Holidays										
17 Solitaire										
18 Movies										
10 Lasturas										-

Comm	nents:					
	27 Traveling					
	25 Barbecues 26 Reading					

20 Swimming 21 Bowling 22 Visiting

23 Mending 24 Chess

Activity	Level of Interest Within the past year		Level of Interest Within the past ten years			Do you currently participate in this activity?		Do you want to pursue this activity in the future? Yes NO		
2026 :: 1	Casual	Strong	No	Casual	Strong	No	Yes	No	Yes	NO
28 Martial										
arts										
29 Parties										
30 Dramatics										
31										
Shuffleboard										
32 Ironing										
33 Social										
Studies										
34 Classical										
music										
35 Floor										
mopping										
36 Model										
building										
37 Baseball										
38 Checkers										
39 Singing										
40 Home										
repairs										
42 Volleyball										
43										
Woodworkin										
g										
44 Billiards										
45 Driving										
46 Dusting										
47 Jewelry										
Making										
48 Tennis				-		 	-	\vdash		
49 Cooking								-		
50 Basketball										
51 History								-		
52 Guitar										
53 Science										
54 Collecting										
55 Ping Pong										

Comments:	<u>-</u>	

Activity	Level of Interest Within the past year		Level of Interest Within the past ten years			Do you currently participate in this activity?		Do you want to pursue this activity in the future?		
	Casual	Strong	No	Casual	Strong	No	Yes	No	Yes	NO
56										
Leatherwork										
57 Shopping										
58										
Photography										
59 Painting										
60 Television										
61 Concerts										
62 Ceramics										
63 Camping										
64 Laundry										
65 Dating										
66 Mosaics										
67 Politics										
68 Scrabble										
69 Decorating										
70 Math										
71 Service										
Groups										
72 Piano										
73 Scouting										
74 Plays										
75 Clothes										
76 Knitting										
77 Hairstyling										
78 Religion										
79 Drums										
80										
Conversation										
81 video										
games										
games (Nintendo										
(Nintendo Wii)										
Other Other										

			3
Comments:			_

	t: Activity Analysis Form ticipant's code: Investigator: Date:
Act	ivity/goal:
**P	lease try to have as much simulation of the participant natural environment as possible.
	Activity Demands Task constraints: How are the person and materials positioned, especially in relation to one another?
	Task constraints: What utensils/tools/materials are normally used to do this activity?
	Environmental constraints: Where is this activity usually carried out?
	 Contextual constraints: Does this activity or the way it is carried out hold particular meaning for certain cultures or social roles? Is there a time factor involved in carrying out the activity?
٠	What capacities and abilities are prerequisite to successful accomplishment of this activity?
	What must be stabilized to enable doing this activity, and how will that stabilization be provided?
*	What precautions must be considered when using this activity in therapy?
nts:	

۰	What adaptations activity	, if any, v	would b	e neede	ed or wo	uld assist l	Hemiplegic persons to do t
٠	List the steps of				Comm		Descent of difficult
	Activity Step		forma Fair	Poor	Yes	ensation No	Reason of difficult
	performance of t	nis activit ory strates	y? nies, te	chnique			using to improve the functi you using to improve the

How can this activity be graded to improve the following:
 Strength:

Participant's code: Date	Investigator:
Affected UE R_ L_	e: Treatment session #:
I. Session intervention goals:	
_	
S:	
0:	
A:	
P:	

II. Treatment Activities:

	Activity/exercise	Duration/frequency	Adaptation/simplification	Goal/purpose
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

III.	Home	assignment	Program:
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	low-up		

B- New assignment(s):

Comments:	2
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