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THE STATE UNIVERSITY OF NEW JERSEY

Title of Project: **Home Based Virtual Rehabilitation for upper extremity**

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1. Purpose/Specific Aims

The overarching aim of this study is to provide a mechanism for patients to engage in progressive motor practice for a meaningful time period. We aim to improve on the positive outcomes found in our work on patients in the chronic phase and the pilot work being done on patients in the acute in-patient phase post stroke to determine whether we can further improve functional recovery using a home based system.

Aim 1: Evaluate compliance with Home-Based Virtually Simulated hand/arm gaming activities and two computer game groups, one with motivation enhanced (ME) simulations and one with non-enhanced (MnE) versions, as compared to compliance with Standard hand/arm home Exercises (HBSE). Hypothesis: Participants in the ME and MnE group will show significant compliance as compared to the control group (HBSE) and the ME group will be superior to the MnE group.
Primary Outcome Measures: For the HBVS group, 1) time on task will be measured by the daily computer file time stamp and 2) amount of moving time will be measured by the actual movement time recorded by the games. For the computer games groups 1) time on task will be measured by recording start and stop time of practice in a notebook and 2) amount of moving time will be measured by commercially available activity monitors.

Aim 2: Evaluate the effectiveness of home-based virtually simulated hand/arm gaming activities (HBVS) for individuals with stroke as compared to a program of standard hand/arm home exercises (HBSE). Hypothesis: Participants completing HBVS training will exhibit significantly improved clinical, kinematic and neurophysiological outcomes as compared to the control group (HBSE).
Primary Outcome Measures for Aim 2: Wolf Motor Function Test, Upper Extremity Fugl-Meyer Assessment of Sensorimotor Recovery after Stroke, Action Research Arm Test, Perception of System Questionnaire, the Stroke Impact Scale, Kinematics, Cortical mapping.

Aim 3: Evaluate the impact of the motivation enhancements designed into computer games to provide a more enjoyable training experience. Hypothesis: Enjoyment of the games will be a more valid predictor of compliance than personal factors.

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Primary Outcome Measures for Aim 3: The Intrinsic Motivation Inventory, The Patient Activation Measure, qualitative data collected during semi-structured interviews.

2. Background and Significance

Studies have shown that sustained hand rehabilitation training is important for continuous improvement and maintenance of function following a stroke. It is unimaginably difficult to pursue education, employment and community participation without being able to independently use one's hands. The primary goal of this study is to test an exciting new technology that can be easily used in the home for long-term hand and upper extremity training. Recovery of hand function post brain injury is particularly recalcitrant to currently available interventions. To date, the best efforts of groups studying traditionally presented as well as technology-based therapeutic interventions for the hemiplegic hand and arm have produced measurable changes in motor function and motor control but fall far short of major reductions in disability.

If the amount of therapy is critical to rehabilitation, our current institutional limitations undermine the probabilities for successful outcomes. After discharge from the inpatient stay, access to rehabilitation therapy can be difficult for some patients. This is due in part to inadequate insurance, lack of transportation, and the patient's dependence on their caregiver. Having access to long-term rehabilitation training anywhere and at any time is necessary for sub-acute and chronic patients to continuously improve their functional abilities.

Innovative telerehabilitation systems have been developed using information and communication technologies to provide rehabilitation services at a distance. Many studies have developed video-game driven systems from commercially available gaming consoles such as Wii and Microsoft Kinect [1]. Other groups have examined the use of custom-made tele-rehabilitation systems [2, 3]. These systems do not address hand rehabilitation. There is a vital need to explore intensive home-based upper extremity interventions that focus on the hand.

3. Research Design and Methods

This study will be a single blind randomized controlled trial. Subjects will be blinded to the purpose of the study. All outcome measures will be performed by a therapist blinded to group assignment. A controlled trial will be utilized to determine the additive effect of presenting rehabilitation activities in a virtual environment as compared to standard upper extremity exercise. We will randomize subjects to treatment and control groups using a computerized random number generator.

3.1. Duration of Study

Each subject will perform a pre-study evaluation, train using one of the protocols for three to twelve months, perform a post study evaluation as well as one and six month retention evaluations.

3.2 Study Sites

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Testing and initial training will take place in the Bergen Building of the Rutgers Biomedical and Health Sciences Campus in Newark. Home training will take place in subjects' homes.

3.3 Sample Size Justification

In this pilot study we will seek sufficient power to detect a clinically significant difference in the Wolf score changes in these two pre-planned, primary comparisons. To evaluate these effects of training, we will assume a power level of .8 and a significance level of 0.05. With presumed correlation among repeated measures of 0.1 and effect size of 0.3, we will need a sample size of 25 subjects in each of the three groups (HBVS, ME and MnE) to observe a significant effect for the first comparison (G*Power, version 3.1.5). Although we will screen for patients with homogeneous impairments, by its nature stroke is an extremely variable condition. Due to possible subject attrition, we will use a total of 30 subjects in each of the two groups.

3.4 Subject Selection and Enrollment Considerations

3.5.1 Inclusion Criteria

1) healthy persons between the ages of 20 and 90
2) persons six weeks post stroke between the ages of 20 and 90
2) person with enough shoulder, elbow, wrist, and hand movement to actively interact with the video games

3.5.2 Exclusion Criteria

1) person with severe arm weakness and cannot move the arm enough to interact with the video games
2) person with severe increase in tone of their weak arm
3) person with difficulty following instructions or paying attention to computer video games for at least ten minutes,
4) person with visual problems that make it difficult for them to interact with an entire computer screen

3.5.3 Subject Recruitment

Subjects will be recruited through flyers, stroke support groups, and clinician referrals. We will assume that approximately 15-20% of the population will satisfy our inclusion criteria based on our previous experience with upper extremity rehabilitation in this population. Hence we will approach 300 persons.

3.5.4 Consent Procedures

Example: The study will be explained to the potential subject by the study staff, the consent will be read, and their questions will be answered. If s/he wishes to enroll, the

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subject will sign the consent form. The study staff obtaining consent will also sign and date the consent form, and a copy will be given to the subject sought from each prospective subject or the subject's legally authorized representative, in accordance with federal & state law and institutional policy. If the study staff member performing the consent process identifies issues suggesting that the prospective subject may not be capable of participating in the consent process due to dementia, a Folstein Mini Mental Status will be performed. Prospective subjects screening positive for dementia will not be included in the study.

3.5.5 Subject Costs and Compensation

There are no costs for the subjects. The subjects will be paid 100$ at each of the retention tests.

4. Study Variables

4.1 Independent Variables or Interventions

The two **computer game groups, Motivation Enhanced (ME) and Motivation Non-Enhanced (MnE)** will use the NJIT- Home Virtual Rehabilitation System (HoVRS) to play a series of computer games developed to practice movement of the hand and fingers. Subjects will first come into our lab, perform pre-tests as well as a pre-intervention training session. Then a physical therapist and engineer will set up the apparatus in subject's home and will train them on how to use the system and play the games in their home during the first week. The physical therapist and engineer will be in contact with subjects throughout the training and will visit subjects' homes as needed if problems are encountered. Additionally, the system allows the therapist to remotely monitor each day's activity.

4.1.1 Device Description

NJIT HoVRS has two sub-systems to deliver home-based training: 1) a patient based platform to provide the training and 2) a server based online data logging and reporting system. In the patient's home, a cross platform virtual reality training application runs video games (developed in the Unity 3D game engine using the language C#) on their home computer.

4.1.11 Hardware

The Leap Motion Controller (LMC) a commercially developed infrared tracking device developed for home video game control is used to capture motion of the hand and arm movement without requiring wearable sensors. The device's USB controller reads the sensor data into its own local memory and performs any necessary resolution adjustments. This data is then streamed via USB to the Leap Motion image API. From there, we programmed the system to feed tracking data into virtual reality activities by calling the Leap Motion API.

If the patient's arm is weak and he/she cannot support the hand against gravity above the Leap Motion Controller, the Armon™ Edero, a commercially available, spring-based arm support, will be provided to the subject (Figure 1). The Edero provides 12 different levels of passive

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support allowing it to accommodate a wide range of patient sizes and strength levels. It requires a single setting that can be provided during the patient's initial evaluation

4.1.1.2 Software

Patients will either use their own home computer or will be provided with a computer if needed. A user-friendly GUI interface lists all of the training activities allowing patients to choose which activity they want to begin with using just one mouse click. Currently twelve games have been developed, each one designed to focus on training a specific hand or arm movement such as wrist rotation or finger individuation. All games are downloadable via HoVRS website.

The **video home exercise** group will be taught a progression of home exercises for their hand and arm. These exercises will be taught to them using web-based movies that they will view on a computer screen. Subjects will first come into our lab, perform pre-tests as well as a pre-intervention training session. The therapist will then work with the subjects in their home and visit them once or twice in the first week to ensure that they are independent exercising with the videos. The video exercise activities will include hand opening activities, reaching and grasping different sized objects, individual finger movements, and forearm rotation activities chosen to ensure the trained movements are similar to the ones addressed by the computer games.

4.1.1.2 Software

Patients will either use their own home computer or will be provided with a computer if needed. A user-friendly GUI interface lists all of the video home exercises allowing patients to choose which activity they want to begin with using just one mouse click. Currently twelve exercises have been developed, each one designed to focus on training a specific hand or arm movement such as wrist rotation or finger individuation. All games are downloadable via the HoVRS website.

4.2 Dependent Variables or Outcome Measures

All subjects will come to our lab and complete a quality of life questionnaire (Stroke Impact Scale) [4] and undergo clinical and kinematic testing immediately pre and post training as well as at 1 and 6 months post training. Additionally they will complete a perception of the system questionnaire [5] after training is completed.

Clinical Measures. The main clinical outcome will be the Wolf Motor Function Test [6] because it is a balanced test of arm and hand use [7, 8]. The secondary measures will be the Upper Extremity Fugl-Meyer Assessment[9], the Action Research Arm test[10], and Kinematic/Kinetic Measures. To explore the mechanism of improvement, changes in kinematics and kinetics of the hand and arm will be used to elucidate recovery of impairment. Two types of kinematic data will be collected; 1) data obtained from the patient's daily performance during the training and 2) data collected during the 4 testing

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periods. Data obtained from the patient's daily gaming performance during the training will include duration of motor activity, hand opening and closing range of motion, pronation and supination range of motion, maximum fractionation (a measure of finger individuation), hand opening velocity, hand trajectory smoothness, game duration and game score.

Data collected during the 4 testing periods includes computer-based outcome measures and the Real-World Reach to Grasp Test. There are four computer based outcome measures in this data set. 1) Maximum Finger Opening is collected using a CyberGlove™ (Immersion, USA) (2) Pinch Force Tracking Error measures the ability to control active finger extension and flexion to modulate their pinch grip force to control a cursor to track a sine wave. (3) Maximum Pinch Force is measured as the maximum force a subject can exert on a force sensor held between their paretic thumb and index finger and, (4) Figure 8 Tracking Error measures forearm and shoulder control needed to trace a horizontal figure 8 shape while the arm is in a supported horizontal position[11] (5) Max finger extension and abduction (collected using a CyberGlove) (6)Maximum supination with hand open, measured with an Optitrack system. (7) Maximum pronation with hand open, measured with an Optitrack system (8) Maximum MCP flexion with PIP and DIP extension measured with an Optitrack system.

The Kinematic Reach-Grasp Test analyzes the kinematics of everyday movements involving grasping and manipulating real-world household objects and will be used to measure changes in real-world function. The Reach-Grasp Test will be administered to both the hemiparetic and non-hemiparetic upper extremity at all assessment time points. Subjects will sit in a chair and reach for objects placed 20 cm from the hand starting position. The subjects will be instructed to grasp the objects from the table and place it onto a 10 cm high platform located 5 cm to the right of the object. Subjects will be required to have all five fingertips touch the object at the time of the grasp[12].

In an attempt to expand our understanding of the motivation and adherence to the autonomous home rehabilitation program, we will perform an in depth qualitative analysis focusing on subjects' unique perceptions and understandings of their participation in the proposed rehabilitation program. Using a Grounded Theory approach, data collection and analysis will follow these steps: 1) A trained interviewer will ask open-ended questions in a telephone interview conducted after follow up testing, allowing participants to reflect on and describe their experiences. 2) Investigators will read participants' narratives to develop a general sense of the subjects' experiences and attitudes toward the rehabilitation program. 3) Investigators will identify emerging narrative themes in participants' experiences and attitudes toward the program. 4) Finally, an iterative coding process will be used to refine initial findings and synthesize these themes.

4.3 Risk of Harm

There is less than minimal risk involved. The VR experiments are non-invasive and pose no obvious risk. Transient fatigue of the hand and arm are possible, but this risk is not greater than that posed by normal daily activities following a stroke.

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4.4 Potential for Benefit

The benefits of taking part in this study may be: Patient may regain better use of their hand and arm. However, it is possible that patients might receive no direct personal benefit from taking part in this study.

5. Data Handling and Statistical Analysis

All efforts will be made to keep subjects' personal information confidential. All subject names will be removed from the data and the data will be tagged using a coded ID number. Demographic, clinical outcome and survey data will first be recorded on paper. All kinematic and computerized performance data will be collected on computer. These computer files will be identified by the coded subject ID number. All data will be transferred to an Excel spreadsheet with subjects identified by this same ID number. Spreadsheets will be stored on a drive that is password protected. Data will only be accessible to study staff and will be retained for seven years. The link between subject identity and subject ID number will be destroyed when data collection is completed.

Our primary outcome measures will be the WMFT (Aim 2) and the duration of motor activity (measure of compliance, Aim 1). The primary outcome measures and all secondary outcome measures described above will be subjected to a repeated measured analysis of variance, with between-group factors Therapy Type (Virtual Simulations (VS), Standard Exercise (SE)) and within-group factor Test (Before, Post, One Month retention, Six Months Retention). Our post-hoc analyses of the Therapy Type by Test interaction effects will focus on the Month 1 versus Month 6 comparison. We will be quantifying training effects by comparing group means as well as by percent change in performance, and by comparing the recovery curves obtained from Tests 1-4. All clinical outcomes used are well established measures of upper extremity functional recovery with published minimum clinically important differences which we will use to evaluate the significance of our findings.

7. Reporting Results

7.1 Individual Results

No disease screening data will be collected. Patient's changes on clinical tests will be shared with them during testing sessions. These sessions are conducted by licensed Physical Therapists who have training to help persons with stroke interpret clinical examination findings.

7.2 Aggregate Results

Subjects will not be informed of aggregate findings.

7.3 Professional Reporting

De-identified, aggregate findings will be published in professional journals and presented at scientific meetings.

8. Bibliography

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