**CLINICAL NOTE**

**Task-Specific Rehabilitation of Finger-Hand Function Using Interactive Computer Gaming**

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The present case study assessed the feasibility of using an interactive gaming system, coupled with the manipulation of common objects, as a form of repetitive, task-specific movement therapy. Three adults with moderate chronic motor impairments of the fingers and hand participated: one 36-year-old man with an incomplete cervical spinal cord injury, one 60-year-old man with a left cortical cerebro-vascular accident, and one 38-year-old woman with left hemiplegic cerebral palsy. Each subject received an intervention of 15 one-hour sessions, which consisted solely of interactive exercise gaming using a diverse range of objects. The objects provided graded and challenging training levels, which emulated the functional properties of objects used in daily life. This in turn produced positive effects on the recovery of active finger range of motion and hand function.

**Key Words:** Computer-assisted therapy; Rehabilitation; Upper-extremity.

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**NEUROLOGIC INJURIES** frequently result in impairments limiting upper-extremity function.1,2 There is significant evidence that targeted physical training improves skills and reduces disability. However, these approaches (eg, constrained use3-5) typically require extreme dedication and are often repetitive and boring.

Several studies have provided preliminary descriptions of the benefits of virtual reality and video games in rehabilitation training.6-12 The results of these studies suggest that many elements of the interactive games have a tremendous potential as rehabilitation tools. In their commercial configuration, however, video games and computer systems do not use a diverse range of objects as inputs to the games. Piron et al13 developed a virtual reality training system that uses multi-axial motion sensors to instrument a small sample of common objects (eg, an envelope used to complete a virtual mailing task). To extend this approach, we developed a custom interface device that uses a miniBIRD or microBIRD4 miniature motion tracking sensor to transform nearly any object into a computer mouse or joystick. Therefore, our approach allows participants to play any commercial video game, by slaving the video game sprite to the object motion. For a full description of the system, see Otto’s article.14

The system reported in this paper was designed to use any commercial game and this is important for many reasons. It is important to identify games that suit individual preferences; the wide range of activities available in commercial games makes this possible. It is important to have a large and ever changing variety of inexpensive games to maintain high levels of motivation and interest. Commercially available games do require a wide range of levels of precision, and movements that vary in speed, amplitude, and direction. By selecting objects used in activities of daily living, the therapy can target specific tasks. Hence, the games can be graded to match a client’s current level of functioning. Finally, many commercially available games involve multi-tasking. Hence, the tasks also engage key attentional, perceptual, and cognitive skills.15-17

In this study, we evaluate the feasibility of our interactive gaming system that couples object manipulation with exercise. Through a variety of common objects, tools, and utensils, our system provides a basis for repetitive, task-specific therapy focused on finger and hand function.

**METHODS**

Three case studies were conducted, and pre- and post-exercise changes in outcome measures were determined. We recruited the participants from an outpatient physical therapy clinic for upper-extremity re-education. Each volunteer gave informed consent. Ethics approval was obtained from the University of Manitoba Human Research Ethics Board.

The participant in Case 1 was a right-handed, 32-year-old man who suffered an incomplete spinal cord injury (C6–C7) 15 months before the start of the study. Clinical assessment revealed: (1) the subject was dependent on tenodesis grip for grasping functions, (2) wrist, elbow, and shoulder movements were intact, (3) sensation was intact, (4) resting posture of the hands was finger flexion with moderate levels of finger flexor spasticity, (5) reduced active finger extension was limited by 45° from neutral, and (6) the subject had considerable difficulty opening the hand for grasping and manipulating objects.

The participant in Case 2 was a right-handed, 60-year-old woman who suffered a left ischemic stroke involving middle cerebral artery 18 months before the start of the study. Clinical assessment revealed: (1) mild aphasia, (2) motor apraxia, (3) score of 5 on the hand and arm component of the Chedoke McMaster Stroke Assessment,18 and (4) moderate limitations and difficulty in handling and coordinating the use of most common household utensils, food, and drinks.

The participant in Case 3 was a right-handed, 38-year-old woman with right-sided hemiplegic cerebral palsy. Clinical

**List of Abbreviations**

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<td>fMRI</td>
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assessment revealed that the subject: (1) had decreased stereognosis of the right fingers, (2) typically would not use the right hand and had poor manual dexterity and difficulty handling and manipulating most common daily used objects, (3) was unable to rotate objects (e.g., to turn a door knob or the top off a bottle), and (4) exhibited a number of visuospatial deficits including left-right confusion.

Treatment Program

Figure 1 shows a sample of the objects used during the interactive exercise gaming program. The program for subject 1 consisted of the manipulation of objects that required active finger extension (with wrist in neutral to preserve tenodesis). Examples included use of fingers to roll cylindrical and cone-shaped objects, and sports balls with different diameters and surface properties. The program for subjects 2 and 3 included objects varying in size, shape, and surface properties, manipulated with both hands, whole hand, progressing to 3- and 2-finger functions. Tasks were selected that required fine finger controls with graded precision.

Figure 2 illustrates set-up of the interactive gaming system. Each exercise object is instrumented with the miniBird motion sensor. When the sports ball was rotated forward, the game sprite moved to the top of the monitor (bottom-left panel); when the ball was rotated to the right, the game sprite moved to the right edge of monitor (bottom-right panel). A short video is available that demonstrates the interactive exercise gaming system.19

Participants could select from 25 different commercial video games (rated “everyone”), each offering different precision levels, speed constraints, visuospatial demands, and either single or dual axis movements. Participants received 15 one-hour therapy sessions, 3 sessions a week. Training consisted solely of the interactive exercise gaming; no other physiotherapy was received.

Configurable difficulty level parameters were included in the system, which allowed participants to remain competitive by matching game play to the abilities of the participant. For example, the sensitivity of the physical object motion range mapping to the game sprite range could be adjusted. Most computer games have adjustable skill levels from novice to expert. Ergonomic properties of different objects also affect task difficulty.

Outcome Measures

We performed the following assessments pre- and post-treatment: Jebsen-Taylor Hand Function Test,20 passive and active range of motion at the metacarpal-phalangeal joint, and the Chedoke-McMaster Stroke Assessment18 (subject 2 only).
A computerized visual-tracking task was used to quantify fine motor manipulation skills. A custom software program was created to control the motion of an on-screen cursor (large bright-colored square). The cursor moved in a predictable sinusoidal manner either horizontally (left to right) or vertically (top to bottom). Participants were instructed to move a test object in concert with the moving target cursor: 9 cursor movement cycles appeared. The miniBird motion sensor was attached to each object at a specified location. The position coordinates of both the target cursor and object motion were synchronously recorded at a sampling rate of 100Hz. The test objects selected for each participant corresponded to his/her motor impairment, functional ability, and personal needs. For subject 1, a light-weight piece of styrofoam (10/5×2.5cm) was used to evaluate hand function. The styrofoam was grasped between the 4 fingers and the thumb. While maintaining his grasp of the styrofoam, subject 1 was instructed to flex and extend his wrist in concert with a vertically moving target (subject 1, task 1); and supinate and pronate his forearm in concert with a horizontally moving target (subject 1, task 2). In both tasks, his elbow was flexed at 90°, his forearm was supported, and external-internal shoulder rotation was restricted. For subject 2 and subject 3, the following 2 tasks were used. The first task used a thin piece of Plexiglas (6 ×12cm), which was grasped between the 4 fingers and the thumb. While maintaining grasp, subject 2 and subject 3 were instructed to flex and extend their wrist in concert with a vertically moving target (subject 2, task 1; subject 3, task 1). The second task involved a pencil held between the thumb, index, and middle fingers, which the subjects used to push/pull a 4-wheeled Lego car forwards/backwards in concert with a vertically moving target (subject 2, task 2; subject 3, task 2). These test objects were not used during the regular therapy sessions. A cross-correlation analysis was used to quantify the similarity between the movement trajectories of the target (reference) and manipulated test object cursors. The peak correlation coefficient represented a global performance index.

We constructed a questionnaire to obtain feedback about the client’s perception of the exercise gaming program, including the following questions: (1) Were the video game exercises fun to play? (2) Did the video games increase your motivation to perform your exercises? (3) Were the video game exercises challenging? (4) Did the video game’s difficulty level enhance the exercises? (5) Did you prefer interactive video game exercise to traditional physiotherapy received in the past? Each question was ranked: (1) I strongly agree; (2) I agree; (3) neutral; (4) I disagree; and (5) I strongly disagree.

Assessments were performed by an independent physiotherapist, who was not informed of the treatment program.

RESULTS

Figure 3 presents the time taken to complete the Jebsen-Taylor Hand Function Test. Posttreatment, all subjects exhibited substantial decreases in the total time. Peak correlation coefficient results from the tracking tasks are shown in figure 4. There was a substantial increase in peak correlation coefficient posttreatment for all subjects.

Example target cursor and object motion trajectories recorded for one tracking task are presented in figure 5. Pretreatment, subject 2 was only able to produce 4 of the 9 tracking cycles; compared with the reference waveform, the amplitudes of his movements were relatively small. Posttreatment, subject 2 was able to produce movements for all tracking cycles; his movements were more consistent and of much greater amplitude. In addition, his posttreatment Chedoke-McMaster hand score improved from 5 to 7. Similar results were obtained for subject 3 (tested with the same object). Pretreatment, only 5 of...
the tracking cycles were evident; posttreatment, she exhibited a marked improvement in movement amplitude and all movement cycles were produced. For subject 1, movement cycles were evident for all tracking cycles. However a 30% increase in the extension amplitude was seen for subject 1, task 1, and a 25% increase in the supination amplitude was seen for subject 1, task 2. Posttreatment, subject 1 increased his active meta-carpal-phalangeal extension by 35°, was able to fully extend his fingers, and to grasp most objects.

The questionnaire results were positive, with subjects answering “strongly agree” to all 5 questions. All participants expressed that they enjoyed the video game-based tool, preferring it to exercise programs, and would like to continue the treatment.

**DISCUSSION**

The present findings show that the interactive exercise program produced positive effects on the recovery of finger motion and hand function. These findings are consistent with studies that have evaluated efficacy of constraint-induced movement therapy. \(^3\)\(^5\) The configurable system parameters, (eg, speed and level of accuracy) permitted the exercises to be challenging. In turn, this allowed the participants to be competitive and enjoy the games.

Specificity of training is an important component in therapy regimens and this is dependent on the quality and quantity of feedback (finger-object contact and slippage) required for handling and manipulation. \(^24\)\(^25\) A recent study by Carey et al \(^21\) investigated fMRI signals during 2 rhythmic finger flexion-extension tasks. In the first task, subjects had to track a moving cursor; in the second task, the movements were free form. Their findings showed that during the tracking tasks, there was significantly greater fMRI signal intensity in both the contra-lateral and ipsilateral primary motor cortex. These findings support the view that precision, goal-directed movements are a preferred method to promote neuro-adaptation during the recovery from central nervous system disorders. This is consistent with the present therapy approach, which incorporates task dynamics and precision movements during object handling and manipulation.

Learning to restore function of fine and gross manual skills requires movement error reduction by the timely processing of tactile and proprioceptive sensory feedback. \(^26\)\(^27\) Task variability during practice is an important factor and studies have shown that introducing variability (random practice) improves performance in subsequent sessions (retention) and is more effective than blocked repetition of a constant task. \(^28\)\(^29\) The present interactive exercise approach uses video games that are typically random tasks with a wide range of adjustable movement amplitudes, speeds, and precision levels. In addition a diverse range of objects can be used, depending on the client’s needs and requirements. With this individualized approach, one could maximize the rehabilitative effectiveness of training.

There is a need for goal-directed therapeutic programs that integrate sensory feedback and motor actions with visuospatial and other cognitive functions. In this regard, video games offer important values that include: facilitation of attention and focus, graded requirements of gaze control, and multi-tasking. \(^13\)\(^17\)

After returning home or to other community sites, many people who have had a stroke, traumatic brain injury, or spinal cord injury will still require and benefit from rehabilitation. Home rehabilitation programs can be effective and comparable to institutional programs. \(^30\) Although not the focus of this study, the interactive exercise gaming system was designed to work as a monitored home program with the future goal of establishing a self-sustained independent rehabilitation program, and thus providing extended practice in the client’s home or in rural and remote settings.

**CONCLUSIONS**

An interactive exercise gaming system has been developed for hand function rehabilitation that involved the manipulation of real objects. The proposed intervention offers a wide range of graded and challenging training tasks that take into account the functional properties of commonly used objects. The present findings show that our therapy approach produced positive effects on the recovery of finger motion and hand function.

**References**


Suppliers