USABILITY OF A VIRTUAL REALITY THERAPY SYSTEM FOR CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

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Children with hemiplegic cerebral palsy (hemiplegia) have difficulty performing motor tasks with their hemiplegic upper extremity (UE). Exercise and practice can result in improvements in motor skills. A Sony PlayStation 2 equipped with an "EyeToy" video camera was adapted for children to practice neuromotor movements. The system captures the child's movements in fun, immersive games in virtual environments. Pilot test sessions with five children with hemiplegia found that the system successfully elicited targeted neuromotor movements of the hemiplegic UE (10.4 ± 0.7 movements/minute of play), particularly reaching activities that involve the shoulder and elbow, over a continuous period of playtime (18.9 ± 1.7 minutes). As well, child and caregiver surveys revealed that the therapy was highly enjoyable and that it would be accepted as part of a home-based therapy program. Usability issues have been identified and will be addressed with system modifications and further testing.

BACKGROUND

Hemiplegic cerebral palsy (CP), or hemiplegia, refers to a brain injury or anomaly of the motor cortex that creates a sensorimotor impairment of the opposite upper extremity (UE). Neuromotor movements that are difficult for children with hemiplegia include shoulder flexion and abduction, elbow extension, forearm supination, wrist and finger extension, thumb extension, and thumb abduction. Consequently, they generally favour the use of their non-involved UE in everyday activities [1].

Current therapies focus on repetition and practice of motor activities with the hemiplegic UE [2]. Forcing such practice by applying a constraint to the non-involved UE is effective [3], but safety and loss of independence are concerns [1]. Virtual reality (VR) therapy, meanwhile, describes an immersive and interactive computer experience for rehabilitation purposes [4], and one camera-based system has induced cortical reorganization and associated motor recovery in adult patients recovering from stroke [5]. While promising, however, existing systems are not conducive to *home-based* therapy activities due to high costs and the need for specialized equipment.

Our aim, therefore, was to develop and evaluate a low-cost VR therapy system that elicits practice of neuromotor movements, accommodates a wide range of abilities, provides a simple way for clinicians to track usage, and could be used at home. In this paper, we describe the system and the results of early usability testing with children with hemiplegia. We evaluated whether users could achieve specified tasks with effectiveness (accuracy and completeness), efficiency (expenditure of resources with respect to achieved effectiveness), and satisfaction (freedom from discomfort and attitudes toward the use of the product) [6].

SYSTEM DESIGN

Video Game System

The setup uses a TV-based PlayStation 2 (PS2) and an accessory called the "EyeToy" (Sony Computer Entertainment America, Foster City, CA, USA). With the appropriate games, players see their mirror image on the screen, and their physical movements are inputs into the games. For this study, two games from the "Play 2" disc were chosen. In "Secret Agent," the player reaches for toys that appear on the screen; in "Mr. Chef," the player reaches for various food items.

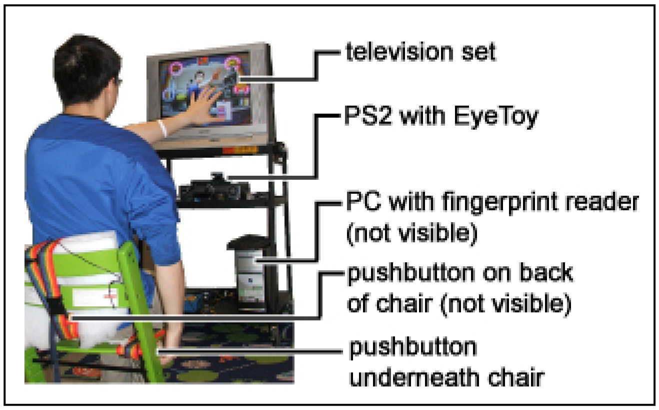

Figure 1: System setup. The participant sits approximately six feet away from the screen and "reaches" for virtual objects visible on the TV.

System Modifications

To play the games, participants sit on a chair with two pushbutton switches (Tash Inc., Richmond, VA, USA). As Figure 1 illustrates, one pushbutton is underneath the seat of the chair on the child's non-involved side and is held with the non-involved hand, while the other is on the back of the chair and must be pressed by sitting upright. These switches encourage movement and extension of the hemiplegic UE in the games. To ensure that they are pressed, the buttons activate an infrared transmitter/receiver (Velleman Inc., Fort Worth, TX, USA) that controls the TV display – if they are released, the TV screen goes blank.

Data Collection

To track usage, the user scans his or her fingerprint with a fingerprint reader (Microsoft Corporation, Redmond, WA, USA) connected to a personal computer (PC) to activate the system. Computer software then logs the amount of time that the pushbutton switches are held. Figure 2 summarizes the system schematically.

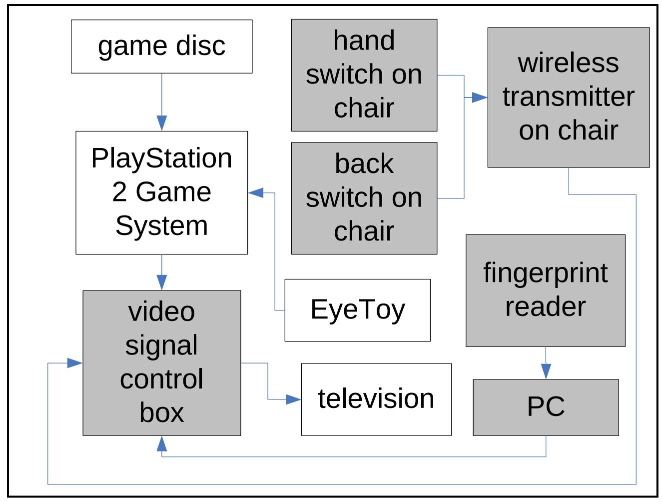

Figure 2: Schematic of VR therapy system. Shaded boxes denote components added to the unmodified PlayStation 2 with EyeToy system.

USABILITY EVALUATION

Test sessions were conducted with five children with hemiplegic cerebral palsy (4 males, 1 female, aged 8.1 ± 1.4 years). The participants had varying levels of fine motor difficulties as indicated by their scores in the House classification system (one participant at level 2, one at level 4, and three at level 5) and the Quality of Upper Extremity Skills Test (QUEST) (52.3 ± 18.2) [7]. The protocol was approved by the research ethics board of Bloorview Kids Rehab. Informed consent was obtained from all of the participants. In the study, participants played "Secret Agent" and "Mr. Chef" with a caregiver and occupational therapist (OT) present. The session was videotaped, and the number, type, and quality (greater or less than 50% range) of neuromotor movements were counted by an OT via video review. Child and caregiver surveys were administered to evaluate user satisfaction.

RESULTS

Figure 3 displays the average rates of each neuromotor movement observed for the five participants. The average playing time was 18.9 ± 1.7 minutes. Next, Figure 4 illustrates a positive correlation between the participants' rate of movements and their total QUEST score.

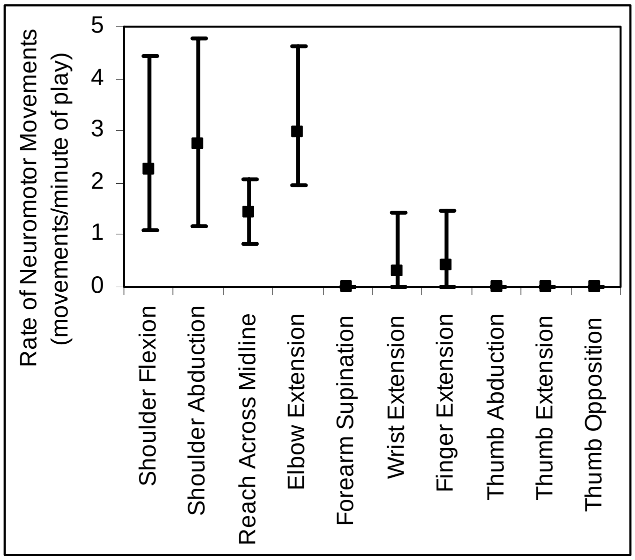

Figure 3: The average rate of targeted neuromotor movements. Error bars represent the maximum and minimum rates among the five participants.

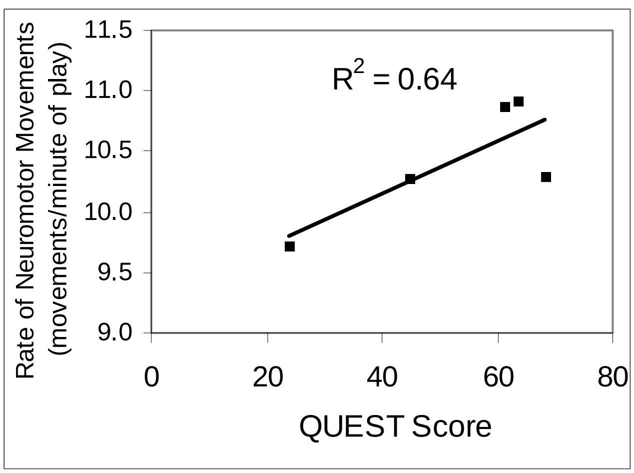

Figure 4: Relationship between average rate of targeted neuromotor movements and level of UE function (QUEST score) for the five participants.

Table 1: Summary Statistics of Test Sessions

Total neuromotor movements/minute	10.4 ± 0.7
Quality of movements (Percentage of movements greater than 50% range	72%
Pushbutton compliance (percentage of playtime that buttons were successfully pressed by user)	91.9% ± 8.9%

Table 2: Average Responses to Selected Questions from Child/Caregiver Questionnaires

1 – Strongly disagree; 2 – Disagree; 3 – Neither agree nor disagree; 4 – Agree; 5 – Strongly agree	
Child Questionnaire	**Average**
I had lots of fun today.	4.2 ± 1.1
I would like to come back another day to play the games again.	4.2 ± 1.1
I would like to take the video games home to play.	5.0 ± 0.0
Parent Questionnaire	**Average**
My child would enjoy using this virtual reality therapy system at home.	5.0 ± 0.0
I think that my child would practice therapy activities every day with this system at home.	4.8 ± 0.4
I would like to have this system at home.	4.6 ± 0.5

Some summary statistics are shown in Table 1. Meanwhile, Table 2 lists responses of the participants and their caregivers to selected survey questions. Caregivers commented that the system was “great to make [child] work” and “a way to make therapy fun.” Their concerns included the speed and difficulty of certain game tasks.

DISCUSSION

Effectiveness and Efficiency

The system elicited movements of the proximal hemiplegic UE at high rates – shoulder abduction, for instance, was performed an average of 52 times per session. However, because the games generally involve gross reaching motions, fewer distal movements involving the wrist, finger, and thumb were seen. Meanwhile, the large spread in pushbutton compliance (91.9% ± 8.9%) occurred because some participants were sliding out of the chair during the games and releasing the back pushbutton. Further design iterations are needed to address this issue.

User Satisfaction

From the survey results in Table 2, the participants reported high levels of satisfaction with using the system. Acceptance was also high among caregivers. Some participants commented that the menus had large amounts of text and disappeared quickly. This may become less problematic as they gain more playing experience.

User Characteristics that Affect Usability

Children with higher baseline UE function, as measured on the QUEST, generally performed more targeted movements. This relationship is expected as higher QUEST scores reflect greater motor control of the hemiplegic arm. It is noteworthy, however, that all of the participants were able to access and enjoy the games, indicating that the system can accommodate a range of functional abilities.

Limitations and Other Applications

To address the need for promoting distal UE practice, our group is currently developing a physical “hands-on interface” in which children must perform movements such as squeezing pressure sensors of turning knobs in order to play computer games. The data logging and pushbutton switches are reused in this new system. Other potential applications of the system, meanwhile, might include home-based rehabilitation exercise for other populations, including adults. Usage logging might be useful for other forms of computer-based therapy to monitor progress.

CONCLUSIONS

We have described the implementation and pilot usability evaluation of a VR therapy system for training upper extremity function of children with hemiplegic cerebral palsy. Based on the evidence presented, the system is usable by children with hemiplegia and elicits targeted neuromotor movements. Further studies to investigate the system’s potential for enhancement of specific upper extremity function are warranted.

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