MOVEMENT-BASED GAMEPLAY THERAPY FOR A CHILD WITH CEREBRAL PALSY: A SINGLE SUBJECT STUDY

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INTRODUCTION

Children with cerebral palsy (CP) often present asymmetrical or unilateral impairments that limit the use of their upper extremity, a condition known as learned nonuse or developmental disregard. Children may be unable to perform daily functional tasks that require the coordinated use of both arms. Some form of constraint-induced movement therapy (CIMT) is frequently used as a treatment strategy. CIMT is designed to improve function in children with motor impairment by constraining the less-affected limb and having the child practice repetitive tasks with the more-affected limb. The purpose of CIMT is to increase spontaneous use of the affected limb and limit the effects of learned nonuse. CIMT has been shown to be useful in children with CP (Y.-P. Chen, Pope, Tyler, & Warren, 2014). Unfortunately, it is not especially child-friendly (Wu, Hung, Tseng, & Huang, 2013). In this paper we present a single-subject study in which a non-immersive, motion tracking-based game is the mechanism for delivering CIMT-like therapy. The game, which was designed to elicit desired therapeutic movements, provides the intensive, structured training required by CIMT in a fun and competitive environment. Repeated measures assessed were speed of reach with the affected upper extremity, dissociation of movement for enhanced upper extremity skills and bilateral integration of the upper extremities in a functional task. The subject's performance improved in all measures, implying that motion-based gameplay may be as effective as CIMT, while being far more enjoyable for the child.

RELATED WORK

Research on the effectiveness of VR therapy for motor impairment has been on-going for several years, with mixed results. Of particular relevance to this work are the studies that have addressed the use of VR therapy for upper extremity impairment. (Y. Chen, Lee, & Howard, 2014) (Reid & Campbell, 2006), (You et al., 2005), (Green & Wilson, 2012) and those that have used various motion-based games for the same purpose (Li, Lam-Damji, Chau, & Fehlings, 2009), (Y. Chen, Kang, Chuang, Doong, & Lee, 2007), (Levac, Miller, & Missiuna, 2012). In this paper we present a single subject study with the following differences from most previous work: The motion-based system used was a "general purpose," noncommercial platform used in multiple previous academic and research projects, but the game developed was targeted specifically toward eliciting the movements desired by the therapist — these requirements were developed prior to programming the game.

METHODS AND PROCEDURES

The participant in this study was a ten-year-old boy with a clinical diagnosis of cerebral palsy. He had low postural tone and exhibited ataxic (uncoordinated) movements when performing functional tasks with his arms and hands. The child was left-hand dominant and avoided using his more-affected right arm and hand. According to his mother, he had difficulty accomplishing tasks that required using both of his arms, such as hand washing, and when reaching with arms extended forward, sideways or up.

The video game developed for this study was a three-dimensional version of the traditional "memory" game in which the player must find six matching pairs of animal images on the faces of cubes arranged in a grid. The position of the blocks was calibrated to the measured limits of the child's right arm reach. A 55-inch HD TV was used as the display, and a Polhemus Liberty™ magnetic motion tracking system was used to track the child's right hand and to update the position of a red sphere representing his hand movement in the game. Since the motion of his left hand could not affect the game, it was unnecessary to constrain this arm. Figure 1 shows this experimental platform.

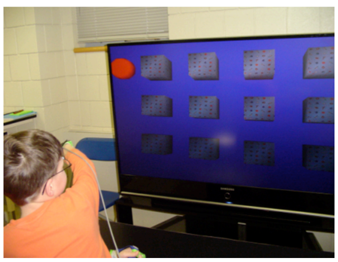

Figure 1: Child playing memory game

A single-subject AB design was utilized to assess within-subject performance. Measures of performance across baseline and intervention phases were used to determine whether the intervention resulted in changes in any of the following repeated measures.

1. Speed of reach with the affected upper extremity, calculated from motion tracker data. Speed was measured in mm/sec.
2. Enhanced upper extremity skills, measured using the dissociated movement subscale from the Quality of Upper Extremity Skills Test (QUEST) (DeMatteo et al., 1993). The dissociated movement subscale includes measures of the limitations of the active range of motion. Raw scores for QUEST range from 50-100; scores are normalized to a range of 0-100.
3. Bilateral integration of the upper extremities in a functional task, measured using the Goal Attainment Scale (GAS) which scores between -2 and +2. Hand-washing was the child's chosen task.

The experimental procedure consisted of a pre-intervention assessment session using the measures described above; five baseline sessions wherein reach data was collected using the trackers as the seated child reached for three dangling plastic fish suspended at the lower left, center, and upper right extremes of his motion; nine intervention sessions using the motion-based memory game; and a post-intervention assessment session using the same outcome measures. Figure 2 shows the experimental setup used gather reach data.

Figure 2: "Dangling Fish" used to measure speed of reach. The position tracker is attached to the subject's hand.

RESULTS AND CONCLUSION

1. Speed of reach to and from the target fish was analyzed using the two standard deviation band method (Nourbakhsh & Ottenbacher, 1994). To use this method, the mean and standard deviation are calculated for the baseline data. Bands are drawn at ±2 standard deviations on a graph containing the post-intervention data points. If two or more consecutive data points fall outside of the two standard deviation range, then a statistically significant change in performance has occurred. Using this method, a statistically significant change in the speed of reach was found for all three positions between the pre-baseline and post-intervention assessments.
2. QUEST dissociated movement scores were 81.25 at pre-baseline, 92.88 at post-baseline, and 100 at post-intervention, demonstrating a ceiling effect. Limitations of range of motion were noted in right shoulder abduction, elbow flexion and extension, and wrist extension at pre-baseline. Limitations persisted in elbow flexion and extension, and wrist extension at post-baseline. These limitations were resolved at post-intervention, when the

child demonstrated full range of motion in all planes of movement.

3. The child scored a -1 on the GAS for bilateral integration at the initial baseline assessment, completing 6 of 15 subtasks. At post-baseline, he scored a 0, completing 9 of 15 subtasks. At post-intervention, he scored a +2, the highest possible score, completing all 15 subtasks independently.

In conclusion, these results imply that motion-based gameplay may an effective adjunct to interventions, such as CIMT, while presenting a more enjoyable experience for the child: The subject rated his satisfaction with the game as a 5 (maximum score) after both the first and last sessions in which it was used. The fact that the game is more enjoyable than traditional CIMT may further encourage continued compliance with the prescribed regimen, as a child is more likely to continue with an activity that is enjoyable than with one that is not

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