Motor learning of the upper limb in children with Cerebral Palsy after virtual and physical training intervention

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***Abstract*—Evidence for improvement and retention of upper limb kinematics in children with cerebral palsy (CP) is scarce especially following training interventions using virtual environments. Children with CP were randomly allocated to one of two groups: task-oriented training with or without trunk restraint. For both groups, training was done in both virtual and physical environments. Motor improvements were retained 3 months after the intervention and transferred to a similar task. Sensory status was related to learning and retention of kinematics. Training in combined virtual and physical environments led to learning and retention of movement patterns in children with CP.**

Keywords–Cerebral Palsy; Motor learning; Upper limb

I. INTRODUCTION

Upper limb motor improvements in children are attributable to maturation in both sensorimotor and cognitive systems [1]. The ability to improve and acquire new motor skills depends on motor learning which is defined as changes in internal neural and cognitive processes leading to a permanent change in performance [2]. Children with CP have impaired upper limb movements because of limited range of motion, deficits in motor control and abnormal muscle tone which can impact the opportunity to develop typical reaching and grasping patterns [3]. The role of sensory feedback for learning new motor skills in adults has been previously investigated [4]. It is recognized that children with CP have sensory deficits that can have an impact on movement production [5]. However, the role of specific sensory deficits in motor learning remains unclear [4]. Our aim was to determine if improved upper limb kinematics in children with CP during a reach-to-grasp task could be retained and transferred to a similar task after combined training in a virtual and physical environment. The second aim was to characterize the relationship between sensation and motor learning.

II. METHODS

We used a prospective, single-subject research design with 16 children (7 males; 6-11yrs; spastic hemiparesis; Manual Ability Classification System 2-4/5). Children were randomly allocated to one of two groups: task-oriented training with or without trunk restraint (see Figure 1C). The intervention consisted of three one hour sessions per week for 5 weeks (total 15 hours). The intervention consisted of a 3 minute warm-up, 20 minutes of activities in each of the physical and virtual environments separated by a 7 minute rest period followed by a 10 minute practice of functional activity.

For training in the virtual environment (Figure 1A), movements of the child's hand were viewed on a computer monitor and movements of the arm and hand were used to control interactive games (IREX: GestureTek, Toronto). Movements throughout the arm workspace were recorded with a webcam and projected into the game scene.

In the physical environment (Figure 1B), the table workspaces were divided into four horizontal and four vertical quadrants in which children practiced task-oriented activities commonly included in therapy. Training was impairment-based and client-centered and consisted of activities such as playing with toys or board games with one or both arms.

Clinical evaluations consisted of upper limb impairments (Melbourne Test; [6]), sensory modalities (tactile threshold, touch, proprioception, stereognosis), upper limb passive range of motion. Kinematic (4) upper limb outcome measures were: shoulder and elbow range of motion, endpoint straightness (index of curvature), and endpoint velocity. Kinematic outcomes were measured during a task in which the child reached to grasp an object located near (close target – CT) and far (far target – FT) from the body and bring it to the mouth in simulated feeding. Only the reach-to-grasp component of the task was assessed. Five assessments were done: three pre-intervention (Pre-Test), one immediately post-intervention (Post-Test) and one 3 months post-intervention (Follow-Up); Figure 1D). Movements were recorded (Optotrak 3020, 100Hz; Northern Digital, Waterloo) from 10 infrared-emitting diodes (IREDs) positioned on the arm and trunk. A single evaluator, blinded to group assignment, completed all outcome assessments.

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III. RESULTS

There were no differences between groups in the number of children who learned or transferred improvements for any of the four kinematic variables. Therefore, the data were combined for all children. Motor improvements were retained 3 months after the intervention and transferred to a similar task in approximately 2/3 of the children for all of the 4 kinematic variables. Proprioception and tactile thresholds were associated with retention of improvements in endpoint velocity (r^2=0.34, $F_{2,13}$=4.832, p<0.03).

Melbourne scores were correlated with the index of curvature at Post-Test (r=-0.63, p<0.02) and Follow-Up (r=-0.60, p<0.03) for CT and at Post-Test (r=-0.75, p<0.004) for FT.

IV. CONCLUSIONS

Practice of activities in a physical and virtual environment aimed at improving upper limb kinematics led to better learning and retention of movement patterns in children with CP. A previous study showed a differential effect of the type of training on improvements in reach-to-grasp kinematics [7] but this was not demonstrated for the learning effect. Nevertheless, motor skills learned through practice may be transferred to similar movements in children with CP. Our results underline the importance of sensation for motor learning in children with CP. Indeed, learning to make faster reaching trajectories was related to better sensation. This study showed the benefits of combining virtual with physical training environments to improve motor outcomes in children with CP.

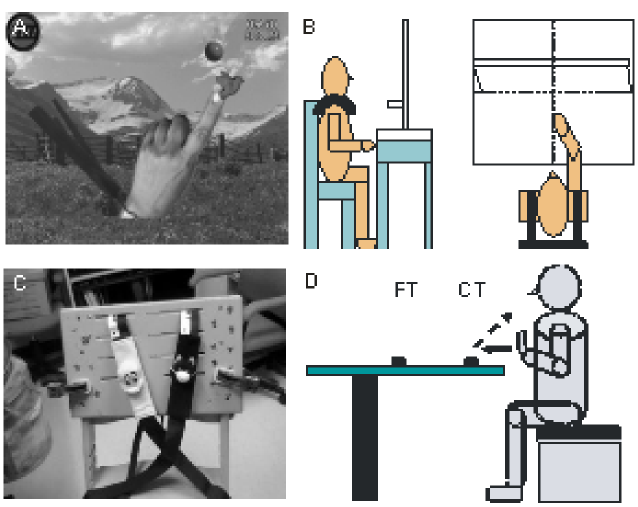

Figure 1: Upper limb motor training (A, B, C) and experimental (D) set-up for kinematic assessment. A. Example of a virtual game used during virtual training. B. Physical environment for reaching tasks. C. Trunk restraint system for upper limb training D. The assessment set-up with close and far target for reach-to-grasps tasks. CT: close target; FT : far target. Adapted with permission from Dev Med Child Neurol.

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