The role of feedback on cognitive motor learning in children with Cerebral Palsy: a protocol

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Abstract—Evidence of provision of extrinsic feedback for improvement and retention of upper limb kinematics in children with cerebral palsy (CP) is scarce, especially following training interventions using virtual environments. Benefits of using a virtual environment can range from increasing the participant's motivation to the ease of adapting extrinsic feedback for optimizing motor learning. In the proposed research, children with CP will be randomly allocated to one of three groups: no additional feedback, continuous feedback and faded feedback. For all groups, upper-limb motor training will be done in a virtual environment using the Jintronix virtual reality system. Motor improvements will be evaluated after an 8 hour training intervention and motor learning will be evaluated after one month. Transfer of motor gains to performance of a similar upper-limb task will also be used to assess learning. Findings from this research will provide crucial information on which frequency of feedback should be used to optimize motor learning and upper-limb rehabilitation in children with CP.

Cerebral Palsy, Motor learning, Upper limb, Feedback

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 that can impact the opportunity to develop typical reaching and grasping patterns [3]. Interventions should aim to reduce the difficulties for children when performing reaching tasks and to prioritize retention of tasks. One way to optimize retention of tasks is to provide specific feedback to the learner [2]. Feedback is crucial to provide information to the learner on either the performance or the quality of the movement. With the arrival of virtual reality systems as an adjunct to conventional therapy, the possibility to modify the frequency of feedback given to children has increased the potential of optimizing motor learning. Despite some evidence in healthy adults and individuals with stroke, there is no evidence to indicate which frequency of feedback can optimize motor learning in children with CP.

Our aim is to determine which frequency of numerical terminal feedback can be recommended by clinicians to improve motor performance and movement quality of the upper-limb in children with CP immediately following the intervention and in the longer-term. The second aim is to determine which frequency of numerical terminal feedback will lead to better functional outcomes immediately following the intervention and in the longer-term.

II. METHODS

A pre-post-follow up intervention paradigm will be used. Thirty-three children with spastic hemiplegic CP, aged between 8 and 17 years old (Manual Ability Classification System (MACS) 2-4) will be recruited. Children will be paired by age (±1yr) and MACS score and randomly allocated to one of three groups by a blinded research assistant: no additional feedback, continuous feedback and faded feedback. For the no additional feedback group, only the feedback from the game will be used. This consists of trunk displacement provided both visually (yellow square) and auditory (beep sound) during the game, remaining time to complete the task and a change of color of targets when reached. For the continuous feedback group, additional feedback will be provided after every trial. Additional feedback consists of knowledge of results about accuracy of performance and knowledge of performance about use of compensatory trunk movements (see below). For the faded feedback group, the frequency of additional feedback will progressively diminish over each session from training session 1 to 4. Arm and hand function of children with CP will be evaluated before (PRE), after 2 hours of training (POST1), after 8 hours of training (POST2) as well as 1 month following the end of training (RETENTION). Movement kinematics of a standardized reach-to-grasp task of an object placed at 3 different distances will also be assessed to evaluate transfer of learning.

The intervention will be given by an experienced physical therapist who will be blinded to the results of the clinical and kinematic evaluations. The four practice sessions consist of repetitive reaching in a virtual reality training environment. The VE serves as the interface for interactive games viewed on a computer monitor via the Jintronix Rehabilitation System (Jintronix, Montreal). The intervention includes the use of four distinct games in which two of the games involve unilateral arm movement and the two other games involve bilateral arm.

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movement (see Figure 1). The intervention consists of 4 training sessions of 2 hours each that spans over one week for a total of 8 hours. The level of difficulty for each session will be determined for each individual according to his/her ability level after a period of familiarization for each game. A total of 450 reaching trials per session will be performed. During sessions 1 through 3, only two games will be played. In the fourth session, all 4 games will be played. Each game will be performed in 3 blocks of trials with a 2 minute rest period between blocks to avoid fatigue of the participant.

**Figure 1:** Four games played on the Jintronix Rehabilitation System. The two games on top involve unilateral arm movement and the two games on the bottom involve bilateral arm movement.

Augmented feedback will be provided at the end of specific trials, consisting of both knowledge of performance and knowledge of results. Knowledge of performance will be given about the amount of trunk displacement used during play. Excessive amount of trunk movement is defined as sagittal displacement of more than 10 cm. An excessive use of trunk displacement is associated with a reduced range of motion of the elbow and the shoulder joints. Terminal numerical knowledge of results feedback will be given on movement precision (number of obstacle hits) and velocity (percentage decrease in optimal speed; see Figure 2).

**Figure 2:** Example of augmented feedback provided at the end of a trial.

Clinical tests will assess upper limb function and impairments (Melbourne Test; [4], Jebsen-Taylor; [5]), sensory modalities (tactile threshold, touch, proprioception), upper limb passive range of motion, participation (Participation and Environment Measure for Children and Youth; PEM-CY [6]) and motivation (Intrinsic Motivation Inventory [7]). Upper limb kinematic outcome measures will be: shoulder, wrist and elbow range of motion, trunk displacement, endpoint straightness, smoothness and velocity. Kinematic outcomes will be measured during a task in which the children will reach-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 will be assessed. Movements will be recorded using an electromagnetic device (G4, Polhemus, Vermont, sampling rate 120 Hz) from 5 sensors positioned on the arm and trunk. A single evaluator, blinded to group assignment will complete all outcome assessments.

### III. Statistical Analysis

Multiple repeated measures two-way ANOVAs with group (control, continuous, faded) and time (PRE, POST1, POST2, RETENTION) as factors will be performed on the quality and motor performance of the reach-to-grasp tasks and the clinical outcomes. Correlation between sensation variables and improvements of quality and motor performance variables will also be performed.

### IV. Discussion

This study will help determine the appropriate schedule of delivery of feedback that can optimize motor learning and lead to better functional outcomes of the upper limb in children with CP. The appropriate frequency of feedback could be implemented in different interventions aiming at improving upper limb function. This study will also demonstrate the possibility of using a virtual reality system for optimizing motor learning in children with CP.

**References**


