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Serious gaming to improve bimanual coordination in children with spastic cerebral palsy

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Abstract—**Based on recent insights regarding bimanual rhythmic coordination, a set computer games were developed to help children with spastic cerebral palsy (CP) to loosen the coupling between their hands. The games were tested in a small sample, to determine its influences on hand function and bimanual coordination.**

Cerebral palsy, bimanual coordination, real-time visual feedback, Lissajous plane.

I. Introduction

Children with spastic unilateral (hemiplegic) cerebral palsy (CP) suffer from unilateral sensory and motor impairments in the extremities. Along with the deficits on the affected side, hemiplegic CP often results in impaired bimanual coordination inducing functional limitations when both hands are needed to perform a task [3, 4, 5]. Training of bimanual coordination in children with CP may therefore improve their functional independence and quality of life.

Bilateral movement does not simply entail the combination of two unilateral movements, but is characterised by interactions between the hands. When healthy persons move their two hands rhythmically at the same frequency, the interlimb coupling results in attraction to two coordination patterns that can be performed stably: in-phase and antiphase (simultaneous contraction of homologous or nonhomologous muscle groups, respectively) [2, 9]. Other coordination patterns have been proven difficult to perform, even with extended practice [10]. In children with CP the interlimb coupling seems to be stronger than in healthy controls, as is reflected by the occurrence of mirror movements and associated movements [1, 11].

Recent results, obtained for healthy adults, have shown that the coupling between the hands may be overcome when performance is guided by perceptual information. When feedback of the bimanual movements was integrated in a Lissajous plane, the participants were able to perform a wide range of bimanual coordination patterns [6, 7, 8]. In Lissajous plots, the oscillations of one limb are presented along the horizontal axis, while the oscillations of the other limb are presented along the vertical axis. The relative phase between the two oscillations determines the shape of the plot, for instance, a circle (90º) or diagonal lines (0º [in-phase] and 180º [antiphase]).

Those results revealed that Lissajous feedback helps to overcome the constraining influences of the interlimb interactions. Therefore, this type of feedback may be instrumental in helping children with CP to weaken the coupling between their hands, which is expected to improve their possibilities for bimanual coordination.

To examine the potential effects of such Lissajous-based training, a set of computer games were developed. In this way the performance of bimanual coordination patterns was made both implicit and appealing. The effects of this training on functional bimanual activities were examined in a group of children with unilateral spastic CP. The games were devised in such a way, that the children were challenged to move both hands simultaneously in various phase relations, without the explicit instruction to do so. The effects of this training were assessed using several clinimetric tests.

II. Methods

A. Participants

Seven children with spastic unilateral CP (age: 7-12 years), participated in the study. Additional inclusion criteria were: (1) level II or III on the Manual Ability Classification Scale (MACS), and (2) level I or II on the Zancolli classification. Children with severe intellectual or visual disabilities were excluded from participation.

The study was approved by the medical ethics committee of the VU Medical Centre. Both the parents and the children received information letters, and the parents provided informed consent prior to the study.

B. Apparatus

The apparatus consists of two horizontal levers, a computer, and an additional monitor (Figure 1). The angle and distance between the levers can be adjusted to meet the child’s demands. The levers are attached to two linear potentiometers that monitor the movements of the levers. The analogue signal from the potentiometers is converted by a 12 bit AD converter (USB-6008, National Instruments, Texas) to a digital signal to use as input for the computer games.

The computer games were developed using the D-flow software (Motek Medical BV, The Netherlands), using real-time feedback to control the movements of the agents in the computer games.

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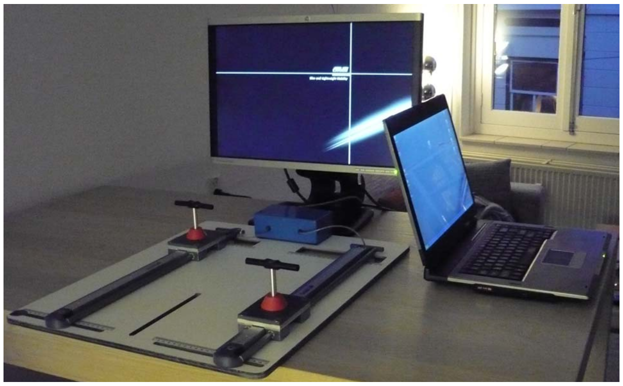

Figure 1. Training setup

C. Training games

The training comprised three computer games that challenged the participants to move their hands according to six different bimanual coordination patterns (viz., phase differences between the hands of 30º, 60º, 90º, 120º, 150º, and 180º) using Lissajous feedback. Left hand movements resulted in vertical displacements on the screen, and right hand movements in horizontal displacements. For example, by moving the hands in antiphase (180º), a penguin could be steered along a diagonal bridge in order to fetch some fish at the other side of an icy stretch of water. The other phase relations corresponded to a circle (90º) and four oval paths, along which a space ship could catch aliens, or a boat could race against another boat. The level of difficulty of the games was adjustable.

The apparatus and training games will be presented during the demo session.

D. Research protocol

A single subject design (ABA-design) was used, consisting of three periods of six consecutive weeks each. During periods A1 and A2, the treatment of the participants was not adjusted (i.e., they receive their usual care, if any). During period B, a training protocol involving the computer games was presented. Period B comprised three training sessions (30 minutes each) per week. These sessions were supervised by an occupational therapist.

The upper extremity performance of each subject was assessed four times: 1) directly prior to period A1; 2) immediately after period A1 and prior to period B; 3) immediately after period B and prior to period A2; 4) immediately after period A2. The following tests were conducted: (1) Assisting Hand Assessment (AHA), (2) Manual Ability Classification Scale (MACS), (3) Zancolli classification, (4) an assessment of the ability to perform in-phase and antiphase arm movements and (5) an unimanual spatial task for both arms. In addition, the degree of spasticity was assessed using the Tardieu scale, by comparing the values prior to the study (steady state) to those obtained at measurement instance 3. Because the AHA score rates the performance on functional bimanual activities, it serves as our primary outcome measure. All tests in the evaluation were conducted by a therapist, who is certified to perform the AHA.

E. Statistical analysis

Repeated-measures ANOVAs are used to assess the differences between the periods for all the variables in the upper extremity performance evaluation.

III. Results

All children improved their performance during the training sessions, as evidenced by their scores on the game that was performed throughout the full training period (viz. the penguin game mentioned before). On average, the number of fishes fetched per minute (corrected for the difficulty setting) increased from 1.5 in the first three sessions to 7.7 in the last three sessions ($t(6) = -3.9$; $p = .008$, 2-tailed paired-samples *t*-test). Whether this positive effect transferred to performance on the various tests, awaits further examination and will be presented on the poster accompanying the demo.

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