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Motor Task Processing After Constraint-Induced Movement Therapy in Children With Cerebral Palsy: A Case Series

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Abstract
Constraint-induced movement therapy (CIMT) has shown positive results in children with hemiplegic cerebral palsy (CP). However, studies on neural basis of such functional gains are limited. This study reports the event-related potential (ERP) changes in two children with hemiplegic CP after receiving CIMT for three weeks. Both cases were nine years old, had a diagnosis of left hemiplegic CP, had normal intelligence, and were able to extend the wrist at least 20° and the metacarpophalangeal joint at least 10° from full flexion. Before and after the three-week intervention, the children participated in ERP sessions with a choice reaction task to capture the changes in neural mechanism after intervention. Both children exhibited improvement in reaction time (RT) in both hand tasks after the intervention. The improvement was larger in the affected hand than the unaffected hand. Improved accuracy rate (AC) and shortened P300 latencies in the affected hand were also demonstrated in both cases. Topographical maps showed that in centro-parietal regions, patterns shifted from central and left-lateralized to more central and right-lateralized. CMIT was a useful method in improving upper limb function in our cases.
Keywords: Constraint-induced movement therapy; Cerebral palsy; Upper limb functional regain; Event-related potentials.

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Introduction

Constraint-induced movement therapy (CIMT) was initially developed for people with stroke.[1-3] It has also been used for children with hemiplegic cerebral palsy (CP) with promising results.[4,5] CIMT involves restraining the unaffected limb so that participants would be forced to use the affected limb.[6] This procedure was theorized to overcome learned non-use or developmental disregard and induces a use-dependent plastic brain reorganization.

Evidence of cortical reorganization from functional magnetic resonance imaging (fMRI) studies include increased cortical representation of the affected extremity,[7] increased activations in the primary sensorimotor cortex of the hemisphere with lesions,[8] and increased bilateral cortical activation in the sensorimotor cortex and a shift in laterality from the ipsilateral hemisphere to the contralateral hemisphere.[9] To our knowledge, there have been no reports on event-related potentials (ERPs) with respect to the use of CIMT on children with CP. Considering their temporal characteristics in identifying neural activities, ERPs allow more precise investigation of cognitive processes associated with CIMT.[10]

This study reports the change in reaction time (RT) and accuracy rate (AC) and the ERP changes of a reaction task in two children with hemiplegic CP after receiving CIMT. Specifically, we investigated the P300 component, which indexes stimulus evaluation and processing,[11] as well as the topographical changes.

Materials and Methods

Participants

The parents of the participants and the participants themselves both gave their written consent to report the results. Children with hemiplegic CP with no previous experience of CIMT were recruited. The two participants (one boy and one girl) were nine years old, both had left hemiplegic CP with normal intelligence, and were able to extend the wrist at least 20° and the metacarpophalangeal joint at least 10° from full flexion. They had no prior experience of CIMT.

CIMT and Procedure

Both children received CIMT for three weeks, five days a week, and six hours a day. They wore a comfortable cotton sling on the unaffected arm. During each 6-hour restraint, a one-hour structured practice incorporating the principle of shaping and repetitive practice was done at the occupational therapy clinic.[12] Prior to the initiation of the treatment and after a three-week period, the children participated in the ERP sessions of a choice reaction task.

Choice Reaction Task and ERP Recording

Each child was required to complete a choice reaction task (a two-choice task) separately for the affected and unaffected hands. They responded by pressing the buttons on an oversized number pad with keys that could be pressed with the index finger or the thumb. Stimuli were pictures of an outlined hand with the responding digit highlighted. When the child saw a thumb highlighted, he or she was required to press the thumb key with his/her thumb. Alternatively, he or she would press the index finger key with the index finger if the index finger was highlighted in the picture. These pictures were modified in a way that the required fingers could be seen easily. Before the experiment, the children were trained to get familiarized with the task. They also completed a practice block of 20 trials to assure that they understood the instruction and the task. The allocation of time in each trial is shown in Figure 1.

There was a total of 8 blocks. Each block was composed of 40 trials. The presentation of the highlighted thumb or index fingers (50% probability each) was randomized in each block.

ERPs were recorded from a 64-channel array of electrodes placed in an extended 10-20 system. The ground electrode was placed at the forehead and these channels were left-mastoid referenced and were re-referenced offline to a linked-mastoid reference. The SymAmps2 EEG amplifier (Compumedics NeuroScan, Charlotte, NC) were used for data capturing. The band-pass filter was set at 0.5–40 Hz, and sampling at 1 kHz. Impedances were set at <5 kΩ. Vertical and horizontal electrooculograms were recorded to monitor eye movements.

Figure 1. A Schematic Display of a Trial (With Left Index Finger Highlighted).

Data Analysis

Data management and analysis of the ERPs were performed with the Scan Version 4.5 (Compumedics NeuroScan, Charlotte, NC). RT and AC of the children's responses were captured as behavioral measures. Recordings were first merged with behavioral data and then linked to an averaged mastoid reference. After that, ocular rejection was applied on all channels. This was followed by filtering (zero phase shift band pass filter 0.1-20 Hz). Stimulus-locked epochs were cut from -200 ms to 800 ms for the male participant and -200 ms to 1150 ms for the female participant and the baseline was corrected to the pre-stimulus interval. Incorrect trials and trials containing artifacts (±75 uV) were rejected. The remaining trials were then averaged for analysis. Peak latency for P300 was measured between 250 ms and 700 ms from the channel CPz and Pz.

Results

Behavioral Results

Both children exhibited improvements in RT in both tasks for the right and left hands after the three-week intervention. The improvement was larger in the affected left hand (733 ms to 659 ms for the boy and 1104 ms to 1051ms for the girl) than the unaffected right hand (583 ms to 573 ms for the boy and 894 ms to 882 ms for the girl). Improved AC in the affected hand was also demonstrated in both cases after the treatment (79%-89% for the boy and 89%-94% for the girl).

ERP Results

P300 latency is shown in Table 1. P300 latency was shorter post CIMT in both cases. Figure 2 presents the ERP waveforms of a channel CPz.

Figure 3 show the topographic map of the children before and after CIMT. In both cases, in the centro-parietal regions, patterns shifted from central and left-lateralized to more central and right-lateralized (from 300-500 ms for the boy and from 420-840 ms for the girl after stimulus presentation).

Discussion

The goal of the present study was to investigate P300 as

Table 1. P300 Latency for the Two Clinical Cases

	P300 Latency (ms)	
	Before CIMT	After CIMT
Boy	332	274
Girl	626	417

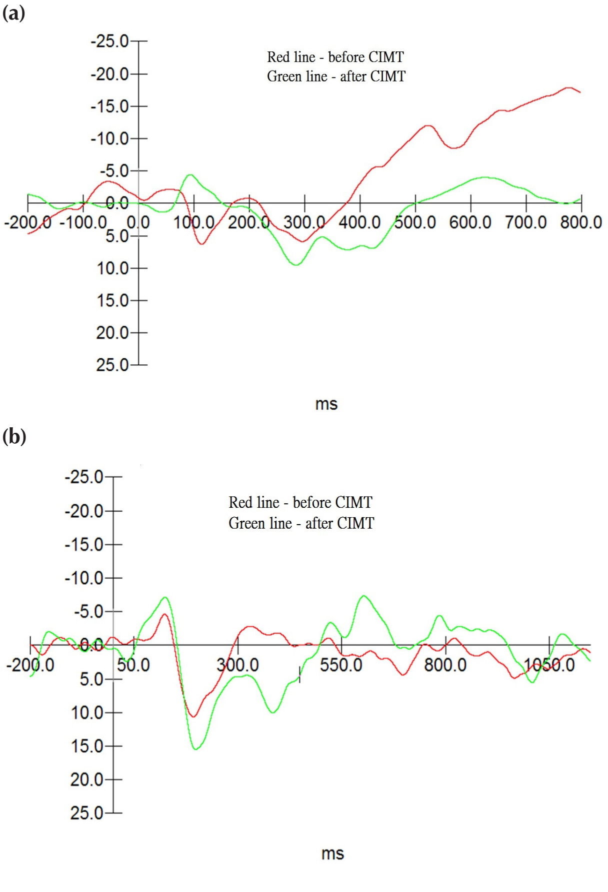

Figure 2. (a) ERPs at CPz of the Boy. (b) ERPs at CPz of the Girl.

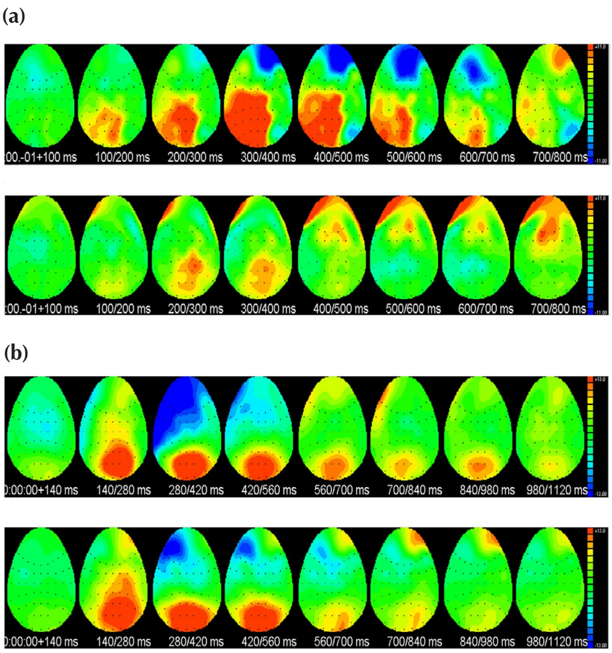

Figure 3. (a) Topographical Maps of the Boy Before and After CIMT. (b) Topographical Maps of the Girl Before and After CIMT. *Note*. Upper row represents pre- and lower row post-treatment. Each map is separated by 100 ms.

well as topographical changes after the children received CIMT. Behavioral data showed shorter RT and higher AC after treatment. P300 latency was shortened as well. Possible meaningful topographical change was evident in the centro-parietal regions.

The RT improvement was larger in the affected left hand than the unaffected right hand in both children. RT improvement in the unaffected hand may be attributed to the learning effect since both children had a second opportunity to perform exactly the same task. The larger RT changes in the affected hand may possibly be accounted for by the treatment effect of CIMT.

Previous findings have suggested that there may be a delay in P300 latency in similar motor tasks for people with brain injuries as compared with healthy participants.[13,14] P300 could be used as a marker for attentional processing as well as stimulus evaluation processes.[11,14] While there was no normal group for comparison, the latency of P300 component was shorter after CIMT for these two children. Thus, it may indicate that changes in the pre-motor stage of the cognitive processes related to this choice reaction task could have occurred because of the treatment provided. This was an important additional finding. Other than the cortical reorganization as revealed by fMRI, in these two cases, CIMT enhanced very initial attentional processing and stimulus evaluation that are important in accurate motor performance.[15] This offers a sound explanation of the clinical evidence that CIMT improved motor functions of people with hemiplegia.

Some evidence of motor-related changes may be gathered from the topographical maps of the two children. In this regard, the activities in the posterior aspect of the brain appear to shift rightward from a more central or left-lateralized pattern. As shown in other fMRI studies, cortical reorganization post-CIMT may include increased activations in the primary sensorimotor cortex of the lesioned hemisphere[7,8] and a shift in laterality from the ipsilateral hemisphere to the contralateral hemisphere.[9] Therefore, the topographical results in this study could also be interpreted along similar lines assuming that the neural substrates generating these topographical patterns are similar.

Conclusion

The results of this case study showed that CIMT could implicate both processes related to interpreting incoming stimulus (attention, perception, and evaluation) as well as motor processes for response execution. The findings of this study may provide additional information that further strengthen the clinical evidence of CIMT. More participants will be needed to confirm these findings and permit statistical analysis.

Conflict of Interest

The authors declare that they have no conflict of interests.

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Authors' Contributions
KL, KT and MK were involved in the study design and the data collection process. KL and MK drafted the manuscript, KL, KT and MK finalized the manuscript. All authors are accountable for all sections of the manuscript and declare that it is written originally and there is no data fabrication and falsification.

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Ethical Statement
The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 1983. The study was approved by the Hong Kong Polytechnic University, Department of Rehabilitation Sciences research ethics committee. The participants were provided with an information sheet and the study was explained to them verbally, providing an opportunity for them to discuss any concerns prior to providing written consent. Informed written consent was obtained for the participants before the start of the study. Confidentiality of information was maintained throughout the study.

Availability of Data and Materials
The datasets used and/or analyzed during the current study are available from the Corresponding author on reasonable request.

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