Measuring the effect of affective stimuli on autonomic responses and task performance in a virtual environment by children with and without cerebral palsy

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ABSTRACT

This study examined whether a functional virtual environment (VE) may be used to provide affective stimuli (AS) that lead to changes in the emotional responses and task performance of children with and without cerebral palsy (CP). Fifteen children with CP and 19 typically developing (TD) peers (6 to 12 years) prepared seven virtual meals in a predefined order within a virtual meal-making VE, referred to as the Emotional Meal-Maker (EMM), run on a 2D video capture VR platform. During each of six meals either a negative, positive, or neutral visual stimulus, selected from the International Affective Picture System (IAPS), was displayed. Heart rate (HR) and skin conductance (SCR) were recorded online in synchrony with stimulus onset. These variables were also recorded when the children passively viewed the same sequence of affective pictures displayed onscreen while rating their valence and arousal levels. Autonomic responses were calculated as the amount of change in the autonomic variables compared to baseline. Correlations between behavioural characteristics (i.e., trait and state anxiety) with both autonomic responses and task performance were also calculated. Significant differences were found between groups in task performance and heart rate variability (HRV) components, i.e., a higher "low frequency" (LF) to "high frequency" (HF) ratio in the children with CP during the meals in which a negative stimulus was displayed ($U= 59.00$, $p= 0.011$) and during the passive visual display, regardless of type of stimulus. For children with CP, the amplitude of skin conductance response during the passive pictures display was significantly higher for negative stimuli (0.80 ± 0.46 µS) than for positive stimuli (0.52 ± 0.28; $Z= -2.38$, $p= 0.017$), but there were no significant changes in autonomic responses as a function of stimuli during meal-making. Positive correlations were found in the CP group between trait anxiety and the LF:HF ratio during virtual meal-making with positive ($p< 0.05$) and negative stimuli ($p<0.01$) but not during meals when stimuli were neutral. The implications of these results are discussed.

1. INTRODUCTION

Children with a diagnosis of Cerebral Palsy (CP) have sustained primary impairments in the neuromuscular system that are activity limiting. The motor disorders are usually accompanied by disturbances of other systems such as sensation, perception, cognition, and behaviour (Rosenbaum et al., 2007). Psychological problems such as anxiety, feelings of helplessness, low self esteem, social problems and dependency have been reported in 25% to 60% of children with CP (Cohen, 2008; Krakovsky et al., 2007; Sigurdardottir et al., 2010). Overall, these problems were found to be significant barriers to participation in many activity domains (Engel Yeger et al., 2009; Imms, 2008; Majnemer et al., 2008; Parkes et al., 2010), as well as in social life and communication (Voorman et al., 2006).

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The influence of affective stimuli (AS) on task performance and children's participation is currently unknown, although there is evidence to suggest that the effect may be substantial at many levels (Mihaylov et al., 2004; Shapiro et al., 2009). The literature emphasizes that visual, auditory and olfactory stimuli can capture and divert attention regardless of their relevance to ongoing tasks (Dolcos and McCarthy, 2006). Helton and Russell (2011) further demonstrated that negative emotional stimuli that are unrelated to a task on attention-disrupted target detection even when the affective stimuli and the targets were not displayed concurrently. Several studies have demonstrated significant differences in emotional responses to stimuli between typically developing children and children with developmental delays and/or behavioural problems (e.g., Boakes et al., 2008; Conrad et al., 2007; Dawson et al., 2004; Mueller et al., 2012). For example, Shapiro et al. (2009) examined the effect of two different dental environments on the arousal level as measured by electrodermal activity in children with and without developmental disabilities. They found that a sensory adaptive environment that included special lighting effects, relaxing music, vibration, and aromas versus a conventional environment had a significantly greater calming effect on children in both groups with the decrease being most pronounced in the children with developmental delays.

Over the past decade, virtual reality technology (VR) has evolved into an evaluation and intervention tool for children with special needs (Laufer and Weiss, 2011; Parsons et al., 2009; Sandlund et al., 2011). Gesturetek's IREX video capture VR system has been shown to provide enjoyable leisure activity for young adults with cerebral palsy and severe intellectual disabilities (Weiss et al., 2003) and appears to lead to increased self-esteem, motivation (Harris and Reid, 2005) and sense of mastery in children with CP (Reid, 2002a). Studies further indicate the effectiveness of VR in promoting motor control (Bryanton et al., 2006), upper extremity functioning (Reid, 2002b) and cortical reorganization (You et al, 2005). Video capture VR may be programmed to present sensory stimuli (e.g., visual images, sounds) that accompany virtual games and functional virtual environments (VEs), providing a controlled environment for the measure of emotional aspects of children during a functional task performance.

The objectives of the study were two folded: 1) to determine whether a functional virtual environment may be used to provide affective stimuli that lead to changes in the emotional responses and in task performance outcomes of children with CP, and 2) to examine differences in emotional responses and task performance between children with CP and typically developing peers.

2. METHODS

2.1 Subjects

Fifteen children with spastic CP (study group, mean ± SD = 9.3 ± 1.4 years, 7 boys, 8 girls) and 19 typically developing (TD) children (control group, mean ± SD = 8.9 ± 1.6 years, 9 boys, 10 girls) participated in the study. Children with CP were included if they had Gross Motor Function Classification System (GMFCS) (Palisano, et al., 1997) score's range 1 to 4, had intact or corrected vision and hearing, were able to reach with their dominant hand, were able to follow multi-step instructions, and were medically stable. Ethical approval was granted by the Institutional Review Boards of the University of Haifa, the Bnai Zion Medical Center, and the Israeli Ministry of Education.

2.2 Virtual Reality Apparatus: the Emotional Meal-Maker

The Emotional Meal-Maker (EMM) VE is a modified version of the Meal-Maker, a virtual kitchen environment developed within the IREX video-capture VR system (gesturetekhealth.com) (Kirshner et al., 2011). Children were instructed to prepare as many repetitions as possible of seven different meals in a predefined order. Each meal included five relevant items for meal preparation and two non-meal distracter items, all located on virtual kitchen shelves. A 2D video camera recorded the child's gestures which thereby controlled navigation and selection of items. Only movements made by the dominant hand which was holding a red cone were captured. Selection of the virtual meal items was accomplished by dwelling over the item for 2 s. Selected items were transferred to a virtual table. Once all correct items were selected, the child hovered over a virtual "finish" button and a visual feedback on success or failure was provided.

Six different pictures from the International Affective Picture System (IAPS) (Lang et al., 2005) were selected to evoke different emotional responses in the children. Except for the first meal (hot chocolate) which was considered as a baseline meal without any AS, each of the remaining six meals presented a different stimulus with the sequence of the AS being randomized across subjects. Pictures were selected based on their valence ratings (Lang, et al., 2005). All the selected stimuli were of adult male faces. The exclusion of other affective picture types was made in order to limit possible interferences by other content, such as in animals and scenes. The onset of stimuli within each virtual meal was programmed to occur after the child had selected the second meal item and before selecting the third item. The duration of each stimulus was set to 4 s.

2.3 Autonomic Recording and Data Reduction

Electrocardiogram (ECG) and skin conductance level (SCL) were monitored to record changes in autonomic responses via the Biopac System (www.biopac.com). These measures were selected since they represent a relatively non-obtrusive way to monitor autonomic functioning and appear to reflect emotional responses that result from affective stimuli (McManis et al., 2001). The EMM and Biopac systems were synchronized using a voice-recognition marker.

ECG Biopac EL 501 electrodes were placed over the lateral aspect of the left and right intercostal space between either the eighth and ninth ribs or ninth and tenth ribs, in a straight line below the axila. This placement was selected to maintain uniform skin contact without disturbance by upper arm and trunk movement. The ground electrode was initially placed about 10 mm above the medial malleolus of the left leg, however due to spasticity related movement of the legs observed in children with CP during the EMM, the ground electrode was placed about 2 cm to the left of the L3-L4 spiny processes.

The data were sampled at 1000 Hz and stored on a computer running Acqnowledge 3.9.1 MP100 data acquisition software. The ECG signal gain was set at 1000. The low pass (LP) filter for ECG was initially set to 35 Hz and the high pass (HP) filter was set to 0.5 Hz, with a further 2 Hz HP filter applied post acquisition.

The time between successive R waves (RR interval) was identified via the MP100 and manually checked and verified. Time domain analysis (NN50, pNN50, square toot of the mean squared differences of successive NN (RMSSD)), representing parasympathetic activity, as well as frequency domain analyses (absolute and normalized powers' values of low frequency (LF) and high frequency (HF), LF:HF ratio), indicating of sympathovagal regulation, were analyzed off-line to measure the change in heart rate variability (HRV) via Kubios HRV software version 2 (www.kubios.uku.fi).

Tonic SCL was recorded via a Biopack TSD203 SCL transducer filled with isotonic electrogel placed over the volar surface of the middle phalanges of the second and third finger of the non-dominant hand. Log transformation was carried out to normalize the distribution. The tonic SCL signal was recorded with the high pass filter set to off (DC mode); the low pass filter (LP) was set at 3 Hz post acquisition. The amplification was set to 5µSiemens/volt. AC-coupled skin conductance fluctuations were analyzed offline using AcqKnowledge 4.1 software by Biopac systems Inc. The phasic signal was derived from the tonic SCL using a smoothing baseline removal method. Amplitude of skin conductance response (SCR), measured in µSiemens (µS), was set to be the largest change relative to baseline within 1 to 6 s after stimulus onset. SCRs were included in the analysis only if the amplitude was at least 0.01 µSiemens. The square roots (SQRT) of all SCR responses were calculated in order to reduce the skewness of the distribution (Hempel et al., 2007).

Autonomic responses were calculated as the amount of change in the autonomic variables compared to baseline. For the EMM task, the baseline was considered to be the magnitude of the response that occurred during the hot chocolate meal, and for the passive visual slide display task, the baseline was considered to be the magnitude of the response that occurred during the calm state. A positive or a negative result denoted either an increase or decrease in a specific autonomic variable compared to baseline. Mean scores for autonomic responses of the same content (negative, positive, neutral) were then calculated.

2.4 Procedure

After signing informed consent, the children and their parents completed behavioural questionnaires (state and trait anxiety (STAI-S, Spielberger, 1973) and were introduced to the VR system by playing the Meal-Maker followed by a short break. ECG and SCL were monitored during three conditions: calm-state (2 minutes steady state while children sat with eyes closed listened to calm statements), while using the EMM, and during the passive visual slide display. In the latter task, the participants were required to view the AS and rate their valence and arousal using the Self-Assessment Manikin (SAM), a non-verbal pictorial rating scale (Bradley and Lang, 1994). The flow of the study protocol is presented in Fig. 1.

Based on recommendations by the Heart Rate Variability (HRV) task-force (Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) the onset of the EMM marker was followed by a 2 min sampling period in order to collect sufficient HRV data for analysis. The children's cooperation during this period was encouraged by instructing them to prepare as many repetitions of each meal as they could within the 2 min period. As in the EMM, the time-interval between each AS presented within the passive visual slide display was 2 min, and was accompanied by narrated stories from the "Grimm Brothers" tales in the same order and similar intonation for all children.

Following completion of both the MM and EMM VR tasks, subjective responses were recorded via the Short Feedback Questionnaire, child version (SFQ-Child). Online performance measures recorded during the EMM included number of correct and incorrect repetitions for each meal, total meal preparation time, and percent success (total number of correct repetitions divided by the total number of meals).

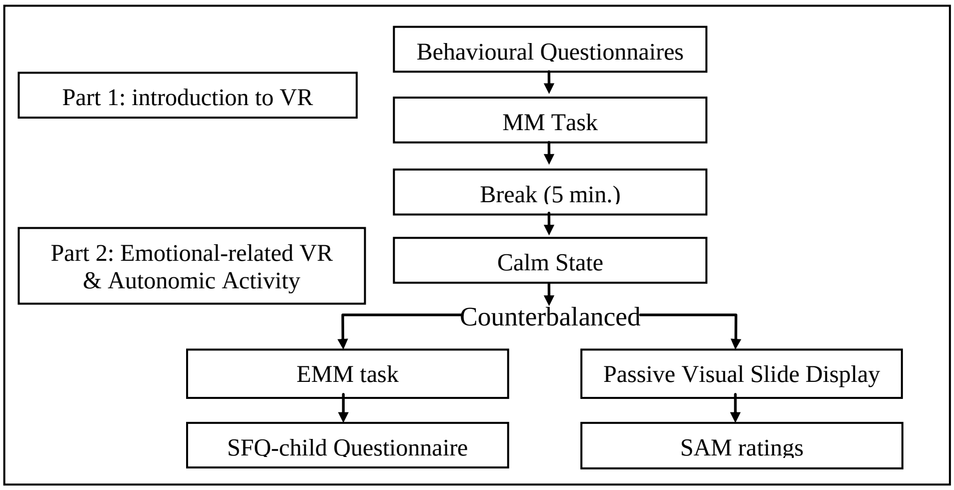

Figure 1: *Overview of study protocol.*

2.5 Statistical Analysis

The Statistical Packages for the Social Sciences (SPSS) version 15 was used for statistical analysis. A mixed design MANOVA (between subjects: CP versus typically developing children; within subjects: emotional subjective and autonomic response and task performance) with repeated measures was conducted to evaluate the differences in emotional responses and task performance while preparing a virtual meal with or without the presence of affective stimuli. Due to non-normal distributions of many of the autonomic and performance variables non-parametric tests were also used to examine differences in autonomic responses and task performance as a function of AS type within groups (Friedman test and Wilcoxon signed ranks test) and between groups (Mann-Whitney test).

Alpha was set at 0.05 but a Bonferroni correction re-defined alpha to be 0.02 for non-parametric comparisons of the three time-domain HRV components (NN50, pNN50, and RMSSD), and 0.01 for non-parametric comparisons of the five frequency-domain HRV components (absolute LF and HF values, normalized LF and HF values, and LF/HF ratio). Correlations between the behavioural questionnaires (anxiety, sensory profile) and SAM ratings with both autonomic responses and performance variables were also calculated. The Spearman correlation test was used to examine the relationships between behavioural, performance and autonomic outcomes.

3. RESULTS

3.1 Differences between Groups

In general, children with CP demonstrated different autonomic responses compared to the TD group as presented in Fig. 2. Children with CP had significantly higher heart rate and shorter RR intervals during both the calm state ($t(31) = -2.665$, $p = 0.012$) and during EMM activity ($t(31) = 2.651$, $p=0.013$) compared to TD peers. Although not significant ($\alpha > 0.01$) the normalized LF powers were higher for children with CP (56.60 ± 19.69 n.u.) than for typically developing (41.82 ± 19.69 n.u.; $U= 76.00$, $p= 0.033$) while the normalized HF values were lower for children with CP (43.40 ± 19.69 n.u.) than for typically developing (58.18 ± 20.19 n.u.; $U= 76.00$, $p= 0.033$). The LF:HF ratio of the CP group (2.15 ± 2.66) was higher than that of the TD group (0.98 ± 0.88; $U= 76.00$, $p= 0.033$).

Furthermore, while for children with CP no significant differences in autonomic activity were found when moving from calm state (hot chocolate meal) to an active EMM task for the control group, the SCL during hot chocolate preparation (0.95 ± 0.19 μS) was significantly higher than for the calm state (0.90 ± 0.16 μS; $t(18) = -3.513$, $p= 0.002$).

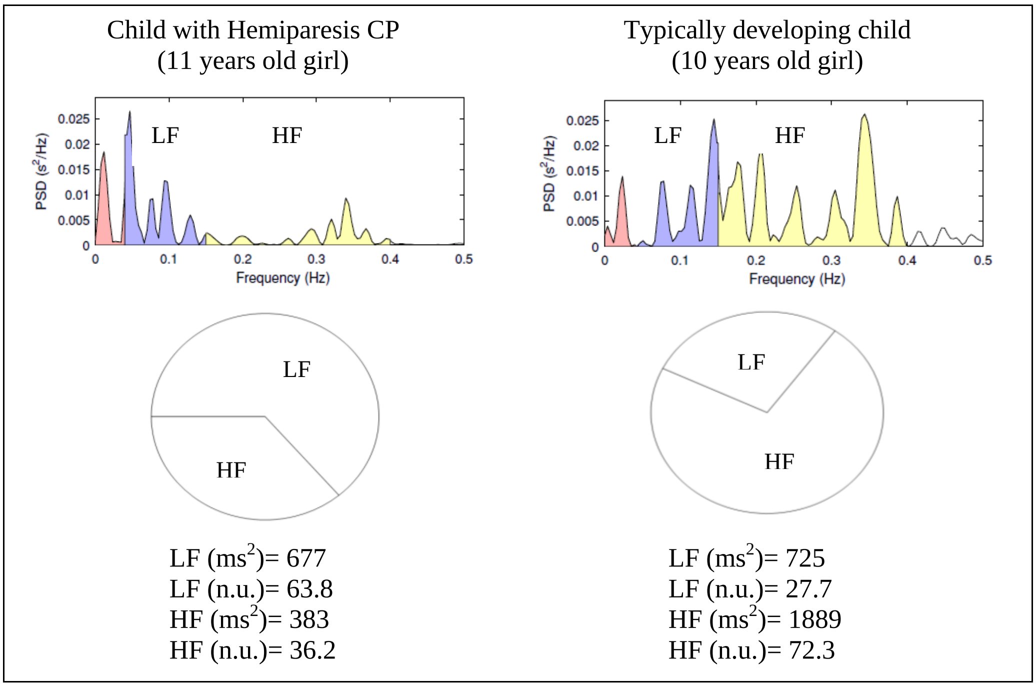

Figure 2: *Spectral analysis of HRV of two subjects during calm state, one with CP and one typically developing child. The FFT spectrum (Welch's periodogram), which indicates the presence of two major components (LF= low frequency; HF= high frequency) is illustrated in the top panels. In this example, the LF component of the child with CP is markedly dominant during calm state as compared to the typically developing child. The pie charts illustrate the distribution of LF and HF components. The graph format was adapted from [Montano et al., 2009].*

For the EMM task, HRV as represented via the LF:HF ratio response, increased significantly for children with CP (1.35 ± 1.40) relative to the typically developing children (-0.14 ± 1.28) only during the negative-related meals (U= 59.00, p= 0.011), as illustrated in Fig. 3. Greater increases in LF:HF responses were further demonstrated for the CP group than for their typically developing peers during passive visual slide display task (negative: U= 74.0, p= 0.027; neutral: U= 79.5, p= 0.045; positive: U= 63, p= 0.009).

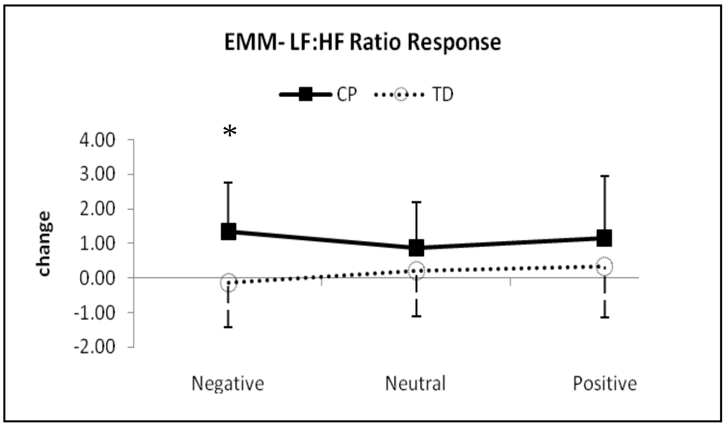

Figure 3: *HRV differences between the CP group (black line) and the typically developing group (dotted line) as a function of affective stimuli type in the EMM task (*p<0.05)*

The Mann-Whitney test found significant differences between children with CP (left panel) versus a typically developing peer (right panel) in several variables: the overall number of meals' repetitions was significantly higher for typically developing children (28.89 ± 2.21) than for children with CP (23.00 ± 4.33, U= 17.0, p= 0.000), and the overall number of correct repetitions was also significantly greater for the control group (24.79 ± 3.57) than for the CP group (17.93 ± 5.11; U= 37.0, p= 0.000). Furthermore, children with CP were in general significantly slower (165.34 sec.± 9.68) compared to typically developing children (156.67 sec. ± 8.01; U= 64.0, p= 0.012) and they invested significantly more time preparing incorrect meals' (37.08 sec. ± 23.65) compared to the control group (21.32 sec. ± 15.0, U= 74.0, p= 0.032). The overall EMM performance success was significantly lower for children with CP (76.94% ± 13.41) than for typically developing children (85.76% ± 9.99; U= 77.0, p= 0.041).

3.2 Differences in Autonomic Responses and Task Performance as a Function of Affective Stimuli

Children with CP rated positive pictures as significantly more pleasant compared to both negative and neutral pictures (p≤ 0.05) and negative pictures were rated as significantly more arousing and less pleasant than both positive and neutral pictures (p< 0.05, p< 0.001, respectively) in the control group. Overall, the valence ratings of both positive and negative pictures, but not of neutral pictures, were significantly higher in the CP group compared to the control group (U= 79.5, p= 0.027; (U= 84.00, p=0.041, respectively). Arousal ratings did not significantly differ between groups.

Within the CP group, SCR amplitude during the passive visual slide display task was significantly higher for negative pictures (0.80 ± 0.46 µS) than for positive pictures (0.52 ± 0.28 µS; Z= -2.38, p= 0.017). However, despite the significant differences reported in the subjective ratings between AS types, children with CP did not have any significant differences in either autonomic responses or performance outcomes as a function of AS type within the EMM task).

Within the control group, the Friedman test showed significant differences in some of the time-domain HRV components (NN50, pNN50) as a function of AS type (negative, neutral, positive) during both the passive visual slide display task (NN50, Chi Square= 9.768, p= 0.008; pNN50, Chi-Square = 11.444, p= 0.003) and the EMM task (NN50, Chi Square= 12.028, p=0.002; pNN50, Chi-Square= 10.11, p=0.006). More specifically, during the passive visual slide display task there were significantly greater decreases in NN50 responses and pNN50 responses for neutral pictures than for positive pictures (NN50, Z= -2.795, p= 0.005; pNN50, Z= -2.678, p= 0.007), and during the EMM task the decrease in NN50 values compared to the baseline meal was significantly greater for neutral-related meals (-9.58 ± 13.76) than for negative-related meals (-3.53 ± 10.75; Z= -2.289, p= 0.022), suggesting that parasympathetic activity was significantly reduced during neutral-related compared to negative-related meals. As in the CP group, typically developing children did not show significant differences in EMM performance outcomes as a function of AS type.

3.3 Correlations with Behavioural Characteristics

Positive correlations were found in the CP group between trait anxiety and LF:HF ratio responses in virtual meals with positive (p< 0.05) and negative stimuli (p<0.01) but not during meals when AS were neutral. For the control group there were significant correlations between trait anxiety and both RR interval response (Rs= 0.585, p= 0.014) and heart rate response (Rs= -0.576, p= 0.012) during negative-related meals in the EMM task, indicating that during negative related meals, the more anxious typically developing children were the greater the increase in RR interval compared to baseline and the greater the decrease in heart rate compared to baseline, and vice versa.

There were no significant differences in trait and state anxiety between the groups (t (32) = -0.12, p= 0.905; t (32)= 0.82, p= 0.418, respectively).

4. DISCUSSION

This study examined whether video capture VR can be used as a platform to measure emotional aspects of function, and to what extent the autonomic responses and related performance of children with CP differ from that of typically developing peers. There were significant differences in task performance between groups in that the children with CP performed the EMM task significantly more slowly than their TD peers, prepared fewer correct meals and fewer total meals, supporting our previous work (Kirshner et al., 2011). With regard to autonomic activity, significant differences were recorded in autonomic activity between children with CP compared to typically developing peers at rest and during activity, e.g., higher heart rate for children with CP during rest and AS conditions, and higher LF:HF response during passive visual slide display task and during negative-related meals' preparation in the EMM task. The present study further found that when task's demands changed, for example, when children shifted from the calm state to active engagement in the virtual meal preparation task, there were significant autonomic adaptations within the typically developing children but not for the CP group.

These results are supported by the study of Park, et al. (2002) who found significant differences in frequency domain HRV components during 3 minutes of supine position and 3 minutes of head-up tilt position between twelve children with CP aged 6 to 11 years compared to twelve typically developing children. During the supine position children with CP had a significantly greater LF: HF ratio compared to the control group, indicating greater sympathetic autonomic predominance in HR than healthy controls. Furthermore, the absolute and normalized LF powers as well as the LF:HF ratio during typically developing children's head-up tilt position were significantly increased compared to supine while the absolute HF power was significantly reduced compared to supine. These changes were not observed in the CP group. Similar results were reported by other studies who examined changes in autonomic activity between children with and without CP during supine and either head-up tilt (Yang et al., 2002) or standing (Zamuner, et al., 2011) positions. The researchers suggested that observed disturbances in cardiac autonomic regulation in children with CP are the result of loss of hemispherical influences on autonomic modulation occurring from the brain lesion itself, which may result in less adaptive reserves of the autonomic cardiac regulation (Yang et al, 2002; Zamunr, 2011). Zamuner et al. (2011) further suggested that children with CP have greater energy expenditure due to muscular tone alterations, involuntary movements, and inefficient use of muscles during compensatory muscle activity, which may account for the observed sympathetic predominance.

The processing of emotional information is considered to be prioritized relative to other incoming data (Pessoa, 2005), and hypothesized to be related to individual survival mechanisms by providing adaptive responses to safe, dangerous and life-threatening events and contexts (Lang and Bradley, 2010; Porges, 2009). Changes in autonomic responses as a function of affective stimuli were observed during the passive visual slide display task, however, they differed between groups; children with CP had significant increases in intensity of skin conductance response in the presence of negative pictures compared to positive, while typically developing children had significant increases in time domain components of HRV indicating greater parasympathetic reactivity in the presence of positive pictures compared to neutral ones. Both groups rated positive pictures as significantly more pleasant compared to both negative and neutral pictures, and negative pictures were rated as significantly less pleasant compared to neutral pictures. Taken together, these outcomes match existing evidence that emotional-related pictures can evoke subjective as well as autonomic responses in children (McManis et al, 2001; Sharp, et al, 2006). This provides support for the use of the EMM as a platform for investigating the emotional responses of children.

In contrast, when children performed a task in a virtual environment, preparing virtual meals in the presence of different affective stimuli, autonomic responses did not differ between stimulus types (in the case of children with CP) nor were greater autonomic responses observed during the neutral-related meals (in the case of typically developing children). Furthermore, there were no significant differences in EMM performance outcomes as a function of affective stimuli for either group of children. These findings are partially supported by the literature, emphasizing the interplay between emotion and cognition (e.g., Dennis, 2010; O'Toole et al., 2011). O'Toole et al. (2011) examined the interplay between task-irrelevant emotional stimuli and attention under different task difficulty demands in a sample of 63 healthy adults. In the case of the easy attention task, threatening pictures facilitated orientation, however, when task difficulty increased there were no significant differences in task performance as a function of stimulus type. A recent review by Dennis (2010) of event related potentials (ERP) studies in typically developing children further indicates that emotion and cognition act in an integrative way, that is, specific emotional state and cognitive functions have a bidirectional effect on one another in several ways, and in fact, at some stage of task processing cognition and emotion equally contribute to behavioural regulation. In the current study, the EMM task was a novel task for children in both groups, and required sustained attention during a minimum period of 14 minutes in order to be able to make as many repetitions of each meal as possible. This in itself may have considerably reduced the amount of attention paid to other, non-task-relevant stimuli, resulting in less interference by affective stimuli within the environment. It may be that a more pronounced or more dominant affective stimuli would have elicited a stronger response even during a continuous task such as the EMM. The literature shows that among the factors that contribute to intensity of emotional reactivity are physical properties of stimuli (e.g., picture size or duration of stimulus exposure), experience with the presented stimulus, and individual differences (Codispoti & De Cesarei, 2007; O'Toole et al., 2011). Moreover, the use of more than one type of affective stimulus may lead to contamination of emotional effects across trials (O'Toole et al, 2011). Since the current study was exploratory, it followed the principal idea that the natural daily environment includes many types of sensory stimuli, and it therefore, more natural to present negative, positive and neutral stimuli within the virtual kitchen task. There is a need to further examine to what extent changing the timing and style of the presentation of affective stimuli within the virtual environment will facilitate interference effects on both autonomic reactivity and task performance.

Trait anxiety was found to be an important factor in the way children handle affective stimuli, suggesting that children with higher trait anxiety have more difficulty in resisting interference effects from threat-related distracters (negative facial pictures) during a cognitive control task (Ladouceur et al., 2009; Mueller et al., 2012). In the current study, trait and state anxiety did not differ between children with and without CP.

However, different correlation patterns were observed between groups in EMM meals with different AS types. Cohen, et al., (2008) examined the associations between locus of control, parenting style, and anxiety in children with CP compared to their typically developing siblings. Their findings support the present study's outcomes, demonstrating that while baseline anxiety levels did not differ between children with CP and their siblings, there were different patterns of interactions between anxiety with psychosocial factors (locus of control, parenting style) in the two groups.

5. CONCLUSIONS

Efforts to improve the participation and performance of children with CP are usually related to the adaptation of environmental conditions to meet their cognitive and motor abilities. However, the influence of affective stimuli within the environment on emotion and performance, and their ability to improve or impede the children's participation has not been investigated in any systematic way although the emerging evidence that it affects the individuals in many levels. In general, video-capture meal-making VE was shown to be a feasible platform for the investigation of the autonomic responses of children with and without CP. Furthermore, it permitted the recording of standard physiological measures (such as skin conductance response and heart rate variability) which may have been difficult to monitor and control otherwise. They were found to be valuable for the understanding of the relation between the subjective feelings of emotions and body function.

Further studies are needed to develop additional measurements of emotional responses and to refine the types of affective interference. It is further recommended to examine the contribution of the severity of the CP type to the way children recognized and responded to affective stimuli and its relationship with autonomic responses, stress, and performance.

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