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Differences in autonomic functions as related to induced stress between children with and without cerebral palsy while performing a virtual meal-making task☆,☆☆

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ABSTRACT

Background: Efforts to improve the participation and performance of children with cerebral palsy (CP) are often 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 suggests that it affects the individuals in many levels.

Objectives: (1) To measure autonomic responses to affective stimuli during a simulated Meal-Maker task in children with CP in comparison to children who are typically developing, and (2) to examine the interactions between autonomic functions, subjective reports of stress, and task performance among children with and without CP.

Methods: Fifteen children with CP and 19 typically developing peers (6 to 12 years) participated. After completing behavioral questionnaires (e.g., State and Trait Anxiety Inventories), children prepared meals within a camera tracking virtual Meal-Maker environment. Either a negative, positive, or neutral visual stimulus was displayed, selected from the International Affective Picture System. Children also passively viewed the same pictures while rating their valence and arousal levels. Heart rate (HR) and skin conductance were recorded synchronously with stimulus onset.

Results: Significant differences in autonomic functions were found between groups, i.e., a higher "low frequency" to "high frequency" (LF:HF) ratio in the children with CP during the meals associated with a negative stimulus ($p = 0.011$). Only children with CP had significant positive correlations between trait anxiety and LF:HF ratio during virtual meal-making associated with positive ($p = 0.049$) and negative stimuli ($p = 0.003$) but not during neutral stimuli. For children with CP the amplitude of skin conductance response during passive picture viewing was significantly higher for negative than for positive stimuli ($p = 0.017$) but there were no significant changes in autonomic responses during virtual Meal-Maker task.

☆ The results presented in this paper were carried out during the doctoral studies of the first author who was a PhD student in the Dept. of Occupational Therapy, University of Haifa. Her doctoral advisors were the second and third authors.
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Significant correlations between trait anxiety, autonomic activity during the calm state and Meal-Maker performance outcomes were found only for children with CP.
Conclusions: In general, the Meal-Maker virtual environment was shown to be a feasible platform for the investigation of the effect of emotionally loaded stimuli on the balance of autonomic functions in children with and without CP. Anxiety level appears to play a significant role in children with CP and should be considered as a potentially important factor during clinical evaluation and intervention. Further studies are needed to develop additional measurements of emotional responses and to refine the types of affective interference.

1. Introduction

Cerebral Palsy (CP) refers to a group of permanent disorders in the development of motor and postural control that are of cerebral origin, acquired either before birth or during the first years of life (Rosenbaum et al., 2007; Shevell, Majnemer, Poulin, & Law, 2008). It is the leading cause of motor impairments in childhood (Kerr, McDowell, Parkes, Stevenson, & Cosgrove, 2011) with an estimated incidence of 2–3 occurrences per every 1000 live births in the developed world (Andersen, 2011). Studies have shown that personal, clinical and environmental factors all pose significant barriers in the engagement, performance and participation of children with CP in everyday tasks (Engel Yeger, Jarus, Anaby, & Law, 2009; Himmelmann & Uvebrant, 2011; Imms, Reilly, Carlin, & Dodd, 2008; Majnemer et al., 2008; Mihaylov, Jarvis, Colver, & Beresford, 2004; Parkes, McCullough, & Madden, 2010; Shikako-Thomas, Majnemer, Law, & Lach, 2008), highlighting the importance of considering the contribution of these factors during the evaluation and treatment of children with CP.

Both task demands and environmental stimuli, such as visual images, temperatures, sounds and smells, have an effect on the way children process incoming information (e.g., Bush, Alkon, Obradovic, Stamperdahl, & Boyce, 2011; McManis, Bradley, Berg, Cuthbert, & Lang, 2001; Sharp, van Goozen, & Goodyer, 2006; Schell & Crone, 2013; Tottenham, Hare, & Casey, 2011). Environmental stimuli including emotionally loaded stimuli, also referred to as affective stimuli, may capture and divert attention regardless of their relevance to ongoing tasks (Dolcos & McCarthy, 2006), affecting children's cognitive control processes (Tottenham et al., 2011; Schell & Crone, 2013) and eliciting a range of subjective and autonomic responses (McManis et al., 2001; Shapiro, Sgan Cohen, Parush, & Melmed, 2009; Sharp et al., 2006). Shapiro et al. (2009), for example, demonstrated the significant value of a sensory adapted environment that included special lighting effects, relaxing music, vibrations, and aromas on the comfort level of children with and without developmental disabilities undergoing dental treatment as measured via electrodermal activity. They found that among the children with developmental delays the calming effect was more pronounced compared to typically developing children.

The ability of a person to perceive the significance of an environmental stimulus and to generate rapidly an appropriate response is an important aspect of optimizing behavior and performance (Nelson, Lau, & Jarcho, 2014). Emotions have an important role in this process, serving as modulators between the internal state of the person and the stimulus or context in which they are encountered (Nelson et al., 2014). Emotions can be described as "dispositions to action", reflecting central activation and preparation for action (Lang & Bradley, 2010). The regulation of emotional reactivity is defined as "a set of processes used to modulate emotional arousal" (Ursache, Blair, Stifter, & Voegtline, 2013, p. 128). Over the past two decades emotion regulation has become a key concept in understanding the adaptive functioning of children across various domains (Graziano & Derefinko, 2013; Bar-Haim, Bar-Av, & Sadeh, 2011; Ursache et al., 2013). Emotion regulation is thought to vary along a continuum from relatively more automatic forms of regulation (e.g., approach or avoidance behaviors during early infancy) to relatively more volitional forms of regulation (e.g., attentional control and executive functioning abilities) (Ursache et al., 2013). Recent literature suggests that the central nervous system of children with CP appears to be less adaptive due to disruption of the neural pathways that are involved in emotion regulation and behavior (Colver, Fairhurst, & Pharoah, 2014). Evidence related to differences in emotion regulation in the presence of affective stimuli between typically developing children and children with a range of developmental disabilities is emerging (e.g., Boakes, Chapman, Houghton, & West, 2008; Conrad et al., 2007; Dimitrovsky, Spector, & Levy-Shiff, 2000; Levine et al., 2012; Mueller et al., 2012). However, neither the extent to which children with CP respond differently to environmental affective stimuli than do typically developing children nor the influence of affective stimuli on emotion and task performance among children with CP are clear.

Measuring the extent of emotion regulation has been elusive (Bar-Haim et al., 2011). Several studies used biological markers associated with emotion regulation (Graziano & Derefinko, 2013), employing measures that are sensitive to autonomic nervous system (ANS) functions (Fusar-Poli, Landi, & O'Connor, 2009; Hempel, Tulen, van Beveren, Mulder, & Hengeveld, 2007; Porges, 2009; Porges et al., 2007; Utendale et al., 2013).

Only a few studies have measured differences in autonomic functions between children with and without CP, most focusing on differences in heart rate variability (HRV) as a biomarker of sympathovagal balance (Bjelakovic et al., 2010; Ferreira et al., 2011; Kholod, Jamil, & Katz-Leurer, 2013; Park, Park, Cho, Lee, & Kim, 2002; Yang et al., 2002; Zamuner et al., 2011). Overall, children with CP were found to have significantly higher sympathetic activity and lower parasympathetic