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Variations in cognitive demand affect heart rate in typically developing children and children at risk for developmental coordination disorder

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ABSTRACT

Background: Developmental coordination disorder (DCD) is a diagnosis for children who present with movement difficulties, but are of normal intelligence without neurological deficits. Previous studies have demonstrated that children with DCD exhibit perceptual deficits and lower cognition performance. To date, their autonomic nervous system (ANS) responses during tasks requiring cognitive and perceptual effort have not been compared to typically developing children (TDC).
Objective: The present study investigated heart rate variability (HRV) as a marker for ANS response differences between DCD and TDC, and the impact of different levels of task difficulty.
Methods: Participants were 60 individuals (9–10 years); 30 children at risk for DCD, and 30 TDC. Each participant performed two tasks each of which demanded enhanced cognitive effort: a visual signal detection task and a digit memory task—each task had two levels of difficulty, low (LD) and high (HD). Heart rate responses were continuously recorded during performance of each task. Frequency domain analysis and heart rate sample entropy (SampEn) were computed to determine ANS responses in each of the tasks.
Results: HRV differences were detected between the two levels of task difficulty, LD and HD, for the visual signal detection task, but not for the digit memory task. HRV differences between LD and HD conditions were greater for TDC children than DCD when engaged in visual signal detection task, compare to the memory task.
Interpretation: The results suggest that children at risk for DCD may show decreased HRV as a marker for altered ANS responses and potential deficits in the linkage between their perceptions and actions.

Psychological states and mental tasks are known to affect autonomic nervous system influence on the cardiovascular system. This link between cognitive and emotional processes, and changes in autonomic function has drawn increasing interest (Suess, Porges, & Plude, 1994; Thayer & Brosschot, 2005). In particular, heart rate exhibits continuous variability under a network of influences including the autonomic nervous system, baroreceptor reflex, respiratory rate and mental load

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(van Ravenswaaij-Arts, Kollee, Hopman, Stoelinga, & van Geijn, 1993). Heart rate variability reflects the moment to moment integration of external stimuli, internal regulatory status and mental tasks. Measurement of heart rate variability is increasingly being employed as a noninvasive and sensitive index of the dynamic interplay between parasympathetic and sympathetic nervous systems. Heart rate variability changes reflect psychophysiological states (Gutin, Owens, Slavens, Riggs, & Treiber, 1997; Nagai, Matsumoto, Kita, & Moritani, 2003; Task Force of The European Society of Cardiology, The North American Society of Pacing and Electrophysiology, 1996; Thayer, Friedman, & Borkovec, 1996). Among various psychophysiological states, increases in mental workload, for example, can affect heart rate variability (Porges, 1992, 1995). Richards and Casey (1991) reported a decline in HRV during presentation of a visual stimulus, and a return to pre-stimulus levels after the stimulus disappeared, even in young infants. In addition, autonomic regulation of heart rate was impaired in children with attention deficit problems (i.e., attention deficit and hyperactivity disorder, ADHD), suggesting that HRV may be a useful correlate for examining cognitive activity (Eisenberg et al., 1996).

Developmental coordination disorder (DCD) is a term describing children who manifest coordination and control problems with their movement skills. By definition, DCD can be diagnosed only when such problems are not due to any general medical condition or pervasive developmental disorder (American Psychiatric Association, 2000). Children with DCD have difficulties performing activities of daily living that depend up precise motor coordination. The disorder can be co-morbid with other problems, such as poorer scores on measures of cognitive activity compared to typically developing children (TDC; Dewey, Kaplan, Crawford, & Wilson, 2002). Accordingly, the autonomic control of heart rate variability in children with or at risk for DCD might differ from their TDC counterparts. Thus HRV may differ between DCD and TDC groups of children.

In the present study, we sought to determine whether this hypothesized difference in heart rate variability in children with or at risk for DCD would be supported when both groups (DCD and TDC) were engaged in cognitive tasks at different levels of difficulty. Participants performed two experimental tasks; a visual detection task, and a digit memory recall task. Each task comprised two levels of difficulty, low and high. We hypothesized that (1) children with DCD would have lower heart rate variability than their TDC peers, and (2) for all children, heart rate variability would change as a function of the level of task difficulty.

1. Methods

1.1. Participants

Sixty children from a Primary School in Kaohsiung, Taiwan, participated in this study. Written parental consent was secured for all participants. The Movement assessment battery for children (MABC; Henderson & Sugden, 1992) was used to identify 30 children at risk for DCD, which we defined as children having MABC scores below the 5th percentile. The TDC group comprised 30 children with MABC scores above the 25th percentile. Since heart rate variability is a function of age and gender (higher in males than in females), gender and age were controlled such that all participants fell within the same age band (9 to 10 years) with an identical gender ratio (1:1 male to female) for both groups. Table 1 shows that there were no differences between groups with respect to age, height, weight, and body mass index (BMI). Also groups did not differ on IQ-WISC scores, or ADHD-diagnostic teacher rating scale (ADHD-DTRS; Dupaul, Power, AnastoPoulos, & Reid, 1998). All participants were of normal intelligence and free from a diagnosis of ADHD. The only significant difference between the TDC and DCD groups was on the MABC total impairment score ($p < .01$). The experimental protocol was approved by the University of Minnesota Institutional Review Board.

1.2. Tasks

1.2.1. The visual vigilance task

We used a visual vigilance task for two reasons. First, visual vigilance requires no verbal response, which can increase respiratory sinus arrhythmia and can impact heart rate variability (Sloan, Korten, & Myers, 1991). Second, the task demands

Table 1
Demographic data in the DCD and the TDC group. BH: body height; BW: body weight; BMI: body mass index, IQ: intelligent quotient, ADHD-DTRS: attention deficit and hyperactivity disorder: diagnostic teacher rating scale, MABC: total impairment score of MABC, PR: MABC percentile range.

	DCD ($n = 30$)	TDC ($n = 30$)
Age	9.40 (.49)	9.20 (.41)
BH	139.07 (6.43)	139.60 (6.17)
BW	37.88 (10.92)	37.73 (9.21)
BMI	19.33 (4.29)	19.22 (3.95)
IQ	99.8 (15.69)	101.46 (15.33)
ADHD-DTRS	2.21 (1.15)	2.23 (1.19)
MABC	19.97 (3.67)	5.33 (1.37)
PR	1–3	26–79