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Auditory-motor coupling of bilateral finger tapping in children with and without DCD compared to adults

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ABSTRACT

The ability to modulate bilateral finger tapping in time to different frequencies of an auditory beat was studied. Twenty children, 7 years of age, 10 with and 10 without developmental coordination disorder (DCD), and 10 adults tapped their left index and right middle fingers in an alternating pattern in time with an auditory signal for 15 s (four trials each, randomly, at 0.8, 1.6, 2.4, 3.2 Hz per finger). Dominant and non-dominant finger data were collapsed since no differences emerged. All three groups were able to modulate their finger frequency across trials to closely approximate the signal frequency but children with DCD were unable to slow down to the lowest frequency. Children with DCD were more variable in tap accuracy (SD of relative phase) and between finger coordination than typically developing children who were respectively more variable than the adults. Children with DCD were unable to consistently synchronize their finger with the beat. Adults were tightly synchronized and often ahead of the beat while children without DCD tended to be behind the beat. Overall, these results indicated that children with DCD can only broadly match their finger movements to an auditory signal with variability and poor synchronicity as key features of their auditory-fine-motor control. Individual inspection of the data revealed that five children with DCD had difficulty matching the slowest frequencies and that these children also had higher variability and lower percentile MABC scores from the movement assessment battery for children (MABC) than other

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children with DCD. Three children with DCD were more variable only at higher frequencies and two performed like typically developing children.

1. Introduction

According to Williams (2002), rhythmic timing and coordination of movements is a well-recognized deficit in children with developmental coordination disorder (DCD). Yet relatively few empirical studies exist of this deficit. A meta-analysis by Wilson and McKenzie (1998) suggests that motor coordination difficulties have primarily been associated with poor visuo-spatial and kinesthetic processing although it did not assess the few studies of auditory temporal processing. Even the movement assessment battery for children (Henderson & Sugden, 1992), which is the most commonly used standardized test for assessing DCD, does not include a rhythmic activity as one of the items. In this study, we address timing and coordination in children with DCD by focusing on the perception–action coupling between an auditory beat set at different tempos and bilateral finger tapping.

Previous studies on finger movements in children with DCD have mainly used one of two experimental paradigms influenced by different theoretical approaches. From an information processing perspective, the continuation paradigm involves participants keeping time by tapping to a specific beat and subsequently trying to maintain the same frequency of tapping without the beat. In these studies, the primary finding has been that children with DCD are more variable in maintaining their timing than children without DCD particularly in unilateral tapping (Lundy-Ekman, Ivry, Keele, & Woollacott, 1991; Williams, Woollacott, & Ivry, 1992) and possibly in bilateral tapping (Geuze & Kalverboer, 1994). In addition, children with DCD are less successful in discriminating sounds (Williams et al., 1992) and those with cerebellar soft signs have increased difficulty in timing leading many to suggest that atypical cerebellar development contributes to the difficulties seen in these children (Lundy-Ekman et al., 1991). Using the Wing and Kristofferson (1973) approach to decomposing the beats into central and peripheral components, Williams et al. (1992) suggested that the primary deficits in children with DCD lie in motor programming or central timekeeping.

The second approach has been to use a "dynamic pattern" paradigm appropriate to bilateral coordination where participants are asked to maintain alternating (antiphase) or simultaneous (inphase) bilateral finger movements to a constant auditory beat before being perturbed, or they are asked to match their movements to the increased frequency of an auditory or visual cue (Volman & Geuze, 1998a; Volman & Geuze, 1998b). Again, the primary finding is that children with DCD are more variable, both spatially and temporally, than control children in their ability to maintain a stable coordination pattern at constant speed, and they demonstrate, also, an increased relaxation time after perturbation and a tendency to transition earlier from the less stable antiphase to an inphase pattern. From these experiments, Volman and Geuze (1998a), Volman and Geuze (1998b) argued that the deficit may not be entirely central in nature and is better characterized as a dynamic control deficit with the underlying structural nature of this deficit unknown although the cerebellum is still suggested as a strong candidate. Taken together, the evidence from these two experimental paradigms suggests that children with DCD are more variable in their ability to maintain timing of a single finger and/or coordination between fingers.

An additional paradigm has been to explicitly investigate visual influences on rhythmic timing (Lord & Hulme, 1988). Volman and Geuze (1998a) looked at the perception–action coupling between a visual cue and unilateral finger movements using the dynamic pattern approach. They found the predictable increase in variability between the DCD group and children without DCD in matching the finger flexion/extension to the cue. Interestingly, however, there was no difference in the absolute error between finger movements and the visual cue. This suggests that the timing problem for children with DCD, at least for visual-motor timing, is not one of being able to synchronize with a sensory cue. In the present study, we pursue a similar strategy of testing perception–action coupling, but measure