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Deficits in the covert orienting of attention in children with Developmental Coordination Disorder: Does severity of DCD count?

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ABSTRACT

Children with Developmental Coordination Disorder (DCD) show deficits in the covert orienting of visuospatial attention, suggesting an underlying issue in attentional disengagement and/or inhibitory control. However, an important theoretical issue that remains unclear is whether the pattern of deficits varies with DCD severity. Fifty-one children with moderate DCD (MDCD), 24 children with severe DCD (SDCD), and 38 typically developing (TD) children participated in the study. Their performance was compared on the covert orienting of visuospatial attention task (COVAT), specifically the voluntary control mode. Results showed that the pattern of performance differed between groups. At a short stimulus–response asynchrony (350 ms), the difference in response times for validly and invalidly cued trials was similar for all three groups. However, at the longer SOA (800 ms), both DCD groups continued to show a relative disadvantage for responses that followed invalid cues. This suggests that a deficit in response inhibition and/or attentional disengagement is manifest in children with both moderate and severe DCD. The implications of these findings for theory and treatment are discussed.

1. Introduction

Motor impairments can result from various disorders such as muscular dystrophy, autism and cerebral palsy. For children with Developmental Coordination Disorder (DCD), motor impairment exists in the absence of any obvious neurological and structural abnormality or intellectual disability, but is severe enough to interfere with activities of daily living and/or academic performance (APA, 2000). According to the Diagnostic and Statistical Manual of Mental Health Disorder (DSM-IV-TR, APA, 2000) and other sources, estimates of the prevalence of DCD vary between 5% and 10% (Barnhart, Davenport, Epps, & Nordquist, 2003; Henderson & Hall, 1982), depending on notional cut-off criteria. This raises an important issue about whether the cognitive and motor control problems we see in DCD vary with severity. This paper addresses this issue in the context of one area of cognitive dysfunction that has been identified in several studies — the covert orienting of visuospatial attention.

Visual information processing problems are almost synonymous with DCD (Wilson & McKenzie, 1998), with work over the past 15 years implicating the control of visual attention as one prominent area of dysfunction. Using the covert orienting of visuospatial attention task (COVAT) modeled on the work of Posner (1980, 1988), a number of studies have suggested that

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children with DCD have difficulty controlling the allocation of voluntary attention (Tsai, 2009; Tsai, Pan, Cherng, Hsu, & Chiu, 2009; Wilson & Maruff, 1999; Wilson, Maruff, & McKenzie, 1997). This is thought to reflect an underlying issue in the disengagement of attention from invalidly cued locations and/or response inhibition (Mandich, Buckolz, & Polatajko, 2003).

The COVAT is a spatial precuing paradigm whereby the nature of attentional shifts can be evaluated by varying the type of precue, its probability, and the stimulus-onset asynchrony (SOA). In the endogenous mode of covert orienting, a central symbolic cue is used with a high probability of valid trials. On such trials, valid precues facilitate attentional shifts to the subsequent target location, reducing response time. By comparison, invalid precues serve to misdirect attention to an opposing location (in the contralateral hemispace), thereby increasing response times to targets. Attentional shifts on invalid trials are thought to involve three, sequential cognitive operations: (a) disengagement of attention from the incorrect location, (b) an attentional shift to the target location, and (c) engagement on the target (Posner, 1988). The difference in response time between invalid and valid trials (termed the *invalid cue effect size* — ICE) is commonly interpreted as a measure of attentional disengagement time (Tsai, 2009; Tsai et al., 2009; Wilson & Maruff, 1999; Wilson et al., 1997).

Children with DCD appear to show a selective deficit in shifting covert attention to a target location after first being misdirected by an invalid cue. Importantly, this deficit in covert orienting was apparent for shifts of attention that were first enlisted by central, symbolic cues, but not peripheral cues (e.g., Wilson & Maruff, 1999). According to Posner's model, this suggests a problem of endogenous control, isolated to the disengage operation. In other words, when misdirected by an invalid cue, children with DCD have difficulty disengaging attention from the cued location, resulting in delayed response times when the target appears in the opposite visual hemispace. Wilson et al. (1997) have argued that dysfunction at the level of posterior parietal cortex may explain this pattern. Mandich et al. (2003) extend this interpretation by suggesting a core deficit of "disengagement inhibition" — i.e., in DCD, more time is needed to intentionally inhibit the online command that keeps attention at the cued location. This command assumes some primacy because attention is shifted voluntarily to this location in view of the high probability that the target will then appear there. Inhibiting this "attentional pull" is more protracted in DCD.

Importantly, the conclusions reached by Wilson and Maruff (1999) and Mandich et al. (2003) and later Tsai (2009) assume that these attentional deficits in DCD manifest in children with both severe and moderate forms of the disorder. However, in the 1999 study, some 15 of the 20 children had levels of motor impairment below the 5th percentile on the MABC, while the criterion for inclusion was an MABC score <15th percentile. Similarly, the DCD sample of Mandich et al. (2003) was also quite impaired: using the same cut point, the mean impairment score on the MABC was nearly 20 (under the 5th percentile). No comparisons were made between DCD groups of different severity. As well, these earlier studies showed greater within-group variability on ICE in DCD compared with typically developing (TD) children (Tsai, 2009; Wilson & Maruff, 1999; Wilson et al., 1997). Whether this variability can be resolved by evaluating performance differences between DCD sub-groups remains to be seen.

A number of theorists have claimed that DCD is a heterogeneous group with respect to profiles of motor problems (Henderson & Barnett, 1998; Lord & Hulme, 1988). Approaches like cluster analysis have been used to examine DCD subtypes in several studies, across different countries (Hoare, 1994; Macnab, Miller, & Polatajko, 2001; Miyahara & Mobs, 1995; Zhu, Li, & Wu, 2010). However, findings have been equivocal: there is debate over the method of classification and no single model has been used to classify children with DCD (Macnab et al., 2001). One reasonable and principled approach is to classify children based on the severity of motor problems, and then evaluate whether neurocognitive profiles vary across these subtypes. Although the underlying neurocognitive profile of children with DCD is still unclear, neurological soft signs have been reported frequently (Henderson & Hall, 1982; Lundy-Ekman, Ivry, Keele, & Woollacott, 1991). Moreover, the incidence of these signs are higher in severe compared with mild-to-moderate DCD (De Kleine, Nijhuis-Van Der Sanden, & Lya Den Ouden, 2006; Jongmans, Mercuri, de Vries, Dubowitz, & Henderson, 1997; Peters, Maathuis, & Hadders-Algra, 2011). Whether this is mirrored by specific markers of neurocognitive dysfunction is a question of particular interest.

The purpose of this study was to investigate patterns of COVAT in DCD, comparing specifically children with severe and moderate motor skill problems. It was predicted that problems of "disengagement inhibition" would be more pronounced in severe DCD compared with either TD or moderate DCD groups.

2. Methods

2.1. Participants

Children with DCD aged 9–10 years were searched from the database of DCD in National Taiwan University of Physical Education and Sport and then they were sent a letter to invite to this study. Seventy-five children with DCD agreed to participate in this study. After using the Movement Assessment Battery for Children test (MABC; Henderson & Sugden, 1992) to evaluate children's motor coordination, participants consisted of 51 children with moderate DCD (18 males and 33 females) and 24 children with severe DCD (9 males and 15 females). All children with DCD were without any definite signs of neurological or physical impairments and developmental disorders or intelligence deficiency by a rehabilitation physician. Thirty-eight TD children (25 males and 13 females) in the ages of 9–10 were recruited from an elementary school in Taichung, Taiwan. All parents signed the informed consent forms before their children attended the research evaluation. Each child needed to attend the MABC test and the covert orienting of visuospatial attention task (COVAT). After normalization (criteria $z = 2.54$) to reduce the intra-group heterogeneity, five MDCD (2 males and 3 females), 4 SDCD