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Cognitive-motor interference during fine and gross motor tasks in children with Developmental Coordination Disorder (DCD)

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ABSTRACT

Background: While typically developing children produce relatively automatized postural control processes, children with DCD seem to exhibit an automatization deficit. Dual tasks with various cognitive loads seem to be an effective way to assess the automatic deficit hypothesis.

Aims: The aims of the study were: (1) to examine the effect of a concurrent cognitive task on fine and gross motor tasks in children with DCD, and (2) to determine whether the effect varied with different difficulty levels of the concurrent task.

Methods and procedures: We examined dual-task performance (Trail-Making-Test, Trail-Walking-Test) in 20 children with DCD and 39 typically developing children. Based on the idea of the Trail-Making-Test, participants walked along a fixed pathway, following a prescribed path, delineated by target markers of (1) increasing sequential numbers, and (2) increasing sequential numbers and letters. The motor and cognitive dual-task effects (DTE) were calculated for each task.

Results: Regardless of the cognitive task, children with DCD performed equally well in fine and gross motor tasks, and were slower in the dual task conditions than under single task-conditions, compared with children without DCD. Increased cognitive task complexity resulted in slow trail walking as well as slower trail tracing. The motor interference for the gross motor tasks was least for the simplest conditions and greatest for the complex conditions and was more pronounced in children with DCD. Cognitive interference was low irrespective of the motor task.

Conclusions and implications: Children with DCD show a different approach to allocation of cognitive resources, and have difficulties making motor skills automatic. The latter notion is consistent with impaired cerebellar function and the "automatization deficit hypothesis", suggesting that any deficit in the automatization process will appear if conscious monitoring of the motor skill is made more difficult by integrating another task requiring attentional resources.

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What this paper adds

Previous studies suggest that individuals with Developmental Coordination Disorder, a chronic neurodevelopmental condition, show not only problems in the motor domain, but specific weaknesses in executive function, visual-perceptual attention and response inhibition within the visuospatial domain. The interference between motor and cognitive performance may result from the fact that the attentional focus has to be repeatedly switched, in a time-critical manner, between information processing, and control operations for adjusting motor performance. However, previous studies have rarely investigated this automatization deficit, which was proposed as a useful model for understanding motor deficits in children with DCD. The findings of this study demonstrate that cognitive motor interference in children with DCD depends heavily on the type and complexity of the motor and cognitive task being performed. Surprisingly, children with DCD did not differ from the controls in the dual task effects for the manual task, supporting a motor rather than an attention deficit. However, significant differences in motor and cognitive dual task effects were observed between children with and without DCD. These findings indicate that the “posture first” strategy to control the motor performance is not an invariant strategy, suggesting that task prioritization is dynamic, and related to aspects of the task, the setting, and the conditions of the child.

1. Introduction

Recent studies suggest that motor and cognitive development is more closely related than previously assumed, depending on movement experiences, skills, age, and gender (Davis, Pitchford, & Limback, 2011). In particular, gross-motor performance such as functional goal-oriented locomotion is not a merely automatic process, but requires higher-level cognitive input, highlighting the relationship existing between cognitive function and walking even in young adults (Yogev-Seligmann, Hausdorff, & Giladi, 2008). Motor and cognitive functions appear to be even more strongly correlated in children with motor and/or cognitive impairment compared to typically developing (TD) children (Schott & Holfelder, 2015). Deficits in fine and gross motor performance and in executive function (EF) are two recognized features of Developmental Coordination Disorder (DCD; Alloway, Rajendran, & Archibald, 2009; Asonitou, Koutsouki, Kourtessis, & Charitou, 2012; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). DCD has an estimated incidence of 5–6% and can thus be regarded as a common neurodevelopmental disability in school-aged children. The condition is typically characterized by delays and deficits in the acquisition and execution of motor skills at an age-appropriate level (American Psychiatric Association, 2013). Children exhibit a wide variety of perceptual motor problems, difficulty with balance and postural control (Fong, Ng, & Yiu, 2013), deficits in motor prediction (Hyde & Wilson, 2013), and visuo-spatial deficits (Alloway, 2011). The underlying etiology of the movement difficulties associated with DCD is largely unknown, but according to the atypical brain development hypothesis (Kaplan, Crawford, Cantell, Kooistra, & Dewey, 2006), the differential behavioral outcomes emerge because of variations in brain structure and function (Brown-Lum & Zwicker, 2015).

An elegant approach to assess the interdependence of motor and cognitive function comes from the cognitive-motor interference (CMI) research using dual task (DT) conditions. CMI refers to the phenomenon in which carrying-out simultaneously a motor and a cognitive task interferes with the performance of one or both tasks. Where the motor task is adequately learned, few attentional resources are needed to perform the task, thereby leaving sufficient resources for the performance of concurrent attention-demanding tasks. However, an overload of attentional resources during DT may disrupt both cognitive and motor performance in TD children and adolescents with e.g. slower walking speed (Abbruzzese et al., 2014), poor postural control (Mitra, Knight, & Munn, 2013), and higher upper body variability (Hinton & Vallis, 2015).

To our knowledge, only four studies have examined CMI using a DT paradigm for static and dynamic postural control tasks in children with DCD. However, these studies have yielded inconsistent results. Studies on static postural control found higher CMI in children with DCD than in TD children (Chen, Tsai, Stoffregen, Chang, & Wade, 2012; Laufer, Ashkenazi, & Josman, 2008; Tsai, Pan, Cherng, & Wu, 2009). For example, while healthy children by the age of 10 years are able to adaptively reduce their postural motion while actively engaged in performing a secondary verbal cognitive task (Digit Memory Test), children with DCD failed to show functional integration of postural activity with suprapostural task demands (Chen et al., 2012). However, younger children by the age of 5 years seem to produce an increase in postural activity (bipedal stance on a firm or a compliant surface) when executing cognitive tasks (naming simple colored objects; Laufer et al., 2008). Only one study on dynamic postural control reported little or no difference between children with and without DCD in gait parameters under a free walking condition, but greater differences under DT walking conditions with a challenging motor (walking while carrying a tray with 7 marbles), but not cognitive task condition (repeating a series of digits forward and backward; Cherng, Liang, Chen, & Chen, 2009). This result suggests that the cognitive tasks were not attentionally demanding enough to elicit DT interference. However, only one study reported a specific measure (NASA Task Load Index, Hart & Staveland, 1988) to assess the difficulty level of the cognitive task across participants (Chen et al., 2012). Additionally, it is difficult to compare results due to a lack of determining DT effects (DTE). Other discrepancies between these studies are probably due to differences in sampling (limited age ranges: 4–6 and 9–10), procedures (verbal cognitive tasks: the articulation of words may inadvertently increase postural sway and thus obscure the isolated effect of the cognitive task), or experimental design (no further examination of the single cognitive task; no examination, of the extent to which different gait and cognitive tasks require additional or different cognitive resources).

In both gross and fine motor DT research, several factors have been suggested to account for differences in DT performance in children with and without motor and/or cognitive impairment (Schaefer, 2014; Tsai et al., 2009; Wilson, 2015). Some of