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The effect of motor load on planning and inhibition in developmental coordination disorder

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ABSTRACT

Previous research has reported mixed findings regarding executive function (EF) abilities in developmental coordination disorder (DCD), which is diagnosed on the basis of significant impairments in motor skills. The current study aimed to assess whether these differences in study outcomes could result from the relative motor loads of the tasks used to assess EF in DCD. Children with DCD had significant difficulties on measures of inhibition and planning compared to a control group, although there were no significant correlations between motor skills and EF task performance in either group. The complexity of the response, as well as the component skills required in EF tasks, should be considered in future research to ensure easier comparison across studies and a better understanding of EF in DCD over development.

1. Introduction

Executive function (EF) is an umbrella term that includes a range of top-down processes of cognitive control, characterised by Miyake, Friedman, Emerson, Witzki, and Howerter (2000) as comprising three core functions, namely response inhibition, shifting between tasks or mental sets, and updating/monitoring of working memory representations. These core functions provide the basis for higher-order functions such as planning and reasoning (Diamond, 2013). EFs develop over a protracted period, emerging before birth and continuing to develop throughout adolescence and into early adulthood (e.g., Anderson, 2002; Best & Miller, 2010). In a variety of psychological and medical conditions, executive dysfunction has been associated with significant negative consequences for daily life functioning, academic achievement, and employability (Altshuler et al., 2007; Biederman et al., 2004; Garcia-Villamisar & Hughes, 2007; Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002). Various patterns of executive dysfunction have been reported across a number of clinical disorders (see reviews by Hill, 2004; Sergeant, Guerts, & Oosterlaan, 2002). For example, Ozonoff and Jensen (1999) reported poor planning and cognitive flexibility but typical inhibitory skill in children/adolescents with autism spectrum disorder (ASD), and the reverse profile in children/adolescents with Attention Deficit-Hyperactivity Disorder (ADHD). Similarly, Happé, Booth, Charlton, and Hughes (2006) reported specific and differing profiles of executive functioning in children and adolescents diagnosed with ASD vs. ADHD, with individuals with ADHD showing a more widespread and general

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impairment, particularly in response inhibition, whereas those with ASD showed greater difficulties with response selection and monitoring.

The literature regarding EF across neurodevelopmental disorders has paid less attention to developmental coordination disorder (DCD), which is diagnosed on the basis of movement difficulties that interfere with academic achievement or activities of daily living, such as dressing or eating (DSM-5, American Psychiatric Association, 2013). These movement difficulties cannot be the result of any known intellectual disability or medical condition such as cerebral palsy. As in ASD and ADHD, reports suggest that individuals with DCD have difficulties in many aspects of EF (see Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2012), particularly in the three key components of EF identified by Miyake et al. (2000) of *response inhibition* (e.g., Mandich, Buckolz, & Polatajko, 2002; Michel, Roethlisberger, Neuenschwander, & Roebers, 2011; Piek et al., 2004; Piek, Dyck, & Francis, 2007; Querne et al., 2008; Wisdom, Dyck, Piek, & Hay, 2007), *working memory* (e.g., Alloway & Archibald, 2008; Alloway, 2007, 2011; Michel et al., 2011; Piek et al., 2004, 2007; Wisdom et al., 2007), and *switching* (e.g., Michel et al., 2011; Piek et al., 2004, 2007; Wisdom et al., 2007; Wuang, Chwen-Yng, & Su, 2011). These studies have suggested that children with DCD perform more poorly or with more variability than their typically developing counterparts on a range of tasks, although the patterns of impairments and variability in DCD groups are not always the same, with areas of relative strength in some studies appearing to be relative weaknesses in others. For example, when testing switching, Michel et al. (2011) and Piek et al. (2004) found no differences between children with motor difficulties and controls in terms of the numbers of errors made, while Wuang et al. (2011) and Piek et al. (2007) reported significantly more errors in children with motor difficulties than controls. Differences between studies may be due to the age ranges and tasks used across research groups, or may rely on the recruitment method used (e.g., screening using different percentile cut-offs for motor difficulty vs. recruitment of clinically referred children). The current study includes only children with a clinical diagnosis of DCD in order to better understand this group in terms of their executive functioning profile.

In terms of inhibition and working memory, some tasks are used to assess both functions (e.g., the trailmaking/updating task used by Piek et al., 2004, 2007), while Michel et al. (2011) used separate tasks for these two functions. The tasks also differ in the extent to which they rely on motor skills, with tasks such as the trailmaking/updating task requiring button press responses, while the 'Fruit Stroop' task used by Michel et al. having no motor demands. Studies within normative samples have reported a significant relationship between motor abilities and response inhibition (Livesey, Keen, Rouse, & White, 2006; Rigoli, Piek, Kane, & Oosterlaan, 2012), and motor skills in DCD have been reported to significantly predict working memory (Michel et al., 2011; Piek et al., 2004). The level of impairment or variability in the DCD group could therefore be affected by the extent to which the EF task relies on complex motor responses. A study by van Swieten et al. (2009) supported this suggestion, demonstrating developmentally inappropriate *motor* planning in 6–13-year-old children with DCD, but appropriate *executive* planning (using a Tower of London task) in 7–11-year-olds in this group. The present study aims to address this issue by comparing performance on tasks that require a greater motor load to those that have a reduced motor load.

Two EF components were selected for the current investigation, namely planning and inhibition, both of which have previously been tested in DCD with tasks that require greater or reduced motor output. While planning is not one of the core EFs identified by Miyake et al. (2000), it is suggested to build on core functions such as working memory (Diamond, 2013), and deficits in the planning and control of motor actions are likely to be key to the movement difficulties seen in DCD (see Hill, 1998, for a review). Inhibition is often investigated using tasks that involve button presses or other motor responses, and so it is important to assess the extent to which any difficulties or additional processing load associated with producing these responses affects inhibition performance in children with DCD. In the current study, tests of planning and inhibition were taken from different executive functioning measures, and were chosen according to their relative motor loads (i.e., high vs. reduced motor response required). Each executive function was therefore measured using two tasks: Planning was assessed by the NEPSY Tower task (Korkman, Kirk, & Kemp, 1998; reduced motor-load) and the Rotational Bar task (Rosenbaum et al., 1990; high motor-load). Inhibition was assessed by the Stroop task (Stroop, 1935; reduced motor-load) and by the NEPSY Knock-Tap task (Korkman et al., 1998; high motor-load). These tasks are described in more detail in Sections 2.2.1 and 2.2.2, and the high motor-load tasks are presented graphically in Fig. 1.

The NEPSY Tower task was used to measure planning with a reduced motor load, in line with van Swieten et al. (2009), and was compared to a motor planning task. Specifically, the Rotational Bar task developed by Rosenbaum et al. (1990) was used, in which participants are required to pick up and rotate a bar so that a coloured end of the bar is placed on a specific coloured disc on a table. This requires participants to plan their grips in order to end in a comfortable position (achieving 'end-state comfort'). Using this task, Smyth and Mason (1997) found no significant differences between 4- and 8-year-old children screened for movement difficulties and a control group with typical movement skills in the proportion of grips ending in a comfortable state, although van Swieten et al. (2009) found increasing differences with age between children with DCD and controls in grip selection on a related task. Given that the children in the current study were of a similar age range to those tested by van Swieten et al. (6–14 years and 6–13 years, respectively), the hypotheses were based on the latter study. Specifically, it was predicted that children in the DCD group would perform more poorly than the control group on the Rotational Bar task (high motor-load) but not on the NEPSY Tower task (reduced motor-load). In the inhibition tasks, participants with DCD were expected to perform more poorly than the control group in the Knock-Tap task (high motor-load), but not in the Stroop task (reduced motor-load).