Journal of Experimental Child Psychology 154 (2017) 1–12

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Hyperactivity in boys with attention-deficit/hyperactivity disorder: The influence of underlying visuospatial working memory and self-control processes

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A R T I C L E I N F O

Article history:
Received 24 June 2016
Revised 26 September 2016

Keywords:
ADHD
Self-control
Working memory
Executive function
Hyperactivity
Actigraphy

A B S T R A C T

Changes in motor activity were examined across control and executive function (EF) tasks that differ with regard to demands placed on visuospatial working memory (VS-WM) and self-control processes. Motor activity was measured via actigraphy in 8- to 12-year-old boys with ($n = 15$) and without ($n = 17$) attention-deficit/hyperactivity disorder (ADHD) during the completion of VS-WM, self-control, and control tasks. Results indicated that boys with ADHD, relative to typically developing boys, exhibited greater motor activity across tasks, and both groups' activity was greater during EF tasks relative to control tasks. Lastly, VS-WM performance, relative to self-control performance, accounted for significantly more variance in activity across both VS-WM and self-control tasks. Collectively, findings suggest that ADHD-related hyperactivity is positively related to increased cognitive demands and appears to be better explained by deficient VS-WM rather than insufficient self-control.

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http://dx.doi.org/10.1016/j.jecp.2016.09.008

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a complex neurodevelopmental disorder that affects approximately 5% of children worldwide (Polanczyk, Silva de Lima, Horta, Biederman, & Rohde, 2007) and is characterized by age-inappropriate inattention and/or hyperactivity/impulsivity (*Diagnostic and Statistical Manual of Mental Disorders* [DSM]; American Psychiatric Association, 2013). This debilitating disorder is associated with several negative outcomes, including academic achievement (Frazier, Youngstrom, Glutting, & Watkins, 2007), behavioral (e.g., substance abuse; Molina & Pelham, 2003), social (Kofler et al., 2011; Luteijn et al., 2000), and familial (Kaplan, Crawford, Fisher, & Dewey, 1998) difficulties. Arguably, the most detrimental outcomes are frequently experienced by children with the combined presentation of the disorder (Babinski, Hartsough, & Lambert, 1999), accentuating the harmful role of hyperactivity in the outcomes of children diagnosed with ADHD.

Several theoretical models provide competing explanations for the etiology and maintenance of ADHD-related hyperactivity. For example, Barkley's (1997) inhibition model suggests that ADHD-related hyperactivity is a ubiquitous byproduct of impaired self-control (i.e., an inability to delay instant gratification) and deficits in children's ability to withhold/discontinue responses to prepotent stimuli. In contrast, Rapport et al. (2008) functional working memory model of ADHD suggests that working memory (WM)—defined as a limited capacity system involved in controlled–focused attention, interference control, and the temporary storage, maintenance, and manipulation of mental information (Baddeley, 2007)—serves as a core deficit that underlies the ADHD phenotype. Moreover, Rapport et al. (2009) suggested that ADHD-related hyperactivity serves a compensatory function to increase cortical arousal needed for effective WM functioning. That is, motor activity increases dopamine and norepinephrine production to subsequently excite underactive/underdeveloped neural regions (e.g., frontal lobes) and improve task-related performance.

Relatively few studies have examined the relationship between ADHD-related hyperactivity and increased demands on WM and/or self-control processes. For example, Porrino et al. (1983) compared objective ratings of motor activity (via accelerometer) between a group of hyperactive boys and a matched sample of healthy boys across several natural environment settings (e.g., home, school). Not surprisingly, significantly greater activity was exhibited by hyperactive boys relative to normal boys across all settings. In addition, compared with healthy control children, hyperactive children exhibited disproportionately greater motor activity during mathematics and English classes relative to lunch, recess, and physical education classes. Mathematics and reading/writing tasks place demands on WM processes by requiring information to be internally stored, manipulated, and processed accurately (de Jong, 1998; McCutchen, 1996; Raghubar, Barnes, & Hecht, 2010). Similarly, many classroom-related tasks place demands on self-control processes by requiring children to double-check work, raise their hand when they wish to speak, and write neatly (Duckworth, Gendler, & Gross, 2014). Consequently, Porrino et al. (1983) findings appear to suggest that increased demands on WM and self-control processes are associated with increased motor activity; however, these specific cognitive processes were not explicitly measured.

Recently, Rapport et al. (2009) used actigraphy to measure hyperactivity exhibited by children with and without ADHD during control tasks (low WM demands) and measures of visuospatial and phonological WM, and they found that boys with ADHD exhibited disproportionately greater activity during the WM tasks relative to the control task that placed few demands on WM or other executive functions. Hudec, Alderson, Kasper, and Patros (2014) subsequently replicated Rapport and colleagues' methodology with a sample of adults and similarly found that participants with ADHD were significantly more hyperactive than healthy controls, and both ADHD and healthy control groups exhibited increased motor activity during WM tasks relative to the low-WM-demand control condition. Together, findings from these studies provide strong support for a robust relationship between ADHD-related hyperactivity and WM demands.

Only one study has examined the relationship between hyperactivity and self-control in children with ADHD (Schweitzer & Sulzer-Azaroff, 1995). Specifically, children completed 20 trials (4 forced/practice trials and 16 free-choice trials) across two phases (distraction and free from distraction) of