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Is hyperactivity ubiquitous in ADHD or dependent on environmental demands? Evidence from meta-analysis

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HIGHLIGHTS

- Excess motor activity in ADHD depends on considerable extent on environmental demands.
- High executive function demands and low stimulation environments predict largest activity effect sizes.
- Diagnostic method, movement technology and topography, and gender also moderated activity magnitude.
- Children & adults with ADHD exhibit similar, high levels of excess motor activity.
- ADHD subtypes/presentations exhibit similar, high levels of excess motor activity.

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ABSTRACT

Hyperactivity, or excess gross motor activity, is considered a core and ubiquitous characteristic of ADHD. Alternate models question this premise, and propose that hyperactive behavior reflects, to a large extent, purposeful behavior to cope with environmental demands that interact with underlying neurobiological vulnerabilities. The present review critically evaluates the ubiquity and environmental modifiability of hyperactivity in ADHD through meta-analysis of 63 studies of mechanically measured activity level in children, adolescents, and adults with ADHD relative to typically developing groups. Random effects models corrected for publication bias confirmed elevated gross motor activity in ADHD ($d = 0.86$); surprisingly, neither participant age (child vs. adult) nor the proportion of each ADHD sample diagnosed with the inattentive subtype/presentation moderated this effect. In contrast, activity level assessed during high cognitive load conditions in general ($d = 1.14$) and high executive functioning demands in particular ($d = 1.39$) revealed significantly higher effect sizes than activity level during low cognitive load ($d = 0.36$) and in-class schoolwork ($d = 0.50$) settings. Low stimulation environments, more rigorous diagnostic practices, actigraph measurement of movement frequency and intensity, and ADHD samples that included fewer females were also associated with larger effects. Overall, the results are inconsistent with DSM-5 and ADHD models that a) describe hyperactivity as ubiquitous behavior, b) predict a developmental decline in hyperactivity, or c) differentiate subtypes/presentations according to perceived differences in hyperactive behavior. Instead, results suggest that the presence and magnitude of hyperactive behavior in ADHD may be influenced to a considerable extent by environmental factors in general, and cognitive/executive functioning demands in particular.

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Attention-deficit/hyperactivity disorder (ADHD) is a complex, chronic, and heterogeneous neurodevelopmental disorder characterized by a triad of cardinal behavioral features that include inattention, impulsivity, and hyperactivity. Hyperactivity is a multifaceted construct that spans a broad range of verbal and physical behaviors, with excess gross motor movement forming a key component as evidenced by its explicit inclusion in 4 of the 6 DSM-5 ADHD hyperactivity symptoms (APA, 2013). This excess gross motor activity has been of longstanding interest and subjected to considerable empirical scrutiny using a broad range of methodologies (Tryon, 1991). While early approaches relied on rating scales (Werry, 1968), direct observations (Abikoff & Gittelman, 1984; Whalen et al., 1978), and floor grid-crossing counts (Milich, Loney, & Landau, 1982), an expanding number of technologically sophisticated methods have followed, including pedometers (Plomin & Foch, 1981), ultrasonic sensors (Saxon, Magee, & Siegel, 1977), stabilometric cushions (Conners & Kronsberg, 1984), infrared motion analysis (Teicher, Ito, Glod, & Barber, 1996), actigraphs (Halperin, Matier, Bedi, Sharma, & Newcorn, 1992), and video compression algorithms (Wehrmann & Müller, 2015).

Subjective measures remain the most frequent indices of the hyperactivity construct (e.g., symptom ratings, clinical interviews), and suggest psychometrically distinct but temporally unstable ADHD subtypes/presentations definable by the quantity/severity of hyperactive symptom ratings (Nigg, Tannock, & Rohde, 2010; Valo & Tannock, 2010). In contrast, mechanical methods consistently indicate elevated gross motor activity across all ADHD subtypes/presentations (Bauermeister et al., 2005; Dane, Schachar, & Tannock, 2000; Miyahara, Healey, & Halperin, 2014), as well as longitudinally for both ADHD persisters and remitters (Cheung et al., 2015; Halperin, Trampush, Miller, Marks, & Newcorn, 2008). This discrepancy highlights the importance of objective methods for clarifying the role of excess gross motor activity in ADHD, and may reflect the modest agreement between subjective and direct measures of gross motor activity ($r = .32$ to .58; Rapport, Kofler, & Himmerich, 2006), informant reporting biases (Harris & Lahey, 1982), the superior reliability of mechanical measures ($r = .90$ to .99; Tryon, 1985), and/or difficulties psychometrically differentiating hyperactivity ratings from distinct behavioral dimensions such as impulsivity and inattention (DuPaul et al., 2015).

The converging evidence suggesting elevated gross motor activity across ADHD-combined and ADHD-inattentive subgroups (Bauermeister et al., 2005; Dane et al., 2000; Hartanto, Krafft, Iosif, & Schweitzer, 2015; Miyahara et al., 2014) appears to contradict the prevailing DSM-5 clinical view (APA, 2013), and suggests that hyperactivity may be a cross-subtype and relatively homogeneous feature of ADHD despite clear differences in subjective perceptions regarding its presence/severity. However, it appears premature to describe hyperactivity as a ubiquitous feature of ADHD due to substantial between-study differences in the presence and magnitude of excess motor movement relative to non-ADHD comparison groups. For example, studies employing mechanical technologies have characterized individuals with ADHD as less active (Plomin & Foch, 1981), minimally different (Bauermeister et al., 2005), moderately more active (Halperin et al., 1992), or highly active relative to controls (Marks et al., 2005). Stated differently, mechanical measurement of hyperactive behavior suggests that the magnitude of the hyperactivity deficit is somewhere between −0.59 standard deviations (ADHD group less active than typically developing [TD] peers; Plomin & Foch, 1981) and +3.45 standard deviations (almost complete non-overlap of the ADHD–TD distributions; Marks et al., 2005). Although this variation does not appear attributable to between-study differences in ADHD subtypes/current presentations (Dane et al., 2000), additional methodological differences warrant scrutiny. In particular, this marked between-study heterogeneity may be related to vast differences in the tasks, tests, and activities in which participants were engaged while their motor activity was being measured — ranging from highly controlled laboratory sessions (Marks et al., 2005) and in-seat academic work (McGrath, Handwerk, Armstrong, Lucas, & Friman, 2004) to recess/physical education (Okada & Tsujii, 2013) and television watching (Porrino et al., 1983). As such, a unique contribution of the current meta-analysis is the systematic examination of demographic, methodological, and environmental factors associated with between-study differences in the magnitude of ADHD-related hyperactivity (Lipsey & Wilson, 2001).

Understanding the extent to which environmental factors provocate or rarefy hyperactive behavior in ADHD is critical for refining theoretical conceptualizations of ADHD and clarifying the disorder's etiology, course, and pathophysiology. Childhood hyperactive behavior predicts adult impairment (Mannuzza, Klein, & Moulton, 2002), and the contextual variability of ADHD-related behavior is increasingly being embraced (Dirks, De Los Reyes, Briggs-Gowan, Cella, & Wakschlag, 2012; Kofler et al., 2013) despite a lack of recognition among contemporary accounts of ADHD. Indeed, competing ADHD etiological models make disparate predictions regarding the underlying mechanisms and processes responsible for hyperactivity's ubiquity or contextual variability. As summarized in Table 1, many contemporary models of ADHD largely disregard the role of hyperactivity, envision it as corollary behavior that accompanies frequent attentional shifts (Sagvolden, Johansen, Aase, & Russell, 2005), or view it as ubiquitous behavior (APA, 2013; Barkley, 1997). Support for ubiquitous deficit models includes evidence that most, but not all, studies find significantly elevated gross motor activity in children with ADHD based on objective, mechanical measurement