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# A quantitative comparison of handwriting in children with high-functioning autism and attention deficit hyperactivity disorder

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ABSTRACT

Children with high-functioning autism (HFA) and attention deficit hyperactivity disorder (ADHD) often experience significant handwriting difficulties, which can hamper their academic progress and ability to express themselves through symbols and words. Handwriting of children with HFA was compared to those with ADHD based on performance on the speed subtest of the Handwriting Performance Test. Differences in handwriting speed, size and alignment of words, and proportion of handwriting errors, such as corrections and substitutions, were assessed between groups. Results indicated distinct profiles of handwriting problems in HFA and ADHD: children with HFA demonstrated poorer spatial arrangement of words and reduced handwriting speed, and those with ADHD made more handwriting errors, such as corrections and transpositions. These findings have important implications in understanding the similarities and differences for children with HFA and ADHD and lay the groundwork for effective intervention strategies.



## 1. Introduction

Autism and attention deficit hyperactivity disorder-combined type (ADHD-CT) are highly prevalent childhood disorders associated with atypical development and behavior. Autism is defined in the *Diagnostic and statistical manual of mental disorders*, 5th edition by communication deficits, impaired social interactions and stereotyped or repetitive behaviors (American Psychiatric Association, 2013). Attention deficit hyperactivity disorder (ADHD) is clinically defined by symptoms of hyperactivity, inattention or impulsivity (American Psychiatric Association, 2013). The release of DSM-5 in 2013 has included many highly anticipated changes to diagnostic criteria for neurodevelopmental disorders, including allowing a dual diagnosis of ASD and ADHD. The change in diagnostic criteria will present new opportunities as well as challenges for understanding similarities and differences between autism and ADHD. While motor abnormalities are increasingly being recognized as a key part of the clinical picture of children diagnosed with neurodevelopmental disorders, there is a lack of research directly focused on comparing the motor profile of autism and ADHD. Handwriting is a skill that requires complex coordination of both motor and cognitive abilities, such as planning,

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working memory, language and visual perception (Cartmill, Roger, & Ziviani, 2009). Consequently, handwriting difficulties are among the most salient problems for both children with autism and ADHD in the classroom environment (Adi-Japha et al., 2007; Cartmill et al., 2009; Racine, Majnemer, Shevell, & Snider, 2008). A study conducted in Queensland, Australia, found that children with ASDs accounted for 40% of occupational therapists' case loads, and that 86% of those with 20 consecutive referrals required assistance with fine motor or handwriting difficulties (Cartmill et al., 2009). With respect to ADHD, a USA-based study found that 70% of children with ADHD had impairments in written expression, which manifested as illegible handwriting, poor letter formation and poor written composition relative to oral expression skills; these deficits were two times more common than difficulties in reading, or mathematics (Mayes, Calhoun, & Crowell, 2000). Despite the clear clinical need to develop effective, targeted intervention strategies for handwriting difficulties in autism and ADHD, we do not yet fully understand the similarities and differences common to each of these disorders. Furthermore, it is necessary to compare and contrast the handwriting impairments in autism and ADHD to help further inform diagnosis, offer insights into functional impairments, and develop appropriate interventions.

Handwriting problems have largely been evaluated independently in autism and ADHD; only two studies have directly compared handwriting or fine motor control in HFA and ADHD (Booth, Charlton, Hughes, & Happe, 2003; Mayes & Calhoun, 2007). Mayes and Calhoun (2007) directly compared graphomotor abilities between the two groups using the Developmental Test of Visual-Motor Integration (VMI) and the coding subtest of the WISC-III. This study revealed that 58% of children with ADHD, and 50% of children with autism had dysgraphia, and both groups performed significantly more poorly on both VMI and coding scores compared to typically developing children. Booth et al. (2003) found qualitative differences in graphomotor performance between children with ADHD and autism using a drawing and planning task. It was found that boys with HFA ($IQ > 80$) tended toward a piecemeal, detail-focused drawing style that resulted in difficulty executing correct spatial arrangement of the picture elements; however, both HFA and ADHD showed planning deficits (Booth et al., 2003).

Of the few studies that have characterized handwriting impairments in children with autism alone, the commonly reported problems relate to overall legibility and poor letter formation (Cartmill et al., 2009; Fuentes, Mostofsky, & Bastian, 2009; Kushki, Chau, & Anagnostou, 2011), and difficulty maintaining consistent size (Cartmill et al., 2009; Hellinckx, Roeyers, & Van Waelvelde, 2013). Macrographia (atypically large handwriting) has been observed in both children (Hellinckx et al., 2013; Johnson et al., 2013) and adults with ASD (Beversdorf et al., 2001). With respect to handwriting speed, reports are conflicting: Hellinckx et al. (2013) found slower handwriting in children with ASD, whereas Cartmill et al. (2009) found no significant difference. Hellinckx et al. (2013) also reported that spatial alignment was significantly poorer in the ASD group. The relationship between IQ, motor skills and handwriting performance in ASD is also unclear. Fuentes et al. (2009) found motor skills but not age or FSIQ were predictors of handwriting performance in children with ASD aged 8–13 (Fuentes et al., 2009), however, in children with ASD aged 12–14, perceptual reasoning index (PRI) but not motor skills predicted handwriting performance (Fuentes, Mostofsky, & Bastian, 2010). Hellinckx et al. (2013) found age, gender, and visual-motor integration were significant predictors of handwriting quality; while age, reading abilities, and fine motor coordination were predictors of handwriting speed (Hellinckx et al., 2013).

With respect to handwriting difficulties in children with ADHD, problems with illegibility and greater proportion of written errors have been identified (Adi-Japha et al., 2007; Racine et al., 2008; Re, Caeran, & Cornoldi, 2008; Tsai, Meng, Hung, Chen, & Lu, 2011). The higher incidence of writing errors in children with ADHD, such as letter transpositions, substitutions and corrections, has been found in English (Re et al., 2008), Hebrew (Adi-Japha et al., 2007) and Chinese written languages (Tsai et al., 2011). Adi-Japha et al. (2007) suggested that spelling problems in children with ADHD occur irrespective of vocabulary and reading ability (VIQ), and instead result from impaired motor processes. Macrographia and difficulty maintaining consistent handwriting size has also been reported in children with ADHD (Frings et al., 2010; Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2012). Reports on handwriting speed are inconsistent: children with ADHD write individual letters faster (Adi-Japha et al., 2007; Langmaid et al., 2012; Tucha, Mecklinger, Walitza, & Lange, 2006), but overall writing speed in ADHD has been found to be slower (Mayes & Calhoun, 2007; Shen, Lee, & Chen, 2012) or no different to typically developing groups (Flapper, Houwen, & Shoemaker, 2006; Racine et al., 2008).

Although both children with autism and ADHD experience handwriting difficulties, to date no study has directly contrasted the types of handwriting difficulties in these groups. Therefore the focus of the present research was to examine whether there are any commonalities or differences in handwriting impairments characteristic to HFA or ADHD and examine predictive factors of handwriting performance in these groups. We used a simple handwriting task, the speed subtest of the Handwriting Performance Test, to assess (1) spatial arrangement of words (handwriting size and spacing, consistency of size and spacing), (2) handwriting errors, such as corrections and letter substitutions and (3) handwriting speed. With respect to handwriting speed, it was hypothesized that children with autism would write significantly more slowly than ADHD or TD children. We predicted that both children with HFA and ADHD would show larger handwriting (Beversdorf et al., 2001; Frings et al., 2010; Johnson et al., 2013) but that HFA group would show reduced spacing between words. Regarding handwriting errors (poor formation, corrections and letter substitutions), we expected to see worse performance in the ADHD group, and that the proportion of errors would relate to overall handwriting speed. We also examined the contribution of age, verbal comprehension, perceptual reasoning and motor coordination to handwriting difficulties in HFA, ADHD and TD groups to determine the extent to which perceptual, cognitive or motoric elements contribute to handwriting deficits.