Research in Autism Spectrum Disorders 11 (2015) 20–26

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

Journal homepage: http://ees.elsevier.com/RASD/default.asp

Do children with autism and Asperger's disorder have difficulty controlling handwriting size? A kinematic evaluation

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ARTICLE INFO

Article history:
Received 5 June 2014
Received in revised form 29 October 2014
Accepted 2 November 2014
Available online 30 December 2014

Keywords:
Autism spectrum disorders
Fine motor
Handwriting
Visual cues

ABSTRACT

Children with autism spectrum disorders (ASD) often show difficulties in controlling letter size and consistent letter formation during handwriting; however, there has been little research into the underlying nature of handwriting impairments in this group. The aim of this study was to assess the ability of children with ASD to regulate the size and consistency of fundamental handwriting movements when using writing guides, and determine whether the kinematic profile during writing is different to typically developing children. Twenty-six boys with ASD (16 with high-functioning autism, 10 with Asperger's disorder) aged 8–13 years (IQ > 75), and 17 typically developing children wrote a series of four cursive letter *l*'s using 10 mm and 40 mm writing guides, using a graphics tablet and stylus. Movement size and consistency was comparable between groups when the writing guides were set at 10 mm; however, handwriting movements of children with ASD were significantly faster and more fluent than typically developing children when writing guides were set at 40 mm. Neuromotor noise was comparable to that of typically developing children across both writing sizes. Clinically, our findings indicate that children with ASD have a well-automated motor plan for simple handwriting movements when writing guides are present and that problems of handwriting legibility in ASD are likely to arise from other factors, such as complex motor chaining (i.e. writing whole words and sentences), or attentional, working memory and linguistic demands when writing.

Autism spectrum disorder (ASD) is characterized by impaired social interaction and communication, and repetitive and stereotyped behaviors and interests (American Psychiatric Association, 2013). In addition to these deficits, children with ASD often experience impairments in motor functioning (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). In particular, more than half of elementary school aged children with ASD receive occupational assistance for fine motor control problems (Cartmill, Roger, & Ziviani, 2009; Church, Alisanski, & Amanulla, 2000), with handwriting problems shown to persist into adolescence (Fuentes, Mostofsky, & Bastian, 2010) and adulthood (Beversdorf et al., 2001). Despite this, very few studies have examined the underlying nature of handwriting difficulties in ASD (Cartmill et al., 2009; Kushki, Chau, & Anagnostou, 2011, Hellinckx, Roeyers, & Van Waelvelde, 2013) or the impact of occupational therapy interventions (Pennington & Delano, 2012). Handwriting impairments, such as difficulty maintaining consistent letter formation and size, have been consistently

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http://dx.doi.org/10.1016/j.rasd.2014.11.001
1750-9467/

reported in studies of handwriting in ASD (Cartmill et al., 2009; Fuentes, Mostofsky, & Bastian, 2009; Kushki et al., 2011; Hellinckx et al., 2013; Johnson et al., 2013).

Simple loops of different sizes, such as *l* and *e*, are the basic motor unit for all cursive writing, which can be chained together to form more complex letters and whole words (Plamondon & Guerfali, 1998). When the motor plan is poorly formed, this will manifest as an impaired ability to control the consistency of writing size and shape, as well as movement dynamics, such as movement duration, velocity, and neuromotor noise. *Neuromotor noise* can be considered the natural variability inherent in the motor system. Where motor control is impaired or inefficient, the motor profile will be characterized by a failure to inhibit this inherent neuromuscular variability. We have recently demonstrated that children with ASD display macrographic handwriting movements and increased neuromotor noise in the absence of writing guides that may reflect difficulties with the internal regulation of the motor plan for basic handwriting movements (Johnson et al., 2013). To better understand why children with ASD have difficulty controlling the size and consistency, and consequently overall legibility of their handwriting, the aim of this study was to investigate how visual cues, such as writing guides, affect the integrity of fundamental handwriting movements.

We firstly assessed the ability of children with ASD to control the size, shape and dynamics (duration, velocity profile) of simple handwriting movements (cursive letter *l*'s) between writing guides of a well-practiced size (10 mm) when compared to control children. Secondly, to further examine the ability to control handwriting size, we also assessed *motor constancy* in children with ASD. *Motor constancy* describes how, in typically developing individuals, when writing at different sizes the overall shape and letter formation (trajectory) and movement dynamics remain relatively constant and only the size will change (Phillips, Ogeil, & Best, 2009). To explore this, we asked participants to write cursive *l*'s at a larger, less practiced size (between 40 mm writing guides), but which can still be performed using the same effectors, i.e. fingers and wrist. This task has previously been used to investigate motor constancy in children with ADHD (Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2013), and other motor disorders such as Parkinson's disease (Caligiuri, Teulings, Filoteo, Song, & Lohr, 2006). Based on previous studies that visual cues improve gait variability in children with ASD (Rinehart et al., 2006), specifically stride length and consistency, we predicted that writing guides across different sizes would constrain writing size and consistency. Based on findings of continuous circle drawing at various sizes in adults with ASD by Fleury, Kushki, Tanel, Anagnostou, and Chau (2013), a task which is similar to writing cursive *l*'s, we predicted that there would be no difference in neuromotor noise between groups as assessed by power spectral density analysis. However, in line with previous studies of upper limb kinematics in children with ASD (Dowd, McGinley, Taffe, & Rinehart, 2012; Glazebrook, Gonzales, Hansen, & Elliot, 2009; Johnson et al., 2013), we predicted that control of overall movement dynamics (velocity, motor smoothness) would be atypical in children with ASD.

1. Method

1.1. Participants

This study was approved and conducted in accordance with Monash University and Southern Health Human Research Ethics Committees. Forty-three boys aged 8–13 years participated in the study: 26 with ASD (16 with high-functioning autism, 10 with Asperger's disorder) and 17 typically developing (TD) children (see Table 1 for a summary of participant demographics); the same cohort of children also took part in our previously published study (Johnson et al., 2013).

Boys with HFA and AD were diagnosed according to Diagnostic and Statistical Manual of Mental Disorders – 4th edition, revised (DSM-IV-TR; American Psychiatric Association, 2000) criteria for either autistic disorder or Asperger's disorder. Participants were recruited from private pediatricians in Melbourne, Australia and the Autism Victoria database. Additional diagnostic information was collected using the Social Responsiveness Scale (SRS; Constantino, 2002), Developmental Behavior Checklist – Parent Version (DBC-P; Einfeld & Tonge, 2002), structured parent interviews, direct child observations and information from teachers and other therapists involved in the assessment process. The DBC-P has good psychometric properties, includes five subscales (disruptive/antisocial, self-absorbed, communication disturbance, anxiety, social relating), and provides an autism screening algorithm (autism-related items are weighted and collated to calculate an overall risk index; Brereton, Tonge, Mackinnon, & Einfeld, 2002; Witwer & Lecavalier, 2007). Children in the clinical group were not medicated. No participants presented with any co-morbid neurological (e.g. tuberous sclerosis), genetic (e.g., fragile × syndrome) or psychiatric diagnosis (e.g. Tourette's syndrome). No children in the ASD groups were reported to have been taking any type of medication.

Typically developing boys were recruited from public schools and community-wide organizations. The DBC-P (Einfeld & Tonge, 2002), and the SRS (Constantino, 2002) were used to exclude the presence of autism, AD or other previously listed psychiatric diagnosis in typically developing boys; no participants were excluded from the study.

All clinical children completed the Wechsler Intelligence Scale for Children – 4th edition (WISC-IV; Wechsler, 2003), while TD children were administered either the WISC-IV (8 TD boys) or Wechsler Abbreviated Scales of Intelligence (9 TD boys; WASI; Wechsler, 1999). As reported previously (Johnson et al., 2013), all children had a full-scale IQ (FSIQ), VCI/verbal IQ (VIQ) and PRI/performance IQ (PIQ) greater than 75; HFA, AD and TD groups did not differ on FSIQ [$F(2, 48) = 2.75$, $p = .07$], VIQ [$F(2, 48) = 1.60$, $p = .20$] or PIQ [$F(2,48) = 0.13$, $p = .88$] (see Table 1 for participant characteristics).

A standardized measure of motor skills for all children was performed using the Movement Assessment Battery for Children – 2nd Edition (M-ABC-2; Henderson, Sugden, & Barnett, 2007), which has previously been used to assess motor