



## An investigation of upper limb motor function in high functioning autism and Asperger's disorder using a repetitive Fitts' aiming task<sup>☆</sup>

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### ABSTRACT

There is now a growing body of research examining movement difficulties in children diagnosed with high functioning autism (HFA) and Asperger's disorder (AD). Despite this, few studies have investigated the kinematic components of movement that may be disrupted in children diagnosed with these disorders. The current study investigated rapid aiming movements in 19 individuals diagnosed with HFA, 20 individuals diagnosed with AD and 18 typically developing (TD) controls. A novel touchscreen version of a Fitts' aiming task was administered that required participants to make 10 reciprocal aiming movements between targets. Task difficulty was manipulated by varying the size and distance between targets. Movement time in the HFA and AD groups was comparable to TD controls. Children with HFA displayed more constant and variable error across repeated aiming attempts compared to the TD group that may be attributed to deficits in feedforward online refinement of movement. These findings are in accordance with previous gait, ocular motor, upper limb and neuroimaging studies that suggest that the cerebellum may underlie movement disturbance in individuals diagnosed with HFA. Additionally, differences in the nature of upper limb motor disturbance in HFA may serve as a useful future adjunct to clinical measures.

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Autism and Asperger's disorder (AD) are neurodevelopmental disorders characterised by social, communicative and stereotyped repetitive behaviours. Currently, autism is distinguished from AD by the presence of language delay that must be present before 3 years of age (American Psychiatric Association, 2000), although the issue of whether autism and AD are separate disorders or are in fact variants of the same disorder is highly contentious. In addition to the more salient social/communication deficits, individuals with autism and AD display a range of motor anomalies evident in studies of standardized motor assessment (Green et al., 2009), gait (Rinehart, Tonge, Iansek, et al., 2006), ocular motor (Stanley-Cary, Rinehart, Tonge, White, & Fielding, 2011) and upper limb movement tasks (Rinehart, Tonge, Bradshaw, Iansek, & Enticott, 2006). Whilst not part of the core diagnostic criteria, there is mounting clinical evidence that these motor symptoms may be a core feature of autism and AD, henceforth referred to as 'autism spectrum disorders' (ASD) (Mostofsky, Powell, Simmonds, Goldberg, Caffo, & Pekar, 2009).

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Traditionally movement has been investigated in children with ASD using standardized motor assessment batteries, for example, the Henderson Test of Motor Impairment (Manjiviona & Prior, 1999); the Bruininks-Oseretsky Test of Motor Proficiency (Ghaziuddin & Butler, 1998) and the Movement Assessment Battery for Children (Green et al., 2009). Using these standardized assessment methods Ghaziuddin and Butler (1998) have reported different neuromotor profiles for autism and AD, whilst others have reported no differences when comparing these groups (Jansiewicz et al., 2006; Manjiviona & Prior, 1995). Inconsistencies in the autism-motor literature may be a result of the inherent difficulties in characterising the movement profile of individuals with ASD using standardized motor measures. For example, measuring motor proficiency using assessment batteries may result in “neuropsychological overshadowing” (Rinehart, Bradshaw, Brereton, & Tonge, 2001) and lack sensitivity in the detection of subtle motor anomalies due to the nature of the tasks.

Kinematic methods investigating the motor profile of ASDs provide insight into the components of motor function which are disrupted, enabling some hypotheses about the nature of underlying brain dysfunction to be formed. Using a reach and grasp paradigm in the first kinematic measure of upper-limb movement, Mari, Castiell, Marks, Marraffa and Prior (2003) reported that 7–13 year old children with autism with intellectual functioning in the average/high range (IQ = 80–109) showed ‘intact’ movement kinematics but displayed “hyperagility and hyperdexterity” (Mari et al., 2003, p. 402). In contrast, children with autism whose IQ was in the low average range (IQ = 70–79) displayed a range of movement anomalies such as greater movement time duration, decreased peak velocity and later time of maximum grip aperture. Rinehart, Tonge, Bradshaw, Iansek, and Enticott (2006) studied upper limb motor functioning in normally intelligent (age range = 6–11 years) children with autism (HFA) and AD (age range = 7–19 years) using a digitised tablet task that recorded movements towards targets across three task levels. Children with HFA had a longer deceleration phase of movement, in which the final adjustments to movement are made to ensure target acquisition, when compared to typically developing (TD) children. In contrast, there were no differences reported in the neuromotor profile between children with AD and TD children. Longer time spent in the decelerative phase of movement was suggested as a possible marker of underlying cerebellar dysfunction (Rinehart, Tonge, Bradshaw, Iansek, & Enticott, 2006). Vlachos, Tsiptzi and Agapitou (2007) has similarly suggested that the clinical deficits in balance and posture found in children with autism may reflect underlying cerebellar dysfunction in this population, and may be a distinguishing feature between children with autism and TD children. Research examining gait function in children with HFA and AD has also shown that children with HFA display variable stride length that may be attributed to underlying cerebellar dysfunction (Rinehart, Tonge, Bradshaw, Iansek, Enticott, et al., 2006). As with the upper-limb studies, the gait pattern for children with AD was reported to be similar to TD children.

Neuroimaging studies have consistently reported abnormal cerebellar functioning in autism (see Bauman and Kemper (1995) for a review). The most recent neuroimaging studies report differential cortical and sub-cortical structural and functional disturbances in autism and AD, including the basal ganglia (BG) and grey and white matter differences in the left cerebellum (McAlonan, Cheung, Cheung, Wong, Suchling & Chau, 2009; McAlonan, Daly, Kumari, Critchley, van Amelsvoort, & Suckling, 2002). Decreased neuromotor connectivity throughout the brain, with particular functional anomalies in the cerebellar region, has also been associated with HFA (Mostofsky et al., 2009). Mostofsky et al. (2009) used fMRI to investigate neural connectivity underlying an oppositional finger tapping task, finding that the pattern of activation of cortical regions such as the cerebellum, critical for motor execution, differed between the children with HFA and TD groups. Children with HFA showed reduced activation in the ipsilateral anterior cerebellum and absent activation of the contralateral cerebellum in comparison to controls. It was suggested that decreased cerebellar activation in the cerebellum may be associated with the switching of effortful control to “habitual execution” (Mostofsky et al., 2009, p. 2413).

The aim of this study was to further investigate the kinematic movement profile of children with autism spectrum disorders. Given our prior upper limb tablet-based task findings that children with HFA had more difficulties in the deceleration phase of movement (online control) (Rinehart, Tonge, Bradshaw, Iansek, & Enticott, 2006), we were interested in ‘how’ individuals with autism perform reciprocal manual aiming movements. The current study investigated rapid reciprocal arm movements using a computerised touchscreen version of a Fitts’ aiming paradigm. Touchscreen technology was used to make the study more appealing to children diagnosed with ASD and to enhance participant motivation during the task. Furthermore the use of a simple aiming task allowed us to examine both the early movement characteristics (movement time, time to peak velocity) as well as the later characteristics (time to zero velocity and constant and variable error). These variables were considered of interest based upon prior movement kinematic studies (see Glazebrook, Elliott, and Lyons (2006)). There were four levels of difficulty defined by the formula: index of difficulty (ID) Fitts’ law =  $\log_2(2A/W)$  (see Hocking, Rinehart, McGinley, Moss, and Bradshaw (2011) for further information). In this task participants were required to make a series of 10 speeded and accurate reciprocal aiming attempts between two targets.

Consistent with Mostofsky et al.’s (2009) suggestion that individuals with HFA have difficulty shifting motor execution from cortical regions associated with effortful control to regions associated with habitual execution, we predicted that children with HFA will show more variability in the endpoints of their movements, as reflected by increased variable error. Based on past studies of upper limb motor functioning in children with ASD with normal intellectual functioning (Rinehart, Tonge, Bradshaw, Iansek, & Enticott, 2006; Mari et al., 2003), we predicted intact movement execution with no differences between groups in the movement time needed to complete aiming movements. Past clinical and kinematic gait and upper body studies would suggest a dissociation in motor profile for HFA and AD (Rinehart, Tonge, Iansek, et al., 2006; Rinehart, Tonge, Bradshaw, Iansek, & Enticott, 2006). Particularly we would predict that children with HFA would display motor anomalies consistent with cerebellar dysfunction which may be manifested by increased time spent in the decelerative

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