Is There a Link Between Motor Performance Variability and Social-Communicative Impairment in Children With ADHD-CT: A Kinematic Study Using an Upper Limb Fitts’ Aiming Task

Nicole Papadopoulos1, Nicole J. Rinehart1, John L. Bradshaw1, John Taffe1, and Jennifer McGinley2

Abstract

Objective: This study investigated the relationship between motor performance and social-communicative impairment in children with ADHD-combined type (ADHD-CT). Method: An upper limb Fitts’ aiming task was used as a measure of motor performance and the Social Responsiveness Scale as a measure of social-communicative/autistic impairment in the following groups: ADHD-CT (n = 11) and typically developing (TD) controls (n = 10). Results: Children with ADHD-CT displayed greater variability in their movements, reflected in increased error variance over repeated aiming trials compared with TD controls. Motor performance variability was associated with social-communicative deficits in the ADHD-CT but not in the TD group. Conclusion: Social-communicative impairments further complicate the clinical picture of ADHD-CT; therefore, further research in this area is warranted to ascertain whether a particular pattern of motor disturbance in children with ADHD-CT may be clinically useful in identifying and assessing children with a more complex ADHD presentation. (J. of Att. Dis. 2015; 19(1) 72-77)

Keywords

ADHD, motor control, comorbidity

ADHD and pervasive developmental disorders (PDD) are the most common, childhood-onset psychiatric disorders affecting the development of fronto-striatal circuits and the cerebellum (Bauman & Kember, 1994; Johnson et al., 2007). Clinically, ADHD is defined by symptoms of inattention, and/or hyperactivity and impulsiveness, which significantly impact an individual’s daily functioning (American Psychiatric Association [APA], 2000). PDD are characterized by deficits in social interaction, language delay, and stereotyped or repetitive behaviors (APA, 2000). Recent empirical studies have indicated that up to 78% of children present with autistic and ADHD symptoms (see Gargaro, Rinehart, Bradshaw, Tonge, & Sheppard, 2011, for a review). The Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5) neurodevelopmental disorder working group has proposed that a comorbid diagnosis of autistic disorder and ADHD will be considered in the new revision of their diagnostic criteria (Swedo et al., 2010).

Motor difficulties are common in children with autism and Asperger’s disorder (henceforth referred to as Autism Spectrum Disorders [ASD]) and ADHD (Papadopoulos et al., in press; Piek, Pitcher, & Hay, 1999). In addition, motor proficiency in children with ASD has been found to correlate with severity of social-communicative impairment, autistic symptoms, and greater emotional-behavioral disturbance on parent report measures (Papadopoulos et al., in press).

To date, our diagnostic criteria (DSM-IV [4th ed.; APA, 1994]) precludes a comorbid diagnosis of autistic disorder and ADHD; therefore, there have been very few studies that have considered the impact of autistic symptoms in samples of...
children with ADHD. A recent large-scale parent-report study of 851 children diagnosed with ADHD reported that individuals aged 7 to 19 years with a diagnosis of ADHD-combined type (ADHD-CT) who reported more motor problems also had greater severity of autistic symptoms (Reiersen, Constantino, & Todd, 2008). To the best of our knowledge, there have been no studies that have examined the relationship among ADHD, autistic symptoms, and direct measures of motor impairment.

There were two aims of this study: (a) to investigate and describe the motor profile of a sample of children diagnosed with ADHD-CT without comorbid diagnoses of autistic disorder, Asperger’s disorder, or developmental coordination disorder and (b) to use a direct measure of motor performance to investigate the association of motor disturbance and social-communication symptoms in children with ADHD-CT, thus extending the findings of the parent-report study of Reiersen et al. (2008).

In the current study, we used the same measures as those in our previous study investigating motor performance in children with ASD. This task was originally chosen in Papadopoulos, McGinley, Tonge, Bradshaw, and Rinehart (2012) as it places demands on the motor rather than cognitive end of the cognitive-motor continuum. Findings reported by Eliasson, Rosblad, and Forssberg (2004) indicate that children with ADHD display subtle motor anomalies characterized by less efficient movement paths when performing goal-directed arm movements, consistent with neuroimaging studies of ADHD implicating the cerebellum (Giedd, Blumenthal, Molloy, & Castellanos, 2006). Based on previous ADHD motor literature (Eliasson et al., 2004), it was hypothesized that children with ADHD-CT would show subtle cerebellar-type motor disturbance (less efficient movements), manifested as increased error variability on the Fitts’ aiming task.

In addition, based on the findings by Reiersen et al. (2008) that children with ADHD-CT who experience co-occurring autistic symptoms also have greater motor difficulties, we further predicted a positive association between social-communication impairment and error variability on the Fitts’ aiming task.

Method

Participants

A subgroup of participants from Langmaid, Papadopoulos, Johnson, Phillips, and Rinehart (in press) ADHD hand-writing study volunteered to also participate in the current study. A total of 12 boys diagnosed with ADHD-CT aged between 7 and 14 years were recruited from private pediatricians in Melbourne. The diagnosis of ADHD-CT was confirmed in a two-stage process (Langmaid et al., in press). Exclusion criteria included a comorbid diagnosis of autistic disorder or Asperger’s disorder and comorbid medical, hearing or visual, movement, psychiatric, or genetic disorders other than the primary diagnosis of ADHD-CT. ADHD participants who entered the study were further screened for a possible autism diagnosis using the Autistic Diagnostic Observation Scale (ADOS; Lord, Cook, Leventhal, & Amaral, 2000). Internalizing disorders as well as social-communicative/autistic symptoms were further assessed with the Developmental Behavioural Checklist (DBC) and Social Responsiveness Scale (SRS), respectively (Constantino & Gruber, 2005; Einfeld & Tonge, 2002). One participant was excluded for having elevated levels of social-communicative/autistic symptoms on the SRS. ADHD participants on medication discontinued their medication at least 24 hr prior to testing (Leitner et al., 2007).

A total of 10 typically developing (TD) boys aged between 7 and 14 years with no prior history of psychological, neurological, or psychiatric diagnoses (see Langmaid et al., in press) were recruited. Intellectual functioning of TD children was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) and the Wechsler Intelligence Scale for Children, fourth edition (WISC-IV; Wechsler, 2005), for the ADHD group. Motor proficiency was assessed using the Movement Assessment Battery for Children–second edition (MABC-2; Henderson, Sugden, & Barnett, 2007). The presence of autistic symptoms and emotional behavioral disturbance was measured using the parent form of the SRS and DBC, respectively (Constantino & Gruber, 2005; Einfeld & Tonge, 2002). The Conners’ Rating Scale Revised (Conners, 1997) was used to screen for the presence of clinically significant ADHD symptoms. No participants were excluded from this group.

Independent measures t tests were conducted to investigate the effect of age, Full Scale Intelligence Quotient (FSIQ), Verbal Comprehension Index (VCI), and Perceptual Reasoning Index (PRI) between the two groups. Participants were matched on age, FSIQ, or PRI consistent with previous ADHD studies (e.g., Silk, Vance, Rinehart, Bradshaw, & Cunnington, 2009). There was a significant difference in VCI between groups, t(19) = 2.27, p = .035 (see Table 1).

Apparatus

To examine movement characteristics, a novel computerized touch screen version of the Fitts’ aiming task was administered (Fitts, 1954). Movement kinematics were recorded using custom-made software (please see Papadopoulos et al., 2012). Each stimulus was presented on a touch screen that was positioned such that the surface subtended an angle of 70° to the participant’s line of gaze. The visual stimuli were two circular yellow targets that appeared in the center of the screen in the vertical plane (see Hocking, Rinehart, McGinley, Moss, & Bradshaw, 2011, for a figure).
Table 1. Participant Characteristics.

<table>
<thead>
<tr>
<th></th>
<th>ADHD-CT</th>
<th>TD controls</th>
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<tbody>
<tr>
<td>No. of participants</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Age M (SD)</td>
<td>128.7 (27.3) months</td>
<td>139.2 (33.1) months</td>
</tr>
<tr>
<td>Age range</td>
<td>87-176 months</td>
<td>84-179 months</td>
</tr>
<tr>
<td>FSIQ M (SD)</td>
<td>97.0 (12.7)</td>
<td>106.1 (18.8)</td>
</tr>
<tr>
<td>FSIQ range</td>
<td>72-115</td>
<td>84-130</td>
</tr>
<tr>
<td>VCI M (SD)</td>
<td>94.9 (12.9)</td>
<td>110.8 (18.9)</td>
</tr>
<tr>
<td>VCI range</td>
<td>69-112</td>
<td>76-136</td>
</tr>
<tr>
<td>PRI M (SD)</td>
<td>99.5 (12.0)</td>
<td>103.5 (15.2)</td>
</tr>
<tr>
<td>PRI range</td>
<td>75-137</td>
<td>85-135</td>
</tr>
<tr>
<td>MABC-2 score M (SD)</td>
<td>82.5 (10.4)</td>
<td>81.6 (11.4)</td>
</tr>
<tr>
<td>CRS</td>
<td>58.7</td>
<td>39.7</td>
</tr>
</tbody>
</table>

Note: CT = combined type; TD = typically developing; FSIQ = Full Scale Intelligent Quotient; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; MABC = Movement Assessment Battery for Children; CRS = Conners’ Rating Scale.

Procedure

The task involved participants making rapid aiming movements between two targets that varied with respect to size (1 or 2 cm) in diameter and distance (12 or 25 cm). As shown in Hocking et al. (2011), this results in three possible indices of difficulty: 2.64 (large, large, near; lln), 3.64 (small, small, near; ssn), 3.64 (large, large, far; llf), and 4.64 (small, small, far; ssf).

The same protocol as administered in Papadopoulos et al. (2012), which included practice trials, verbal instructions to “stop” at the end of a trial, and verbal instruction at the beginning of the next trial, was also used in this study.

Data Analysis

Movements were analyzed using customized Matlab software consistent with previous studies (Hocking et al., 2011; Papadopoulos et al., 2012). The start of the movement was defined when velocity rose above 0. Trials excluded from further analysis consisted of incomplete movements where participants stopped in the middle of a trial, or lifted the stylus off the touch screen before completing the trial, and where the movement time (MT) fell outside ± 2.5 SD of the mean for that participant. To assess movement accuracy, mean error and error variability (error standard deviation) were calculated. Mean error has been referred to as constant error and error variability as variable error in the literature (Eliasson et al., 2004).

Random effects regression was used to model the outcomes’ mean error, error variability, MT, time to peak velocity, and time to zero velocity as functions of ADHD status (0 control, 1 ADHD), target distance (0 near, 1 far), and target size (0 large, 1 small). In addition, random effects regression was used to model the same movement variables above as functions of SRS score and ADHD by SRS interaction.

Results

Random effects regression was used to model five movement performance variables: MT, time to peak velocity, time to zero velocity, mean error, and error variance. Small size of target was associated with longer MT ($p < .01$), time to peak velocity ($p < .01$), and time to zero velocity ($p < .01$), but lower error variance ($p < .001$; see Table 2). See figure 1.

To assess whether accommodating for SRS (autistic symptoms) would be associated with these five motor performance variables, we added SRS score for ADHD and TD groups and its interaction term (ADHD × SRS) to the random effects regression analysis (see Table 3). Although none of the five variables show evidence of association with SRS on average for the two groups (ADHD and TD), error variability was shown to be positively associated with SRS score in the ADHD group; that is, there was a significant ADHD × SRS interaction (estimated increase in error variance per unit SRS in ADHD = 0.02, $p < .05$). See figure 2.

Discussion

This study used an upper limb Fitts’ aiming task that involves minimal cognitive load to more directly investigate motor disturbance in individuals diagnosed with ADHD-CT. As hypothesized, children with ADHD-CT were more variable in their movement profile, as reflected by greater scatter in end point over repeated aiming attempts. This subtle pattern of motor disturbance is consistent with previous upper limb studies that describe goal-directed arm movements of children with ADHD as inconsistent or “jerky” (Brossard-Racine, Majnemer, & Shevell, 2011; Eliasson et al., 2004, p. 24). In addition, the current study further adds to the literature by supporting a specific link between motor variability and social-communicative impairments in children with ADHD-CT using a direct measure of motor performance.

There are several possible explanations and ways to conceptualize the variable motor profile evident in the ADHD group. To perform consistent, repeated, and precise movements over repeated aiming attempts, individuals need to be able to store information to program subsequent movements (Eliasson et al., 2004). As children with ADHD commonly experience working memory deficits (Pereira, Eliasson, & Forssberg, 2000) thought to be underpinned by disruption to higher order fronto-parietal brain regions (Silk et al., 2009), they may have difficulty using previous information to program subsequent goal-directed movements. In addition to disrupted fronto/parietal brain regions, the cerebellum may also be compromised in ADHD (Christakou et al., 2012; Mackie et al., 2007); it is thought to play a key role in...
nontaxing tasks (Smits-Engelsman, Van Galen, & Duysens, 2002) such as the Fitts’ task (Hocking et al., 2011). Furthermore, the association between cerebellar-type motor disturbance and social-emotional problems has been reported in children with cerebellar lesions (Bolduc et al., 2011).

When comparing the motor error pattern evident in the ADHD group in this study with the findings of our previous ASD study using the same Fitts’ task (Papadopoulos et al., 2012), it is evident that the ADHD motor deficit is rather more subtle than that found in autism. Interestingly, the motor pattern of ADHD more closely resembles that seen in autism rather than Asperger’s disorder. These findings challenge the current tendency for people to consider ADHD as a milder disorder than Asperger’s disorder.

The combination of parent-reported motor difficulties (Reiersen et al., 2008), together with a direct measure of motor performance in this study, strengthens the argument for an association between autistic and motor impairment in ADHD. These findings provide preliminary evidence that children with ADHD with motor impairment may experience greater social-communicative impairments or have a more

<table>
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<tr>
<th>Table 2. Random Effects Regressions of Movement Variables on ADHD Status, Target Distance, and Target Size.</th>
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<tbody>
<tr>
<td>ErrMean (cm)</td>
</tr>
<tr>
<td>ADHD</td>
</tr>
<tr>
<td>Large distance to target</td>
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<tr>
<td>Small size of target</td>
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<td>Constant</td>
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Note: ErrMean = mean error; ErrVar = error variance; MT = movement time; PeakVel = peak velocity; ZeroVel = zero velocity. *p < .05. **p < .01. ***p < .001.

<table>
<thead>
<tr>
<th>Table 3. Random Effects Regressions of Movement Variables on ADHD Status, SRS Score and SRS/ADHD Interaction, and Target Distance and Target Size.</th>
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</thead>
<tbody>
<tr>
<td>ErrMean (cm)</td>
</tr>
<tr>
<td>ADHD</td>
</tr>
<tr>
<td>SRS</td>
</tr>
<tr>
<td>ADHD × SRS</td>
</tr>
<tr>
<td>Large distance to target</td>
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<tr>
<td>Small size of target</td>
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<tr>
<td>Constant</td>
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</tbody>
</table>

Note: ErrMean = mean error; ErrVar = error variance; MT = movement time; PeakVel = peak velocity; ZeroVel = zero velocity; SRS = Social Responsiveness Scale. *p < .05. **p < .01. ***p < .001.

Figure 1. Box plot of error variability by target size and target distance for typically developing and ADHD groups.

Figure 2. The relationship between error variability and SRS score in the ADHD and TD groups.
Note: TD = typically developing.
complex ADHD presentation. This association between motor dysfunction and social-communicative impairment is consistent with previous studies in individuals diagnosed with ASD (Papadopoulos et al., in press; Qiu, Adler, Crocetti, Miller, & Mostofsky, 2010). Together, these findings suggest that identification of motor problems in individuals with ADHD may be a useful marker for comorbid autism.

There are a number of limitations of this study that need to be considered. Although children in this study were not medicated at the time of testing, the use of a medication-naïve ADHD population would have allowed us to better control for the long-term effects of medication (Rubia, Noorloos, Smith, Gunning, & Sergeant, 2003). In addition, the small sample size in this study limits our ability to generalize our findings. Neuroimaging techniques while participants were performing the upper limb task would also provide a direct measure of underlying brain functioning (Brossard-Racine et al., 2011). In addition, the ADHD and TD group also differed in VCI; although given that both groups were still in the “average” clinical range, it is unlikely that this would have affected our results. Lastly this study did not directly compare motor performance between a group of children with ADHD, and those with ADHD and comorbid autism; therefore, this limits our ability to directly investigate the link between comorbid autism and motor disturbance in ADHD. Future research investigating motor performance in subgroups of children diagnosed with ADHD-autism is recommended.

Motor problems and social-communicative impairments are consistently reported for children with ADHD, although the association between social communicative symptoms and motor problems in this group is only beginning to emerge in the literature. This study emphasizes the importance of considering social-communication symptoms when investigating motor problems in ADHD children using direct measures of motor performance. Furthermore, it is recommended that motor disturbance be standardly assessed and targeted in ADHD management practices. Specifically, psychosocial interventions may help children with ADHD cope with their motor and psychosocial difficulties. These findings are in line with DSM-V revisions to allow a comorbid diagnosis of autistic disorder and ADHD, where motor assessment in children with ADHD may trigger further assessment for autistic-like symptoms and allow interventions to be tailored to the needs of the individual.

Acknowledgments

The authors would like to thank all the children and families who participated in this research study, and Dr. Anne-Marie Turner, Dr. Katie Heathershaw, and Dr. Harriet Hiscock from the Melbourne Children’s Clinic.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Nicole J. Rinehart is a professor at Monash University and is also a clinical psychologist who consults at the Melbourne Children’s Clinic where children with ADHD were recruited from. She is also a member of the Australian National Health and Medical Research Council Expert Working Group on ADHD Clinical Practice Points.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The funding for this research was provided in part by the National Health and Medical Research Council and Monash University (Project grant 436609; Project grant APP1004387).

References


Author Biographies

Nicole Papadopoulos, BBNsc, Grad Dip (Psych), is a PhD candidate investigating motor functioning in children with autism, Asperger’s disorders, and ADHD at Monash University under the supervision of associate professor Nicole J. Rinehart and Dr. Jennifer McGinley. She is also completing her masters of clinical psychology at the Australian Catholic University.

Nicole J. Rinehart, M Clin Psych, PhD, professor of clinical psychology, completed her doctoral work at Monash University. Her research interests are in Asperger’s disorder, autism, and ADHD. She is a practicing clinical psychologist specializing in neurodevelopmental disorders at the Melbourne Children’s Clinic.

John L. Bradshaw, MA, PhD, DSc, FBPsS, emeritus professor (experimental neuropsychology and behavioral neuroscience), has a particular interest in neurodegenerative and neurodevelopmental disorders of the fronto-striatal and fronto-cerebellar systems, together with impulsivity, violent aggression, addiction, and problem gambling. He also works on synaesthesia, embodiment, and phantom limb phenomena.

John Taffe, BA, MSc, PhD, is a biostatistician at the School of Psychiatry and Psychology, Monash University. He has more than 10 years experience in providing statistical advice to students and staff in mental health-related research projects.

Jennifer McGinley, BAppSci (PT), Grad Dip (Neurosci), PhD, is a physiotherapist and senior lecturer at the University of Melbourne and the Clinical Research Centre for Movement Disorders and Gait at Southern Health. She has research expertise in the measurement and understanding of motor function and gait across the life span.