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Research Paper

Comparing motor performance, praxis, coordination, and interpersonal synchrony between children with and without Autism Spectrum Disorder (ASD)

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ABSTRACT

Children with Autism Spectrum Disorder (ASD) have basic motor impairments in balance, gait, and coordination as well as autism-specific impairments in praxis/motor planning and interpersonal synchrony. Majority of the current literature focuses on isolated motor behaviors or domains. Additionally, the relationship between cognition, symptom severity, and motor performance in ASD is unclear. We used a comprehensive set of measures to compare gross and fine motor, praxis/imitation, motor coordination, and interpersonal synchrony skills across three groups of children between 5 and 12 years of age: children with ASD with high IQ (HASD), children with ASD with low IQ (LASD), and typically developing (TD) children. We used the Bruininks-Oseretsky Test of Motor Proficiency and the Bilateral Motor Coordination subtest of the Sensory Integration and Praxis Tests to assess motor performance and praxis skills respectively. Children were also examined while performing simple and complex rhythmic upper and lower limb actions on their own (solo context) and with a social partner (social context). Both ASD groups had lower gross and fine motor scores, greater praxis errors in total and within various error types, lower movement rates, greater movement variability, and weaker interpersonal synchrony compared to the TD group. In addition, the LASD group had lower gross motor scores and greater mirroring errors compared to the HASD group. Overall, a variety of motor impairments are present across the entire spectrum of children with ASD, regardless of their IQ scores. Both, fine and gross motor performance significantly correlated with IQ but not with autism severity; however, praxis errors (mainly, total, overflow, and rhythmicity) strongly correlated with autism severity and not IQ. Our study findings highlight the need for clinicians and therapists to include motor evaluations and interventions in the standard-of-care of children with ASD and for the broader autism community to recognize dyspraxia as an integral part of the definition of ASD.

Abbreviations: ASD, Autism Spectrum Disorder; IQ, Intelligent Quotient; LASD, children with ASD with low IQ; HASD, children with ASD with high IQ; TD, Typically Developing; BOT-2, Bruininks-Oseretsky Test of Motor Proficiency-2nd Edition; SIPT-BMC, Bilateral Motor Coordination subtest of Sensory Integration and Praxis Tests; CV, Coefficient of Variation; IPS, Interpersonal Synchrony

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1. Introduction

Autism Spectrum Disorder (ASD) is a multisystem neurodevelopmental disorder characterized by primary deficits in social communication skills and highly repetitive and restricted behaviors and interests (American Psychiatric Association, 2013). In addition to these diagnostic impairments, around 50–85% children with ASD demonstrate consistent deficits in several aspects of perceptuo-motor performance (Bhat, Landa, & Galloway, 2011; Chukoskie, Townsend, & Westerfield, 2013; Green et al., 2009; Hilton, Zhang, Whilte, Klohr, & Constantino, 2012). A systematic examination of motor deficits in ASD is warranted for several reasons. First, motor symptoms are some of the earliest identifiable impairments noticed in infants and toddlers who may go on to develop a diagnosis of ASD (Bhat, Galloway, & Landa, 2012; Bedford, Pickles, & Lord, 2016; Flanagan, Landa, Bhat, & Bauman, 2012; Landa & Garrett-Mayer, 2006). Second, there is substantial evidence suggesting that motor skill development is intimately linked to social communication and cognitive development in children with ASD (Bhat, Srinivasan, Woxholdt, & Shield, 2016; Dziuk, Larson, Apostu, Mahone, Denckla, & Mostofsky, 2007; Dowell, Mahone, & Mostofsky, 2009; Leary & Hill, 1996). Lastly, a detailed examination of the motor system can provide insights into the functioning of the well-understood neural substrates underlying motor performance as well as its neighboring brain regions responsible for social performance, and ultimately the neuropathology of ASD (Dowell et al., 2009; Gizzonio et al., 2015). Therefore, in the current study, we used a comprehensive set of measures to assess different axes of motor performance in school-age children with ASD with a wide range of intellectual abilities and autism severity.

1.1. Motor impairments in ASD

Research on motor impairments has suggested that children with ASD have substantial deficits in basic motor control skills as well as specific impairments in praxis (Dewey, Cantell, & Crawford, 2007; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Hallett et al., 1993; Jansiewicz et al., 2006; Mostofsky et al., 2006; Noterdaeme, Mildenberger, Minow, & Amorosa, 2002; Srinivasan, Lynch, Bubela, Gifford, & Bhat, 2013). In terms of basic motor skills, children with ASD demonstrate poor postural control (Freitag, Kleser, Schneider, & von Gontard, 2007; Minshew, Sung, Jones, & Furman, 2004; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998), gait abnormalities (Hallett et al., 1993; Rinehart et al., 2006; Vilensky, Damasio, & Maurer, 1981), as well as impairments in bilateral coordination (Fournier et al., 2010; Isenhower et al., 2012; Kaur, Gifford, Marsh, & Bhat, 2013; Marsh et al., 2013). Children also demonstrate poor fine motor control including manual dexterity, handwriting, object control, and visuo-motor integration skills (Berkeley, Zittel, Pitney, & Nichols, 2001; Fuentes, Mostofsky, & Bastian, 2009; Green et al., 2002; Kushki, Chau, & Anagnostou, 2011; Mayes & Calhoun, 2003; McPhillips, Finlay, Bejerot, & Hanley, 2014; Miyahara et al., 1997; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, & Heimerl, 2007; Sacrey, Germani, Bryson, & Zwaigenbaum, 2014). Children with ASD received lower scores on multiple standardized tests of basic motor performance compared to typically developing (TD) children as well as children with other developmental diagnoses (Ament et al., 2015; Barbeau, Meilleur, Zeffiro, & Mottron, 2015; Ghaziuddin & Butler, 1998; Green et al., 2009; Hilton, Graver, & LaVesser, 2007; Jansiewicz et al., 2006; Liu & Breslin, 2013; Manjiviona & Prior, 1995; Miyahara et al., 1997; Provost, Heimerl et al., 2007; Provost, Lopez et al., 2007; Staples & Reid, 2010; Whyatt & Craig, 2012). In addition to these basic motor deficits, children with ASD also demonstrate dyspraxia, i.e. impaired performance of skilled motor sequences/gestures during imitation, on verbal command, and during tool use, that cannot be wholly explained by basic perceptuo-motor deficits (Carmo, Rumiati, Siugzdaite, & Brambilla, 2013; Dewey et al., 2007; Dowell et al., 2009; Dziuk et al., 2007 ; Ham et al., 2011; Mostofsky et al., 2006; Srinivasan et al., 2013; Vanvuchelen, Roeyers, & De Weerdt, 2007). While impairments in basic gross and fine motor skills are also found in children with other developmental disorders including children with Attention Deficit Hyperactivity Disorder and Developmental Coordination Disorder, impairments in praxis seem to be specific to autism (Dewey et al., 2007; MacNeil and Mostofsky, 2012). Children with ASD demonstrated both spatial (incorrect body positioning, body-part-for-tool errors) and temporal (poor movement timing, increased time to initiate movement) errors during imitation/praxis tasks (Dewey et al., 2007; Gizzonio et al., 2015; Mostofsky et al., 2006; Salowitz et al., 2013; Vanvuchelen et al., 2007). Overall, there is considerable evidence for the presence of robust impairments in non-specific basic motor skills as well as more specific motor functions such as praxis abilities in ASD.

1.2. Neural mechanisms underlying motor impairments in ASD

The broad range of motor impairments in gait, posture, coordination, and imitation/praxis in ASD could be attributed to abnormal brain connectivity reported in this population (Courchesne, Campbell, & Solso, 2011; Just, Keller, Malave, Kana, & Varma, 2012). There is mounting evidence to support the presence of excessive short-range connectivity within cortical regions (such as the frontal and parietal cortices) as well as poor long-range connectivity between cortico-cortical structures (such as the frontal and occipital cortices) or cortico-subcortical structures (including the primary motor, premotor, and supplementary motor cortices with the cerebellum or basal ganglia) (Mostofsky et al., 2009; Turner, Frost, Linsenbardt, McIlroy, & Müller, 2006). For instance, atypical long-range functional connectivity between the motor areas and the visual areas of the brain is thought to underlie poor imitation skills in individuals with ASD (Nebel et al., 2016). Similarly, greater movement variability and poor movement timing may be related to abnormal cortico-cerebellar and cortico-striatal connections (Mostofsky et al., 2009; Rinehart et al., 2006). In fact, the pattern of movement slowing in ASD has been likened to bradykinesia seen in patients with Parkinson's disease (Hallett et al., 1993; Mari, Castiello, Marks, Marraffa, & Prior, 2003; Vilensky et al., 1981). The more specific praxis impairments in ASD have been attributed to deficits in the bilaterally distributed brain network thought to underlie praxis comprising areas V1 and V5 of the occipital cortex, the superior temporal sulcus, inferior parietal region, premotor region, and the primary motor cortex (Mahajan, Dirlikov,