Assessment of motor behaviour among children and adolescents with ASD

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Abstract

Social communicative deficits are the hallmark characteristic of autism, also referred to as autism spectrum disorders (ASD). Given the depth of these social communicative deficits, the role of movement skills in development has gone relatively underexplored, by comparison. However, children with ASD demonstrate impaired performance of fundamental movement skills early in life, which in turn impacts nearly every aspect of subsequent development. These performance differences are persistent and prevalent; ongoing debate exists whether these differences simply reflect delays or if development among children with autism follows a different developmental trajectory than their typically developing peers. These movement skill differences become more obvious with increasing age and children with autism appear to fall further behind -- these increasing differences may reflect the limited opportunities of children with autism to practice and improve their movement skills. However, teasing apart these developmental differences becomes a challenge, which necessitates the use of appropriate assessment measures. Understanding the impact of motor skills in development and how the role of movement changes over time is important.

Motor Abilities versus Movement Skills and Implications for Development

The terms “movement” and “motor” are often used interchangeably to describe performance or skill level; however, these terms are different concepts (for review Burton & Miller, 1998). Nonetheless there are inconsistencies in their use across varying disciplines. Movement refers to the observable act of moving, reflecting change in the position of any body part. Motor on the other hand refers to neuromuscular processes underlying a movement (e.g.,

balance or coordination). In essence, motor abilities are not directly observable and must be inferred from performance. Differentiating between the two concepts is necessary for utilization of appropriate movement assessment tools.

Movement performance is defined as goal-directed movement that can be described with respect to quality or quantity. Qualitative descriptors of performance refer to the components of the skill such as the movement form or pattern used. On the other hand, quantitative descriptors focus on products or outcomes such as distance or amount (Burton & Miller, 1998). Processes underlying performance are motor abilities; general traits of an individual that are inferred from one's performance and are considered to be difficult to modify by practice or experience. Similarly, movement skill is used to describe qualitative expression of movement performance (e.g., high or low) and a particular set of goal-directed movement patterns (e.g., running, throwing). Movement is often divided for measurement purposes into two general types, process and product. Movement process refers to the movement pattern, the arm movements making-up a throw and movement performance, the accuracy of the throw. Although the majority of assessments focus on the product, it is the components (or coordination) of these movements that provide the greatest insight when trying to determine which aspect of the movement is impaired. Alternatively, movement product consists of several variables – distance, time, mass, energy, frequency, or number of repetitions - that define the movement outcome (Burton & Miller, 1998). Measurement of motor skills highlights the relationship between movement skills and different levels of information processing, placing specific focus on perceptual-motor, psychomotor, and sensorimotor skills. These measures are better suited as descriptors of motor processes rather than movement skills, per se (Burton & Miller, 1998).

The emergence of early movement milestones reflects the development of postural control to support the movement (Shumway-Cook & Woollacott, 2011). Movement milestones range from crawling, sitting, and standing to object manipulation. The transition from infancy to toddlerhood is marked by the onset of independent walking at approximately 12 months, which is considered the last of the movement milestones (Burton & Miller, 1998). Subsequently, locomotor and object control skills performed in an upright or bipedal position, that generally emerge between 1 and 7 years of age, are referred to as fundamental movement skills (Burton & Miller, 1998). Performance of these skills is more complex and requires greater coordination of the body. These fundamental movement skills are learned primarily through play and imitation of others (Provost, Heimerl, & Lopez, 2007). These fundamental skills are also considered to be the basis for more advanced, or sport specific, movement skills (Burton & Miller, 1998). All of the categories of movement skills have the potential to be classified as functional in that they are movement skills that can be performed in a natural and meaningful context. The importance of examining movement in the context with which they will be performed cannot be overlooked since it generally differs from an experimental one.

While one's performance or skill level can be measured at a specific point in time, it can also be examined as a function of change over time. Movement skill development and motor development are characterized as adaptive or functional changes of movement behaviour and the processes that underlie these changes, occurring over the lifespan (Burton & Miller, 1998). The former part of this definition indicates movement skill development (observable changes in movement), whereas the latter signifies motor development (underlying mechanisms that cause changes in movement behaviour).

For the most part, there is general consensus that early motor development (i.e., age at which movement milestones are attained) is delayed among young children with ASD (e.g., Hauck & Dewey, 2001; Lloyd, Macdonald, & Lord, 2011; Ornitz, Guthrie, & Farley, 1977). While much of the research examining motor abilities suggests that impairments are common among children and adolescents with ASD (Ghaziuddin & Butler, 1998; Green, Baird, Barnett, Henderson, Huber, & Henderson, 2002; Miyahara, Tsujii, Hori, Nakanishi, Kageyama, & Sugiyama, 1997), these impairments do not appear to be universal (Dewey, Cantell, & Crawford, 2007; Manjiviona & Prior, 1995). However, much of the varied results may be related to the task used or the composition of participants, which includes the comparison groups or normative data. With respect to fundamental movement skills, children and adolescents with ASD consistently demonstrate impaired performance compared to normative data (Berkeley, Zittel, Pitney, & Nichols, 2001) or typically developing peers (Pan, Tsai, & Chu, 2009; Staples & Reid, 2010a). To date, the performance of movement skills in the context with which they are used (i.e., play or physical education) has not been examined.

The Role of Movement Skills in Play

Play is considered to be a vital aspect of children's physical, cognitive, social, linguistic, and emotional development. However, the qualities that researchers believe to be crucial aspects of children's play and the components that define it differ (Jordan & Libby, 1997). The range of "playful" behaviour is diverse and cannot be defined as play without taking into consideration the context in which it occurs. An activity is considered play when it is enjoyable, spontaneous, voluntary, and intrinsically motivating. In addition, play involves active engagement, while also consisting of flexibility or the ability to change (Garvey, 1977; Rubin, Fein, & Vandenberg, 1983).

The nature of children's play changes over the course of their development in a relatively systematic fashion. Developmental milestones are often measured based on age and children become more interested in peer interactions around 2 years of age. Behaviours associated with peer interaction consist of looking, offering, or taking toys and objects. Early signs of reciprocal social interaction are acknowledged through moments of joint attention, a difficult skill for children with ASD (Kasari, Gulsrud, Wong, Kwon, & Locke, 2010). Early joint attention is typically a shared moment with the child's parent or caregiver. In short, joint attention is a moment of non-verbal communication about a third entity with another person.

The development of gross motor skills, including fundamental movement and active play skills, afford opportunities for children to participate in physically vigorous play. However, successful interactions with peers may be related to how well a child with ASD is able to perform fundamental skills (Provost, Lopez, & Heimerl, 2007). Play that involves physical activity and movement skills promotes and stimulates social interactions since it often requires the formation of teams. Therefore, active play benefits physical development, as well as cognitive and social domains (Pellegrini & Smith, 1998).

Play and joint attention are considered important developmental milestones in childhood. Impairments in early development of skills such as joint attention, indicates social information processing difficulties (Thurm, Bishop, & Shumway, 2011). These constructs are used as outcome measures to indicate success in early intervention for children with ASD (Kasari, Freeman, & Paparella, 2006). The effect of early intervention on play skills and joint attention among preschool children with autism was examined (Wong, Kasari, Freeman, & Paparella, 2007). Results indicated the acquisition of joint attention skills took a greater amount of time than play skills, but were mastered more quickly. As expected, children with higher

developmental skills demonstrated learning skills more quickly in addition to generalizing skills beyond the treatment setting (Wong, et al., 2007). Specific early interventions for young children with autism focused on joint attention and symbolic play skills show positive results towards increasing social communicative skills. These early interventions show immediate success as well as generalized success (Lawton & Kasari, 2012).

Play skills as well as social communicative, adaptive, and imitation skills have been studied from various aspects of development. Given the strong interaction between physical and social "worlds" during critical periods in development (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010), it should come as no surprise that motor and movement skills are embedded in each of these domains. These developmental domains will be outlined briefly, with the role of movement skills considered in each.

Social Communication

Although not an official diagnostic term, some children with ASD are classified as "high functioning" when they do not have associated intellectual impairment (i.e., IQ > 70). Level of functioning is typically determined through the use of standardized developmental assessments, which rely heavily on social and communication domains. As such, there may be increased opportunities for inclusion with peers in educational and recreational settings provided to children with ASD who demonstrate strengths in these areas, in turn providing additional opportunities to practice social and communication skills. The same could be considered true with respect to movement skills, better skills should provide more opportunities and ultimately afford increased participation in active play (MacDonald, Esposito, et al., 2011; MacDonald, Jaszewski, Esposito, & Ulrich, 2011) or team-based activities. Children who have more difficulty performing movement skills participate less often and ultimately spend less time

interacting socially with peers (Bouffard, Watkinson, Thompson, & Causgrove Dunn, 1996; Wrotniak, Epstein, Dorm, Jones, & Kondilis, 2006). For school-aged children, play involves games and activities, consisting of various fundamental movement skills. Specific activities, like bike riding, have been successful at increasing social skills in children with autism (MacDonald, Jaszewski, et al., 2011). The context of these activities provides unique opportunities for practicing movement and social skills. This reiterates the importance of providing early (learning) opportunities for children with ASD to master the performance of fundamental movement skills.

Given the reciprocal relationship between the ability to perform movement skills required in the context of play and the social skills required to interact successfully with their peers, it is likely that each provides reciprocal opportunities to practice and further develop the other (MacDonald, Jaszewski, et al., 2011). However, when a child is not competent performing physical (or social) skills, they are more likely to withdraw from play with other children (Pan, et al., 2009), which further limits their opportunities for practice in both domains. Over time, and with fewer opportunities for practice, developmental gaps between themselves and their peers continue to widen (Bouffard, et al., 1996). Intervention needs to be explored as an avenue to close the gap and provide increased opportunities to use motor skills for play and physical activity.

Adaptive Skills

Adaptive behaviour refers to the functional use of age-appropriate communication, socialization, daily living, and motor skills required for day-to-day self-sufficiency (Sparrow, Balla, & Cicchetti, 1984; Sparrow, Cicchetti, & Balla, 2005). A typical "autism profile" of adaptive behaviours consists of substantial delays in socialization and communication, with

relative strengths in daily living skills (Bolte & Poustka, 2002; Carter, et al., 1998; Volkmar, Sparrow, Goudreau, Cicchetti, Paul, & Cohen, 1987). It has been suggested that children with autism who have higher levels of cognitive functioning, have adaptive skills that do not increase accordingly (Klin, Saulnier, Sparrow, Cicchetti, Volkmar, & Lord, 2007; Liss, et al., 2001). A common term coined in autism literature is high-functioning autism, which typically means this child has an IQ within the typical range for their age and development. However, these high-functioning children with ASD do not demonstrate adaptive skills commensurate with their intellectual abilities (Perry, Flanagan, Dunn Geier, & Freeman, 2009). Research has shown that regardless of intellectual ability, adaptive functioning appears to either plateau or decrease, compared to age expectations, in the autism population (Freeman, Del'Homme, Guthrie, & Zhang, 1999; Gabriels, Ivers, Hill, Agnew, & McNeill, 2007; Schatz & Hamdan-Allen, 1995). Longitudinal studies examining individuals with autism from early childhood to adolescence have documented modest, positive change in social interaction skills; however, improvement was slower between middle childhood and adolescence than early and middle childhood (Baghdadli, et al., 2011; McGovern & Sigman, 2005; Shattuck, et al., 2007). In short, adaptive social abilities appear to increase with age, but at a slower rate than would be expected given chronological age and intellectual ability levels (Anderson, Oti, Lord, & Welch, 2009). It is important to note that adaptive social improvements have been documented as a result of intervention, which further highlights the importance of intervention for children with autism (for review see McConnell, 2002; Rogers, 2000).

Adaptive skills have been noted as a better prognostic indicator for children with autism, compared to other developmental assessments, such as traditional IQ tests. Adaptive skills are unique in that they focus on skills used in daily living. Often intervention studies, for this group

of children, focus on change in specific target skills (using standardized assessments of social skills, etc). The emphasis of the environment in adaptive skills poses unique qualitative aspects that beg the question of the use and function of motor skills within adaptive function. The use of adaptive skills in a natural context seems like a relatively important content area to explore, especially given the relationship of adaptive skills to positive outcomes (Anderson, et al., 2009).

Imitation

Early communication and adaptive learning among children occurs naturally through imitation. This important developmental skill requires motor, cognitive, and social abilities (Zachor, Ilanit, & Itzchak, 2010). Research has provided relatively consistent evidence of imitation impairment among children and adolescents with ASD (for review see Rogers & Williams, 2006; Williams, Whiten, & Singh, 2004). One of the earliest accounts of this impairment suggested that difficulties with imitation reflected difficulties with coordination of movement skills (Damasio & Maurer, 1978). The ability to organize and execute a movement clearly plays a role in imitation because successful performance is relative to both the perception of another's behaviour and the production of the appropriate action. The majority children with ASD were able to "imitate" the end goal of simple goal-directed actions, but they had particular difficulty imitating *how* movements were performed (Aldridge, Stone, Sweeney, & Bower, 2000; Carpenter, Pennington, & Rogers, 2001; Hobson & Lee, 1999). Imitation of nonmeaningful, or unfamiliar, actions tends to be more difficult than imitation of meaningful, familiar actions (Stone, Ousley, & Littleford, 1997; Vanvuchelen, Roeyers, & De Weerdt, 2007). Similarly, imitation of body movements is difficult compared to manipulating objects (Stone, et al., 1997). This suggests the familiarity of the task or the affordance of the object may help children with ASD to imitate appropriate actions (Vanvuchelen, et al., 2007). This idea is supported by

research, where children with ASD were impaired on imitation tasks requiring them to perform actions that were contradictory to the use or function of an object, or when the affordances (Warren, 1984) of an object were not as clear (Rogers, Hepburn, Stackhouse, & Wehner, 2003).

Assessment Measures

Assessment is important to understanding the complex behaviours of children and adolescents with ASD. However, the most salient point to be made, regardless of the area, is there is *no one size fits all* approach to assessment. Assessments are used for a variety of reasons, each valid in their own right -- the process of assessment begins by determining which measure to use. In other words, an individual needs to first know why they are doing the assessment and consider who they will be assessing. They also need to be clear on what they are hoping to learn and what information will be conveyed from the results of the assessment before they even begin.

Table 1 provides an overview of the age ranges and skills that can be measured for each of the assessments commonly used with toddlers, children, and adolescents with ASD. An overview of the composite scores and subtests included in each will be listed. An indication of standard administration time will be included, as well as administration strategies that can be considered for children with ASD. The choice of which assessment to use can be a challenge, especially considering the number of available developmental assessments. In order to meet everyone's need for assessment, the measures differ with respect to their purpose, method, administration, scoring, and even how the results can be interpreted. To facilitate the selection process, this section will review assessments commonly used in clinical and research contexts for toddlers, children, and adolescents with ASD (from birth to 21 years).

Bayley Scales of Infant and Toddler Development

The *Bayley Scales of Infant and Toddler Development* (*BSID*) is a clinical evaluation developed to help identify children with developmental delay who may require intervention services (Bayley, 1969, 1993, 2005). The *BSID-III* consists of three areas of development: cognitive, language and motor as well as two parent report subtests reflecting social-emotional and adaptive behaviours as they are performed in natural contexts. The motor score includes both fine and gross motor skills and is comprehensive in terms of the number of skills included; however, it is limited in that it does not provide separate scores for fine and gross motor skills.

Traditionally the Bayley scales are used as a developmental assessment for young children. They are more commonly used as a reference point, primarily in practice versus research. Based on standard scores, the *BSID* classifies performance into 1 of 4 categories to provide an indication of development: (a) accelerated development, (b) within normal limits, (c) mildly delayed, and (d) significantly delayed, with lower scores being indicative of greater impairment. These standard scores can also be converted to reflect age equivalence. Normative data for the *BSID-III* included a wider age range and clinical populations to establish the standard and age equivalent scores (Bayley, 2005). The age range extended the established floor and ceiling, thereby increasing the range of performance that can be measured, which is critical to examining change over time. A screener is also available for the *BSID*. The purpose of the screener is to determine if a child is developing as would be expected given their age, or if further assessment with the complete *BSID* is warranted. Screeners are not intended to be a comprehensive measure of motor skills, and therefore are not used often in research.

Mullen Scales of Early Learning

The *Mullen Scales of Early Learning* (*MSEL*) is a standardized assessment that is commonly used in clinical psychology as a developmental measure of cognitive development

(Mullen, 1989, 1995). The *MSEL* is organized into 5 subscales: (a) gross motor, (b) fine motor, (c) visual reception (or nonverbal problem solving), (d) receptive language, and (e) expressive language. An early learning composite score can be derived from fine motor, visual reception, receptive language, and expressive language scales. For young children this early learning composite score is considered equivalent to a more traditional "IQ" score or a developmental standard score. Each subscale is standardized to calculate a standard score, percentile and age-equivalent score. Although the subscales that make-up this early learning composite score have not been standardized specifically in young children with autism, the non-verbal problem solving has been considered a better representation of "IQ" for young children with autism, given ASD deficits in language (Luyster & Lord, 2009). Although most commonly used to obtain the early learning composite or measure of cognition, the subtests included in the *MSEL* can also be used individually to measure fine and gross motor skills.

Peabody Developmental Motor Scales

The *Peabody Developmental Motor Scales* (*PDMS*) are a standardized assessment commonly used in clinical and research settings (Folio & Fewell, 1983, 2000). The *PDMS-2* provides one of the most comprehensive assessments of motor skills in young children and includes a total 249 items representing 6 subtests: (a) reflexes (only administered to children from birth to 11 months), (b) stationary, (c) locomotion, (d) object manipulation (only administered to children 12 months and older, (e) grasping, and (f) visual-motor integration. The total motor quotient both gross and fine motor quotients, although each can also be examined separately. The gross motor quotient includes reflexes, object manipulation, stationary, and locomotion subtests. While the fine motor quotient reflects the grasping and visual-motor integration subtests. Based on the distribution of standard scores, the *PDMS-2* categorizes

performance into 1 of 7 categories: (a) very superior, (b) superior, (c) above average, (d) average, (e) below average, (f) poor, and (g) very poor, with higher scores reflective of better performance.

Batelle Developmental Inventory

The *Batelle Developmental Inventory* (*BTI*) screens and evaluates early developmental milestones, from birth to 7 years of age, based on a total of 450 items (Newborg, 2005; Newborg, Stock, Wnek, Guidibaldi, & Svinicki, 1984). Similar to the *PDMS-2*, the items in each domain are ordered by developmental difficulty. Only the items between the basal and ceiling levels are administered for each child.

The *BTI* is directly related to practice as it provides a total domain score in each of the 5 developmental areas included in IDEA: (a) motor (gross, fine, perceptual), (b) adaptive (self-care, personal responsibility), (c) cognitive (attention and memory, reasoning and academic skills, perception and concepts), (d) personal social (adult interaction, peer interaction, self-concept and social role), and (e) communication (receptive, expressive). Due its comprehensive nature, the *BTI* is widely used to determine a child's eligibility for early intervention or preschool special education programs and monitor progress while they are receiving those services. This assessment is used in the US as a state wide assessment based on norms to make decisions for educational placement and consequently less seen in research. There is also a screening test that consists of a subtest of items (20 from each of 10 age levels) from the complete inventory reflecting important developmental milestones. There is high agreement between the full *BTI* battery and its' shorter screening test (Elbaum, Gattamorta, & Penfield, 2010). Because of its decreased length, the screening test is frequently administered first to determine if there is a need for further assessments.

Vineland Adaptive Behavior Scales

The *Vineland Adaptive Behavior Scales* (*VABS*) is a commonly used measure of adaptive behaviour skills for children and adolescents up to 18 years of age (Sparrow, et al., 1984; Sparrow, et al., 2005). Although it is based on parental report of behaviour observed in natural contexts, the *VABS* has been correlated with gross and fine motor subtests from the *MSEL* (Lloyd, et al., 2011) and *PDMS-2* (Jasmin, Couture, McKinley, Reid, Fombonne, & Gisel, 2009). In addition to providing an overall composite score, it consists of three subscales: (a) communication (receptive, expressive, written), (b) socialization (interpersonal relationships, play and leisure, coping skills), and (c) daily living (person, domestic, community). Embedded in overall play and daily living skills, the *VABS* provides an indirect measure of gross and fine motor skills. Normative data has also been provided for individuals with ASD (Carter, et al., 1998), which makes comparison to these norms more meaningful with respect to level of functioning among children and adolescents with ASD.

Test of Gross Motor Development

The *Test of Gross Motor Development* (*TGMD*) provides a developmental framework for examining the performance of twelve fundamental movement skills in terms of the movement patterns used (Ulrich, 1985, 2000). These skills are necessary for successful play in physical education and playground settings, including locomotor skills (running, galloping, hopping, sliding, leaping, jumping) and object control skills (striking and kicking a stationary ball, dribbling, catching, throwing and rolling). The locomotor skills require fluid coordinated movements, while the object control skills focus more specifically on the child's ability to play with and/or manipulate balls. The *TGMD-2* is standardized for children aged 3 to 10 years 11 months; normative data suggests that by 10 years of age, majority of typically developing

children are able to achieve all of the performance criteria for a particular skill. The *TGMD-2* focuses on fundamental movement skills under the assumption that once the child masters these skills, they are ready to learn how to use them in more sport-specific activities, requiring skills to be used in context (Burton & Miller, 1998). The twelve movement skills included in the *TGMD-2* also reflect the skills being taught in physical education and are therefore deemed to be skills that would afford children with ASD to participate in additional physical activity pursuits.

Movement Assessment Battery for Children

Original *Movement Assessment Battery for Children* (*MABC*) was developed and validated for use with children ages 4 to 12 years (Henderson & Sugden, 1992). The majority of research has used the original version of the *MABC,* rather than the revised and more recently validated version that has been standardized for children and adolescents aged 3 to 16 years (Henderson, Sugden, & Barnett, 2007). The tasks and normative samples are divided into 3 age bands (3-6, 7-10, and 11-16 years). There are 8 tasks per age band, divided into 3 domains: (a) manual dexterity, (b) balls skills, and (c) balance. Standard scores for each domain can be compared to normative data and interpreted in terms of percentile equivalents (a) ≤ 5th percentile reflecting definite motor impairment, (b) ≤ 15th percentile reflecting borderline motor impairment, or (c) > 15th percentile reflecting no motor impairment, where higher standard scores represent greater impairment. These cut-offs are most commonly used in interpreting results following assessment, particularly when it comes to making referrals for specialized education programming. There is also a 60 question checklist that requires a parent or teacher to make a qualitative judgement as to how a variety of movement skills are performed in natural contexts. It is scored according to how well the child can perform each item and identifies whether or not the child should be further assessed using the complete *MABC-2*. This checklist

has not been revised since its' original version, which means the movement behaviours being evaluated are restricted to ages 5 to 12 years (whereas the *MABC-2* is standardized for ages 3 to 16 years).

Physical and Neurological Examination for Subtle Signs

The *Physical and Neurological Examination for Subtle Signs* (*PANESS*) was developed to provide an improved description to quantify the range of subtle signs and speed-related skills that are commonly seen in children (Denckla, 1974, 1985), including those with ASD. This assessment compares skills performed using both dominant and non-dominant sides of the body (eye, foot, hand) and groups these skills into subtests reflecting (a) gaits and stations and (b) timed tasks requiring rapid and/or sequential movements. Gait is examined by having children walk on their heels, toes, sides of feet, and forwards and backwards in tandem. Stations include a variety of static balance tasks where the child is also asked to execute concurrent movements, such as closing eyes or sticking tongue out. Timed tasks reflect repetitive or patterned movements involving a variety of body parts. While each these skills are not functional tasks in and of themselves, the *PANESS* does relate more specifically to (neuro)motor abilities underlying performance with higher scores being indicative of poor motor functioning.

Bruininks Oseretsky Test of Motor Proficiency

A norm-referenced test used to provide an overview of general motor functioning; it is based on the assumption that motor abilities develop with age and underlying abilities are subtasks to performance of functional tasks (Bruininks, 1978; Bruininks & Bruininks, 2005). As such, it is primarily used to detect potential motor impairment and delays in the performance of movement skills. The 2nd edition included children requiring special education services (i.e., learning disabilities, language impairments, developmental delays) in the normative data and was

standardized using clinical samples (i.e., developmental coordination disorder, ASD, mild to moderate intellectual impairment). The complete battery includes 53 items that are divided among 8 subtests reflecting gross and fine motor skills. Gross motor skills include: (a) bilateral coordination, (b) balance, (c) running speed / agility, (d) upper-extremity coordination, and (e) strength, while fine motor skills include: (a) precision, (b) integration, and (c) manual dexterity areas. The items included in each subtest become progressing more difficult. Scoring is based on performance of each task (e.g., time to complete a task, number completed within a fixed time, number errors made, or is the task met specified performance criteria). In addition to providing an overall measure of motor proficiency, standard scores are provided in 4 areas: (a) fine manual control, (b) manual coordination, (c) body coordination, and (d) strength / agility.

A short form version of the BOTMP includes 14 items and is intended to provide a brief overview of general motor proficiency. The items included in the short form represent each of the subtests and are selected from the complete battery. The short form requires approximately 15 to 20 minutes to administer, and has shown to have good correlation with the complete battery.

Criteria to Consider When Choosing an Assessment

As with cognitive and diagnostic assessments, the selection of a motor assessment tool needs to relate to the reason for testing. Motor assessments can be used to provide information for services and to identify children with developmental delays or those who are “at risk” for developmental delays (i.e., scoring below a set cut-point). Assessment outcomes can also be used to inform an intervention team regarding the specific skills that need to be targeted for that child in their program.

As with all assessments the administrator needs to use behaviour strategies to maximize participation. In working with children with autism this can be particularly important. In addition to standardized assessments it is important to consider the environment, mood and to it is also important to consider natural observation in addition to other factors that are inherent in performance of these skills in day to day functioning. There are benefits to all of the assessments that have been discussed, but it is important to understand the assessment and how it can best be used to inform the research question or clinical practice.

Purpose

Regardless of the purpose of assessment, whether it be for clinical practice or research, it is important that the assessment being used measures the specific skills of interest. For example, if a physical therapist wants to examine how a child catches and throws a ball to help them learn to play with their peers at recess, the assessment needs to consider all of the skills that would inevitably be required. Tossing a bean bag into a box as a younger child would do in the *MABC* would not likely provide the same level of information as looking at the specific performance criteria used when throwing a ball in the *TGMD-2*. In addition to examining the components of each skill that would inform instruction, such as foot placement or rotation of the upper body, the assessment should also include interaction with another individual because playing catch inevitably requires at least two people. On the other hand, if a researcher was interested in examining how speed and accuracy of throwing change as a function of age, they should be using an assessment that includes both timed and aiming components rather than looking at the characteristics of the movement pattern.

In addition to the skills being targeted, the assessment of choice must also be appropriate for the individual or population that you are assessing, primarily in terms of age and level of

functioning. Many of the assessments designed specifically for young children establish basal levels. A basal level typically consists of 2 or 3 maximum scores in a row. Young children usually begin an assessment at their chronological age. One issue facing assessment is "aging out of an assessment". In short, this means transitioning between assessments. Although assessments are based on standardized norms, children who fall within the higher age range have more value assigned to some of the more difficult or "older" developmental criteria. Choosing the appropriate motor assessment, which accommodates age is an important part of choosing the appropriate assessment.

There also exists a trade-off in terms of the time required to administer a comprehensive assessment. For example, the *MSEL* is commonly used in clinical assessment, and the gross motor subscale is brief and easy to administer. However, it is not as sensitive as a more comprehensive assessment such as the *PDMS-2* that also has the longest assessment time.

Administration

Some assessments require specific training to administer. For example, in the *TGMD-2*, demonstration of each skill must meet all performance criteria. In order to administer this assessment, one needs to know all of the performance criteria and be able to perform each skill successfully. Standardized assessments also include specific administration criteria, such as how the testing environment should be structured or the number of trials a child is allowed to complete a task, which varies from task to task on the *BOTMP*. Some tasks only require a second trial if the maximum score is not obtained on the first trial. This necessitates not only being aware with administration protocol, but also scoring criteria. While the 12 skills being assessed in the *TGMD-2* are the same for all ages, the equipment used (i.e., ball size and weight) changes at age 6 to reflect developmental changes.

Assessments that can be naturally broken up to allow administration to be conducted across a number of days or to allow for frequent breaks may be best for children and adolescents with ASD. These breaks allow the child to maintain their attention on task, and although they may take longer, the movements are usually more indicative of their potential to perform these skills. Some assessments have flexibility naturally embedded in them (e.g., *PDMS-2*), while others are more structured and designed to be completed in a specific sequence or time frame.

Scoring and Interpretation

The majority of assessments were developed and norm established with a typically developing sample, often to the exclusion of clinical samples. As such, the scoring and interpretation of results should be interpreted with caution. For example, norms established in the UK did not seem to provide a culturally normative comparison for Japanese children (Miyahara, et al., 1997) as findings suggested significantly greater impairment among children with ASD than was found in previous, or subsequent, studies.

Several "key" studies in movement and ASD have also included participants older than standardized norms, yet results were compared relative to norms (e.g., Ghaziuddin, Butler, Tsai, & Ghaziuddin, 1994). When age exceeds the age for which the assessment has been standardized, raw scores should be used rather than standard scores (which are established relative to the norms that do take age into account). Similarly, when children and adolescents with ASD exceed the age with which the assessment has been standardized, comparison to normative data for purposes of percentile or age equivalents provides limited information.

Several assessments (e.g., *MABC*, *PDMS-2*) are commonly utilized to examine motor abilities among children and adolescents with ASD, where performance is compared to cut-off scores based on normative data. Generally speaking, a definite impairment is said to exist when

standard scores are below the 5th percentile (or 2 SD) and borderline impairment below the 15th (e.g., *MABC*).

The TGMD- 2 is a norm-referenced test for children aged 3 - 10 years old, but has been used frequently in older children with ASD, especially those with movement difficulties or developmental disabilities where performance is not likely to ceiling (Morin & Reid, 1985; Staples & Reid, 2010a). These motor assessments have the ability to be a powerful tool, using the above mentioned assessments as criterion-referenced, means that each assessment can also be used for purposes of tracking progress (or rate of change) on a specific skill or domain. Although most of the assessments are built on standardized norms, the use of raw scores or criterion reference helps to better understand motor skill change in children with ASD.

It is important to consider using raw scores or comparison groups that are matched on specific developmental variables (e.g., Staples & Reid, 2010a). Raw and age equivalence scores do increase over time among children with ASD, just not at a rate comparable to their same aged peers. Cross-sectional assessment demonstrates that performance of movement skills start below and progress slower, which widens the performance gap. Assessment can also be used to examine or quantify change over time, which essentially uses each child as their own comparison or frame of reference over a series of points. Assessment is not just about a percentile score or whether a child meets a specific criterion, we need to learn how a child does something or where their strengths are (not just what they can not do). It is important to use assessment as a means to learn more about the pattern of deficits or areas that need to be targeted for improvement.

Ecological Validity

The majority of movement skills performed in play and physical education are open skills that require consideration of the context and environment in which they are performed. The

majority of assessments take place in controlled environments, which are inherently different than performance in day to day settings. As such, some movement skills cannot always be performed or measured in a clinical office or laboratory setting using discrete tasks. Observation of skill quality, or the component processes used to produce the movement, should be an integral aspect of determining which skills need to be targeted for children to be more successful. Other important considerations in assessing children with ASD include sensory sensitivities and following instruction. It is important to ensure that the testing environment is as realistic as possible and individualized in order to provide an optimal testing environment.

Motor Abilities and Movement Skills and Autism Spectrum Disorders

In the original description of what is now referred to as Asperger's syndrome, there was considerable weight attached to motor clumsiness (Asperger, 1944, 1991). Although Kanner (1943) suggested that gross motor skills were not a significant problem, he inadvertently reported that almost 30% of children with autism in his sample did not walk independently until 18 to 24 months. This latter point is perhaps the first evidence to support contentions for delayed attainment of developmental milestones among children with ASD. Since those initial observations, difficulties in the performance of movement skills have been found quite consistently across all ages and subtypes (for review see Fournier, et al., 2010). As such, we will refer collectively to autism, Asperger's syndrome, and pervasive developmental disorder, not otherwise specified as ASD. This review will focus on the development and performance of movement skills from birth to age 21 years.

Delayed Milestones

In addition to the core characteristics (i.e., social communication deficits, repetitive behaviours and restricted interests), movement behaviour may be one of the earliest detectable

signs of ASD (Baranek, 1999; Sutera, et al., 2007; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Although delays in walking are typically among the first concerns reported by parents of children who later received an ASD diagnosis (e.g., Chawarska, Paul, Klin, Hannigen, Dichtel, & Volkmar, 2007), retrospective video analyses suggest that motor delays are present in children with ASD prior to walking (Baranek, 1999; Ozonoff, et al., 2008; Teitelbaum, et al., 1998). Through video analysis Teitelbaum, et al. (1998) reported qualitative differences in the movements involved in the major milestones (e.g., lying, righting, sitting, crawling, walking) as early as 6 to 12 months.

These movement differences persist -- between 14 to 24 months seems to be a critical point at which development seems to change among young children with ASD (Landa & Garrett-Mayer, 2006; Lloyd, et al., 2011). A prospective study that examined children at 6, 14, and 24 months found an unusual slowing in the development of motor skills between 14 and 24 months. These findings were further supported when a large cross-sectional study of young children with ASD (12 to 36 months) found significant fine and gross motor delays that seemed to get worse with age, even when visual receptive organization (non-verbal problem solving) was controlled for in the analysis (Lloyd, et al., 2011). To examine trajectories of development more explicitly, a subset of these children were assessed again approximately one year later and found that their rate of development for both fine and gross motor skills did in fact slow down (Lloyd, et al., 2011). The rate of development is critical, especially in comparison to the gains being made among typically developing children of the same age. By the ages of 3 and 4, young children with ASD were found to have significant gross motor delays and poor fine more skills compared to normative data (Jasmin, et al., 2009). As children with ASD get older (3 to 7 years), their performance on fine and gross motor tasks begins to resemble that of younger typically

developing children, aged 2 to 5 years, matched on MA equivalence (Hauck & Dewey, 2001). The extent of delays among young children with ASD appears to widen and persist. In fact it is hypothesized that these motor delays become cumulative and contribute to deficits in the performance of motor skills (Ozonoff, et al., 2008).

Collectively, these findings suggest motor delays are present by preschool age and have the potential to become a diagnostic indicator. When Chawarska, et al. (2007) questioned the parents of 75 toddlers with ASD regarding symptoms between the ages of 2 and 4 years, they found that early delays in social communication and motor development contributed to (retrospective) recognition of young children later diagnosed with ASD.

Motor Abilities

Majority of children and adolescents with ASD demonstrate impaired performance on the *MABC* when compared to normative data (Green, et al., 2002; Green, et al., 2009; Hilton, Wente, LaVesser, Ito, Reed, & Herzberg, 2007; Manjiviona & Prior, 1995; Miyahara, et al., 1997; Van Waelvelde, Oostra, Dewitte, Van Den Broeck, & Jongmans, 2010). Children with ASD were also more significantly impaired when compared to same-aged children who were diagnosed specifically for deficits in the motor domain (Green, et al., 2002) or who were matched on either receptive vocabulary or non-verbal IQ(Whyatt & Craig, 2012). When looking more specifically at these impairments, Whyatt and Craig (2012) propose that children with ASD have the greatest difficulty completing tasks in the domains requiring manual dexterity and ball skills, while Green, et al. (2009) have noticed that greater difficulties with tasks that have inherent dual nature to them such as the accuracy and speed trade-off seen in timed peg board task.

Similarly, performance of children and adolescents with ASD reflected impaired motor abilities on the *BOTMP* relative to normative data (Ghaziuddin & Butler, 1998) and typically

developing children of similar age and IQ (Dewey, et al., 2007). Ghaziuddin and Butler (1998) examined the performance of children and adolescents spanning the autism spectrum in terms of diagnosis. Coordination deficits were found in all 3 groups compared to normative data, but initial findings revealed that individuals in the autism group were the most impaired. However, when IQ was controlled for in the analysis, the between group differences were no longer significant. This underscores the importance of trying to separate motor and cognitive functioning.

Although the *MABC* and *BOTMP* are the most common assessments used to examine the contribution of underlying abilities to the performance of movement skills, they provide limited information about *how* the movements are performed and therefore contribute very little to determining which skills may require further examination. The *PANESS*, on the other hand, does provide detailed information that can be particularly useful to describe the performance of other movement skills. For example, the rhythm or speed with which movements are performed, or the presence of extraneous or involuntary movements can serve to provide systematic observations of age-related changes in performance (Gidley Larson, Mostofsky, Goldberg, Cutting, Denckla, & Mahone, 2007). With the exception of one research group (e.g., Jansiewicz, Goldberg, Newschaffer, Denckla, Landa, & Mostofsky, 2006; Mostofsky, Powell, Simmonds, Goldberg, Caffo, & Pekar, 2009), the PANESS is rarely used in clinical practice or research despite its potential to contribute an additional level of description to the movements.

Fundamental Movement Skills

Research examining the performance of movement skills among children and adolescents with ASD has been limited, but results have consistently associated ASD with poor movement skills compared to peers without ASD. School-aged children with autism demonstrate

significant deficits in the performance of both locomotor and object-control skills included in the *TGMD* (Berkeley, et al., 2001; Pan, et al., 2009; Staples & Reid, 2010a). One study reported that all girls and 70% of boys with ASD, aged 6 to 8 years, were impaired on the performance of locomotor skills when compared to normative data (Berkeley, et al., 2001). However, many of the children included in this study seemed to focus on the function (or the end goal) of the task instead of the process or form used to perform the actual skill. For example, during the performance of locomotor skills, the children with ASD many have interpreted the goal of the task as moving from point A to point B, rather than the actual movement pattern used to get there. This is a common observation among young children with ASD during the execution of imitation tasks (e.g., Carpenter, et al., 2001).

Similarly, the performance of locomotor skills by 28 boys with ASD, aged 6 to 10 years, was significantly impaired compared to their same aged peers (Pan, et al., 2009). The boys with ASD had particular difficulty performing the gallop and leap. These findings were replicated with a slightly older age group (9 to 12 years). The performance of 21 boys and 4 girls with ASD was found to be impaired on all skills in the locomotor subtest compared to sex and age-matched peers (Staples & Reid, 2010a). Similarly, Morin and Reid (1985) reported that poorly coordinated arm movements and a lack of opposition between arms and legs was characteristic of both running and jumping performance for adolescent males with ASD compared to a clinical control group matched on age and IQ.

In terms of object control skills, Berkeley, et al. (2001) reported that only 53% of their sample (100% of girls, but only 30% of boys) of 6 to 8 year old sample of children with ASD demonstrated difficulty. This finding suggests that object control skills are not as impaired as locomotor (Berkeley, et al., 2001), which essentially parallels the finding that children with ASD

have less difficulty imitating actions that require the manipulation of objects (Stone, et al., 1997). It may not be the skills that are impaired, but rather that the affordances of the objects provide an indication of the movement to be performed (Vanvuchelen, et al., 2007). However, this finding of relatively spared performance of object control skills among children with ASD did not hold (entirely) true as two studies found performance of the same skills to be significantly impaired among slightly older children with ASD (Pan, et al., 2009; Staples & Reid, 2010a). Although when Pan, et al. (2009) examined individual object control skills, the significant differences were attributed primarily to 4 skills: strike, dribble, catch, and roll. Nonetheless, in other research, majority of boys (DeMyer, 1976) and adolescent males (Morin & Reid, 1985; Reid, Collier, & Morin, 1983) with ASD demonstrated immature throwing and catching patterns, with many children with ASD having particular difficulty controlling the direction and force of the ball when throwing (Manjiviona & Prior, 1995).

Generally speaking, many of the skills that children with ASD had difficulty performing required specific timing and coordination of multi-sequence movements (Bauman, 1992) that may involve 2 or more limbs or both sides of the body at the same time (Ghaziuddin & Butler, 1998; Jones & Prior, 1985; Morin & Reid, 1985; Reid, et al., 1983; Staples & Reid, 2010a). In summary, many performance differences also seem related to the concepts of momentum/force and timing/coordination (Staples & Reid, 2010a). Significantly lower means and much greater variability are also found when examining locomotor and object control scores for the children with ASD compared to typically developing children of the same chronological age (Pan, et al., 2009; Staples & Reid, 2010a).

Staples and Reid (2010a) also included two developmentally-matched comparison groups to explore the nature of these movement skill differences. When the same children with ASD

were closely matched on performance (± 3 on raw score of each subtest on the *TGMD-2*), they found that 9 to 12 year old children with ASD performed movement skills comparable to typically developing children approximately half their age (i.e. 4 to 6 years). There were no differences found between the two groups when the 12 fundamental movement skills were examined separately, with the exception of dribbling where the older children with ASD were able to control the ball more efficiently (Staples & Reid, 2010b).

The second developmentally-matched comparison demonstrated that children with ASD performed significantly worse on both locomotor and object control skills when compared to a typically developing group of children matched on mental age (MA) equivalence (Staples & Reid, 2010a). However, when looking at the individual locomotor skills, significant differences were found between the groups on only the run, hop, and leap (Staples & Reid, 2010b). Perhaps more surprising was when it comes to object control skills, where significant differences did not exist on any of the individual skills, but rather reflected cumulative impact of poor performance across many skills (Staples & Reid, 2010b). However, these results can also be attributed to the large range in scores for the younger group matched on MA due to the fact that the children in this group span 4 to 11 years! So we're seeing a developmental effect here among the typically developing children on individual skills, as we would expect given the range in age.

Comparisons to this MA-matched group also provides evidence to suggest that differences in movement skill among children with ASD cannot be accounted for entirely in terms of cognition (Staples & Reid, 2010a).

Life Span Movement Behaviour

We have reviewed the cross-sectional evidence to support the argument that majority of children with ASD demonstrate impaired performance of movement skills that are pervasive

from early infancy well into adolescence. However, the majority of these empirical investigations include a limited number of participants spanning a relatively wide age range. Although cognitive impairment is common among many individuals with ASD, many descriptive studies have limited participation to "high functioning" children with ASD. In essence this eligibility criterion neglects the autism "spectrum" and focuses on a relatively small sub-sample. Collectively, these limitations make it challenging to examine patterns of change over time or infer patterns and rates of development in the motor domain.

Although longitudinal research about the movement skills of children with ASD are lacking, there are a number of papers that when examined together show that deficits in movement skills are present at an early age and persistent with time. Early fine and gross motor skills of toddlers with ASD are delayed when compared to norms (Lloyd, et al., 2011; Provost, Lopez, et al., 2007) and become increasingly more so as these young children reach school age (Hauck & Dewey, 2001). This gap continues to widen and by late childhood, performance of fundamental movement skills is comparable to typically developing children approximately half their age and not commensurate with their MA equivalence (Staples & Reid, 2010a). This widening would imply different rates of development; children with ASD may in fact follow a unique developmental trajectory (Staples & Reid, 2009), which would suggest there is more than just a delay in the development of these movement skills.

Intervention

In 2001, the National Research Council (NRC) recognized motor skills as being 1 of 8 areas that should be specifically targeted in the intervention curriculum for young children with ASD. Despite these recommendations and the evidence that demonstrates motor skill deficits are prominent in ASD and pervasive across ages and time (for review see Fournier, et al., 2010), the

primary focus of early intervention programs has remained almost exclusively on improving social communication skills (Dawson, et al., 2010; Kasari, et al., 2006; Kasari, Freeman, Paparella, Wong, Kwon, & Gulsrud, 2005). The National Standards Report (National Autism Center, 2009a, 2009b) further reviewed educational and behavioural treatments targeting the core behaviours of ASD to address the need for evidence-based guidelines to inform decisions regarding effective intervention practices for children and adolescents with ASD. However, much of the discussion stemming from this recent report has been about characteristics that should be inherent in effective intervention programs (such as frequency or intensity), rather than the actual skill areas that should be targeted.

Although we are learning more about ASD every day, the most widely cited and understood message about treatment is the earlier the intervention and the younger the children, the better outcome (Dawson, et al., 2010; Kasari, et al., 2005; National Autism Center, 2009a; National Research Council, 2001). Early intervention has tended to focus on social communication skills, core diagnostic characteristics of ASD (National Autism Center, 2009a; National Research Council, 2001). For these young children this includes skills such as imitation, joint attention and play (functional and symbolic play skills) (Kasari, et al., 2005). Randomized control trials have clearly displayed that intensive early intervention significantly improves behaviour in the social communicative domain as well as other aspects of autism symptomology (Dawson, et al., 2010; Kasari, et al., 2010; Wong & Kwan, 2010). Outcome measures to gauge the effectiveness of the intervention or the progress of the child are based on IQ (Lovaas, 1987), language, adaptive behaviour, or a change in autism diagnosis (i.e., moving from ASD to PDD-NOS) (Dawson, et al., 2010). Although there is widespread agreement on the necessity of early

intervention, there is less consistent agreement on what that intervention should consist of and motor skills has been underexplored (Dawson, et al., 2010; Kasari, et al., 2005; Lovaas, 1987).

Aside from the clear indication of social, communicative and motor relationships in neurodevelopmental research, behaviour-driven research has suggested that motor skills could hinder success in early intervention (Sutera, et al., 2007). Early intervention is focused on the social communication deficits in children with autism and in typically developed children the relationship of motor development and movement skills have been made in both language production and active play (Kasari, et al., 2006; Kasari, et al., 2005; Kasari, Paparella, Freeman, & Jahromi, 2008; Luyster, Lopez, & Lord, 2007; Luyster & Lord, 2009). In older children with autism, motor behaviour assessments (e.g., *TGMD-2*) have been developed based on the foundational skills needed to participate in physical education and playground activities (Ulrich, 2000). Arguably the same concept exists for young children, better motor skills allow children to explore their environment, and with exploration participation may occur and therefore practice of other social communication skills, such as play can take place. The results of descriptive studies provides a great deal of insight into the performance of fundamental movement skills among children and adolescents with ASD, but there is still much to learn about the observable (and quantifiable) differences that exist, particularly when it comes to the performance of locomotor skills.

Evidence based research has shown that with individualized instruction and/ or adaptive equipment age-appropriate movement skills can be learned (e.g., MacDonald, Esposito, et al., 2011). For example children with autism successfully learned how to ride a two-wheel bicycle, and furthermore this new skill provided additional opportunity for social skill practice (MacDonald, Jaszewski, et al., 2011). This emphasizes the importance of movement skills to

increased participation, which in turn provides social communicative opportunities among school-aged children with autism.

Future Direction

What does improvement in movement skills mean in the context of life for children with ASD? For example, if children with ASD can learn to perform each of the skills required to play baseball, will they be able to participate successfully on a little league team? As mentioned earlier, intervention for children with autism typically resides in the social communicative domain, and rightfully so given the hallmark characteristics of autism. Research has already demonstrated initial relationships between motor behaviour and social skills among children with ASD (MacDonald, Jaszewski, et al., 2011), yet this content area needs to be explored further for school-aged children and adolescents. Movement skills are a critical component to childhood development and provide the foundational skills needed for active play. Play and movement-based activities provide a context for interaction, and social "practice", a common goal in social communicative interventions. With the structured practice, systematic instruction, and adaptive equipment, participation on the little league team is possible (for review see Staples, Todd, & Reid, 2006).

We are just starting to understand the extent of delays in the performance of movement skills among school-aged children with ASD, but is this enough? As researchers and practitioners, the next step is to understand factors underlying this delay. Longitudinally, children need to be followed over time to determine what factors (or combination of factors) might lead to more favourable outcomes (Thurm, et al., 2011). For the most part, there is general consensus that early motor development (i.e., age at which developmental milestones are attained) is delayed among young children with ASD. As children with ASD age, they are not

able to perform movement skills commensurate with their age and seem to fall further and further behind. As this developmental age gap widens, these delays appear to become motor deficits. Intervention approaches need to target these different rates of development, which may perhaps be entwined with unique profiles of learning. The use of developmental trajectories puts a focus on examining change over time within the same individuals (Thomas, Annaz, Ansari, Scerif, Jarrold, & Karmiloff-Smith, 2009), which may also afford specific examination of learning profiles (Mostofsky, Goldberg, Landa, & Denckla, 2000). This focus will begin to examine how patterns of behaviours and symptoms may evolve into different developmental outcomes, underscoring the importance of movement, its role in the autism profile and further more how intervention can target improvements in this developmental area.

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