EXPRESSIVE AND PERCEPTUAL MOTOR FUNCTIONING IN ADULTS WITH AUTISTIC TRAITS

A Thesis

By

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ABSTRACT

The DSM-5 characterizes autism spectrum disorder (ASD) as a gross impairment in social cognition and functioning. Recent research indicates that motor dysfunction may be a critical component to the disorder and serve as a precursor to hallmark social deficits. Very little research has studied perceptual motor abilities (e.g. biological motion processing) compared to expressive motor behaviors (e.g. gross/fine motor skills) in autistic individuals. Further, the trajectory of ASD-related motor impairments beyond early development and into adulthood is unknown. The present study examined if adults higher in autistic traits demonstrate greater impairment in both perceptual and expressive motor domains. A total of 621 adults, aged from 18 to 73 years, were assessed on measures of autistic traits and motor functioning. Results indicated that adults with greater autistic traits also reported greater expressive motor difficulties (e.g. coordination) childhood and adulthood. Autistic traits as well as expressive motor dysfunction were predictive of biological motion processing abilities. The results also revealed sex differences in expressive motor functioning, autistic traits, and biological motion processing. Overall, these findings suggest that adults with greater autistic traits experience both deficits in motor activities as well as underlying motor perceptual abilities.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Professor Gerianne Alexander and Professor Rebecca Brooker of the Department of Psychological and Brain Sciences and Professor Jay Ganz of the Department of Education and Human Development.

All other work conducted for the thesis was completed by the student independently.

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CHAPTER I

INTRODUCTION

Autism spectrum disorder (ASD) is one of several neurodevelopmental disorders marked by social deficit. According to the Diagnostic Statistical Manual of Mental Disorders (DSM-5), a diagnosis is primarily based on two core domains of social deficit: (1) impairment in social communication and interaction and (2) repetitive and restricted behaviors and interests (RRBIs). In comparison to children with ASD, ASD symptomatology in adulthood is staggeringly understudied (Piven & Rabins, 2011). Most ASD symptomatology research has focused on the identification of early behavioral and neurological markers of social deficit and RRBIs (e.g. minimal eye contact, overall reduced visual attention to socially-salient stimuli, stereotyped movements (Zwaigenbaum, et al., 2015). Among the few systematic reviews and meta-analyses focusing on adulthood, researchers have mostly discussed broad lifetime deficits including limited social integration, higher rates of mental health problems, and poor occupational prospects (Howlin & Magiati, 2017). There is some evidence that core symptoms of ASD improve throughout adolescence and into adulthood, however more research is needed to understand the clinical manifestation of symptoms within this age group (Seltzer et al., 2003). One area outside core social domains that has garnered research focus in recent years is motor functioning.

Motor functioning as it relates to ASD is often associated with the DSM-5 criterion, RRBIs. The notion of repetition is central to RRBIs as a group, which includes overt motor behaviors (e.g. hand flapping), complex cognitive repetition (e.g. adhering to specific routines or rituals), and complex behavioral repetition (e.g. perseverative fascination with transportation). These three classes of behavior are categorized by one term, RRBIs, to highlight the

commonality of repetition. Perhaps the most researched motor-related RRBIs are the stereotypic, self-stimulatory behaviors (e.g. hand flapping) which often emerge in toddlerhood and are most commonly observed in males (Militerni et al., 2002; Mandy et al., 2012). Motor-related RRBIs continue to be a significant aspect of the disorder, one associated with other clinical features including sleep problems, adaptive deficits, and lower cognitive functioning (Gabriels, Cuccaro, Hill, Ivers, & Goldson, 2005). However, these types of behaviors are not found in all individuals with ASD and are not stable over time (Militerni et al. 2002). More research is need to examine if motor impairments outside of RRBIs are more stable and persist into adulthood.

In comparison to studies of children, very little research has focused on motor functioning in adults with ASD. To examine the literature on motor functioning, it is helpful to separate motor impairments into two categories: expressive and perceptual deficits. Expressive deficits relate to impairments in gross and fine motor coordination as well as motor stereotypies. Most research on motor functioning among children and adults alike focus on expressive motor impairments. A lesser studied area of motor functioning is perceptual motor deficits, which relate to an individual's ability to regulate and organize sensory input relating to movement. Typically-developing children learn to organize spatial information and perceive patterns of movement which contribute to the mastery of motor skills (Adolph & Johnson, 2007) Therefore, it is conceivable that perceptual motor skills serve as building blocks for expressive motor skills.

1.1. Expressive Motor Impairments

Expressive motor impairments are generally categorized by a failure to meet motor milestones. Children and adults with ASD typically demonstrate impairments in both gross and fine motor domains. In children, gross motor deficits include disturbances in abilities of lying, sitting, crawling, walking, and balance (Teitelbaum et al., 1998; Dawson & Watling, 2000). Fine

motor deficits in children include difficulties with grip, pinch strength, and other skills that involve smaller muscle movements (Grace, Enticott, Johnson, & Rinehart, 2017). In adults, gross motor impairments include poor upper- and lower-limb coordination, deficit postural control, and slowed gait (Bhat, Landa, & Galloway, 2011; Armitano et al. 2020). Fine motor impairments for both groups include weak grip strength and slower finger tapping speed (Travers et al. 2017). Despite a consensus on shared gross and fine motor impairments, it is unclear if expressive motor impairments decline as ASD individuals enter adulthood or if impairments in this population are subtler or go unnoticed.

Few studies have examined the age-related trajectory of motor skills beyond early adolescence in individuals with ASD. One longitudinal study examined the development of motor abilities from childhood to mid-adulthood, and found that manual motor performance (i.e. grip strength, finger tapping speed) in ASD adults predicts future adaptive living skills (Travers et al., 2017). This suggests that subtle motor difficulties such as moving one's fingers and manipulating objects can significantly impact adaptive daily living (Travers et al. 2017). Poor grip strength can make daily tasks such as opening jars, carrying grocery bags, and pouring liquids, more difficult. Travers et al. (2017) also suggest that the compounding of poor manual motor skills can lead to increased disability over time. More research is needed to understand how motor abilities in adulthood is associated to outcomes such as daily living skills, employment, and quality of life.

1.2. Perceptual Motor Impairments

In addition to expressive motor abilities, motor functioning also includes perceptual motor abilities. Proficient motor perception involves the capacity to integrate multiple sensory inputs which in turn contributes to motor behavior. Typically-developing individuals are capable

of drawing on perceptual information in order to develop competence in motor behaviors (Adolph & Johnson, 2007). Those with and at-risk for ASD demonstrate a weaker ability to integrate auditory, visual and motor stimuli (Dawson & Watling, 2000). This directional link between perception and behavior is not implied in all disorder areas. For example, within language disorders, a malfunctioning perceptual system (i.e. Wernicke's area) does not necessarily reflect a malfunctioning expressive system (i.e. Broca's area). However, there is evidence to indicate that impaired perceptual mechanisms within the motor system may also underlie receptive and expressive social deficits (Fabbri-Destro et al. 2013).

To further illustrate perceptual motor dysfunction, an understanding of relevant neurobiological evidence is valuable. Fabbri-Destro et al. (2013) discuss the mirror mechanism as a fundamental component to link motor perception and behavior within the context of ASD. The mirror mechanism refers to the process by which humans use sensory information to inform motor behavior. Evidence for mirror neurons was first found in the premotor and parietal cortex of monkeys. In this study, brain activation occurred as monkeys observed and performed various motor acts (Rizzolatti et al. 1996). Since then, researchers have moved beyond animal models to examine if mirror neurons are present and behave in the same ways in human brains. Williams et al. (2001) was the first to propose the link between a malfunctioning mirror mechanism and the development of ASD. This link was based on theoretical considerations of the role of motor systems in ASD symptomatology. Although researchers are not able to record single neuron activity in humans using the invasive procedures that are performed with monkeys, various forms of imaging data (i.e. TMS, EEG, MEG, PET, fMRI) have shown evidence of the presence of mirror neurons in motor areas of the human brain (Fabbri-Destro et al., 2013). Fabbri-Destro

et al. (2013) provide a detailed review of the many empirical studies that have since been published to support this link.

It is possible that a malfunctioning motor system may underlie all three classes of RRBIs (i.e. overt motor behaviors, complex cognitive repetition, and complex behavioral repetition), but may more clearly manifest in one concept (e.g. stereotypies) over another (e.g. perseverative interests). Moreover, a distinction between cognitive and behavioral perseveration may allow for greater sensitivity to the differed phenotypes associated with ASD. For example, an individual may demonstrate cognitive perseveration by reciting scripts of a television show but may not engage in physical stereotyped behaviors.

Biological Motion Perception

Perceptual motor deficits that may underlie expressive motor deficits include difficulties in visual-spatial awareness and organization (Tseng & Chow, 1999). A relatively novel yet emerging development in the ASD literature of perceptual motor deficits is the study of biological motion perception. In the early 1970's, Johansson (1973) observed that individuals were capable of perceiving human movement with minimal visual cues. Biological motion (BioM) is depicted by point-light animations of dots attached to the joints of an organic figure. Individuals are typically able to perceive the spatial organization of these dots as a biological figure producing movement. It has been suggested that the ability to interpret biological motion is related to proficiency in motor movement (Federici et al., 2020). Of particular relevance to an understanding of ASD is the theory that perceptual systems involved in interpreting BioM are also tied to social abilities (Pavlova, 2011). A preference for BioM and upright figures compared to non-BioM and upside-down figures has been found in as early as two-day-old newborns, and this preference extends into adulthood for typically-developing individuals (Simion et al., 2008).

Furthermore, one study demonstrated that infants aged 9-months with a preference for viewing BioM also had higher scores on the developmental index (e.g. physical motor, receptive language, social relationships) (Kutsuki et al, 2009).

Given evidence that BioM perception may be a basic social cognitive ability, it is also not surprising that individuals with more severe social cognitive impairments show deficits in this perceptual domain. For example, a plethora of studies have demonstrated BioM processing deficits in schizophrenia, a population of individuals whose social cognitive processes are greatly impaired; a review of 15 studies involving individuals with schizophrenia revealed moderate to large deficits in BioM processing including higher-level processes, such as emotion recognition and intention attribution (Okruszek & Pilecka, 2017).

BioM Processing in Adults with ASD

Researchers have utilized common behavioral measures such as reaction time and accuracy to assess different processing abilities from point-light displays (PLDs) including the discrimination of BioM from non-BioM (e.g. scrambled motion) and the recognition of emotional and subjective states. This research reveals mixed findings regarding the abilities of adults with ASD to discriminate BioM from non-BioM; two studies using similar stimuli found that an ASD-group performed comparably to a non-ASD group while the other study revealed a deficit to discriminate BioM in the ASD-group (Hubert et al., 2007; Blake et al., 2003).

More consistent evidence exists related to ASD-adults' ability to extract higher-order information (e.g. emotion) from PLDs. Although Hubert et al. (2007) found that high-functioning adults with ASD were able to distinguish BioM actions from non-BioM actions, these participants demonstrated an impaired ability to extract information regarding subjective

states (e.g. tired, hurt, cold) from emotional displays. This finding is consistent with another study that found that adults with ASD also have difficulty extracting emotional information (e.g. angry, happy) from stimuli (Atkinson et al. 2009). Nackaerts et al., (2012) also found that compared to typically developing adults, adults with ASD were less accurate in extracting emotional information and produced more saccades and shorter fixation durations for BioM stimuli. In sum, there is evidence that adults with ASD demonstrate greater difficulty at extracting higher-order information of moving figures, suggesting a possible deficit in motor-related perceptual skills.

1.4. Present Study

Following the vast amount of research supporting the presence of motor dysfunction in ASD, a more current conceptualization of the disorder is to consider perceptual and expressive impairments distinctly. Further, very little is known about the trajectory of motor functioning in adults with ASD. It is conceivable that there are detectable disruptions to sensory-motor processes that underlie expressive behaviors. A further exploration of the occurrence of explicit (i.e. expressive) and implicit (i.e. perceptual) processes in adulthood may also have implications for motor interventions in adults with ASD, a group that is often understudied in regards to intervention.

The present study will examine both facets (i.e. expressive and perceptual) of motor dysfunction in adulthood. Expressive motor skills will be assessed with a standardized self-report measure of motor abilities. Perceptual motor skills will be assessed utilizing two computer tasks assessing participants' ability categorize BioM from non-BioM (Task 1) and extract higher-order information (i.e. emotional state) from stimuli (Task 2). Based on previous research, it is hypothesized that adults with greater self-reported ASD traits will demonstrate more pervasive

impairment in expressive motor skills and biological motion processing. Adults with impairments in expressive motor domains should also demonstrate perceptual deficits, while the converse may not be true. Further, based on research regarding sex differences in ASD symptomology and motor abilities, it is hypothesized that autistic traits and motor dysfunction will differ among males and females. Studying expressive and perceptual motor processes in adulthood may provide valuable insight into the mechanisms that persist after the developmental period.

CHAPTER II

METHODS

2.1. Participants

The initial sample included 943 participants who volunteered to participate through one of two recruitment pools. Seven hundred and forty-three participants were recruited through Amazon Mechanical Turk (mTurk) and 200 participants were recruited through an undergraduate psychology pool at Texas A&M University (SONA). Inclusion criteria for SONA included an age of 18 years or older, and mTurk participation was restricted to profile ratings of at least 95%. Exclusion criteria included failing one or more attention-check items (e.g. select definitely agree), inputting an incorrect survey code, or clear evidence of low effort (i.e. selecting all 1's). These data exclusion practices as well as our overall rate of exclusion is consistent with recommendations for assuring mTurk data quality (Ahler et al., 2020). The final sample consisted of 621 participants (see Table 1).

Participants (320 males, 295 females) ranged from 18 to 73 years of age (M=36.66, SD=12.33) and were primarily (65.8%) White/Caucasian (15.4 % Black/African-American, 5.8% Asian, 7.0% Hispanic, 5.3% Mixed Race, 0.5% American Indian/Alaskan Native, 0.2% Other Race). Participants also reported on handedness (83.9% usually to always right-handed), preterm status (33.2% Preterm), paternal education (51.2% College Graduate), maternal education (41.8% College Graduate), personal history of serious illness/injury (70.3% none), and personal/sibling history of developmental delays or disorders (86.4% personal none, 89.2% sibling none).

2.2. Measures

Demographic Questionnaire

A demographics questionnaire asked participants to fill out general information including several variables that relate to a diagnosis of ASD. These factors included age, sex, ethnicity, preterm status, personal report of medical illness/injury, personal and sibling report of medical illness/injury and developmental delays, parental education, parental age, as well as handedness as measured by the Edinburgh Handedness Inventory (Short Form) (Veale, 2013).

Autism Spectrum Quotient – Short (AQ-28)

The original Autism Spectrum Quotient (AQ-50) is a 50-item self-report questionnaire that measures autistic traits in adults (Baron-Cohen et al., 2001). The AQ-50 comprises five domains of ASD-related deficits: social skills, attention switching, attention to detail, communication, and imagination. The AQ-50 has been found to demonstrate good diagnostic validity, including sensitivity and specificity in clinical as well as non-clinical samples (Woodbury-Smith et al., 2005; Hurst et al., 2007). However, there are mixed findings regarding positive and negative predictive values as well as the factor structure of the AQ-50 (Woodbury-Smith et al., 2005; Ashwood et al., 2016). There have also been discrepancies in scoring practices including use of the original 0-1 compared to the more recently suggested 1-4 point scoring system. Baron-Cohen et al. (2001) also originally proposed a cut-off score of 32 as most predictive of ASD, whereas other studies have recommended a cut-off of 26 when using the AQ for screening purposes (Woodbury-Smith et al., 2005; Ruzich et al., 2015).

Following mixed findings regarding the predictive validity of the AQ-50, many studies have since empirically tested alternative models with the purpose of enhancing psychometric properties. A recent comprehensive analysis of various proposed factor structures for the AQ

found the most support for the three-factor structure proposed by Russell-Smith et al. (2011) (English et al., 2019). Based on findings from this analysis, the present study utilized this model which consists of a 28-item version of the AQ comprising three domains of ASD-related deficits: social skills, details/patterns, and communication/mindreading (Russel-Smith et al. (2011). Further, a 1-4 point scoring system is utilized and an emphasis on AQ subscale scores over total-scale scores are considered in analyses based on recent recommendations (English et al., 2019).

Adult Repetitive Behaviors Questionnaire-2 (RBQ-2A)

The Adult Repetitive Behaviors Questionnaire-2 (RBQ-2A) is a 20-item self-report questionnaire that measures restricted and repetitive behaviors and interests (RRBIs). The RBQ-2A was developed to address the gap in the literature examining RRBIs in adults and is based on the RBQ-2, a parent-report of RRBIs in children. The RBQ-2A has been shown to be a reliable and valid self-report measure of RRBIs in adults (Barrett et al., 2018; Jia et al., 2019). For the purposes of the present study, the RBQ-2A served as a measure of expressive motor functioning.

The Adult Developmental Coordination Disorder/Dyspraxia Checklist (ADC)

The Adult Developmental Coordination Disorder/Dyspraxia Checklist (ADC) is a 30-item self-report questionnaire that measures movement difficulties in adulthood. Developmental coordination disorder (DCD) is a developmental disorder that was considered a childhood disorder until more recent evidence suggesting that persistent difficulties extend into adulthood (Kirby & Rosenblum, 2010). The subscales of the ADC assess both childhood history and current report of motor-related daily difficulties. The ADC has been shown to have high levels of internal validity, construct and concurrent validity, and discriminant validity (Kirby &

Rosenblum, 2010). For the purposes of the present study, the ADC served as a measure of expressive motor functioning along with the RBQ-2A.

Perceptual-Motor Assessment: Biological Motion Processing

BioM perception was assessed utilizing three computer tasks. BioM stimuli utilized in these tasks consist of 12 moving PLDs of a male actor walking (Figure 1) as well as 12 scrambled/non-BioM versions of these stimuli (Figure 2). The presented PLDs contain three exemplars of a male walking in one of four emotional states neutral, happy, sad, angry. Within each emotion category, three perspectives of PLDs are included: front, medium, side. Stimuli were acquired from a group of researchers who found that ASD-subjects were less accurate in recognizing biological motion and emotions from PLDs (Nackaerts et al., 2012). See Nackaerts et al. (2012) for a more detailed description of the creation of these stimuli.

Perceptual Task 1: BioM Recognition

The first paradigm assessed for recognition of biological motion and is modeled after Nackaerts et al. (2012). Nine randomized PLD's, looped to 10-seconds each, were presented to all participants. Characteristics of the PLDs included a male actor, neutral emotion, three perspectives (front, medium, side), and three actions (walk, jump, kick). Standardized instructions were provided on the monitor at the start of each test before subjects were presented with a series of PLDs that either depicted a person's movements ('biological motion') or did not depict a person's movements ('scrambled'). Participants were asked to categorize each clip as "person" or "not a person."

Perceptual Task 2: BioM Emotion Categorization

The third paradigm assessed for categorization of emotion PLDs using a forced-choice response task. Similar to the first paradigm, the task included 12 PLD's looped to 10-seconds each. Characteristics of the non-scrambled PLDs included a male actor, four emotions (neutral, happy, mad, sad), one perspective (front), and three actions (walk, jump, kick). The decision to include only a male actor and one perspective was to present participants with as few PLDs as possible to answer the research question while also limiting potential fatigue of task length. Participants categorized each clip as one of four emotions: neutral, happy, mad, sad. The purpose of the categorization task was to see how participants extracted higher-order information from PLDs when they are presented with given emotion words.

2.3. Procedure

Participants signed up for the study through mTurk or the TAMU Psychology SONA system. Each participant tested remotely in one session lasting a maximum of 60 minutes. Participants provided informed signed consent before completing the five questionnaires and the two computer tasks. Individuals recruited through mTurk received $2.00, and students recruited through SONA received credit to apply towards undergraduate course requirements.

CHAPTER III

RESULTS

3.1. Predicting BioM Processing

Means and standard deviations for all demographic and study variables can be found in Table 1 and Table 2. First, several relevant assumptions of hierarchical multiple regressions were assessed. According to previously established statistical recommendations, a sample size of 500 is statistically adequate for 12 independent variables to be included within the regression analysis (Tabachnick & Fidell, 2001). Second, an examination of correlations between independent variables revealed that several were moderately to highly correlated. However, a further examination of the collinearity statistics revealed that the variance inflation factor (VIF) for Step one and two of all regressions were below 1.8, which is well below the threshold for substantial issues related to multicollinearity (Cohen et al. 2003). The variables ADC-Childhood, ADC-Adulthood, and RBQ-2 in Step 3 in all regressions revealed a VIF of below 3.4, which is still below the threshold for excessive multicollinearity. Given that tolerance values for all variables were also within accepted limits, it was deemed the assumption of multicollinearity was met (Coakes, 2005). Third, assumptions of normality and linearity were assessed and deemed to be met as indicated by P-P plots for all regressions. Finally, a preliminary examination of residual and scatter plots suggested no evidence of heteroscedasticity. A Breusch-Pagan test was run to further explore the presence of heteroscedasticity and revealed non-significant p-values, which suggests the assumption of homoscedasticity was met (Breusch & Pagan, 1979).

Four sets of three-Step hierarchical multiple regressions were run to predict BioM processing. BioM scores were calculated as proportion of correct items over completed items: ((items correct / items completed) * 100). BioM Recognition (Task 1 performance) was entered

as the dependent variable for the first two regressions, and BioM Emotion Categorization (Task 2 performance) was entered as the dependent variable for the third and fourth regressions. Several demographic variables were entered at Step one of all four regressions including Sex (male, female), PSAI, Age, Preterm Status, Sibling with Developmental Disorder/Delay, Parental Education, and Handedness to control for the proportion of variance accounted for by factors relevant to a diagnosis of ASD as indicated by previous research. Recruitment Pool (mTurk, SONA) was also entered in Step one to control for other extraneous differences between the two samples. Step two of all four regressions included Autistic traits as measured by the AQ-28 (AQ-SS, AQ-DP, AQ-CM). Step three of all four regressions included expressive motor behaviors as measured by the ADC and RBQ-2. However, given that expressive motor functioning in childhood and adulthood as measured by the ADC were highly correlated ($r(622) = .908$, $p < .001$), Step three included either ADC-Childhood or ADC-Adulthood for both BioM Recognition and BioM Emotion Categorization regressions. Intercorrelations between the variables were reported in Table 2 and the summary of hierarchical regression statistics are reported in Tables 4 and 5.

Predicting BioM Recognition (Task 1)

For Task 1, both hierarchical multiple regressions revealed that at Step one, demographic factors significantly contributed to the model, $F(8, 492) = 4.704$, $p < .001$ and accounted for 7.1% of the variance in the ability of individuals to discriminate between BioM and non-BioM. Two significant predictors emerged within step 1. Individuals who reported having at least one sibling with a developmental disorder/delay scored poorer on Task 1 ($\beta = -126$, $p < .01$). Individuals who reported a greater preference to use the left-hand more than the right-hand also scored poorer on BioM Recognition ($\beta = .091$, $p < .05$).

In Step two, it was revealed that adding autistic traits to the model did not account for a significant proportion of the variance above and beyond demographic variables. Only report of siblings with developmental disorder/delay maintained as a significant predictor ($\beta = -.123$, $p < .01$).

In Step three, the inclusion of repetitive behaviors and movements (RBQ-2A) as well as motor dysfunction in childhood (ADC-Childhood) explained an additional 4% of the variance and was statistically significant, F (13, 487) = 4.886, $p < .001$. Report of siblings with a developmental disorder/delay once again maintained as a significant predictor ($\beta = -.098$, $p < .01$). ADC-Childhood emerged as a significant predictor, such that individuals who reported greater expressive motor difficulties performed poorer on BioM Recognition ($\beta = -.222$, $p < .01$). In Step three of the other regression, the inclusion of repetitive behaviors and movements (RBQ-2A) as well as motor dysfunction in adulthood (ADC-Adulthood) explained an additional 3% of the variance and was statistically significant, F (13, 487) = 4.404, $p < .001$. Report of siblings with a developmental disorder/delay maintained as a significant predictor ($\beta = -.104$, $p < .05$). Age emerged as a significant predictor, such that older individuals performed poorer on BioM Recognition ($\beta = -.114$, $p < .05$). Unlike the previous regression, ADC-Adulthood did not emerge as significant predictor as did ADC-Childhood.

Post-Hoc Comparisons for BioM Recognition (Task 1)

A series of post-hoc analyses were conducted in order to further explore the subset of individuals who performed exceptionally poorly on BioM Recognition. First, a nominal variable was created and the dataset was filtered to categorize individuals who performed at or below chance (50%) (N = 59). A series of bivariate correlations were conducted to examine the relationship between autistic traits and motor dysfunction within this subsample. Results

revealed that the AQ-CM was positively correlated with all measures of expressive motor functioning, including RBQ-2A ($r(59)=.548$, $p<.001$), ADC-Childhood ($r(59)=.402$, $p = .002$), and ADC-Adulthood ($r(59) = .393$, $p = .002$). The AQ-SS and AQ-DP were not correlated with expressive motor functioning within this subset of individuals who performed poorly on BioM Recognition. A multivariate analysis of variance (MANOVA) was also run to examine if mean differences between these variables vary as a function of sex. The MANOVA revealed that RBQ-2A, ADC-Childhood, and ADC-Adulthood scores were significantly dependent on sex, ($F(1,55) = 4.783$), $p = .03$, $\eta_p^2 = .08$; $F(1,55) = 4.213$, $p = .05$, $\eta_p^2 = .07$; $F(1.55) = 4.055$), $p = .049$ $\eta_p^2 = .07$). For the RBQ-2A, males (M=2.7, SD=.54) reported more RRBIs than females (M=1.96, SD=.54). Males (M = 15.14, SD = 7.97) also reported greater childhood movement difficulties than females (M = 10.76, SD = 8.15) on the ADC-Childhood. Finally, males (M = 43.54, SD = 23.03) also reported more adulthood movement difficulties than females (M = 31.83, SD = 20.84) on the ADC-Adulthood. None of the AQ subscales significantly depended on sex.

Predicting BioM Emotion Categorization (Task 2)

For Task 2, both hierarchical multiple regressions revealed that at Step one, demographic factors significantly contributed to the model, $F(8, 492) = 19.105$, $p < .001$ and accounted for 23.7% of the variance in the ability of individuals to categorize BioM displays of emotion. Four significant predictors accounted for the variance above and beyond other variables. Gender-stereotyped play behavior as indicated by the PSAI emerged as significant predictor, such that individuals who reported more feminine behavior in childhood performed poorer on BioM Emotion Categorization ($\beta = .120$, $p < .05$). Another significant predictor was age, such that younger individuals performed poorer on Task 2 ($\beta = .154$, $p <.01$). Preterm status was also a

significant predictor, such that individuals born pre-term performed poorer on BioM Emotion Categorization (β = -.234, p <.001). Recruitment pool was also a significant predictor, such that individuals recruited from the mTurk pool performed poorer on BioM Emotion Categorization (β = .406, p < .001).

Unlike the BioM Recognition task, the inclusion of autistic traits in Step two significantly predicted an additional proportion of the variance (5.2%) in the BioM Emotion Categorization task above and beyond demographic variables, F (11, 489) = 19.098, p < .001. Scores on the PSAI, Age, Preterm Status, and Recruitment Pool maintained as significant predictors and matched directionality of previous Steps (β = .097, p < .05; β = .118, p < .05; β = -.161, p < .001; β = .395, p < .001). Two subscales of the AQ emerged as significant predictors: AQ-CM, AQ-SS. Individuals who reported more communication/mindreading difficulties performed poorer on BioM Emotion Categorization (β = -.234, p < .001). Contrary to our hypothesis, individuals who reported less social skill difficulties performed poorer on BioM Emotion Categorization, (β = .130, p < .01).

In Step three, the inclusion of RBQ-2A and ADC-Childhood scores further accounted for an additional statistically significant proportion of the variance (1.9%) above and beyond demographic variables and autistic traits, F (13, 487) = 16.694, p < .001. Age, preterm status, recruitment pool, AQ-CM, and AQ-SS maintained as significant predictors and matched directionality of previous Steps (β = .105, p < .05; β = -.100, p < .05; β = .368, p < .001; β = -.169, p < .001; β = .123, p < .01). Neither RBQ-2A nor ADC-Childhood scores emerged as significant predictors. In Step three of the other regression, the inclusion of RBQ-2A and ADC-Adulthood scores was statistically significant, explaining an additional 2.2% of the proportion of variance, F (13, 487) = 4.404, p < .001. Age, Preterm status, Recruitment Pool, AQ-CM, and

AQ-SS maintained as significant predictors and matched directionality of previous Steps (β = .109, $p < .05$; β = -.096, $p < .05$; β = .370, $p < .001$; β = -.167, $p < .01$; β = .139, $p < .01$). Unlike Step three of the other regression, ADC-Adulthood emerged as a significant predictor, such that individuals who reported more expressive motor difficulties in adulthood performed poorer on BioM Emotion Categorization (β = -.155, $p < .05$).

Post-Hoc Comparisons for BioM Emotion Categorization (Task 2)

A series of post-hoc analyses were conducted in order to further explore the subset of individuals who performed exceptionally poorly on BioM Emotion Categorization. First, a nominal variable was created, and the dataset was filtered to categorize individuals who performed at or below chance (25%) (N = 77). A series of bivariate correlations were conducted to examine the relationship between autistic traits and motor dysfunction within this subsample. Results revealed that the AQ-CM was positively correlated with all measures of expressive motor functioning, including RBQ-2A ($r(77) = .408$, $p<.001$), ADC-Childhood ($r(77) = .716$, $p < .001$), and ADC-Adulthood ($r(77) = .795$, $p < .001$). The AQ-SS and AQ-DP were not correlated with any expressive motor functioning variables within this subset of individuals who performed poorly on BioM Emotion Categorization. A multivariate analysis of variance (MANOVA) was also run to examine if mean differences between these variables vary as a function of sex. The MANOVA revealed that neither the variables of expressive motor functioning nor the AQ variables significantly differed as a function of sex.

3.2. Motor Functioning Within Individuals

A repeated-measures analysis of variance was conducted to examine the individual trajectories of motor functioning within participants. Utilizing scoring guidelines of the ADC, a binary variable was created to indicate if individuals endorsed significant past motor difficulties

in childhood (i.e. score of at least 17). A within-subjects variable included both scores of BioM Rec and BioM Emotion Categorization. The analysis revealed an interaction between BioM Task and Childhood Motor Problems, F (1, 621) = 6.845, $p < .01$, $\eta_p^2 = .011$. Individuals with significant childhood motor difficulties performed poorer (M = 66.61, SD = 20.17*)* on BioM Recognition than individuals who did not report significant past motor difficulties (M = 75.75, SD = 16.04*)*. Individuals with significant childhood difficulties also performed worse on BioM Emotion Categorization (M = 37.47, SD = 14.80*)* than individuals who did not (M = 51.95, SD = 15.73).

Following scoring guidelines of the ADC, adulthood motor difficulties were considered only as a scaled score. A bivariate correlation revealed significant negative relationships between ADC-Adulthood and BioM Recognition ($r(623) = -.198$, $p < .001$) as well as BioM Emotion Categorization ($r(623) = -.394$, $p < .001$). Overall, individuals who reported more adult motor difficulties performed poorer on both perceptual tasks.

3.3. Sex Differences in Autistic Traits and Motor Functioning

A multivariate analysis of covariance (MANCOVA) was conducted to examine if autistic traits and motor functioning varied as a function of sex when controlling for age. The means and standard deviations for the analysis are presented in Table 3. The MANCOVA revealed significant main effects of Sex for RBQ-2A (F(1, 571) 10.853, p = .001 η_p^2 = .019), ADC-Childhood (F(1, 571) 8.471, p = .004, η_p^2 = .015), ADC-Adulthood (F(1, 571) 5.822, p = .016, η_p^2 = .010), AQ-DP (F(1, 571) 6.664, p = .010, η_p^2 = .012), and BioM Emotion Categorization (F(1, 571) 6.104, p = .014, η_p^2 = .011). Males reported greater deficits in autistic traits and expressive motor functioning across the RBQ-2A, ADC-Childhood, ADC-Adulthood, and AQ-DP. Females performed better than males on categorizing emotion displays of BioM as measured

by Task 2. Main effects of Sex for AQ-SS, AQ-CM, and BioM Recognition were not significant. Age was a significant covariate in the model for all variables.

CHAPTER IV

DISCUSSION

The present study explored the relationship between autistic traits and motor functioning. The results supported our hypothesis that individuals with greater autistic traits also reported greater expressive motor deficits. Also consistent with our hypothesis, expressive motor dysfunction in childhood and adulthood predicted BioM performance differently. Expressive motor dysfunction in childhood was predictive of individuals' abilities in recognizing BioM from scrambled motion, but not in categorizing emotion PLDs. Expressive motor dysfunction in adulthood was only predictive of individuals' abilities in categorizing emotion PLDs.

Contrary to our hypothesis, not all domains of autistic traits were predictive of BioM performance deficits. Neither deficits in social skills, details/patterns, nor communication/mindreading were predictive of BioM recognition. However, impairment in communication/mindreading predicted poorer performance on BioM emotion categorization.

The results also supported our hypothesis that there are sex differences across ASD variables as well as expressive/perceptual motor variables. These differences were found in domains of expressive motor functioning, autistic traits related to details/patterns, and BioM emotion categorization.

4.1. Autistic Traits and Perceptual Motor Dysfunction

BioM Recognition (Task 1)

The finding that autistic traits were not predictive of BioM recognition is consistent with studies suggesting a distinction between higher- and lower-order BioM abilities. Unlike Task 2, the stimuli used in Task 1 consisted only of neutral walkers. The absence of information pertaining to emotional state and action characterize Task 1 stimuli as less socially complex

(Todorova, Hatton, & Pollick, 2019). The finding that individuals performance on BioM recognition did not vary as a function of autistic traits is consistent with evidence that autistic individuals may be more successful in lower-order BioM processing (Hubert et al., 2007; Murphy et al., 2009; Parron et al., 2008). Other studies have found that group differences in BioM performance exist when individuals are required to extract higher order information, such as emotional content, from BioM stimuli (Parron et al., 2008; Nackaerts et al., 2012). A recent meta-analysis of BioM processing abilities in autistic individuals revealed the strongest processing impairment for simple and complex emotional recognition tasks while only small effects were found for simple BioM detection (Todorova et al., 2019). Our finding that no group differences were found in BioM recognition suggests that autistic traits in adulthood are not associated with impairment in extracting simple social information from BioM stimuli.

BioM Emotion Categorization

Our finding that individuals with greater autistic traits (social skills, details/patterns) showed decreased performance in categorizing emotion point-light displays (PLD) is consistent with previous studies (Todorova, Hatton, & Pollick, 2019). Biological motion (BioM) can convey various types of social information even in the absence of recognizable features of human faces and bodies (Johansson, 1973). If dynamic elements of BioM are responsible for conveying critical social information, it is conceivable that individuals with ASD, who experience deficits in social interactions, may also experience deficit in underlying motor processing abilities. This finding within a general population sample suggests that even sub-clinical autistic traits are associated with deficits in higher-order BioM processing. The ability to extract social information from PLDs may require an underlying proficiency to process motion, which may not be developed in individuals with greater autistic traits.

Results also revealed that ASD-related deficits in social skills and communication/mindreading predicted decreased performance on emotion categorization. Performance on BioM tasks depended on the domain of ASD deficit. These results suggest that social competence as it relates to interaction, communication, and interpretation of others' thoughts and feelings is related to the ability to successfully extract social information from BioM. This interpretation is consistent with other studies that have examined the relationship between social cognitive autistic traits and BioM perception (Pavlova, 2012). Interestingly, ASD traits related to attention to details and patterns did not predict decreased performance in BioM processing. A possible interpretation is that hyper-attention to details and patterns, which may have real-world negative social implications, may be considered an adaptive skill when it comes to processing BioM stimuli. This finding warrants further exploration into the re-conceptualization of autistic traits as impairment or expertise. More research is needed to provide a distinction between the weight of social and motor proficiency in BioM processing abilities.

Whether or not the ability to extract social information from BioM influences how individuals develop social competence has not yet been studied. Existing and future literature on BioM processing in early infancy may serve to answer this question. There is evidence that preferential attention to BioM changes during the first months of life, however the extent to which the development of motor competence coincides with that of social competence is understudied (Sifre et al., 2018). In order to better understand if underlying motor processing abilities are necessary for the development of social competence, future research should expand study of expressive motor deficits in infancy to include how motor perceptual processes develop and interact with social development.

4.2. Expressive and Perceptual Motor Deficits

Within the ASD literature, no studies have examined the co-occurrence of expressive and perceptual motor deficits at any age. While there is research to indicate a general ASD-related impairment in both domains of motor deficit, the present study is the first to indicate that individuals with greater expressive motor impairments also demonstrate greater perceptual motor impairments. Our study revealed significant relationships between all expressive motor measures and all perceptual motor measures, but performance on BioM tasks significantly differed depending on if motor difficulties occurred in childhood or adulthood. That is, childhood motor difficulties were only predictive of lower-order BioM detection, and adulthood motor difficulties were only predictive of higher-order BioM emotion categorization. Our hypothesis that childhood motor difficulties would be predictive of both BioM tasks was based on evidence that motor difficulties in childhood have pervasive implications for later motor competence (Travers et al. 2017). However, the finding that childhood motor difficulties were only predictive of simple BioM detection may reflect a discrepancy between the difficulty between the tasks, as participants scored higher on simple detection overall. The finding that adult motor difficulties only predicted emotion categorization is consistent with our hypothesis that the co-occurrence of expressive and perceptual deficits exists in adulthood. More research is needed to determine if a diagnosis of ASD moderates the relationship between motor difficulties and complex BioM processing. It will also be important for future studies to examine the co-occurrence of expressive and perceptual deficits within a clinical sample as well as within an at-risk sample.

4.3. Sex Differences in Autistic Traits and Motor Functioning

As diagnostic criteria currently stand, males are four times more likely than females to receive a diagnosis of ASD (Duvekot et al., 2017). Early ASD research traditionally included predominantly male samples, which has raised concerns that females with ASD may be under-

identified and miss opportunities for early diagnosis and intervention (Duvekot et al., 2017). Recently, more efforts have been made to recruit females in equal proportion to males. The present study included a comparable sample of males and females in order to identify if true group differences exist in motor functioning abilities.

Males were more likely to endorse autistic traits as measured by AQ-DP, a subscale that measures hyper-attention to details and patterns. This gender-linked pattern is generally consistent with studies testing the empathizing-systemizing theory originally proposed by Baron-Cohen (2006). Autistic males are more likely to be experts at systemizing, or recognizing repeating patterns in stimuli (Escovar et al., 2016). It has been suggested that excellent attention to detail is related to sensory hypersensitivity in autism (Baron-Cohen et al., 2009). Our finding that AQ-DP was the only autistic trait not predictive of BioM processing also warrants further exploration into the developmental trajectory of hyper-attention to detail/patterns in males and females. It is possible that the development of both motor proficiency and social proficiency may, at an early age, be disrupted across genders.

The finding that females performed better than males on categorizing emotion displays of BioM is also consistent with the systemizing-empathizing theory. Adult females tend to score higher on empathizing, which is the related to abilities to perceive the emotional states of others (Escovar et al., 2016). Our finding is contrary to a recent meta-analysis that found no effects of sex on BioM paradigms in ASD individuals (Todrova et al., 2019) However, it should be noted that the meta-analysis focused on a clinical sample while ours did not. It is possible that there is more variability in BioM performance across males and females at the sub-clinical level, which may have implications for improving the under-dentification of individuals.

The present study also found that males reported greater deficits in all measures of expressive motor functioning. Our finding that males reported greater deficits on the RBQ-2A is consistent with previous research indicating that restricted and repetitive behaviors and interests (RRBIs), which are most related to motor stereotypies, occur more frequently in males (Knutsen et al., 2018). The ADC, which measures the presence of motor difficulties associated with a diagnosis of adult developmental coordination disorder, yielded greater scores for males than females in our sample. The ADC is the first screening tool designed to specifically identify motor difficulties experienced by adults (Kirby, Edwards, Sugden, & Rosenblum, 2009). Although developmental coordination disorder has historically been considered a childhood disorder, there is recent evidence to suggest that expressive motor difficulties persist into adulthood (Roberts & Purcell, 2018). Further, there is evidence that motor difficulties in adulthood predict quality of life (Engel-Yeger, 2020). More research is needed to examine the extent to which motor difficulties present in adulthood for males and females.

These combined findings suggest that an exploration beyond core social domains may reveal gender differences that are not included in the current conceptualization of ASD. There is continued debate as to whether or not males are at a greater susceptibility for the disorder or if the bias in prevalence rate reflects issues with the conceptualization and assessment of the disorder (Lai et al. 2015). Our findings did not reveal motor functioning as an area in which females reported more deficit than males or inform a male-biased phenotype of ASD. However, further exploration into motor functioning and other areas outside core domains will serve to help identify where true group differences exist.

4.4. Limitations

The present study faced several limitations. First, the sample was drawn from two recruitment pools which differed significantly across performance on several study variables. It should be noted that a cognitive measure was not included, which may have been a primary significant difference between the college sample (SONA) and the general sample (mTurk). Although a recent meta-analysis suggested no effect of intelligence scores on BioM performance, future research may benefit from investigating how cognitive factors beyond intelligence scores moderate the relationship between autistic traits and BioM performance (Todrova et al., 2019).

The present study also utilized a non-clinical sample, which poses limitations regarding the relationship between variables in an ASD diagnostic group. However, our findings imply that BioM processing abilities are relevant even at a sub-clinical level. One significant change from the DSM-5's predecessor is the collapse of diagnostic subcategories (e.g. Asperger's syndrome) to shift from a categorical to dimensional conceptualization of the disorder. From a dimensional approach, it is important to explore motor functioning in individuals who do not meet diagnostic criteria for ASD. In doing so, more emphasis is given to the degree in which various symptoms manifest in severity and frequency across individuals and better represents the existing heterogeneity across individuals. Furthermore, the identification of deficits outside of core domains may contribute to the evolving conceptualization of the disorder.

Table 1.
Descriptive Statistics of Demographic Variables

Demographic variable	N	% of mTurk n=452	% of SONA n=169	M (SD)
Age	--	--	--	*mTurk:* 36.72 years (11.00) *SONA:* 18.51 years (1.34)
Handedness	--	--	--	*mTurk:*
More Left	100	18.1%	10.7%	63.89
More Right	523	81.9%	89.3%	(61.61) *SONA:* 79.81 (52.94)
Sex				
Female	320	43.8%	71.6%	--
Male	295	55.3%	26.9%	--
Prefer not to answer	4	.7%	.6%	--
Ethnicity				
American Indian/Alaskan Native	3	.7%	0%	--
Asian	36	3.5%	11.8%	--
Black/African-American	96	20.9%	.6%	--
Hispanic	44	3.5%	16.6%	--
White/Caucasian	410	68.7%	58%	--
Mixed	33	2.4%	13%	--
Other	1	.2%	0%	--
Preterm Status				
Pre-term	179	32.6%	18.3%	--
Full-term	360	56.6%	60.9%	--
Maternal Education				
Some High School	39	5.7%	7.7%	--
High School Graduate	145	30%	5.3%	--
Some College	178	35%	11.2%	--
College Graduate	260	29.3%	75.1%	--
Paternal Education				
Some High School	45	7%	7.7%	--
High School Graduate	103	20.3%	6.5%	--
Some College	156	30%	11.8%	--
College Graduate	319	42.7%	74%	--
Serious Illnesses/Injuries				
Yes	184	33.7%	18.3%	--
No	438	66.1%	81.7%	--

Developmental Delays/Disorders				
Yes	77	16.1%	2.4%	--
No	538	83%	95.3%	--
Siblings Yes	64	12.1%	5.3%	--

Table 2.
Descriptive Statistics and Correlations of Study Variables

Variable (*N*=623)	M (SD)	1	2	3	4	5	6	7	8	9	10
1. AQ-28 Total	65.15 (10.68)	--									
2. AQ-SS	30.26 (7.53)	.787 **	--								
3. AQ-DP	17.67 4.61)	.447 *	-.084 *	--							
4. AQ-CM	17.23 (3.96)	.682 **	.318 **	.201 **	--						
5. RBQ-2A	1.86 (.56)	.404 **	.055	.421 **	.497 **	--					
6. ADC Childhood	8.08 (7.68)	.383 **	.121 **	.279 **	.478 **	.760 **	--				
7. ADC Adulthood	27.10 (21.57)	.439 **	.212 *	.245 **	.495 **	.771 **	.908 **	--			
8. PSAI	47.85 (15.81)	-.007	-.007	.079 *	-.097 *	-.036	.005	-.034	--		
9. Task 1 (BioM vs Non-BioM)	73.74 (17.43)	-.015	0.36	-.059	-.040	-.168 **	-.239 **	-.198 **	.071	--	
10. Task 2 (Emotion)	48.76 (16.64)	-.198 **	-.037	-.129 **	-.313 **	-.371 **	-.393 **	-.394 **	.010	.229 **	--

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

Table 3.
Means and Standard Deviations for Variables Across Sex

	Males N = 284 M (SD)	Females N = 290 M (SD)
Autistic Traits		
AQ-SS	30.57 (6.73)	30.03 (7.92)
AQ-DP*	18.26 (4.80)	17.33 (4.42)
AQ-CM	17.49 (3.91)	17.10 (3.90)
Motor Functioning		
RBQ-2A**	1.94 (.58)	1.80 (.55)
ADC-Childhood**	9.32 (8.06)	7.38 (7.44)
ADC-Adulthood*	30.06 (22.78)	25.48 (20.81)
Task 1 (BioM Recognition)	73.77 (17.50)	73.21 (17.70)
Task 2 (BioM Emotion)*	46.11 (16.24)	49.85 (16.77)
Other		
PSAI***	57.20 (12.46)	39.31 (12.97)
Handedness	64.81 (61.55)	69.06 (58.48)

Note. MANCOVA (see 3.3) *p < .05, **p<.01, ***p<.001

Table 4.
Hierarchical Regression Analysis for Variables Predicting BioM Recognition (Task 1)

Variable	β	*t*	*R*	R^2	ΔR^2
Step 1			.267	.071	***.071
Sex	-.024	-.437			
PSAI	.088	1.633			
Age	-.095	-1.756			
Preterm Status	-.058	-1.218			
Sibling with DD	-.126	**-2.739			
Parental Education	.019	.428			
Handedness	.091	*2.049			
Recruitment Pool	.074	1.301			
Step 2			.273	.075	.004
Sex	.-.022	-.404			
PSAI	.093	1.695			
Age	-.097	-1.761			
Preterm Status	-.047	-.958			
Sibling with DD	-.123	**-2.646			
Parental Education	.030	.641			
Handedness	.094	*2.120			
Recruitment Pool	.081	1.390			
AQ-SS	.041	.838			
AQ-DP	-.045	-.981			
AQ-CM	-.011	-.208			
Step 3 (Regression #1)			.340	.115	***.041
Sex	-.007	-.129			
PSAI	.080	1.495			
Age	-.109	-2.002			
Preterm Status	.042	.812			
Sibling with DD	-.098	*-2.138			
Parental Education	.039	.866			
Handedness	.067	1.526			
Recruitment Pool	.043	.751			
AQ-SS	.034	.710			
AQ-DP	.010	.218			
AQ-CM	.081	1.498			
RBQ-2A	-.071	-.917			
ADC-Childhood	-.222	**-2.978			
Step 3 (Regression #2)			.324	.105	***.030
Sex	-.010	-.175			
PSAI	.077	1.425			
Age	-.114	*-2.070			
Preterm Status	.028	.537			

Sibling with DD	-.104	*-2.266
Parental Education	.038	.835
Handedness	.071	1.609
Recruitment Pool	.050	.867
AQ-SS	.044	.902
AQ-DP	.008	.174
AQ-CM	.072	1.315
RBQ-2A	-.123	-1.542
ADC-Adulthood	-.127	-1.793

Note. $N = 501$, *p < .05, **p<.01, ***p<.001

Table 5.
Hierarchical Regression Analysis for Variables Predicting BioM Emotion Categorization (Task 2)

Variable	β	*t*	*R*	R^2	ΔR^2
Step 1			.487	.237	***.237
Sex	-.058	-1.153			
PSAI	.120	*2.465			
Age	.154	*3.131			
Preterm Status	-.234	***-5.434			
Sibling with DD	-.051	-1.214			
Parental Education	.052	1.271			
Handedness	.057	1.429			
Recruitment Pool	.406	***7.882			
Step 2			.538	.289	***.052
Sex	-.036	-.749			
PSAI	.097	*2.019			
Age	.118	*2.446			
Preterm Status	-.161	***-3.700			
Sibling with DD	-.026	-.627			
Parental Education	.070	1.728			
Handedness	.060	1.544			
Recruitment Pool	.395	***7.758			
AQ-SS	.130	**3.049			
AQ-DP	-.057	-1.435			
AQ-CM	-.234	***-5.204			
Step 3 (Regression #3)			.554	.308	**.019
Sex	-.024	-.503			
PSAI	.086	1.813			
Age	.105	*2.164			
Preterm Status	-.100	*-2.164			
Sibling with DD	-.009	-.211			
Parental Education	.076	1.894			
Handedness	.041	1.063			
Recruitment Pool	.368	***7.252			
AQ-SS	.123	**2.914			
AQ-DP	-.014	-.321			
AQ-CM	-.169	***-3.517			
RBQ-2A	-.087	-1.280			
ADC-Childhood	-.119	-1.808			
Step 3 (Regression #4)			.558	.311	***.022
Sex	-.028	-.587			
PSAI	.085	1.801			

Age	.109	*2.251
Preterm Status	-.096	*-2.086
Sibling with DD	-.010	-.254
Parental Education	.078	1.956
Handedness	.041	1.053
Recruitment Pool	.370	***7.305
AQ-SS	.139	**3.228
AQ-DP	-.020	-.476
AQ-CM	-.167	**-3.485
RBQ-2A	-.059	-.844
ADC-Adulthood	-.155	*-2.309

Note. $N = 501$, *p < .05, **p<.01, ***p<.001

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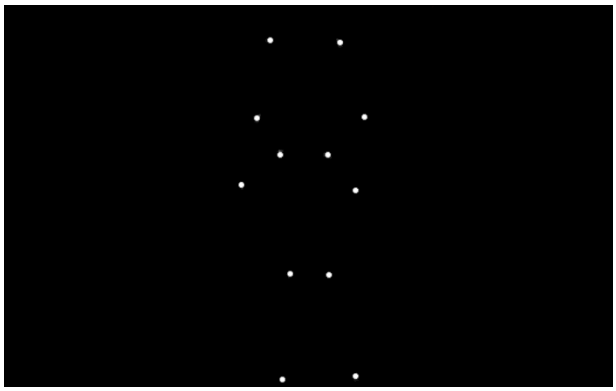
APPENDIX A

A.1. Example of BioM PLD – Neutral Male Walk



A.2. Example of non-BioM PLD – Scrambled Neutral Male Walk