Correlates of Social Functioning in Autism Spectrum Disorder: The Role of Social Cognition

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Abstract

Background: Individuals with autism spectrum disorder (ASD) experience marked challenges with social function by definition, but few modifiable predictors of social functioning in ASD have been identified in extant research. This study hypothesized that deficits in social cognition and motor function may help to explain poor social functioning in individuals with ASD.

Method: Cross-sectional data from 108 individuals with ASD and without intellectual disability ages 9 through 27.5 were used to assess the relationship between social cognition and motor function, and social functioning. **Results:** Results of hierarchical multiple regression analyses revealed that greater social cognition, but not motor function, was significantly associated with better social functioning when controlling for sex, age, and intelligence quotient. Post-hoc analyses revealed that, better performance on second-order false belief tasks was associated with higher levels of socially adaptive behavior and lower levels of social problems. **Conclusions:** Our findings support the development and testing of interventions that target social cognition in order to improve social functioning in individuals with ASD. Interventions that teach generalizable skills to help people with ASD better understand social situations and develop competency in advanced perspective taking have the potential to create more durable change because their effects can be applied to a wide and varied set of situations and not simply a prescribed set of rehearsed situations.

Keywords: theory of mind; motor function; second-order false belief; adaptive behavior; social impairment; motor function; manipulative dexterity

Introduction

Much of the extant literature on autism spectrum disorder (ASD) has focused on describing the social, cognitive, and functional deficits that are thought to be characteristic of the condition. For instance, we know that individuals with ASD have a number of neurological and behavioral challenges that broadly affect the way that they perceive and receive the social environment (Dawson & Bernier, 2007). In adulthood, studies indicate that individuals with ASD experience widespread problems with social integration, daily living skills, education, employment, and independent living (Anderson, Liang, & Lord, 2014; Gray et al., 2014; Howlin, Goode, Hutton, & Rutter, 2004; Levy & Perry, 2011), which may be driven by challenges with social cognition (Baron-Cohen, 1989) and motor function (Travers et al., in press). Thus, overall outcomes for individuals with ASD based on the metrics of becoming self-supporting, living independently, and developing a network of friends have been characterized as poor for the majority of individuals with ASD (Henninger & Taylor, 2013). However, it is also clear that outcomes are more favorable for a small minority of individuals with ASD (Anderson et al., 2014), stressing the importance of understanding factors associated with different outcomes.

A growing body of longitudinal research identifies predictors of social functioning throughout the life course in ASD. In preschoolers, greater symptom severity in early childhood tends to be associated with poorer functioning and lesser gains in skills in childhood (Fountain, Winter, & Bearman, 2012; Hedvall et al., 2015). In adolescents and adults, the best evidence indicates that higher childhood intelligence quotient (IQ) and better childhood language ability predict better adult outcomes (Magiati, Tay, & Howlin, 2014). In adults, preliminary studies suggest that better daily living skills (Bishop-Fitzpatrick et al., 2016; Smith, Maenner, & Seltzer, 2012), better adaptive behavior (Woodman, Smith, Greenberg, & Mailick, 2016), and more

vocational engagement (Taylor, Smith, & Mailick, 2014) in adulthood may also be predictive of better outcomes and social functioning. However, it is likely that a wide range of challenges are associated with poor outcomes in ASD beyond those that have been identified in the research literature to date, and more research is needed in order to better understand the link between well-documented social, cognitive, and motor deficits and functioning in individuals with ASD. This is particularly important given movement in the field away from a single cause model and towards a model that accounts for considerable genetic and behavioral heterogeneity (Happé, Ronald, & Plomin, 2006).

Of note, deficits in social cognition may be central to the social impairment that is a hallmark of ASD (Baron-Cohen, 1989). Social cognition refers to cognitive abilities involved in the processing and interpretation of socio-emotional information in oneself and others (Newman, 2001). A large body of social-cognitive research supports the finding that the majority of individuals with ASD have marked impairments in Theory of Mind (ToM), or the ability to attribute beliefs to others (e.g., Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1989; Happé & Frith, 2006). This research suggests that individuals with ASD experience a specific developmental delay in social cognition (Baron-Cohen, 1989) that may be particularly pronounced in early development (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). Classic experiments that target ToM in children with ASD through first- and second-order false belief tasks have found that individuals with ASD have marked deficits in both the ability to think about another person's thoughts about an objective event (first-order false belief; Baron-Cohen et al., 1985) and the ability to think about another person's thoughts about a third person's thoughts about an objective event (second-order false belief; Baron-Cohen, 1989). However, evidence does indicate that some individuals with ASD without delays in language development

pass first- and second-order false belief tasks (Baron-Cohen et al., 1997), suggesting the need to more fully explore the impact of social cognition on functioning.

These categorical challenges in social cognition likely play out in a number of impactful ways in the lives of individuals with ASD. Research on typically developing individuals and non-ASD clinical populations suggests an association between social cognition and functioning. For instance, Fink, Begeer, Peterson, Slaughter, and de Rosnay (2015) found that typically developing children with mutual friends outperformed typically developing children without a mutual friend on a battery of ToM tasks, indicating that poor social cognition may be associated with a lack of quality friendships in childhood. Additionally, a meta-analysis of the impact of social cognition on functioning in schizophrenia found that social cognition was strongly related to functional outcomes, with the strongest associations being between ToM deficits and functional outcomes (Fett, Viechtbauer, Penn, van Os, & Krabbendam, 2011). Recent research indicates that adults with ASD and adults with schizophrenia are quite similar in their social cognition profiles (Couture et al., 2010; Eack, Bahorik, et al., 2013) and often fail to pass first- and second-order false belief tasks like individuals with ASD (Bora, Yucel, & Pantelis, 2009), suggesting that these associations found in schizophrenia may also hold in individuals with ASD.

Deficits in social cognition may not fully account for deficits in social functioning in ASD, particularly in higher functioning individuals (Frith, 1997), and may be further compounded by a number of associated factors (i.e., motivational, perceptual, and emotional challenges) as well as broader and more general challenges with motor function (Sumner, Leonard, & Hill, in press). Research indicates that individuals with ASD have poorer motor function, with greater clumsiness, more motor coordination abnormalities, greater postural instability, and poorer performance on standardized tests of motor speed such as the finger tap

and grooved pegboard tests, with a large effect size for motor coordination deficits identified by a recent systematic review (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). Recent findings indicate that motor coordination deficits may be neurobiological in nature. More specifically, differential activation in brain areas related to motor speed suggesting a reliance on alternative motor pathways is likely (Verhoeven, De Cock, Lagae, & Sunaert, 2010), especially on more difficult motor tasks (Duffield et al., 2013), and poorer motor function may be associated with atypical white matter microstructure in the brain stem (Travers et al., 2015).

Motor function and social cognition may be intrinsically linked. Indeed, how we think about the actions of others and engage in social interactions with them likely arises from our ability to synchronize motor actions with our own communication and to correctly interpret the co-occurrence of motor movements (gestures) with social communication, or social synchronization (Sommerville & Decety, 2006). In ASD, early motor delays and motor clumsiness may limit the social opportunities of young children, thus reducing opportunities to practice social cognition (Meltzoff, 2007; Sommerville & Decety, 2006). Core impairments with interpreting the social cues of others may also limit motor learning in ASD (Dawson & Bernier, 2007), as many motor skills are learned by watching others (Travers et al., 2015). The connection between motor function and social cognition in ASD may be evidenced by impairments in social synchronization, or the ability of two people to communicate while taking turns appropriately and match each other's gestures and body language (Feldstein, Konstantareas, Oxman, & Webster, 1982; Fitzpatrick et al., 2016). This suggests the need to study the impact of both social cognition and motor function on social functioning in ASD.

In terms of motor function, recent research indicates that motor difficulties may intensify over time, and more challenges with motor function are associated with poorer functioning.

Research suggests that motor difficulties increase over time from the preschool years (Ben-Sasson & Gill, 2014; Lloyd, MacDonald, & Lord, 2013) to adulthood (Travers et al., in press). In addition, studies indicate that individual differences in motor function impairments are associated with the severity of core symptoms of ASD (Travers et al., 2015), and greater motor function impairment is associated with more challenges with adaptive functioning and daily living skills in both preschoolers (Jasmin et al., 2009) and adolescents and adults with ASD (Travers et al., in press). Of note, these findings about the association between motor impairment and functioning in ASD hold for participants in different age groups and across the spectrum of support needs (Travers et al., 2015). This literature on motor function in ASD suggests that deficits in motor function in individuals with ASD start early and compound over time. These deficits also likely have a substantial impact on adaptive functioning.

Taken together, the literature indicates that individuals with ASD experience broad and pervasive issues with social cognition and motor function, yet little research to date has investigated whether social cognition or motor function are associated with challenges with social functioning in ASD across the lifespan. We sought to explore the association between social cognition and social functioning and motor function and social functioning in a broad age range of individuals with ASD. We hypothesize that both social cognition and motor function would be positively associated with social functioning, such that individuals with higher levels of social cognition and higher levels of motor function would experience better social functioning.

Method

Participants

Cross-sectional data were from 108 participants with ASD who were recruited through advertisements in newsletters, postings on autism-related websites, and presentations for parents

and professionals. Potential participants were excluded if they had associated diagnoses of neurologic, genetic, infectious, or metabolic disorders. Potential participants were also excluded if they had severe comorbid diagnoses such as major depression and psychotic disorders. All participants had full-scale and verbal IQ scores that were greater than 70 as assessed by the Wechsler Intelligence Scale for Children-III (Wechsler, 1991) or Wechsler Adult Intelligence Scale (Wechsler, 2008) depending on age, and were able to speak in complete sentences. In addition, individuals needed to have the ability to participate in a battery of neuropsychological assessments and brain imaging, which were part of a larger study.

A diagnosis of ASD was confirmed using the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000) and the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Lecouteur, 1994). In addition, all participants experienced abnormal development before three years of age. Finally, the established ASD diagnosis was verified by expert opinion based on accepted clinical descriptions (Minshew & Payton, 1988).

Participants were ages 9 through 27.5 ($M = 17.5$, $SD = 4.6$), 87.0% male ($n = 94$), and 94.4% European American ($n = 102$). In addition, their full-scale IQ ($M = 107.3$, $SD = 15.1$), verbal IQ ($M = 105.8$, $SD = 15.3$), and performance IQ ($M = 107.1$, $SD = 15.1$) scores were within the normal range. The age range and gender distribution of participants was constrained and determined by the availability of previously collected data, which focused largely on later childhood, adolescence and early adulthood. Later childhood, adolescence, and early adulthood are particularly important developmental periods during which to examine correlates of social functioning (Kohlberg & Kramer, 1969), and this data is thus a good match for our research questions. More detailed descriptive statistics for participants, separated by age group, are displayed in Table 1.

[Insert Table 1 about here.]

Measures

Our primary measures of interest included z-metric composites of social functioning, social cognition, and motor function. **Standard scores (z-scores) represent number of standard deviations of the raw score from the sample mean (i.e., a z-score of 1 represents 1 standard deviation above the mean) and were used in order to facilitate interpretation and the creation of composite scores.** Internal consistency of composite measures is not reported for the social functioning or motor function composites because alpha cannot be reliably estimated for two-item measures (Eisinga, Grotenhuis, & Pelzer, 2013).

Dependent variable: social functioning. A z-metric composite score of social functioning was created to account for both adaptive and problematic aspects of social functioning, with both domains weighted equally. Higher scores are indicative of better social functioning. Socially adaptive behavior was assessed using the socialization domain score from the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984), a parent-report survey of adaptive behaviors. Higher scores indicate better adaptive behavior. The socialization domain consists of items assessing interpersonal relationships (“Starts small talk when meets people he or she knows”), leisure (“Goes places with friends during the day without adult supervision”), and coping skills (“Controls anger or hurt feelings due to constructive criticism.”). Social problems were assessed using the social problems subscale of the Child Behavior Checklist/4-18 (CBCL; Achenbach & Edelbrock, 1981), a parent-report measure used to determine the presence or absence of emotional, behavioral, and social problems. Items on the social problems subscale range from “Doesn’t get along with other kids” to “Gets teased a lot” and assess the presence of significant social challenges. **Although originally designed to measure social problems in**

children, the CBCL was used in the present sample of children and adults with ASD because many young adults with ASD are in school or school-like settings into young adulthood (Chiang, Cheung, Hickson, Xiang, & Tsai, 2012). Elevated scores on the CBCL are indicative of greater problem behavior. The CBCL social problems scale was significantly and negatively correlated, $r = -.42, p < .01$, with our measure of socially adaptive behavior, which was expected given that higher scores on the CBCL are indicative of more social problems while higher scores on the Vineland indicate better socially adaptive behavior. The CBCL social problems scale was therefore reverse coded for analyses in order to facilitate interpretation of the composite social functioning measure.

Independent variable: social cognition. A z-metric composite score of three different false belief tasks (Wimmer & Perner, 1983) that assess ToM, with each task/measure weighted equally, was used to assess social-cognitive ability. Higher scores are indicative of better social cognition. Internal consistency for our social cognition composite was good ($\alpha = .80$). A first-order false belief task, the Sally-Anne experiment, was adapted by Baron-Cohen et al. (1985) from Perner, Leekam, and Wimmer (1987) and used to test the degree to which the participant could recognize that another person is able to have a belief that is not true. Individuals were scored as correct (1) or incorrect (0) in response to four questions (i.e., “Where will Sally look for her marble”). In the present study, individuals with ASD participated in two trials of the Sally-Anne experiment, and an average score for the two trials was calculated. Two second-order false belief tasks, the John-Mary experiment (Baron-Cohen, 1989) and the Peter-Jane experiment, assess the degree to which a participant can recognize that another person can hold a belief about some else’s belief that is false. For both experiments, individuals were scored as correct (1) or incorrect (0) in response to either eight (John-Mary) or nine (Peter-Jane) questions

(i.e., “Where does Mary think John has gone to buy ice cream?” or “Where does Jane think Peter has gone to buy his coat?”). These false belief tasks have been validated in children and adults with ASD who experienced delayed development in early childhood like the individuals who were part of our sample (Ozonoff, Pennington, & Rogers, 1991). Additionally, these first- and second-order false belief tasks have been successfully used in adults with schizophrenia (Bora et al., 2009), who exhibit similar profiles of social cognitive deficits to higher-functioning adults with ASD (Eack, Bahorik, et al., 2013).

Independent variable: motor function. A z-metric composite score of motor function was created to account for both motor speed and manipulative dexterity, with each measure weighted equally. Higher scores are indicative of better motor function. Motor speed was assessed via measurement of finger tapping for the dominant hand (average number of taps for five trials), a measure of motor speed, as part of the Halstead-Reitan battery (Reitan & Wolfson, 1985). A higher frequency of finger taps (better motor speed) tracks closely with better motor and neuropsychological function in typical community volunteers (Shimoyama, Ninchoji, & Uemura, 1990). Manipulative dexterity was assessed for the dominant hand via the Grooved Pegboard Test (Heaton, Miller, Taylor, & Grant, 2004) as part of the Halstead-Reitan battery (Reitan & Wolfson, 1985). Faster speeds indicate better manual dexterity. For the purpose of creation of the composite, this measure was reverse coded. For both tests, appropriate adjustments for children and adults were made based on the manual (Reitan & Wolfson, 1993). For instance, on the Grooved Pegboard test, children aged 5-9 only filled the first two rows of the Pegboard rather than all five rows. This does not change scoring because the score that we used for the Grooved Pegboard Test was time to complete the task, and only one participant completed (i.e., the single nine-year-old participant included in this study) completed the shorter, age-adjusted version of

this task. The correlation between our composite measures of social cognition and motor function was not significant, $r = .09$, $p = .35$.

Demographic factors. Biological sex was established based on parent report. Age was calculated based on date of birth. Full-scale IQ was assessed by trained testers.

Analyses

Preliminary analyses were conducted to ensure that parametric tests were appropriate. Hypotheses were examined using hierarchical multiple regression predicting social functioning from social cognition and motor function. Demographic factors were entered into the model in the first step in order to account for their contribution to functioning, and then the main independent variables were entered in the second step. Exploratory post-hoc analyses tested the moderating effect of age on the association between the main independent variables and the dependent variable, which were centered in order to reduce the risk of multicollinearity (Marquardt, 1980). Post-hoc analyses were then conducted in order to determine the impact of individual components of social cognition and motor function on individual components of social functioning (all z-scores) using hierarchical multiple regression.

Results

Examination of Hypotheses

Results of analyses are displayed in Table 2 and Figure 1. Results partially supported our hypothesis that individuals with higher levels of social cognition and higher levels of motor function would experience higher levels of social functioning. More specifically, we found that better social cognition was significantly associated with better social functioning, $B = .22$, $t(102) = 2.05$, $p < .05$, $sr^2 = .03$, when controlling for age, IQ, gender, and motor function. Contrary to

our hypotheses, motor function was not significantly associated with social functioning. Finally, older age was significantly associated with better social functioning in our model, $B = .06$, $t(104) = 3.18$, $p < .01$, $sr^2 = .09$, while other demographic factors (IQ and gender) were not significantly associated with social functioning at the $p < .05$ level. Results of exploratory post-hoc analyses revealed that age did not significantly moderate the association between either social cognition and social functioning, $B = -.01$, $t(101) = -.09$, $p = .94$, $sr^2 = 0$, or motor function, $B = -.03$, $t(101) = -.28$, $p = .78$, $sr^2 = 0$, and social functioning.

[Insert Table 2 and Figure 1 about here.]

Post-Hoc Analyses

A series of post-hoc analyses were conducted in order to determine the impact of individual components of social cognition and motor function on individual components of social functioning. We first computed Pearson's correlation coefficients, which are displayed in Table 3. Then, hierarchical multiple regression models tested the association between variables identified as significant in post-hoc univariate analyses, controlling for age, gender, and IQ.

[Insert Table 3 about here.]

Post-hoc Pearson's correlation analyses suggested the necessity of testing hierarchical multiple regression models for the association between second-order false belief tasks and socially adaptive behavior, second-order false belief tasks and social problems, and second-order false belief tasks and manipulative dexterity. Follow-up hierarchical multiple regression analyses revealed that better performance on the Peter-Jane second-order false belief task was associated at the trend-level with higher levels of socially adaptive behavior, $B = .19$, $t(103) = 1.92$, $p = .06$, $sr^2 = .03$, and significantly associated with lower levels of social problems, $B = .22$, $t(103) = 2.04$, $p < .05$, $sr^2 = .04$, when controlling for age, IQ, gender. Other significant correlations

were no longer significant after controlling for age, IQ, and gender. Of note, 51.9% and 55.6% of participants performed with 100% accuracy on the first and second trials, respectively, of the first-order false belief task, while 31.5% of participants performed with 100% accuracy on the John-Mary second-order false belief task and 5.9% performed with 100% accuracy on the Peter-Jane second-order false belief task, suggesting modest ceiling effects.

Discussion

This study sought to explore the impact of social cognition and motor function in a wide age range of individuals with ASD. Our hypotheses predicted that both social cognition and motor function would be positively associated with social functioning, such that individuals with higher levels of social cognition and higher levels of motor function would experience higher levels of social functioning. Findings partially supported our hypotheses: we found that higher levels of social cognition were associated with higher levels of social functioning, but that motor function was not significantly associated with social functioning. Additionally, we found that individuals with ASD who were older were likely to have higher levels of social functioning. Our finding that only social cognition, and not motor function, was associated with social functioning was unexpected given our hypotheses, and increasingly suggests the importance of targeting social-cognitive impairments to improve social functioning in ASD.

In order to better understand the association between components of social cognition and motor function and social functioning variables, we conducted a number of univariate analyses, which were followed by analyses that controlled for age, IQ, and gender. These findings suggest nuance in the association between social cognition and social functioning measures. More specifically, findings related to social cognition reveal that better performance on second-order false belief tasks is associated with better socially adaptive behavior and fewer social problems.

This indicates that performance on second-order false belief tasks, or ability to think about another person's thoughts about a third person's thoughts about an objective event, may be driving this association between the social cognition and social functioning composite scores. However, this finding may be accounted for by less variance in performance on first-order false belief tasks (i.e., ceiling effects) than on second-order false belief tasks in our sample.

Our findings **related to social cognition** align with a growing body of research that suggests that deficits in social cognition are particularly impactful on the relative level of social functioning in individuals with schizophrenia (Fett et al., 2011; Green, Horan, & Lee, 2015), which is an expected finding given evidence that individuals with ASD have similar deficits in social cognition to individuals with schizophrenia (Couture et al., 2010; Eack, Bahorik, et al., 2013). More specifically, like the body of literature on the relationship between social cognition and social functioning in schizophrenia (Fett et al., 2011), we found an association between ToM deficits and social functioning composite scores, with a significant association between better second-order false belief task performance and more socially adaptive behavior and fewer social problems at the bivariate level which was revealed by our post-hoc analyses. This study thus provides further evidence of specific impairments in social cognition in ASD that may lead to deficits in social functioning.

Our findings related to the association between motor function and social functioning differ from other findings in the literature. There are a number possible reasons why we found that motor function was not significantly associated with social function in our sample. Two possible explanations related to the measures that we used and the age range of our sample seem most compelling. First, it is possible that our measures, which captured fine and not gross motor skills, did not fully represent the potential limiting nature of problems with gross motor function

on daily living skills (Jasmin et al., 2009) and the social perception of motor abnormalities on social functioning (Sommerville & Decety, 2006). Second, it is possible that the age range of individuals with ASD included in our sample did not fully represent the potential challenges associated with poor motor function throughout development and into middle- and old age. Travers and colleagues (in press) recently found that individuals with ASD improve in their fine motor skills into their early 20s, and then fine motor skills plateau before a decline that begins during the early 30s. This pattern mirrors patterns in social functioning identified in other samples of adults (Smith et al., 2012). Thus, it is possible that the age range of participants included in this sample limited our ability to pick up a correlation between motor function and social functioning because of reduced variation as a result of these co-occurring plateaus. Future research should therefore include older samples of individuals with ASD (i.e. middle-aged and older adults) in order to determine if this association represents an aging effect.

Of note, we found a strong association between older age and higher levels of social functioning in our sample of individuals with ASD, and this association was stronger than the identified association between social cognition and social functioning. This finding aligns with research that indicates that autism symptomatology and challenges with adaptive behavior lessen in early adulthood before plateauing later in life (Smith et al., 2012; Taylor & Seltzer, 2010). Indeed, like the relatively large body of research that finds modest improvement in autism symptomatology from early childhood to young adulthood in longitudinal samples (e.g., Anderson et al., 2014; Howlin, 2000; Mawhood, Howlin, & Rutter, 2000; Seltzer et al., 2003), our cross-sectional study finds better social functioning in adulthood than in middle childhood. Additionally, our finding that age does not moderate the association between social cognition and social functioning provides evidence that age-related improvements in social functioning

have an effect that is not dependent on one's relative level of social cognition. However, it is possible that the wide age range of individuals with ASD included in this study affects our findings given that social and adaptive demands differ substantially for children and adults with and without ASD.

This study has several limitations. First, although our hypotheses framed deficits in social cognition and motor function as possible contributors to poorer social functioning in ASD based on the previous literature, our cross-sectional design precluded a test of directionality, and a bi-directional relationship is possible. Our findings, and the possibility that this relationship works in both directions, also suggest the need to test the effect of interventions that improve social functioning, social cognition, and motor function in individuals with ASD in order to establish causality (Hill, 1965). Second, these findings are based on the study of children and adults (range: ages 9 through 27.5) with ASD with relatively intact cognitive and language abilities who were capable of participating in a battery of neuropsychological assessments and brain imaging, which were part of a larger study. In addition, individuals with ASD were excluded if they had associated diagnoses of neurologic, genetic, infectious, or metabolic disorders and were also excluded if they had severe comorbid diagnoses such as major depression and psychotic disorders. Participants also included a greater proportion of males than would be expected in the general population of individuals with ASD using current prevalence estimates (Centers for Disease Control and Prevention, 2014) but are similar to estimates of the proportion of males and females with ASD when many of the participants in this study were first diagnosed (Shattuck, 2006). Thus, participants in this study are not representative of all individuals with ASD, which may limit the generalizability of our findings. Third, the CBCL, which was designed for children, was used in mixed-age sample of children, adolescents, and adults with ASD. This

decision was made because many young adults with ASD are in school or school-like settings into young adulthood (Chiang et al., 2012) but nevertheless may have biased results. Fourth, age of first ASD diagnosis and location of diagnosis were not available. Thus, the effect of age on social functioning may reflect a bias in sample selection for young adults, and not true age-related changes in social functioning. Fifth, while motor function is an important aspect of neurocognitive functioning, more detailed neurocognitive measures were not available, and we were therefore unable to examine neurocognitive predictors more broadly. Such an examination is an important direction for future research. Sixth, both of our motor function measures focused on movement speed during manual tasks, and although unavailable in the present dataset, measures of gross motor function might be a better indicator of the type of whole body movements that are coordinated between people during both intentional and spontaneous social synchronization. Future research could investigate similar associations with gross motor tasks. Finally, the battery of social cognitive and motor measures used was limited by availability of data in our dataset, and both our social cognitive and motor measures assess limited aspects of these domains. Findings may thus not represent some key aspects of social cognition and motor function.

Implications

The development and testing of psychosocial interventions in individuals with ASD throughout the life course (Bishop-Fitzpatrick, Minshew, & Eack, 2013) has been greatly limited by a lack of modifiable predictors of social functioning identified by extant research. Social functioning has been shown to be modifiable with targeted cognitive remediation interventions designed to improve social cognition in both individuals with schizophrenia (Eack et al., 2009; Eack, Hogarty, Cho, & et al., 2010) and in pilot studies in adults with ASD (Eack, Greenwald, et

al., 2013), and may thus be an effective target for the development of future treatments. Social cognition training is different from existing social skill interventions which intervene primarily on a behavioral level in specific, rehearsed social situations (e.g., initiating a conversation with a friend). Such social skill interventions divide social scenarios into their component behaviors, and then use modeling, feedback, and rehearsal to shape behavior toward the desired result (e.g., Gantman, Kapp, Orenski, & Laugeson, 2012; Laugeson, Frankel, Gantman, Dillon, & Mogil, 2012). In contrast, social cognition training aims to address thinking deficits that have a downstream impact on behavior and to enhance social information processing so that individuals are able to effectively respond to novel, unrehearsed social exchanges. These interventions hypothesize that theory of mind, perspective-taking, and other brain-based social-cognitive deficits in ASD lead to poor social function, and without their remediation, generalizable improvements in social behavior cannot be realized (Eack, Greenwald, et al., 2013; Eack et al., 2009; Hogarty & Greenwald, 2006). As such, social cognition training focuses on repeated exercises (often computer or group-based) and secondary socialization experiences designed to improve theory of mind, social context appraisal, perspective-taking, and other core social information processing abilities in support of enhancing interpersonal effectiveness.

Interventions that teach generalizable skills to help people with ASD better understand social situations and develop skills in advanced perspective taking have the potential to create more durable change because their effects can be applied to a wide and varied set of situations and not simply a prescribed set of rehearsed situations. Notably, most interventions focus on strategies for managing behavior, and poor social cognition may limit the capacity of individuals with ASD to consider and apply such strategies, especially in novel social situations. Future

research should explore the utility of cognitive remediation interventions that specifically target social cognition to improve social functioning in individuals with ASD.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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Table 1

Descriptive Statistics for Participants by Age Category

Variable	Overall (N=106)	12 and Under (N=16)	13 through 17 (N=45)	18 and Older (N=47)
Age	27.5 (17.5)	11.3 (0.9)	15.1 (1.4)	22.0 (2.7)
Male (%)	94 (87.0)	13 (81.3)	40 (88.9)	41 (87.2)
Full-Scale IQ	107.3 (15.1)	115.4 (16.7)	109.2 (13.6)	102.6 (14.5)
ADOS Social Communication	13.1 (3.1)	12.6 (3.1)	12.4 (2.8)	14.0 (3.1)
ADI-R Social	21.4 (4.5)	21.1 (5.3)	21.1 (4.8)	21.9 (4.0)
Socially adaptive behavior	70.2 (15.9)	83.4 (12.7)	69.6 (14.5)	66.3 (16.1)
Social problems	65.9 (9.5)	62.0 (8.9)	67.6 (10.3)	65.6 (8.7)
First-order false belief trial 1	3.7 (0.5)	3.5 (0.6)	3.8 (0.2)	3.8 (0.4)
First-order false belief trial 2	3.7 (0.6)	3.4 (0.8)	3.8 (0.3)	3.8 (0.5)
Second-order false belief (John-Mary)	6.2 (1.3)	5.1 (1.3)	6.0 (1.2)	6.7 (1.3)
Second-order false belief (Peter-Jane)	6.6 (1.9)	5.7 (2.2)	6.6 (1.6)	7.0 (1.9)
Motor speed	41.7 (7.7)	37.7 (5.7)	40.7 (8.0)	44.0 (7.3)
Manipulative dexterity	86.2 (25.3)	75.3 (26.2)	85.9 (25.3)	90.1 (24.5)

Note. Mean and standard deviation are reported for all variables except for gender, for which we reported number and percentage of males.

Table 2

Summary of Hierarchical Multiple Regression Analyses

Variable	β
Step 1	
Gender	.16 [†]
Age	.32**
Full-scale IQ	.09
Step 2	
Social cognition	.23*
Motor function	-.05

Note. [†]p < .10, *p < .05, **p < .01, ***p < .001; β = standardized beta

Table 3

Correlations between Variables of Interest

	1	2	3	4	5	6	7	8
<i>Social Functioning</i>								
1. Socially adaptive behavior	--							
2. Social problems	-.42**	--						
<i>Social Cognition</i>								
3. First-order false belief trial 1	-.12	.13	--					
4. First-order false belief trial 2	.19†	.09	.64**	--				
5. Second-order false belief (John-Mary)	.25*	.27*	.57**	.52**	--			
6. Second-order false belief (Peter-Jane)	-.22*	.28**	.52**	.59**	.51**	--		
<i>Motor Function</i>								
7. Motor speed	-.12	.02	.15	.20*	.20*	.06	--	
8. Manipulative dexterity	.20*	.01	-.02	-.01	.05	.04	.03	--

Note. † p < .10, * p < .05, ** p < .01, *** p < .001.

Figure 1

The Association between Z-Metric Composite Scores of Social Cognition and Social Functioning