Published in final edited form as:

Autism. 2020 October ; 24(7): 1758–1772. doi:10.1177/1362361320922058.

Prediction of Social Behavior in Autism Spectrum Disorders: Explicit Versus Implicit Social Cognition

Cara M. Keifer^{1,*}, Amori Yee Mikami^{2,3}, James P. Morris³, Erin J. Libsack¹, Matthew D. Lerner^{1,3}

¹Psychology, Stony Brook University, Stony Brook, USA

²Psychology, University of British Columbia, Vancouver, Canada

³Psychology, The University of Virginia, Charlottesville, USA

Abstract

Deficient social communication and interaction behaviors are a hallmark feature of individuals with Autism Spectrum Disorder (ASD). These social communication and interaction deficits potentially stem from problems with explicit social cognition (i.e. processes that are controlled and largely conscious) as well as with implicit social cognition (i.e. processes that are fast, spontaneous, and primarily unconscious). The current study aimed to investigate the relative contributions of implicit and explicit social cognition factors as predictors of multi-informant measures of social communication and interaction behaviors in a sample of 34 youth with clinical diagnoses of ASD. Behavioral, cognitive, and electrophysiological indices of implicit and explicit social cognition were entered into partial least squares regression models designed to identify latent factors that optimally predict parent-report, observer-coded, and clinician-rated social communication and interaction outcomes. Results indicated that while both implicit and explicit social cognition factors optimally predicted outcomes, implicit social cognition factors were relatively more predictive. Findings have important implications for the conceptualization and measurement of social functioning as well as the development of targeted social interventions in ASD populations.

Keywords

autism spectrum disorder; social cognition; partial least squares regression; electroencephalography; ERP; social perception

*Cara M. Keifer: Corresponding author. Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500. Phone: 631-632-7857. cara.keifer@stonybrook.edu.

Amori Yee Mikami: Present Address; Department of Psychology, University of British Columbia, British Columbia, CA.

James P. Morris: Present Address; Department of Psychology, University of Virginia, Charlottesville, Virginia, 22903.

Erin J. Libsack: Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500.

Matthew D. Lerner: Present Address; Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500.

Declaration of Interest Statement

Cara Keifer declares that she has no conflict of interest. Amori Mikami declares that she has no conflict of interest. James Morris declares that he has no conflict of interest. Erin Libsack declares that she has no conflict of interest. Matthew Lerner declares that he has no conflict of interest.

Difficulties in social communication and interaction behaviors are pathognomonic among individuals with autism spectrum disorders (ASD), and a core part of the diagnostic criteria in this disorder. Such difficulties may stem from problems with *explicit social cognition*, or social processes that are controlled and largely conscious (Callenmark, Kjellin, Rönqvist, & Bölte, 2014). Conversely, problems with fast, spontaneous, and primarily unconscious processes may also be contributors, and can be thought of as deficits in *implicit social cognition* (Callenmark et al., 2014). Although deficits in explicit social cognition have been widely documented in the ASD population (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Dawson et al., 2004; Harms, Martin, & Wallace, 2010), less research has examined deficits in implicit social cognition, and no known research has examined the relative contributions of implicit versus explicit social cognition for socially competent behavior. The current study used a data-driven approach to examine the contributions of aspects of explicit versus implicit social cognition to social communication and interaction behaviors in youth with ASD.

Explicit and Implicit Social Cognition Factors

These terms “implicit” and “explicit” social cognition have been used to refer to a range of social and cognitive processes in the literature (e.g. Callenmark et al., 2014; Kana et al., 2016; Nosek et al., 2011; Rosenblau et al., 2015). In the current study, we employ the terms most similarly to Callenmark et al. (2014), who uses explicit social cognition to refer to prompted, controlled, and largely conscious processes, such as the effortful acquisition and recalling of social knowledge, whereas implicit social cognition refers to spontaneous, fast, and mostly unconscious processes, such as the efficient integration of social information. Both explicit and implicit social cognition have been theorized to contribute to the development of social competence (de Boo & Prins, 2007; Gresham, 1997; Ladd & Mize, 1983). However, while Gresham (1997) considered both explicit and implicit social cognition as necessary for skilled social behavior, only recently has research begun to explore whether social communication and interaction behavior problems derive from impairments in explicit or implicit social cognition (Matson, Matson, & Rivet, 2007; McMahon, Lerner, & Britton, 2013) or can be remediated by treating one or the other (Guivarch et al., 2017; Lerner & Mikami, 2012).

Traditional models posit that explicit social cognition is crucial for attaining competent social behavior in ASD populations (Koenig, De Los Reyes, Cicchetti, Scahill, & Klin, 2009). The explicit social cognition deficit model underlies common social skills intervention approaches that focus on increasing conscious knowledge of the correct social behavior (Kasari & Patterson, 2012; Laugeson, Frankel, Mogil, & Dillon, 2009; Mesibov, 1984). On the other hand, implicit social cognition models state that deficits in spontaneous, rapid, and largely unconscious social processes are central to the social behavioral problems experienced by those with ASD (Callenmark et al., 2014; Guivarch et al., 2017). Importantly, such models do not suggest that explicit social cognition is unrelated to social behavior. Rather, explicit social cognition is a necessary, but not sufficient, condition for competent social behavior, and that implicit social cognition may play an equally important role in predicting deficits. These hypothesized implicit processes exist independent of

explicit social cognition and affect the ability to perform known social skills by interfering with the integration of social information (Gresham, 1997; Nixon, 2001).

Numerous reviews have sought to integrate social cognition and its relation to social behavior into a coherent theoretical model (e.g., Beauchamp & Anderson, 2010; Crick & Dodge, 1994; Mendelson, Gates, & Lerner, 2016) but researchers have yet to coalesce around a single model that is both theoretically consistent and objectively measurable. Foundational models tend to define social functioning abstractly (i.e. “effectiveness in social situations”; Waters and Sroufe, 1983; Crick and Dodge, 1994; Rose-Krasnor, 1997), however, it is difficult to translate broad models into concrete and measurable behaviors. A second approach to modeling social functioning involves boiling it down to specific competencies or measurable elements. Yet, it is not readily apparent how individual competencies fit into the abstract models of social functioning. Thus, the majority of research on social functioning focuses on specific competencies and has not been united in a coherent theoretical model. Additionally, no comprehensive model of social competence accounts for distinct stages of social information processing *and* distinguishes between implicit and explicit models of analysis.

The Social-Emotional Learning Framework (SELF; Lipton & Nowicki, 2009) is a contemporary integrative model that builds on previous foundational models of social functioning. Unlike other abstract theoretical models, the SELF has empirical support at both the factor analytic level and the level of measure development, and it contains discretely identified, measurable “specific competencies.” Thus, as an organizing model it provides a way to connect specific competencies with abstract theory in a predictive, functional way, for a population that exhibits unambiguous social challenges (those with ASD). The SELF posits that social competence is influenced by three elements of social cognition, which cut across both implicit and explicit processes: social reasoning, meaning, and awareness (McKown, Allen, Russo-Ponsaran, & Johnson, 2013). Lipton & Nowicki (2009) identified lab-based measures to operationalize each of these three elements of social cognition; these measures, which are included in the present study, can be categorized into assessments of aspects of explicit or implicit social cognition. The explicit measures share the common feature that they reflect social knowledge, as consciously reported; thus, they capture accuracy in identifying emotions, Theory of Mind, and the “right” thing to do in hypothetical social situations. The implicit measures, by contrast, reflect intuitive, largely unconscious, processes; thus, they assess processing speed of social information and generation of social responses, regardless of accuracy. These measures can be conceptualized as indicators of the underlying constructs of implicit and explicit social cognition insofar as they capture key aspects of these constructs but are not equivalent to the constructs themselves. Rather, the variables included in the study tap into explicit or implicit aspects of distinct social cognitive entities.

Uniting the SELF model with the implicit vs. explicit social cognition theory for the first time would fill an important gap in the literature by providing a more nuanced and integrative approach to modeling social competence and behavior.

Social awareness

Social awareness refers to the recognition of social-emotional information. One aspect of social awareness at the level of explicit social cognition is accuracy of facial emotion recognition, a domain widely studied in individuals with ASD. A meta-analysis by Lozier et al. (2014) reported that the association of ASD with deficits in facial emotion recognition across all emotions showed a consistent, if small, effect size. On the other hand, an aspect of implicit social awareness is the speed with which individuals engage in facial emotion recognition, regardless of accuracy. A recent meta-analysis indicates that individuals with ASD demonstrate delayed processing of faces as measured by the N170 event-related potential (ERP) latency, with a small effect size (Kang et al., 2018). The N170 is an indicator of the spontaneous and obligatory processing of faces.

Social meaning

Social meaning is the interpretation of social-emotional information through associations made between information, motivation, empathy, and cognition. An aspect of explicit social meaning making is the conscious engagement in theory of mind, or the act of making inferences about other's mental states. Decades of research have revealed that while theory of mind deficits are often observed in ASD (Baron-Cohen, 2001), this ability is heterogeneous across the ASD population and many individuals with ASD pass explicit theory of mind tasks (White, Frith, Rellecke, Al-Noor, & Gilbert, 2014). ASD symptom severity is not a reliable indicator of individual differences in theory of mind (Bennett, Bolling, Anderson, Pelphrey, & Kaiser, 2013; Joseph & Tager-Flusberg, 2004; Loth, Gomez, & Happe, 2011). A recent meta-analysis (Bottema-Beutel, Kim, & Crowley, 2019) suggests that taken individually, the cognitive constructs (including theory of mind) which constitute the most influential theoretical explanations for social functioning deficits in ASD only account for a minimal portion of the variance observed in social functioning outcomes. Importantly, the authors suggest that while not accounting for large amounts of variance in broad social functioning overall, cognitive factors (e.g., theory of mind) may more directly contribute to specific components of social functioning. Furthermore, the authors highlight the importance of considering the effects of different measurement techniques for capturing specific subdomains within cognitive constructs such as theory of mind and call for future research to control for the effects of measurement type on the relationships between cognitive constructs and domains of social functioning.

If one aspect of explicit social meaning is the identification of another person's mental state (i.e. intention), an aspect of implicit social meaning is the speed with which an individual makes such inferences regardless of accuracy. When compared with typically developing individuals, those with ASD have slower reaction time on theory of mind tasks (Kaland, Mortensen, & Smith, 2011). Slower reaction time in individuals with ASD may represent an indicator of slowed engagement of the implicit processes (i.e. spontaneous and unconscious encoding and processing of relevant social information) supporting explicit identification of another person's mental state.

Social reasoning

Social reasoning is the use of social-emotional information to prepare for the production of social behavior. One aspect of explicit social reasoning is an individual's knowledge of appropriate behavior in various social situations, including the ability to consciously identify or label inappropriate social behavior. Studies have shown that individuals with ASD tend to make errors in detecting social faux pas (Pedreño, Pousa, Navarro, Pàmias, & Obiols, 2017) and demonstrate inappropriate reasoning for accurate labeling of social behavior (Marom et al., 2011; Pedreño et al., 2017; Zalla, Sav, Stopin, Ahade, & Leboyer, 2009).

One aspect of implicit social reasoning is the rapid and spontaneous generation of novel social responses, regardless of the correctness or social acceptability of such responses –the social reasoning equivalent of set-shifting. This ability to come up with unique responses to social problems has been referred to as *social creativity* (Mouchiroud & Lubart, 2002), and does not require explicit knowledge of social norms. In fact, knowledge of what constitutes acceptable behavior may hinder social creativity by limiting the number of potential response options generated to only those responses deemed “correct” (Lerner & Girard, 2018). In typically developing children, social creativity is associated with peer acceptance and social competence (Mouchiroud & Bernoussi, 2008). Compared to typically developing individuals, those with ASD demonstrate less social creativity during play, which has been hypothesized to contribute to broader social deficits (Hobson, Hobson, Malik, Bargiota, & Caló, 2013).

Social Behavior and Variation across Context

Multi-method and multi-informant assessment of social behavior is necessary to capture the variability in behaviors across settings and to minimize biases associated with any one rating source. While parent-report of behavior benefits from knowledge of developmental history, clinician-report offers an assessment of behavior by a highly trained professional that is not colored by past interactions. Finally, the use of observational coding in a laboratory setting conducted by blinded raters ensures that the environment is tightly controlled, and the coding system is applied in an objective and consistent manner. Relying upon multiple methods and informants to assess social communication and interaction behavior may be particularly important for individuals with ASD, for whom informant ratings of behavior vary widely (Lerner, Calhoun, Mikami, & De Los Reyes, 2012; McMahon & Solomon, 2015).

Current Study

This study examined the relative roles of aspects of implicit and explicit social cognition across social reasoning, meaning, and awareness (Table 1; Koenig et al., 2009), as predictors of social communication and interaction behaviors measured through multiple informants. To achieve this aim, we relied upon Partial Least Squares Regression (PLSR), a machine-learning type approach, which allows for the use of many independent variables. PLSR is robust to multicollinearity and may even benefit from highly correlated independent variables, such as implicit and explicit social cognition variables (Cassel, Hackl, & Westlund, 1999). Although measures of aspects implicit and explicit social cognition are

theoretically related, existing frameworks modeling these variables have failed to account for and leverage these associations. PLSR optimizes the prediction of dependent variables by creating latent factors based on formative indicators. This differs from other latent factor models in that the formative indicators are thought to cause, rather than underlie, the latent factor. Given that social behaviors are thought to be the product of a combination of implicit and explicit social cognition, PLSR thus provides a conceptually consistent approach to modeling our outcomes. Additionally, this approach benefits from internal cross-validation of effect estimates to optimally identify the best-fitting model. PLSR has previously been used to predict social outcomes, but not in ASD, and with a less specific array of predictor variables (Lerner, Potthoff, & Hunter, 2015). Therefore, PLSR is uniquely suited to achieve the aims of the present study.

We hypothesized that implicit and explicit social cognition variables can be used to optimally predict 1) clinician-rated, 2) parent-reported, and 3) observer-coded communication and interaction behavioral outcomes in a population of youth with ASD. We anticipated that 4) the resulting latent factor solutions would be consistent with the implicit social cognition model, reflecting aspects of implicit and explicit social cognition with aspects of implicit social cognition variables weighted more heavily. Finally, in an exploratory fashion, we examined the relative contribution of social reasoning, social meaning, and social awareness measures in predicting behavioral outcomes.

Method

Participants

Participants were 42 youths between 9 and 16 years of age who were consented under a University IRB. Eight participants were excluded due to missing data and the final sample was composed of 34 youths (Table 2). All had pre-existing diagnoses of ASD, and were screened to ensure they surpassed clinical cutoffs (Norris & Lecavalier, 2010) on the parent-report Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003); internal consistency (Cronbach's α) was acceptable (.79). Diagnoses were then confirmed with the gold-standard Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999), administered by a research-reliable examiner; internal consistency was acceptable (.80). Finally, a reliable, valid, abridged version of the Wechsler Intelligence Scale for Children-IV (Ryan, Glass, & Brown, 2007; Wechsler, 2003) was administered to confirm IQ scores above 70. As can be seen in Table 2, participants displayed moderate autism symptomatology as measured by the ADOS, and average IQ.

Procedure

Participants attended two visits at a university research laboratory. At the first visit, they and their parents completed written and verbal consent and assent procedures; diagnostic, cognitive, social knowledge, and creativity measures were collected. At the second visit, participants reviewed consent information, then completed emotion recognition and theory of mind tasks (order counterbalanced). Measures of the speed of social information processing were collected during emotion recognition tasks. Then, participants were paired together in a same-age, same-gender dyad and brought to a video-equipped observation

room with several age-appropriate games (e.g. cards, Connect Four); one participant did not complete this procedure. The dyad was informed that the research assistants had work to do in the next room but would return soon. The dyad was left in the room for 10 minutes while their unstructured interactions were videotaped; these tapes were later coded (see below).

Measures – Explicit Social Cognition Predictors

Social Reasoning—This was assessed using the *Children's Assertive Behavior Scale* (CABS; Michelson & Wood, 1982), a multiple-choice self-report measure of social skills knowledge where participants are presented with 27 social situations. As has been done previously (Maedgen & Carlson, 2000), in the present study the CABS was adapted to assess social skills knowledge by asking participants what they thought “the right thing to do” was in each situation. The CABS generates three scales reflecting endorsement of passive, aggressive, and assertive strategies. For the present study, only the “correct” (i.e. assertive) scale was used, and it was reversed-scored such that higher values correspond to more knowledge. Additional information about the CABS provided in Appendix A.

Social Meaning—The *Stories from Everyday Life- Mental Inference* (SEL-MI; Kaland et al., 2002) is an advanced theory of mind battery appropriate for youth with ASD (Kaland, Callesen, Møller-Nielsen, Mortensen, & Smith, 2008; Kaland et al., 2002), which focuses on the ability to make distinctions about physical and mental states (see Appendix A). Participants are presented with a story that leads towards a climax, then are asked to answer questions regarding the physical condition and mental state of a character in the story. As it has shown the best ability to discriminate individuals with ASD from typically developing individuals, only the mental inference task (SEL-MI) was used (Kaland et al., 2002) with the four story types that best discriminated these groups (figures of speech, irony, contrary emotions, mistaken intentions).

Social Awareness—The *Diagnostic Analysis of Nonverbal Accuracy-2* (DANVA-2; Nowicki, 2004) is a widely-used, age-normed, standardized measure of emotion recognition in adult and child faces (Nowicki & Carton, 1993) and voices (Baum & Nowicki, 1996; Demertzis & Nowicki, 1998). Participants rate 24 child and 24 adult faces and voices indicating high- or low-intensity happy, sad, angry, and fearful emotion, by pressing a button to select the emotion conveyed (see Appendix A). The DANVA-2 produces scores indicating the raw number of errors in emotion recognition such that lower numbers indicate better performance. Stimuli were presented in a 2×2 (adult/child x faces/voices) block design, randomized within and between blocks. Overall facial and vocal emotion recognition scales were derived and reverse-scored such that higher scores correspond to better ability.

Measures – Implicit Social Cognition Predictors

Social Reasoning—This was assessed with the *Social Creativity Task* (SCT; Mouchiroud & Lubart, 2002), a measure of creative responses to social scenarios. As this study was principally concerned with social creativity in the peer domain, the “peers” and “dyad” tasks (Mouchiroud & Lubart, 2002) were used. In a verbal interview, children were asked to generate as many creative solutions as possible to social problems. Responses were scored according to a 7-point Likert scale (1 = *not at all creative* to 7 = *extremely creative*). The

sum of each participant's scores was divided by the total number of answers to control for fluency (Mouchiroud & Lubart, 2002), generating a final SCT score (see Appendix A).

Social Meaning—This was assessed using the *Stories from Everyday Life- Mental Inference Reaction Time* (SEL-MI-RT; Kaland et al., 2002). Reaction times to the SEL-MI task (measured as length of time preceding participants' verbal response to SEL-MI questions) were extracted and reverse scored such that larger scores indicated faster response time. Reaction time in this context represents social processing speed in response to the SEL-MI theory of mind task (see Appendix A).

Social Awareness—*Social Information Processing Speed* (Lerner, McPartland, & Morris, 2013) was measured via the latency of the N170, an ERP-indexed response to facial stimuli, and the N100, an ERP-indexed response to vocal stimuli, on the DANVA-2. N170 and N100 latencies have been shown to be uniquely delayed in response to social stimuli (Kang et al., 2018; McPartland et al., 2011) and to represent a unified multimodal emotion processing construct (Lerner et al., 2013) among individuals with ASD. In the present study, ERPs were collected during the DANVA-2 using a 32-Channel BioSemi Active 2 system. For facial and vocal stimuli, ERPs were time-locked to the presentation of the stimulus. Data were digitally filtered at a low-pass filter of 30 Hz. Artifact rejection was conducted manually. Data were baseline corrected relative to a 150ms baseline period and were segmented 700ms post-stimulus onset. Finally, ERPs were extracted from electrode sites homologous to those in the previous literature (N170 extracted from PO4, N100 from Cz; Pinheiro et al., 2011). Latencies were reverse scored to facilitate interpretation with larger values indicating faster processing speed.

Measures – Social Behavior Outcomes

Clinician-Rated Social Communication and Interaction—The *Autism Diagnostic Observation Schedule* (ADOS; Lord et al., 1999) is a standardized assessment of communication, social interaction, and imaginative use of play materials for individuals suspected of ASD. An ADOS-trained clinician administered either Module 3 or 4 of the ADOS to participants; these modules are designed for children and adolescents who are verbally fluent. The modules consist of a series of structured and unstructured situations that allow for clinical observation of spontaneous social-communicative behaviors and the ability to respond to social cues and social “presses” in the evaluation session. The ADOS has been extremely well-validated and is considered to be the gold standard for assessing the presence of symptoms associated with a diagnosis of ASD. Scores were converted to Calibrated Severity Scores (ADOS CSS), with higher scores indicating more impairment, to facilitate comparison of symptom severity across modules.

Parent-Reported Social Communication and Interaction—Parents completed the *Social Communication Questionnaire* (SCQ; Rutter et al., 2003) containing 40 items that assess social communication skills and social functioning across the participant's lifetime. The SCQ yields subscale scores for communication, reciprocal social interaction, and restricted/repetitive behaviors. Higher scores on this measure indicate more parent-reported difficulties with social communication and interaction. The SCQ is also commonly used as

screening questionnaire for the presence of social impairments associated with ASD (Chandler et al., 2007).

Observer-Coded Social Communication and Interaction—Participants' dyadic peer interaction in the lab was coded using the *Social Interaction Observation Scale* (SIOS; Bauminger, 2002, 2007a, 2007b). The SIOS is an observational measure of social interaction designed for use with individuals with ASD (see Appendix A). It assesses overall social interaction, as well as three qualitative subscales. The first scale, positive interaction, includes overtly positive social behaviors such as eye contact with a smile and sharing. The second scale, negative interaction, includes overtly negative social behaviors such as physical and verbal aggression. The third scale, low-level interaction, encompasses behaviors that fall somewhere between positive and negative social behavior. Examples of low-level interaction include standing in close proximity to another child but not engaging, using idiosyncratic language, repetitive behavior, or looking at another child's face or body without making eye-contact; they are described as indicating social intent, but with minimal social enactment (Bauminger, 2002). While not overtly negative, these behaviors are often socially inappropriate, while also suggesting intention to engage socially (e.g., close physical proximity, functional communication). The SIOS was used to rate video recordings of each participant's behavior in the unstructured peer interaction. However, there was little variance in (few incidents of) negative interaction in the present study; therefore, negative interaction was not included in analyses. Positive and low-level interactions were scored as the proportion of each interaction type relative to the individual's total interactions.

Data Analytic Plan

To examine if optimized linear combinations of aspects of explicit and implicit social cognition measures can predict social behavior outcomes and to adjudicate between the explicit and implicit social cognition hypotheses, four partial least squares regression (PLSR) analyses were conducted using RStudio Version 1.1.383. PLSR is the optimal analytic method for the present study given its robustness to abnormal data distributions, multicollinearity, and misspecification of the model (Cassel et al., 1999). This approach also allows for the use of many independent variables with relatively few observations. Additionally, it is theoretically consistent with our study aims given that it optimizes the prediction of dependent variables via *formative indicators* that are thought to underlie the latent factors (as opposed to other latent factor methods in which the latent variables underlie the indicators). The formative indicators load onto latent factors which are created to maximally predict the dependent variable. We hypothesized that implicit and explicit social cognition variables combine to produce social communication and interaction outcomes and thus are best represented as formative indicators.

PLSR—We conducted four PLSR analyses using leave-one-out cross validation and extracting orthogonal components as is typically done in PLSR (see Appendix B). PLSR estimates the optimal combination of *formative* indicators to create latent factors that best predict the dependent variable. The first model examined the optimal linear combination of the independent measures of aspects of explicit and implicit social cognition (CABS, SCT, SEL-MI, SEL-MI RT, DANVA-2 faces, N170 latency, DANVA-2 voices, and N100 latency)

to predict the clinician-rated outcome measure of social communication and interaction behavior (ADOS CSS). To determine the number of components to be extracted, we examined the Root Mean Squared Error of Prediction (RMSEP) and identified the lowest RMSEP value after the intercept using Random Segment Cross-Validation. After extracting the appropriate number of components, we examined the loadings to generate a theoretical interpretation of each component. A second PLSR model following the same procedure was conducted using the same measures of aspects of implicit and explicit social cognition to predict parent-reported social communication and interaction behavior (SCQ). The third and fourth models used the same procedure to predict the observer-coded low-level interaction and positive interaction behaviors with a peer (SIOS).

Results

Descriptive Statistics

Bivariate correlations are shown in Table 3. Poorer social communication and interaction behavior as measured by the clinician-coded ADOS CSS was significantly associated with this construct as measured by the parent-reported SCQ, as well as with lower IQ scores, poorer social creativity as measured by the SCT, lower scores on the SEL-MI, and slower reaction time on the SEL-MI. Poorer social communication and interaction behavior on parent-reported SCQ was significantly associated with slower reaction time on the SEL-MI.

Assumption Testing

Although PLSR is robust to skewness and kurtosis, we examined these statistics to characterize the data. All variables fell between the recommended range (−2 to 2) for skewness and kurtosis (Tabachnick & Fidell, 2001). The key assumption of the PLSR model is that all measured variance is important and should be explained (including measurement error). This shortcoming of the model must be acknowledged and interpretation of results should be tempered in relation to this limitation. However, this model is still useful when the number of latent variables is smaller than the number of measured variables and in the context of the present analyses, that condition is satisfied.

PLSR Analyses

Clinician-Rated Social Communication and Interaction—The cross-validated RMSEP curve of the first model indicated that one component optimally predicted clinician-coded social communication and interaction behavior on the ADOS (RMSEP = .91; Figure 1a). Component loadings .40 were considered meaningful. The extracted component consisted of one aspect of explicit social cognition (SEL-MI) and two aspects of implicit social cognition (SCT and SEL-MI-RT; Table 4) and accounted for a large amount (43.03%) of the variance in the outcome variable. Component loadings suggest that the combination of low SCT and SEL-MI, and slower SEL-MI-RT optimally predict increased social communication and interaction difficulties as measured by the clinician-coded ADOS.

Parent-Reported Social Communication and Interaction—Again, the cross-validated RMSEP curve of the second model indicated that one component optimally predicted parent-reported social communication and interaction behavior on the SCQ

(RMSEP = 1.00; Figure 1b). The extracted component was comprised of the same three variables as the ADOS component; one aspect of explicit social cognition (SEL-MI) and two aspects of social cognition (SCT and SEL-MI-RT; Table 4). This component accounted for a medium to large amount (24.60%) of the variance in SCQ scores. Examination of the component loadings indicates that poorer performance on SCT and SEL-MI, and slower SEL-MI-RT optimally predict increased social communication and interaction difficulties as measured by parent-report SCQ.

Observer-Coded Social Communication and Interaction—For the third model, the cross-validated RMSEP curve again indicated that one component optimally predicted the lab-based observation measure of low-level interactions on the SIOS (RMSEP = 1.00; Figure 1c). The extracted component was comprised of two aspects of implicit social cognition (N170 latency and N100 latency) and no aspects of explicit social cognition. This component accounted for a large amount (27.21%) of the variance in the proportion of SIOS low-level interactions. The component loadings suggested that longer N170 and N100 latencies predicted more low-level interactions on the SIOS.

The fourth model predicting positive interactions on the SIOS was not interpretable. The cross-validated RMSEP curve indicated that the component solutions did not improve fit of the data (Figure 1d).

Discussion

Theoretical models and interventions in the ASD literature have emphasized the controlled and largely conscious explicit social cognition processes, such as acquiring and recalling social knowledge, as central to explaining social behavior problems (Koenig et al., 2009). Meanwhile, alternative models have theorized that the spontaneous and primarily unconscious implicit social cognition processes involved in planning, processing, and executing appropriate social behavior may augment explicit social cognition or be incrementally important in their own right (Koenig et al., 2009; McMahon et al., 2013). The current study is the first to examine the relative contributions of aspects of implicit and explicit social cognition factors in predicting social communication and interaction behaviors in youth with ASD.

Prediction of Social Behaviors

Largely consistent with our hypotheses, three of the four PLSR models were interpretable and each accounted for a large portion of the variance in outcome measures of social communication and interaction behaviors. These findings represent the first time that this analytic approach has been applied to social behavior outcomes in youth with ASD. Additionally, our results support the notion that aspects of both explicit *and* implicit social cognition variables optimally predict social behavior in ASD populations. This is consistent with several recent theories about how social cognition processes relate to behavioral outcome variables in ASD (Lipton & Nowicki, 2009; Mendelson et al., 2016), and which have shown the processes contributing to social competence outcome measures to be complex, multi-faceted, and interwoven (Callenmark et al., 2014; Guivarch et al., 2017).

The current study responds to recent calls in the literature (Bottema-Beutel et al., 2019) to utilize innovative statistical methodologies capable of modeling the complex interconnectedness of social cognition constructs. The current study utilized a form of statistical analyses rarely used in psychological research and represents the first time this analytic approach has been applied to social behavior outcomes in youth with ASD. These results provide new evidence showing that complex constellations of social cognition factors can be meaningfully connected using statistical approaches such as PLSR. The current findings further demonstrate that discrete combinations of specific social cognition variables can impart important information about real world social behavior. The successful implementation of PLSR in this context supports the use of this analytic strategy in future investigations of the relationships between components of social cognition and real-world social competence outcomes.

The results of the first and second PLSR models indicated that a combination of poorer aspects of implicit (slower SEL-MI-RT) and explicit (SEL-MI) social meaning and poorer aspects of implicit social reasoning (SCT) optimally predicted poorer social communication and interaction behavior scores as observed and coded by a clinician on the ADOS (PLSR model 1), as well as those parent-reported on the SCQ (PLSR model 2). The results of these first two models are consistent with our second hypothesis; while aspects of both implicit and explicit social cognition contributed to predicting social behavior outcomes, the aspects of implicit social cognition appeared to be relatively more important in that they significantly loaded onto components more frequently than did the aspects of explicit social cognition. Interestingly, while the parent-report SCQ reflects the parent's perception of their child's behaviors in the "real world", clinician-coding on the ADOS reflects observed behaviors in a controlled environment with maximal opportunity for social interaction. Thus, results of these first two models may suggest a robust effect given that the same combination of social cognitive measures optimally predicted both parent- and clinician-reported behaviors across a range of social contexts.

The findings of the first two models are consistent with prior theoretical work proposing that social difficulties characteristic of ASD result from core deficits in theory of mind reasoning (Baron-Cohen, 2001). Results further expand on this theory by demonstrating the importance of both implicit and explicit aspects of theory of mind for predicting social behavior outcomes. It is also notable that neither implicit nor explicit social awareness loaded onto these components. It may be that relative to social meaning and reasoning, social awareness is less important in predicting parent- and clinician- perceptions of social behaviors. Lastly, the results of these two models add to our understanding of the contribution of social creativity to social competence outcomes. Future research into cognitive factors related to social functioning in ASD would benefit from including measures of social creativity to further assess the contribution of this factor to social competence.

In the third PLSR model, poorer aspects of implicit social awareness (slower N170 and N100 latencies) optimally predicted increased low-level interactions (i.e. close proximity, functional communication) observed in a lab-based peer interaction. These results are particularly interesting considering that ERPs do not consistently relate to self-report

measures of social functioning and are rarely examined in relation to observed behavior (Clarkson et al., 2019). Results of the third model indicate that ERPs are in fact a useful tool for predicting social behavior and future investigators should further examine relationships between ERPs and real-world social outcomes. Results show slower engagement in implicit social awareness predicted more low-level interactions. However, it is important to note that low-level behavior is not necessarily effective prosocial behavior. Low-level social interaction indicates some social engagement although these behaviors tend to be more passive and less skilled than positive peer interactions (i.e. eye-contact paired with a smile). Results of the third PLSR model are therefore consistent with Mendelson et al.'s (2016) theory which poses that social interaction difficulties in ASD result from slower social information processing speed. Thus, individuals with poorer aspects of implicit social awareness may demonstrate social intent and engage in more low-level social interaction due to difficulties processing social information efficiently and at the speed necessary for successful engage in more socially-skilled interaction. Results of the third model are partially consistent with our second hypothesis because they indicate that aspects of implicit social cognition were relatively more important compared to aspects of explicit social cognition in the prediction of this outcome. The fourth PLSR model predicting observer-rated positive interactions was not interpretable and future studies should aim to include positive peer interactions as an outcome measure.

Implications for Research and Practice

Overall, our results support the implicit social cognition model (Callenmark et al., 2014; Guivarch et al., 2017). While aspects of both implicit and explicit social cognition contributed to predicting social behavior outcomes, the aspects of implicit social cognition appeared to be relatively more important (significantly loaded onto components more frequently). These findings also suggest that the optimal configuration of measures to predict competent social communication and interaction behavior varied somewhat depending on the informant source (clinician-coded, parent-reported, or observed). This is relevant in both clinical and research settings since relying on a single measure of social behavior is unlikely to provide a comprehensive picture of an individual's true functioning (Kanne, Abbacchi, & Constantino, 2009).

The current investigation employed study design and measurement procedures which are in line with recent meta-analytic findings (Bottema-Beutel et al., 2019) indicating the need for more complex and nuanced approaches to conceptualizing social competence. The authors have advocated for the utility of re-conceptualizing subdomains of social functioning as being composed of multifaceted processes with interactive components, a theoretical proposal supported by the current novel analytical approach and findings. Bottema-Beutel et al. (2019) further hypothesized that rather than accounting for large amounts of variance in broad social functioning overall, cognitive factors (e.g., theory of mind) may more directly contribute to specific components of social functioning. Consistent with this hypothesis, results from the exploratory analyses in the current study suggest that certain aspects of social cognition may be more important in predicting outcomes than others. That is, social meaning may be most related to social behavior, relative to social reasoning or social

awareness. This may underscore a larger contribution of theory of mind abilities to social communication and interaction, which may be specific to ASD populations.

One implication for practice is that assessments of individuals with ASD may benefit from including implicit as well as explicit measures of social cognition to best understand contributions to social behavior problems. However, most of the measures of social cognition included in the present study are lab-based measures that are impractical to implement in clinical settings. This is particularly the case for the implicit social cognition measures. Therefore, future research is warranted to determine the feasibility and utility of implementing implicit measures of social cognition in clinical settings. Additionally, these results may have important implications for clinical interventions. If implicit social cognitive processes appear to be most predictive of social behavior, future interventions should evaluate whether targeting implicit, explicit, or a combination of implicit and explicit social cognition leads to meaningful change in social communication and interaction behavior.

Although a majority of social skills interventions for youth with ASD involve explicit social cognition training (White et al., 2007), there exist multiple empirically supported interventions which aim at increasing overall social functioning through targeting implicit social cognition. One such example is Socio-Dramatic Affective Relational Intervention (SDARI; Lerner et al., 2011) which aims to improve social skills through implicit social cognition training in the form of improvisational theater games and activities. While explicit social skills training programs focus on teaching individuals “correct” responses to specific social cues and accurate interpretation of social information, the nature of improvisation requires individuals to reason about and respond to social situations very quickly, without the time required to engage in slower explicit forms of social problem-solving. For instance, instead of explicitly teaching an individual that a facial expression with a smile indicates happiness, improv games utilized in SDARI require attention to individuals’ differing facial expressions in order to respond to that information through behavior, with the ultimate goal of improving implicit social awareness (e.g. decrease latency of the N170 ERP) via increasing attention to faces.

As an example, in a game called “Change,” two participants act out an improvisational scene based on a novel scenario (e.g., buying chocolate on the moon). When a clinician calls out “Change!” the last person who spoke must then change the last line they said, thus altering the course of the scene. For example, a participant says, “This is the most amazing chocolate I’ve ever tasted!” “Change!” “This is the most amazing chemical reaction I’ve ever seen,” etc. When the participant has finished changing the line, the scene resumes and follows the new storyline based on how the line was changed. Thus, such improv techniques also promote engagement of implicit social reasoning (practicing social creativity in the range of plausible responses), social meaning (e.g., rapid perspective-taking in order to follow the lead of the scene partner), and awareness (quick social information processing speed).

Limitations and Future Directions

Given the lack of clarity in the literature on how best to conceptualize and measure social cognition, it was not possible to situate the results of this study in the context of a single

theoretical model of social competence. To compensate for the lack of a parsimonious explanatory model of social competence, we overlaid the SELF model, an empirically supported integrative model, with the theory of implicit and explicit social cognition. While this approach enabled us to model and examine social cognition in a more nuanced way, the resulting theoretical model is somewhat structurally inelegant. It is our hope that this study will provide a foundation for future investigations to continue to refine and adapt models of social cognition to better account for multiple levels of analysis.

In PLSR analyses, all variance in the model, including error variance, is treated as meaningful and is optimally explained by the model. Thus, at least some of the predictive variance in these models can be attributed to stochastic individual differences rather than true patterns of social cognition. Nonetheless, there are numerous benefits of using the PLSR analytic approach including robustness to multicollinearity, allowance of several indicators with relatively few observations, and creation of formative rather than latent factors. The PLSR analyses also benefited from internal cross-validation which involved iteratively running the model on a subset of the data, extracting estimates, and then applying these estimates to an independent subset of the data to evaluate fit. The use of cross-validation procedures increases the likelihood that resulting solutions are generalizable to other samples. Ultimately, the benefits of the PLSR approach outweigh its limitations.

In light of interpretative limitations imposed by the treatment of error variance in PLSR, future investigations should build upon these analyses to examine whether similar combinations of explicit and implicit social cognitive variables predict social behavior outcomes in larger samples and with other methods of multivariate modeling. Another limitation of the PLSR approach is that the factors extracted are forced to be orthogonal. There is no theoretical reason to assume that these latent factors would necessarily be orthogonal and thus forcing them to do so may result in a model that fits less well than one in which the factors were allowed to correlate. Again, future studies should investigate the relative contribution of explicit versus implicit social cognition using a variety of analyses to converge on a model that better reflects naturalistic social functioning. Additionally, PLSR is not able to account for dyadic nesting (e.g., in the SIOS social interaction task). While this is a limitation of the approach, this statistical method did enable us to account for shared variance among predictors - a unique strength. Future studies may wish to build on the results of the current study by measuring social behavior via interactions with confederates which would eliminate dyadic nesting in the data.

Another limitation concerns the sample, which was relatively small and consisted of only individuals with ASD. Thus, conclusions cannot be drawn about the predictive utility of social cognition for behavioral outcomes in typically developing youth or in youth with other disorders associated with social challenges (e.g., ADHD; Mikami, Miller, & Lerner, 2019). Additionally, the present analyses did not take into account participant individual differences such as the presence of co-occurring disorders. Co-occurring disorders are highly prevalent in individuals with ASD (Simonoff et al., 2008), and the presence of one or more comorbid psychiatric disorders, including anxiety disorders, attention deficit hyperactivity disorder (ADHD), and oppositional defiant disorder (ODD), has been associated with social functioning deficits among youth with ASD (Rosen, Mazefsky, Vasa, & Lerner, 2018). Thus,

the presence of such disorders may moderate the impact of social cognition on social behaviors.

Future investigations should consider including other measures of explicit and implicit social cognition as well as other measures of social behavior as outcomes. The implicit and explicit aspects of social cognition included in the current study were selected due to their overlap with the SELF model. However, there are several other important aspects of implicit and explicit social cognition not captured in the present study that warrant future investigation. For instance, individuals with ASD demonstrate latency and amplitude differences on other ERPs such as the P300 (Cui, Wang, Liu, & Zhang, 2017) and Late Positive Potential (Benning et al., 2016) as compared to typically developing individuals, and these may serve as candidate indicators of implicit social awareness. Similarly, passive eye-tracking behavior on social tasks including latency and fixation duration may also represent potential indicators of implicit social awareness. In terms of aspects of explicit social cognition, future studies may consider examining identification of social norm violations using measures such as the Dewey Story Test (Callenmark et al., 2014). Furthermore, peer-rated outcome measures, such as friendship nominations, may capture unique and meaningful information about an individual's social functioning not accounted for by parent, clinician, and observer ratings of social communication and interaction.

Conclusion

Aspects of both explicit and implicit social cognition may predict social communication and interaction in youth with ASD. However, aspects of implicit social cognition appear relatively more predictive of these social behavior outcomes. While social meaning and social reasoning abilities were associated with clinician-coded and parent-reported social behaviors, social awareness was related to observations of social behaviors. Taken together, these findings underscore the importance of taking a multi-method approach to the assessment of social cognition and social behavior in youth with ASD. Additionally, results indicate that it may be helpful for interventions to target implicit social cognition in addition to - or perhaps instead of - explicit social cognition to promote competent social behavior.

Acknowledgments

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by Fellowships from the American Psychological Foundation, Jefferson Scholars Foundation, and International Max Planck Research School, and grants from the American Psychological Association and Association for Psychological Science, and NIMH grant R00MH079617-03.

Appendix A

Children's Assertive Behavior Scale (CABS; Michelson & Wood, 1982)

A sample item of the CABS is: "You made a mistake and someone else is blamed for it. The right thing to do is to: (a) Say nothing. (b) Say, 'It's their mistake!' (c) Say 'I made the mistake.' (d) Say, 'I don't think the person did it.' (e) Say, 'That's their tough luck!'". Using the assertive scale, normative samples of comparably-aged typically developing youth have

mean scores of approximately 43.77 ($SD = 4.87$; Maedgen & Carlson, 2000); youth with ASD vary widely in their performance on this measure (Lerner & Girard, 2018; Marro et al., *in press*). The CABS has been shown to correlate with peer, parent, and teacher reports of social competency and to discriminate between children with and without a history of social skills training (Michelson & Wood, 1982); it has also demonstrated strong convergent validity with multiple measures of related constructs (Scanlon & Ollendick, 1986). Internal consistency in our sample was acceptable (.87).

Stories from Everyday Life- Mental Inference (SEL-MI; Kaland et al., 2002)

A sample item from the SEL-MI is as follows; a story is presented (e.g. the brother of a child who never cleans his room declares that said brother has done “a splendid job of tidying up”), questions about the physical condition of the story are presented (e.g. how does the child’s room look?), and then questions about the mental state of the character are presented (e.g. why does the brother make this statement?). Responses to each question were taped, and later coded by trained coders on a 0 – 2 scale (*incorrect* to *correct*). All answers were double-coded, with coders assigned randomly, counterbalanced by pair. Inter-rater reliability of ratings was excellent for all stories, $ICC(1,2) > .85$. Internal consistency of the mental inference scale was acceptable (.58).

The Diagnostic Analysis of Nonverbal Accuracy-2 (DANVA-2; Nowicki, 2004)

Both the facial (Solomon, Goodlin-Jones, & Anders, 2004) and vocal (Lerner, Mikami, & Levine, 2011) modules of the DANVA-2 have been used with youth who have ASD. Internal consistency was high across the facial (.91) and vocal (.89) scales in the present study.

Social Creativity Task (SCT; Mouchiroud & Lubart, 2002)

The SCT has been used in one study among youth with ASD (Lerner & Girard, 2018), and expands upon an existing social flexibility/creativity construct (Hobson et al., 2009). A team of undergraduate coders were trained to judge the creativity of each answer provided by participants in the present sample. All answers were double-coded, with coders assigned randomly, counterbalanced by coder pair. Reliability of these ratings was excellent, $ICC(1,2) = .79$ (Cicchetti, 1994).

Stories from Everyday Life- Mental Inference Reaction Time (SEL-MI-RT; Kaland et al., 2002)

Reaction time to the SEL-MI task has previously been used with children and adolescents with ASD and results indicate that youth with ASD demonstrate slower reaction times than typically developing individuals (Kaland et al., 2011; Kaland, Smith, & Mortensen, 2007).

Social Interaction Observation Scale (SIOS; Bauminger, 2002, 2007a, 2007b)

SIOS has shown sensitivity to both explicit and implicit social cognition training in youth with ASD (Lerner & Mikami, 2012). The SIOS was used to rate video recordings of each participant’s behavior in the unstructured peer interaction using 10, 1-minute segments of

behavior. For each 1-minute sample, coders identified up to three salient behaviors that best characterized the given segment and then, for each behavior, determined whether each behavior was positive, negative, or low-level. Subscale averages were calculated across segments, such that overall scores for each subscale ranged from 0 to 3. Coders were trained on the SIOS manual and achieved high reliability ($ICC(2,3) > .80$) on all subscales with master codes on tapes from a previous sample (Lerner & Mikami, 2012). Coders were then randomly assigned to double-code the tapes from the present sample and were counterbalanced by coding pair. Reliability ($ICC(1,2)$) for total (.92), positive (.94), negative (.77), and low-level (.93) interactions was excellent.

Appendix B

Missingness

Eight participants had missing data. To ensure conservative results interpretation, no imputation procedures were used; these cases were removed from the final dataset. Analyses were conducted on the final sample of 34 youths (Table 2). Independent samples t-tests indicated that the participants excluded from the final sample did not significantly differ from the included participants on age or IQ (all $p > .12$). A chi-square test of independence indicated that the excluded participants did not differ from the included participants on sex ($p = .13$).

Data Transformation

For ease of interpretation, the CABS, SEL-MI-RT, DANVA faces, DANVA voices, N170 latency, and N100 latency variables were reverse scored prior to the PLSR analyses such that high scores indicated better performance. All variables were z-scored to facilitate scaling and interpretation of the resulting PLSR linear combinations.

References

- Baron-Cohen S, Jolliffe T, Mortimore C, & Robertson M (1997). Another advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger syndrome. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 38(7), 813–822.
- Baum K, & Nowicki S (1996). A measure of receptive prosody for adults: The Diagnostic Analysis of Nonverbal Accuracy-Adult Voices. *Journal of Nonverbal Behavior*.
- Bauminger N (2002). The Facilitation of Social-Emotional Understanding and Social Interaction in High-Functioning Children with Autism: Intervention Outcomes. *Journal of Autism and Developmental Disorders*, 32(4), 283–298. 10.1023/A:1016378718278 [PubMed: 12199133]
- Bauminger N (2007a). Brief report: Group social-multimodal intervention for HFASD. *Journal of Autism and Developmental Disorders*, 37(8), 1605–1615. 10.1007/s10803-006-0246-3 [PubMed: 17072752]
- Bauminger N (2007b). Brief report: Individual social-multi-modal intervention for HFASD. *Journal of Autism and Developmental Disorders*, 37(8), 1593–1604. 10.1007/s10803-006-0245-4 [PubMed: 17072753]
- Beauchamp MH, & Anderson V (2010). SOCIAL: an integrative framework for the development of social skills. *Psychological Bulletin*, 136(1), 39–64. 10.1037/a0017768 [PubMed: 20063925]
- Benning SD, Kovac M, Campbell A, Miller S, Hanna EK, Damiano CR, ... Dichter GS (2016). Late Positive Potential ERP Responses to Social and Nonsocial Stimuli in Youth with Autism Spectrum

- Disorder. *Journal of Autism and Developmental Disorders*, 46(June), 3068–3077. 10.1007/s10803-016-2845-y [PubMed: 27344337]
- Bottema-Beutel K, Kim SY, & Crowley S (2019). A systematic review and meta-regression analysis of social functioning correlates in autism and typical development. *Autism Research*, 12(2), 152–175. 10.1002/aur.2055 [PubMed: 30575308]
- Callenmark B, Kjellin L, Rönqvist L, & Bölte S (2014). Explicit versus implicit social cognition testing in autism spectrum disorder. *Autism*, 18(6), 684–693. 10.1177/1362361313492393 [PubMed: 24104519]
- Cassel C, Hackl P, & Westlund AH (1999). Robustness of partial least-squares method for estimating latent variable quality structures. *Journal of Applied Statistics*, 26(4), 435–446. 10.1080/02664769922322
- Chandler S, Charman T, Baird G, Simonoff E, Loucas T, Meldrum D, ... Pickles A (2007). Validation of the Social Communication Questionnaire in a population cohort of children with autism spectrum disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, 46(October), 1324–1332. 10.1097/chi.0b013e31812f7d8d [PubMed: 17885574]
- Clarkson T, Kang E, Capriola-Hall N, Lerner MD, Jarcho J, & Prinstein MJ (2019). A meta-analysis of the RDoC social processing domain across units of analysis. *Journal of Clinical Child & Adolescent Psychology*.
- Crick NR, & Dodge KA (1994). A Review and Reformulation of Social Information-Processing Mechanisms in Children's Social Adjustment. *Psychological Bulletin*, 115(1), 74–101. 10.1037/0033-2909.115.1.74
- Cui T, Wang PP, Liu S, & Zhang X (2017). P300 amplitude and latency in autism spectrum disorder: a meta-analysis. *European Child and Adolescent Psychiatry*, 26(2), 177–190. 10.1007/s00787-016-0880-z [PubMed: 27299750]
- Dawson G, Toth K, Abbott R, Osterling J, Munson J, Estes A, & Liaw J (2004). Early Social Attention Impairments in Autism: Social Orienting, Joint Attention, and Attention to Distress. *Developmental Psychology*, 40(2), 271–283. 10.1037/0012-1649.40.2.271 [PubMed: 14979766]
- de Boo GM, & Prins PJM (2007). Social incompetence in children with ADHD: Possible moderators and mediators in social-skills training. *Clinical Psychology Review*, 27(1), 78–97. 10.1016/j.cpr.2006.03.006 [PubMed: 16814435]
- Demertzis A, & Nowicki S (1998). Correlates of the ability to read emotion in the voices of children. Mobile, AL: Southeastern Psychological Association.
- Gresham FM (1997). Social Competence and Students With Behavior Disorders: Where We've Been, Where We Are, and Where We Should Go. *Education and Treatment of Children*, 20(3), 2233–2249.
- Guivarch J, Murdymootoo V, Elissalde S-N, Salle-Collemiche X, Tardieu S, Jouve E, & Poinso F (2017). Impact of an implicit social skills training group in children with autism spectrum disorder without intellectual disability: A before-and-after study. *Plos One*, 12(7), e0181159 10.1371/journal.pone.0181159 [PubMed: 28715464]
- Harms MB, Martin A, & Wallace GL (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, 20(3), 290–322. 10.1007/s11065-010-9138-6 [PubMed: 20809200]
- Hobson JA, Hobson RP, Malik S, Bargiota K, & Caló S (2013). The relation between social engagement and pretend play in autism. *British Journal of Developmental Psychology*, 31(1), 114–127. 10.1111/j.2044-835X.2012.02083.x [PubMed: 23331110]
- Kaland N, Callesen K, Møller-Nielsen A, Mortensen EL, & Smith L (2008). Performance of children and adolescents with asperger syndrome or high-functioning autism on advanced theory of mind tasks. *Journal of Autism and Developmental Disorders*, 38(6), 1112–1123. 10.1007/s10803-007-0496-8 [PubMed: 18058213]
- Kaland N, Møller-Nielsen A, Callesen K, Mortensen EL, Gottlieb D, & Smith L (2002). A new "advanced" test of theory of mind: Evidence from children and adolescents with Asperger syndrome. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 43(4), 517–528. 10.1111/1469-7610.00042

- Kaland N, Mortensen EL, & Smith L (2011). Social communication impairments in children and adolescents with Asperger syndrome: Slow response time and the impact of prompting. *Research in Autism Spectrum Disorders*, 5(3), 1129–1137. 10.1016/j.rasd.2010.12.009
- Kana RK, Patriquin MA, Black BS, Channell MM, & Wicker B (2016). Altered Medial Frontal and Superior Temporal Response to Implicit Processing of Emotions in Autism. *Autism Research*, 9(1), 55–66. 10.1002/aur.1496 [PubMed: 25962831]
- Kang E, Keifer CM, Levy EJ, Foss-Feig JH, McPartland JC, & Lerner MD (2018). Atypicality of the N170 Event-Related Potential in Autism Spectrum Disorder: A Meta-analysis. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, 3(657–666).
- Kanne SM, Abbacchi AM, & Constantino JN (2009). Multi-informant ratings of psychiatric symptom severity in children with autism spectrum disorders: The importance of environmental context. *Journal of Autism and Developmental Disorders*, 39(6), 856–864. 10.1007/s10803-009-0694-7 [PubMed: 19191016]
- Kasari C, & Patterson S (2012). Interventions addressing social impairment in autism. *Current Psychiatry Reports*, 14(6), 713–725. 10.1007/s11920-012-0317-4 [PubMed: 23055002]
- Koenig K, De Los Reyes A, Cicchetti D, Scahill L, & Klin A (2009). Group intervention to promote social skills in school-age children with pervasive developmental disorders: Reconsidering efficacy. *Journal of Autism and Developmental Disorders*, 39(8), 1163–1172. 10.1007/s10803-009-0728-1 [PubMed: 19326199]
- Ladd GW, & Mize J (1983). A cognitive-social learning model of social-skill training. *Psychological Review*, 90(2), 127–157. 10.1037/0033-295X.90.2.127 [PubMed: 6867217]
- Laugeson EA, Frankel F, Mogil C, & Dillon AR (2009). Parent-assisted social skills training to improve friendships in teens with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 39(4), 596–606. 10.1007/s10803-008-0664-5 [PubMed: 19015968]
- Lerner MD, Calhoun CD, Mikami AY, & De Los Reyes A (2012). Understanding parent-child social informant discrepancy in youth with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 42(12), 2680–2692. 10.1007/s10803-012-1525-9 [PubMed: 22456819]
- Lerner MD, & Girard RM (2018). Appreciating and promoting social creativity in youth with Asperger's Syndrome In Kaufman SB (Ed.), *Twice-Exceptional: Supporting and Educating Bright and Creative Students with Learning Difficulties*. New York: Oxford University Press.
- Lerner MD, McPartland JC, & Morris JP (2013). Multimodal emotion processing in autism spectrum disorders: An event-related potential study. *Developmental Cognitive Neuroscience*, 3(1), 11–21. 10.1016/j.dcn.2012.08.005 [PubMed: 23245216]
- Lerner MD, & Mikami AY (2012). A preliminary randomized controlled trial of two social skills interventions for youth with high-functioning autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*.
- Lerner MD, Potthoff LM, & Hunter SJ (2015). Optimizing cross-sectional prediction of social functioning in youth referred for neuropsychological testing. *PLoS ONE*, 10(5), 1–16. 10.1371/journal.pone.0128303
- Lipton ME, & Nowicki S (2009). The Social-Emotional Learning Framework (SELF): A Guide for Understanding Brain-Based Social-Emotional Learning Impairments. *The Journal of Developmental Processes*, 4(2), 99–115. 10.3102/0034654308325693
- Lord C, Rutter M, DiLavore P, & Risi S (1999). *Autism diagnostic observation schedule-WPS edition*. Los Angeles, CA: Western Psychological Services.
- Lozier LM, VanMeter JW, & Marsh AA (2014). Impairments in facial affect recognition associated with autism spectrum disorders: A meta-analysis. *Development and Psychopathology*, 26(4), 1–13. 10.1017/S0954579414000479 [PubMed: 24280315]
- Maedgen JW, & Carlson CL (2000). Social Functioning and Emotional Regulation in the Attention Deficit Hyperactivity Disorder Subtypes. *Journal of Clinical Child Psychology*, 29(1), 30–42. 10.1207/S15374424jccp2901 [PubMed: 10693030]
- Marom EM, Milito MA, Moran CA, Liu P, Correa AM, Kim ES, ... Swisher SG (2011). Computed tomography findings predicting invasiveness of thymoma. *J Thorac Oncol*, 6(7), 1274–1281. 10.1097/JTO.0b013e31821c4203 [PubMed: 21623235]

- Matson JL, Matson ML, & Rivet TT (2007). Social-Skills Treatments for Children With Autism Spectrum Disorders An Overview. *Behavior Modification*, 31(5), 682–707. [PubMed: 17699124]
- McKown C, Allen AM, Russo-Ponsaran NM, & Johnson JK (2013). Direct assessment of children's social-emotional comprehension. *Psychological Assessment*, 25(4), 1154–1166. 10.1037/a0033435 [PubMed: 23815117]
- McMahon CM, Lerner MD, & Britton N (2013). Group-based social skills interventions for adolescents with higher-functioning autism spectrum disorder: a review and looking to the future. *Adolescent Health, Medicine and Therapeutics*, 2013(4), 23–28. 10.2147/AHMT.S25402
- McMahon CM, & Solomon M (2015). Brief Report: Parent–Adolescent Informant Discrepancies of Social Skill Importance and Social Skill Engagement for Higher-Functioning Adolescents with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 45(10), 3396–3403. 10.1007/s10803-015-2494-6 [PubMed: 26077952]
- McPartland JC, Wu J, Bailey C. a, Mayes LC, Schultz RT, & Klin A (2011). Atypical neural specialization for social percepts in autism spectrum disorder. *Social Neuroscience*, 6(5–6), 436–451. 10.1080/17470919.2011.586880 [PubMed: 21777159]
- Mendelson JL, Gates JA, & Lerner MD (2016). Friendship in School-Age Boys With Autism Spectrum Disorders: A Meta-Analytic Summary and Developmental, Process-Based Model. *Psychological Bulletin*. 10.1037/bul0000041
- Mesibov GB (1984). Social skills training with verbal autistic adolescents and adults: A program model. *Journal of Autism and Developmental Disorders*, 14.
- Michelson L, & Wood R (1982). Development and psychometric properties of the Children's Assertive Behavior Scale. *Journal of Behavioral Assessment*, 4, 3–13.
- Mikami AY, Miller M, & Lerner MD (2019). Social functioning in youth with attention-deficit/hyperactivity disorder and autism spectrum disorder: transdiagnostic commonalities and differences. *Clinical Psychology Review*, 68(June 2018), 54–70. 10.1016/j.cpr.2018.12.005 [PubMed: 30658861]
- Mouchiroud C, & Bernoussi A (2008). An empirical study of the construct validity of social creativity. *Learning and Individual Differences*, 18(4), 372–380. 10.1016/j.lindif.2007.11.008
- Mouchiroud C, & Lubart T (2002). Social creativity: A cross-sectional study of 6- to 11-year-old children. *International Journal of Behavioral Development*, 26(1), 60–69. 10.1080/01650250042000591
- Nixon E (2001). The Social Competence of Children with Attention Deficit Hyperactivity Disorder: A Review of the Literature. *Child and Adolescent Mental Health*, 6(4), 172–180. 10.1111/1475-3588.00342
- Norris M, & Lecavalier L (2010). Screening accuracy of Level 2 autism spectrum disorder rating scales. A review of selected instruments. *Autism : The International Journal of Research and Practice*, 14(4), 263–284. 10.1177/1362361309348071 [PubMed: 20591956]
- Nosek BA, Hawkins CB, & Frazier RS (2011). Implicit social cognition: From measures to mechanisms. *Trends in Cognitive Sciences*, 15(4), 152–159. 10.1016/j.tics.2011.01.005 [PubMed: 21376657]
- Nowicki S (2004). *Manual for the Receptive Tests of the Diagnostic Analysis of Nonverbal Accuracy* (vol. 2). Atlanta, GA: Emory University.
- Nowicki S, & Carton J (1993). The Measurement of Emotional Intensity from Facial Expressions. *The Journal of Social Psychology*, 133(5), 749–750. [PubMed: 8283869]
- Pedreño C, Pousa E, Navarro JB, Pàmias M, & Obiols JE (2017). Exploring the Components of Advanced Theory of Mind in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 47(8), 2401–2409. 10.1007/s10803-017-3156-7 [PubMed: 28516423]
- Pinheiro AP, Galdo-Álvarez S, Rauber A, Sampaio A, Niznikiewicz M, & Gonçalves ÓF (2010). Abnormal processing of emotional prosody in Williams syndrome: An even-related potentials study. *Research in Developmental Disabilities*, 32(1), 133–147. 10.1016/j.ridd.2010.09.011 [PubMed: 20961731]
- Rose-Krasnor L (1997). The nature of social competence: A theoretical review. *Social Development*, 6(1), 111–135. 10.1111/j.1475-3588.2012.00663.x

- Rosen TE, Mazefsky CA, Vasa RA, & Lerner MD (2018). Co-occurring psychiatric conditions in autism spectrum disorder. *International Review of Psychiatry*, 30(1), 40–61. 10.1080/09540261.2018.1450229 [PubMed: 29683351]
- Rosenblau G, Kliemann D, Heekeren HR, & Dziobek I (2015). Approximating Implicit and Explicit Mentalizing with Two Naturalistic Video-Based Tasks in Typical Development and Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 45(4), 953–965. 10.1007/s10803-014-2249-9 [PubMed: 25267068]
- Rutter M, Bailey A, & Lord C (2003). *The social communication questionnaire: Manual*. Western Psychological Services.
- Ryan JJ, Glass LA, & Brown CN (2007). Administration time estimates for Wechsler Intelligence Scale for Children-IV subtests, composites, and short forms. *Journal of Clinical Psychology*, 63(4).
- Tabachnick BG, & Fidell L (2001). *Using multivariate statistics*. Boston Massachusetts. Boston, Massachusetts: Allyn and Bacon.
- Waters E, & Sroufe LA (1983). Social competence as a developmental construct. *Developmental Review*, 97(3), 79–97. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0273229783900102%5Cpapers2://publication/uuid/7936D3EA-F595-4CFF-BEF7-E861D5A107ED>
- Wechsler D (2003). *Wechsler Intelligence Scale for Children* (4th ed.). San Antonio, TX: PsychCorp.
- Zalla T, Sav AM, Stopin A, Ahade S, & Leboyer M (2009). Faux pas detection and intentional action in asperger syndrome. A replication on a French sample. *Journal of Autism and Developmental Disorders*, 39(2), 373–382. 10.1007/s10803-008-0634-y [PubMed: 18726150]

Figure 1.

The point at which the Root Mean Square Error of Prediction (RMSEP) value is the lowest determines the number of components extracted for that analysis. A) RMSEP plot depicting the RMSEP value for factor solutions of 0 to 5 components in the PLSR analysis predicting z-scored ADOS CSS. B) RMSEP plot depicting the RMSEP value for factor solutions of 0 to 5 components in the PLSR analysis predicting z-scored SCQ. C) RMSEP plot depicting the RMSEP value for factor solutions of 0 to 5 components in the PLSR analysis predicting z-scored SIOS Low-Level Interaction. D) RMSEP plot depicting the RMSEP value for factor solutions of 0 to 5 components in the PLSR analysis predicting z-scored SIOS Positive Interaction; for this model, the RMSEP value does not decrease after the intercept and thus this model is not interpretable.

Table 1

Theoretical model representing explicit and implicit social cognition variables overlaid with the Social-Emotional Learning Model (Lipton and Nowicki, 2009).

	Explicit Social Cognition	Implicit Social Cognition
Social Reasoning	CABS: Knowledge of appropriate social behaviors	SCT: Generation of novel responses to social scenarios
Social Meaning	SEL-MI: Theory of Mind knowledge	SEL-MI-RT: Theory of Mind efficiency
Social Awareness	DANVA-2: Facial emotion recognition	SIPS: N170 latency to faces and N100 latency to voices

CABS = Children's Assertive Behavior Scale. SCT = Social Creativity Tasks. SEL-MI = Stories from Everyday Life – Mental Inference. SEL-MI-RT = Stories from Everyday Life – Mental Inference Reaction Time. DANVA-2 = Diagnostic Analysis of Nonverbal Accuracy-2. SIPS = Social Information Processing Speed.

Table 2

Descriptive Statistics of Study Sample

Variable	Frequency	Mean (SD)
N	34	
Age		13.07 (2.07)
Sex	26 male, 8 female	
FSIQ		111.06 (15.58)
ADOS Module	23 Mod 3; 11 Mod 4	
ADOS CSS		6.29 (1.98)
ADOS Diagnosis	16 ASD; 18 Autism	
SCQ		20.59 (6.38)
SIOS Pos		1.01 (.76)
SIOS Low		1.15 (.39)
CABS		43.32 (7.90)
SCT		2.61 (.96)
N170 Latency		185.77 (11.76)
N100 Latency		109.70 (20.27)
SEL MI		.57 (.52)
SEL MI RT		5.04 (5.43)
DANVA-2 – Faces (reverse scored)		38.79 (4.07)
DANVA-2 – Voices (reverse scored)		33.06 (4.98)

N = 34. FSIQ = Full Scale IQ. ADOS CSS = Autism Diagnostic Observation Schedule Calibrated Severity Score. SCQ = Social Communication Questionnaire. SIOS Pos = Proportion of SIOS Positive Interaction. SIOS Low = Proportion of SIOS Low Interaction. CABS = Children's Assertive Behavior Scale. SCT = Social Creativity Task. N170/N100 Latency = ERP latency to emotional faces (N170) and voices (N100). SEL MI = Stories from Everyday Life – Mental Inference. SEL MI RT = Stories from Everyday Life- Mental Inference Reaction Time. DANVA-2 = Diagnostic Analysis of Nonverbal Accuracy-2.

Table 3

Correlations between implicit social cognition, explicit social cognition, social communication, and social interaction variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
Outcome Measures													
1. ADOS CSS	1	.50**	-.07	.24	-.34*	-.26	-.37*	-.42*	-.43*	-.12	.02	.16	.11
2. SCQ		1	-.20	.28	-.34	.07	-.22	-.31	-.36*	.18	-.01	.15	.11
3. SIOS Pos			1	-.55**	.18	-.32	.32	-.04	.20	.02	-.16	-.03	.17
4. SIOS Low				1	-.12	.19	-.18	-.04	-.27	-.07	.04	-.27	-.37*
Demographic													
5. FSIQ					1	.00	-.02	.47**	.25	.36*	.34	.05	.20
Social Reasoning													
6. CABS (reversed) ^a						1	-.12	.07	.00	-.09	-.14	.11	-.02
7. SCT ^b							1	.18	.27	.15	-.03	-.10	-.04
Social Meaning													
8. SEL-MI ^a								1	.23	.21	.27	-.07	.06
9. SEL-MI RT (reversed) ^b									1	-.01	.07	.04	-.08
Social Awareness													
10. DANVA-2 Faces (reversed) ^a										1	.31	.25	.16
11. DANVA-2 Voices (reversed) ^a											1	.07	.44**
12. N170 Latency (reversed) ^b												1	.48**
13. N100 Latency (reversed) ^b													1

^aExplicit social cognition variable.^bImplicit social cognition variable.

* p < .05.

** p < .01.

ADOS CSS= Autism Diagnostic Observation Schedule Calibrated Severity Score. SCQ = Social Communication Questionnaire. SIOS Pos = Proportion of SIOS Positive Interaction. SIOS Low = Proportion of SIOS Low Level Interaction. FSIQ = Full Scale IQ. CABS = Children's Assertive Behavior Scale reverse scored. SCT = Social Creativity Task. SEL MI = Stories from Everyday Life – Mental Inference. SEL MI RT = Stories from Everyday Life – Mental Inference Reaction Time reverse scored. DANVA-2 = Diagnostic Analysis of Nonverbal Accuracy-2 reverse scored. N170/N100 Latency = ERP latency to emotional faces (N170) and voices (N100) reverse scored.

Table 4

Partial Least Squares Regression Loadings of Predictors for First Component.

	ADOS CSS	SCQ	SIOS Low-Level Interactions
CABS	-.20		.25
SCT	-.51	-.46	-.33
SEL-MI	-.56	-.49	-.17
SEL-MI-RT (reversed)	-.57	-.61	-.38
DANVA-2 Faces	-.16	.16	-.30
N170 Latency (reversed)	.18	.35	-.55
DANVA-2 Voices			-.28
N100 Latency (reversed)	.18	.27	-.60

All $N = 34$. **Bold loadings** = .40. All variables transformed to Z scores. Independent variables scored such that higher values = “better” performance. ADOS, SCQ, and SIOS Low-Level Interactions scored such that lower scores = “better” performance. ADOS CSS = Autism Diagnostic Observation Schedule Calibrated Severity Score. SCQ = Social Communication Questionnaire. SIOS = Social Interaction Observation Scale. CABS = Children’s Assertive Behavior Scale. SCT = Social Creativity Tasks. SEL-MI = Stories from Everyday Life – Mental Inference. SEL-MI-RT = Reverse-Scored Stories from Everyday Life – Mental Inference Reaction Time. DANVA-2 = Diagnostic Analysis of Nonverbal Accuracy-2. N170/N100 Latency = Reverse-Scored ERP latency to emotional faces (N170) and voices (N100).