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Wanting it Too Much: An Inverse Relation Between Social Motivation and Facial Emotion Recognition in Autism Spectrum Disorder

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Abstract

This study examined social motivation and early-stage face perception as frameworks for understanding impairments in facial emotion recognition (FER) in a well-characterized sample of youth with autism spectrum disorders (ASD). Early-stage face perception (N170 event-related potential latency) was recorded while participants completed a standardized FER task, while social motivation was obtained via parent report. Participants with greater social motivation exhibited poorer FER, while those with shorter N170 latencies exhibited better FER for child angry faces stimuli. Social motivation partially mediated the relationship between a faster N170 and better FER. These effects were all robust to variations in IQ, age, and ASD severity. These findings augur against theories implicating social motivation as uniformly valuable for individuals with ASD, and augment models suggesting a close link between early-stage face perception, social motivation, and FER in this population. Broader implications for models and development of FER in ASD are discussed.

Keywords

Autism spectrum disorder; Social motivation; Emotion recognition; N170; Social perception

Introduction

As social cognition is a core process implicated in autism spectrum disorder (ASD), many studies have examined facial emotion recognition (FER)[1] ability in this population [1, 2]. Within this literature, youth with ASD exhibit a wide range of functioning, from seemingly

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Compliance with Ethical Standards

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intact ability [1–5] through frank impairment [6–8]. The processes that underlie variability in FER performance are largely unknown. However, two processes have been proposed as essential in the emergence of FER in ASD [9]. These processes are early-stage face perception, [e.g., as indexed by the latency of the electroencephalogram (EEG)-derived event related potential (ERP) component N170; 10, 11], and the drive to interact with others [social motivation; 9, 12]. Yet, no study to date has examined both of these processes in terms of their involvement in FER.

Early-Stage Face Perception and Social Motivation as Contributors to FER

A seminal contribution by Dawson, Webb and McPartland [9] provides an avenue for considering specific fundamental processes as underlying constructs for FER in ASD. Two hypotheses are proposed as the source of FER deficit: (1) perceptual/cognitive and (2) motivational/affective. The perceptual/cognitive explanation proposes that (a) there is a deficit in the perceptual binding of social information; (b) there are limitations in the ability to draw out applicable information from faces; and/or (c) the neural mechanism itself (e.g. activity of fusiform gyrus in processing faces) is compromised. The social motivation/affective explanation suggests that deficits in attention and interest in social cues early in life lead to overall lack of social learning experiences, thereby impacting development of FER. Thus, these deficits may impede normal development of brain circuity for social stimuli. Dawson et al. [9] point out that these two hypotheses, although seemingly contradictory, may not be mutually exclusive. Indeed, these two processes may uniquely facilitate FER. Research indicates that deficits in FER are varied and may be affected by multiple components [13–15]. Examination of these two hypotheses (perceptual/cognitive and motivational/affective) is crucial for clarifying the role of social motivation and perceptual aspects of FER in ASD. To our knowledge, no study to date has taken up this challenge and directly compared indices of these two hypotheses to assess their relative contribution to FER in ASD.

Social Motivation

Recent work highlights the importance of social motivation in ASD [9, 12, 16, 17] and posits that deficits in social motivation or 'wanting' may be the origin of the deficits in FER in individuals with ASD [9, 17]. The social motivation hypothesis of ASD proposes that lack of interest in faces in early development may lead to less exposure to emotional information in facial stimuli [12, 18, 19]. This may subsequently lead to a lack of cortical specialization in regions of the brain dedicated to facial stimuli (e.g. fusiform gyrus) and decreased efficiency of perceptual processing of faces [9, 20]. This hypothesis is based on empirical and clinical observation suggesting that children with ASD show lack of initiation of social interaction and interest in peers [9]. Consistent with this hypothesis, Chevallier, Grèzes, Molesworth, Berthoz and Happé [21] found that children with ASD reported lowered levels of enjoyment in social situations but comparable levels of enjoyment for other activities relative to typically developing (TD) children. Additionally, Kim et al. [22] found that children with ASD displayed less approach behavior to positive expressions than TD

[1]Consistent with the meta-analysis by Harms et al. [1], we use this term to refer specifically to performance on behavioral tasks indicating correct identification of emotions in visually-presented facial stimuli.

children. This evidence suggests that children with ASD may display diminished social motivation; however, the role of social motivation in FER in individuals with ASD has yet to be explicitly tested.

Perceptual Components of Face Processing

Individuals within ASD may also differ in FER because they perceive and process facial stimuli at different rates or with differing efficiency [9, 11, 14]. Neural processes that respond uniquely to facial emotional stimuli have been extensively measured via EEG-indexed ERPs [23–26]. The N170 ERP component latency has been used as an index of early-stage face perception [for review, see 27], including preliminary detection of configural facial features [23, 28]. N170 has been shown to be responsive to emotional expressions [29–32]; however, this result is not always found [33–35]. N170 appears to originate in regions of the brain associated with social awareness such as the fusiform gyrus [36] and superior temporal sulcus [37].

Recording N170 while presenting facial stimuli can provide valuable information regarding the relationship between perceptual processing and behavioral FER. Extensive research on N170 suggests that school-age and adolescent youth with ASD show categorical delays in early perceptual processing of faces and associated behavioral deficits in FER [10, 11, 14, 38–40]. FER paradigms afford the opportunity to investigate the early stages of perceptual and cognitive processing of facial emotional stimuli and allow comparison of FER accuracy in individuals with ASD.

Stimulus Variation as a Contributor to Heterogeneity in FER

Behavioral deficits in FER have long been linked to ASD [7]. There is consistent evidence, including two recent meta-analyses [6, 8] of mean group differences in FER between ASD and non-ASD populations. Nonetheless, even within studies sampled by these meta-analyses, findings show substantial variation in FER, with some individuals not demonstrating impairment [3–5]. Both meta-analyses reported that IQ had no impact on FER performance; however, conflicting reports suggest it is unclear whether age influences FER. Accumulating evidence suggests patterns of variation across facial stimuli (i.e. different facial types and expressed content) as a source of heterogeneity in FER.

Greater deficits in FER are found when individuals with ASD are presented with adult facial expressions [14] and subtler ‘‘low intensity’’ emotions [15], particularly among negative emotions such as anger [15, 41]. Recognition of anger has been found to be particularly difficult for individuals with ASD [41–43]. Notably, a recent study by Leung et al. [44] found impaired recognition for, and atypical neural activation to, angry faces but not happy faces in adolescents with ASD, suggesting that FER impairments are both behaviorally most prominent, and electrophysiologically most evident, for anger recognition. Unlike recognition of other negative emotions (fear, disgust and sadness), recognition of anger does not improve with age in individuals with ASD [6], suggesting that FER for this particular emotion may be disrupted throughout development. Overall, extant literature suggests that the examination of recognition of angry faces may be uniquely suited to capture individual differences in FER in ASD. Thus, stimuli in FER paradigms such as adult faces, subtle emotions, and angry emotional expressions appear to elicit particularly substantial difficulty for individuals with ASD.

Aims and Hypotheses

The aim of this study was to directly test the hypothesis articulated in the Dawson, Webb and McPartland [9] paper. As such, we intended to evaluate social motivation and early-stage face perception as possible independent and conjoint contributors to FER in ASD. Evidence suggests that specific types of stimuli may underlie the heterogeneity of FER in ASD. First, adult facial expressions compared to child facial expressions have been shown to present greater difficulties for individuals with ASD during FER tasks [14]. Second, more subtle low intensity (versus high intensity) emotional stimuli have been found to be more difficult during FER tasks for participants with ASD [15]. Third, FER for negative emotions, especially anger, compared to positive emotions has been shown to be diminished in individuals with ASD [41].

To this end, we proposed three hypotheses. First, we hypothesized that social motivation would be positively correlated with performance on the FER task. As previous studies [6, 14, 15] have indicated specific stimuli that produce difficulty in FER, we hypothesized that this effect would be especially evident for low intensity emotions, adult faces, and anger. Second, we hypothesized that early-stage face perception, or N170 latency, would be negatively correlated with performance on the FER task (i.e. shorter latency relating to better performance). We hypothesized that this effect would be especially evident for low intensity emotions, adult faces, and anger. Similarly, we predicted that there would be a negative correlation between the two main processes proposed as contributing to FER; that is, we hypothesized that shorter N170 latency would correlate with greater social motivation [9, 10]. Third, seeking to build on the premise that both perceptual and motivational processes may work in tandem to give rise to FER [9], we hypothesized that social motivation and N170 latency would exhibit an additive relationship when concurrently predicting FER. To maximize our ability to ascertain patterns of shared variance among these constructs, we specifically hypothesized that the additive relationship would be apparent among the subset of FER stimuli that exhibited the clearest and most consistent effects via hypotheses 1 and 2.

Method

Participants

Participants were 40 youth with ASD, drawn from a larger study of social functioning in ASD [14, 45, 46]. IQ was assessed via an abridged version of the Wechsler Intelligence Scale for Children-IV (Wechsler 2003) and IQ cutoff for inclusion was 70. Recent guidelines for EEG data collection in ASD [47] suggest maximizing the range of IQ of participants in a given study paradigm is important to the extent it is possible. As such, the IQ cutoff for this study allowed for a maximally-wide range of verbally-able participants (who could reliably complete the measures), facilitating a more comprehensive consideration of the heterogeneity in FER across youth with ASD. As such, the IQ cutoff for this study was set to support the investigation of the variability in FER in youth with ASD, and facilitate reliable data collection on all the included measures. After EEG testing, five of the subjects were excluded due to insufficient quantity of usable EEG data (see below; EEG processing), therefore the final sample contained 35 individuals (27 male; M_{age} = 13.17, *SD* = 2.12). To determine any disparities between excluded and included participants, we performed independent samples *t*-tests. No differences were found in terms of age ($t(38) = -1.75$, $p = .09$), IQ ($t(38) = -.25$, $p = .80$), ADOS score ($t(38) = -.66$, $p = .51$) or sex ($\chi^2 = 1.43$, $p = .23$).

Measures

Diagnostic and Cognitive Assessment—All participants had previous diagnoses of ASD and diagnostic status was confirmed via administration by a research-reliable examiner of the Autism Diagnostic Observation Schedule [ADOS; 48]. IQ cutoff for inclusion (>70) was assessed via an abridged version of the Wechsler Intelligence Scale for Children-IV [Vocabulary and Matrix Reasoning; 49, 50].

Social Motivation—Parents of participants completed the Dimensions of Mastery Questionnaire subscale, Social Persistence with Peers (DMQ-SPP) [51], which contains six items (sample item: ‘‘Tries to get included when other kids are playing’’) rated on a Likert-type scale of 1 (*not at all typical*) to 5 (*very typical*). Higher scores indicate greater motivation. This subscale is intended to measure the motivation for social interaction with peers. This scale was chosen based on the following criteria: it has previously been used as a measure of social motivation in children with ASD [52]; it correlates with positive social behaviors in children with developmental disabilities [53]; and it focuses on motivation for peer interaction, rather than adult-child interaction (which may confound measurements of motivation given that adults may orient attention). This measure has been used to rate children 6 months to 19 years of age, and has shown good internal consistency (alphas >.70) for each age and type of rater [51]. The current sample also shows good internal consistency ($\alpha = .74$).

FER—Participants completed the Diagnostic Analysis of Non-verbal Accuracy-2 [DANVA-2; [54, 55], a well-established and widely-used measure of FER for school aged youth. Stimuli include 24 child faces and 24 adult faces divided into 50 % high and 50 % low intensity emotions (6 happy, 6 sad, 6 angry, and 6 fearful), for a total of 48 faces. The task is computerized; as each face is presented, participants are asked to indicate each emotion by selecting the corresponding button. High scores indicate a higher number of correct responses. In the larger study from which the present analyses were drawn, DANVA-2 voices modules were also used, and so stimuli were presented in a 2 × 2 (adult/child × faces/voices) block design, randomized within and between blocks. Data from the DANVA-2 voices modules were not used for this study. The DANVA-2 has been used extensively in the ASD literature [56, 57].

ERP Procedures

EEG Data Collection: During presentation of DANVA-2 stimuli, EEG data were recorded. All stimuli were presented using MatLab 7.9.0. The EEG room consisted of low ambient light, sound tempered walls and a 24 in. flat-screen color monitor (60 Hz, 1024 × 768 resolution). The monitor was 75 cm from the participant and a keyboard for responses was within reach. On-screen instructions and verbal instructions were provided to confirm participants' understanding of the task. As each stimulus was presented on screen, the participants were instructed to choose the appropriate emotion from the list (on screen) and indicate it by selecting the corresponding button. Each stimuli was presented for 3000 ms against a black background. The participant was given as much time as needed to make a selection, and if the selection was made after 3000 ms the stimuli would disappear and the selection would be made against a black background. After each selection a blank screen 1000 ms inter-stimulus interval appeared.

EEG Acquisition: A combination of active referencing and Actiview Software was applied to record EEGs continuously at ~2000 Hz. Each participant was equipped with a 32-channel BioSemi Active 2 cap, which included Ag/AgCl-tipped electrodes positioned according to the 10/20 international labeling system; Electrolyte gel was applied to each electrode. Vertical and horizontal eye movements were examined with the positioning of additional electrodes at the supra and infra orbital sites of each eye. The data were sampled with the ground electrode being formed by the Common Mode Sense active electrode and the Driven Right Leg passive electrode, as specified in the BioSemi hardware specifications (BioSemi, Amsterdam, The Netherlands); this feature of the active electrode setup allows the signal to be unaffected by interference and precludes the need to specify impedance thresholds (producing an output impedance of $< 1\ \Omega$). ERPs were time-locked to each stimulus onset.

EEG Processing: EEG Lab (version 9.0.3.4b) and ERPLab (version 1.0.0.42) MatLab packages were used to process ERPs. Data were processed by re-sampling at 500 Hz, re-referencing against a whole-head average, and filtering using a Butterworth filter at a low-pass of 30 Hz. Researchers held blind to condition and participant, conducted visual examination for artifact rejection. Exclusion criteria included epochs with an identifiable ocular or movement artifact. The averaged N170 latency from all trials for each participant was used for each analysis. We included participants that had greater than 16 artifact free trials. In the ASD population, N170 latency has been reliably measured in many recent published studies using at least 10 (and often no more than 20) artifact-free trials per participant [10, 11, 14, 58–60]. To limit ocular artifacts emerging due to lengthy epochs, epochs of 150 ms pre-stimulus to 700 ms post-stimulus were created and a 100 ms baseline correction was applied to each epoch. After confirming waveform morphology in the grand average and from each individual participant's data, ERPs were extracted from electrode sites corresponding to those indicated in previous literature [23, 29]. Specifically, N170 (latency; between 160 and 220 ms) was identified at the right PO4 electrode [10, 27, 61, 62], which was selected based on evidence suggesting greater right hemisphere cortical specialization for faces [63]. Peak N170 latencies across all ''good'' trials were averaged for each participant and subsequently used in the analyses below.

Data Analysis

Consistent with the aim of this study, Hypotheses 1, 2 and 3, directly test the theoretical claim in the Dawson, Webb and McPartland [9] article regarding the relationships between social motivation, early-stage face perception and FER. Each sub-hypothesis is testing the relationships between well-established contrast subtypes of FER stimuli (adult vs child, high vs low intensity emotions, and anger vs other emotions) and the putative processes (social motivation and early-stage face perception). Specifically in our first hypothesis, we hypothesized that social motivation would be positively correlated with FER performance. We hypothesized that low levels of social motivation would be correlated with poorer FER for adult faces, low intensity emotions and anger. In our second hypothesis, we hypothesized that early-stage face perception, or N170 latency, would be negatively correlated with performance on the FER task (i.e. shorter latency relating to better performance). We hypothesized that slower N170 latency would be correlated with poorer FER for adult faces, low intensity emotions and anger. Third, we hypothesized that social motivation and early-stage face perception would additively contribution to FER, especially for stimuli that exhibited a strong relationship with N170 latency. These particular stimuli were chosen based on the well-studied relationship between N170 latency and FER [10, 11, 14, 38, 40].

To test our first hypothesis, that social motivation would be positively correlated with FER performance, we conducted a Pearson's *r* correlation on DMQ-SPP scores and total DANVA-2 scores. To test our second hypothesis, that N170 latency would be negatively correlated with FER, we ran a Pearson's *r* correlation to determine if shorter N170 latencies correlated with better performance on the DANVA-2. Additionally, to test the hypothesis that N170 latencies would be negatively correlated with social motivation, we performed a Pearson's *r* correlation.

To test our third hypothesis, that N170 latency and social motivation exhibit an additive relationship in predicting FER, we ran a hierarchical multiple regression predicting FER to the DANVA-2 stimuli that exhibited the strongest effect in hypotheses 1 and 2. As the data are cross-sectional, and the temporal ordering of the potential relations of these variables has not been well-specified in the literature, we ran this model twice: once with N170 at step 1, and DMQ-SPP at step 2, and vice versa.

If evidence was found supporting the first three hypotheses, we ran an exploratory κ^2 mediation analysis [64] using the SPSS PROCESS procedure, specifically focusing on the stimuli for which the effect obtained in the regression model was most evident. Likewise, we conducted an exploratory moderation analysis examining the effect of the interaction between N170 and DMQ-SPP on DANVA-2, also using the PROCESS procedure.

The literature reveals differences in FER performance for adult vs child faces [10, 11, 14] and high vs low intensity emotions [65] in children with ASD. Additionally, among subtle faces there is more inconstancy as to which emotions are most difficult for individuals with ASD [41]. Therefore, in an effort to understand the contribution of N170 and social motivation to these discrete conditions of FER, we explored the DANVA-2 stimulus subtypes (e.g. high vs low intensity, adult vs child faces, and among these subtypes: child angry faces vs child happy faces) that showed the strongest relationships with N170 and social motivation.

This study is the first to directly test the theoretical claim proposed by Dawson, Webb and McPartland [9]. Thus, our analyses focused on the specific relationships between social motivation, early-stage face perception, and FER. Given that the Dawson, Webb and

McPartland [9] model is widely-referenced in this literature, we investigated face stimuli that have been found to contribute to the range of FER ability in individuals with ASD [14, 15, 41], among the specific relationships proposed in the model. Multiple comparison corrections were not used in these analyses in order to reduce Type II error and to support more specific future hypothesis generation [66]. That said, in order to balance Type I and Type II error, we constrained our exploratory analyses of the contribution of social motivation and early-stage face perception to FER such that we only examined the specific stimuli that were shown to strongly correlate with N170 latency, a well-studied indicator of early-stage face perception [10, 11, 14, 38, 40]. That is, we used a stepwise analytical approach to reduce the number of comparisons while increasing focus on stimuli that evinced the strongest empirical relations at each prior step.

Results

Descriptive Statistics

Table 1 presents demographics and descriptive statistics. Participants had average IQ. Scores on the DMQ-SPP varied widely, though they were normally distributed around the center of the available range (i.e. modest amount of social motivation). For DANVA-2 total faces, adult stimuli and child stimuli, participants with ASD made significantly more FER errors compared to age group norms (see Table 1). Notably, for all DANVA-2 scales, there was considerable variability in performance across participants. For total stimuli, the top quartile performed at least three standard deviations above the mean of the standardization sample, and the bottom quartile performed at least two standard deviations below standardization mean. For adult stimuli, the top quartile performed at least two standard deviations above the mean of the standardization sample, and the bottom quartile performed within one standard deviation below standardization mean. For child stimuli, the top quartile performed at least one standard deviation above the mean of the standardization sample, and the bottom quartile performed at least one standard deviation below standardization mean.

Hypothesis 1: Social Motivation and FER

DMQ-SPP and DANVA-2 scores were negatively correlated, such that greater social motivation indicated poorer FER (see Table 2). DMQ-SPP was most strongly correlated with DANVA-2 scores with low intensity emotions and child faces.[2] Among the child faces stimuli, low intensity was most strongly negatively correlated with DMQ-SPP, such that higher levels of social motivation were related to poorer performance for low intensity child faces (see Table 3).

Hypothesis 2a: N170 Latencies and FER

N170 latencies were not correlated with DANVA-2 overall (see Table 2). However, post hoc probing indicated that the correlation was marginally significant for DANVA-2 child faces (see Table 2). Among the child faces stimuli, angry faces showed the largest relation to

[2]Fischer's *r*-to-*z* transformations did not reveal a significant difference between these coefficients (all $p > .12$); however, to limit multiple comparisons, we probed only the conditions wherein the correlations were largest (even if not significantly different from the other condition).

N170 latencies relative to the other emotions, such that shorter N170 latencies were correlated with better performance for child angry faces (see Table 3).

Hypothesis 2b: N170 Latencies and Social Motivation

The N170 latency was not correlated with DMQ-SPP ($r = .223$, $p = .20$).

Hypothesis 3: Effect of Social Motivation and N170 Latency on FER

A hierarchical multiple regression predicting DANVA-2 child angry faces was conducted (see Table 4). N170 latency alone predicted DANVA-2 child angry faces, representing a small to medium effect. When the DMQ-SPP was added to the model, it produced a small incremental effect, and attenuated the effect between a faster N170 latency and better recognition of child angry faces.

Mediation of Relationships Between N170, DMQ-SPP, and FER

To better elucidate how—and under what conditions—basic perceptual and motivational processes may give rise to FER, we sought to explore cross-sectional mediating pathways and moderating relationships between N170 latency, social motivation, and FER. In order to examine conceptual pathways between N170, social motivation, and FER, we performed a κ^2 mediation analysis [64], examining effects on DANVA-2 child angry faces. DMQ-SPP was found to partially mediate the effect of N170 on child angry faces ($\kappa^2 = .04$ [.002–.181]). That is, poorer social motivation partially explained the relationship between faster N170 latencies and better DANVA-2 child angry faces performance. Since the data are cross-sectional, the direction of the exploratory mediation was not indicated a priori. However, when DMQ-SPP was placed at step 1 of the regression model predicting DANVA-2 child angry faces, it exhibited a nonsignificant relationship ($p > .05$). As such, the mediation of this relationship could not be probed, as there was no main effect to explore.

Moderation of Relationships Between N170, DMQ-SPP, and FER

We probed moderation effects to examine potential interactions between DMQ-SPP, N170 and DANVA-2 child angry faces. No moderation effects were found for DMQ-SPP nor N170 (all $p > .38$).

Influence of IQ, ASD Severity and Age

Finally, due to known relationships between, age, IQ, and ASD severity and the constructs under investigation here [6, 13, 67–69], we aimed to explore whether these factors influenced obtained results. IQ was positively correlated with DANVA-2 scores ($r = .36$, $p < .05$), DANVA-2 child faces ($r = .39$, $p < .05$), DANVA-2 child faces high intensity ($r = .35$, $p < .05$), and DANVA-2 child fearful faces ($r = .40$, $p < .05$). ADOS scores were negatively correlated with DANVA-2 child sad faces ($r = -.45$, all $p < .01$). Age was negatively correlated with DMQ-SPP ($r = -.44$, $p < .01$), and positively correlated with DANVA-2 low intensity faces ($r = .34$, $p < .05$), and DANVA-2 child sad faces ($r = .33$, $p < .05$). All of the significant relations of these covariates were then probed for their potential moderating role in the relationships among DMQ-SPP and DANVA-2 stimuli as well as N170 and

DANVA-2 stimuli. However, neither IQ, age, nor ADOS were found to moderate these relationships (all $p \geq .10$).

Exploration of Additional Aspects of Social Motivation and FER

Given that there is no ‘‘gold standard’’ measure of social motivation, it is plausible that the DMQ-SPP may only reflect one aspect of social motivation (i.e. social persistence). In the context of the broader study from which the present investigation was drawn [14], a widely-used parent-report measure of ASD symptoms (the Social Responsiveness Scale; SRS [70]) was employed. This measure includes a Social Motivation subscale (SRS-SMS), which is intended to measure a facet of social motivation that overlaps with lack of social anxiety and inhibition (e.g., not fidgety or tense in social situations; social confidence); this facet is conceptually distinct from social persistence. Indeed, the DMQ-SPP was moderately correlated with the SRS-SMS ($r = -.425$, $p = .011$), supporting the notion that they are related, yet non-redundant. However, the SRS-SMS was not correlated with DANVA-2 scores ($r = -.084$, $p < .630$).

Discussion

In this study, we tested the claims of a seminal model of FER in ASD [9], examining the associations between social motivation, early-stage face perception, and FER in adolescents with ASD. To our knowledge, this was the first study to examine the relation between social motivation and FER in youths with ASD. Results indicated that, contrary to hypotheses and prevailing theory [9, 12], greater social motivation was associated with poorer FER overall. Conversely, shorter N170 latencies indexing faster early-stage face perception were related to better FER, especially for child angry faces. This is also the first study to concurrently examine the contribution of social motivation and N170 to FER. Notably, social motivation attenuated the relationship between faster N170 latencies and more accurate FER of child angry faces, indicating that social motivation may partially account for the relationship between N170 and FER.

Relationship Between Social Motivation and FER

Intriguingly, greater social motivation was related to diminished performance for FER. While the social persistence aspect of social motivation (measured by the DMQ-SPP) was correlated with FER, another aspect (measured by the SRS-SMS), was not; thus, FER appeared to be specifically associated with the non-shared portion of the variance in DMQ-SPP. This suggests that, relative to other aspects of social motivation, social persistence may be uniquely associated with FER in ASD. Our results suggest that social motivation or persistence for social interaction lies on a continuum. Some youth with ASD show less social motivation than others. Notably, some youth with ASD show increased social motivation. More specifically, some individuals who display increased social persistence and diminished FER may exemplify Wing’s [71] description of children with ASD who are reported as ‘‘active but odd.’’ Although these children may be persistent and spontaneous in their social approaches, the social interaction may seem overzealous, socially insensitive to others’ cues, and therefore ‘‘odd’ [e.g. based on fixated or restricted interests; [72]. Successful social interactions are contingent on processing information from multiple sensory modalities as well as integrating details with global contextual information. ‘‘Weak central coherence’’ [73], or difficulties with such integration, in the context of perceiving social information, may yield individuals who are socially persistent, yet do not integrate facial emotions into the social scenario or may focus on conveying information to another individual rather than communicating in a socially reciprocal manner.

Stimulus Variation Contributing to FER and Social Motivation—Contrary to our hypothesis, greater social motivation was related to poorer FER for child faces. We suggest that this may occur because some children with ASD may have less experience with child (i.e. peer) faces. That is, adults may prompt children with ASD for eye contact during interactions while peers likely do not, thereby impoverishing the experience with emotive child faces. Such a dynamic may be magnified among the so-called ‘‘active but odd’’ subtype of ASD, for whom social approach is thought to be more frequent with adults [71, 72]. If indeed the high social motivation participants in our sample conform to this subtype, they may represent precisely the youth for whom social persistence is high, but experience (and FER) with child faces is low. Thus, relation of social motivation with social perception with this potential subtype would likely be a fruitful domain for further investigation.

The results show that some children that exhibit higher social persistence also show diminished FER, and this relation is strongest for low intensity emotions. Although FER for subtle emotions may be similarly difficult for youth with heightened social persistence, as for other individuals with ASD [15], our results suggest that some highly socially persistent children with ASD process information from faces differently from individuals with less social persistence, particularly for subtle emotions. These results extend prior findings that subtle emotions may require more effortful processing than high intensity emotions [15], and individuals with ASD have been found to show FER impairments primarily during more demanding conditions [3]. Future research should investigate processing load in the relationship between social persistence and FER for low intensity emotions in youth with ASD.

Alternatively, age may also contribute to better FER for specific face stimuli. Notably, the results showed that age was related to FER and social motivation, such that older youth were less socially motivated but better able to recognize low intensity faces and child sad emotions. It has been shown that emotion processing in adolescents is similar to adults but not quite mature yet [74]. While some previous studies [3, 75] did not find impairment in emotion recognition in adolescents, a number have noted impairment even in adults with ASD [76, 77]. Additionally, Kuusikko et al. [78] noted that older youth (12 and up) with ASD differed more from their typical peers in FER ability than younger youth with ASD. Thus, despite developmental differences, there is reason to believe these impairments exist in varying degrees through the lifespan for individuals with ASD.

Interestingly, parent report of social motivation suggests that instead of a general deficit of social motivation in ASD, a wide range of social motivation exists across youth with ASD. More precisely, equal numbers of children scored very low in social motivation (11 %; DMQ-SPP < 10) or very high in social motivation (9 %; DMQ-SPP > 20). Previous studies examining putative aspects of social motivation in adolescents with ASD [12] have found deficits in hedonic value in social interaction [21] and lower scores on a measure that evaluates enjoyment of interaction with others [79] compared to TD individuals. Yet, other studies have found adults with ASD report a desire to make friends [80, 81] and experience substantial loneliness [82]. Our results extend these previous findings and propose that social motivation or persistence for social interaction may lie on a continuum in individuals with ASD.

Moreover, individuals with low social motivation with ASD may share similar qualities to individuals with depression, some of whom exhibit superior FER. Previous studies have found that social anhedonia is related to both autism severity [12, 21] and depression [83]. Interestingly, certain cognitive processes (e.g. emotional inhibition) may facilitate better FER in individuals with depression relative to TD individuals [84]. Individuals with ASD with low social motivation may employ similar processes to attain greater attention to detail in facial expressions. Exploration of the role of cognitive processes associated with improved FER in low social motivation individuals with ASD may be valuable for future investigation.

Relationship Between N170 and FER

Contrary to previous reports [10, 11, 14], we did not find a significant relation between N170 latency and FER. However, we did find a marginal relationship between N170 and FER for child faces.[3] Among child faces, as hypothesized, anger was the only emotion that was significantly correlated with N170 latency. Since perception of facial information happens prior to behavioral recognition, the findings show that slower social information perception resulted in poorer recognition of child angry faces.

Previous research has found recognition of anger to be especially impacted in children with ASD [41]. Some studies suggest that when examining FER in individuals with ASD, anger may be a more appropriate emotion to study since it is primarily understood in the context of social rules [44, 85]. Likewise, Leung et al. [44] found that while processing angry faces, individuals with ASD may not be able to effectively synchronize activation of neural structures involved in social reward (orbitofrontal, limbic, and temporal). Other studies have indicated that FER for negative emotions may yield more difficulty for youths with ASD [15], therefore, it may be that anger is mistaken for other negative emotions. Our results support the literature suggesting that specific emotional expressions, like anger, may be unique in their degree of impairment in terms of FER in ASD.

Contribution of Social Motivation and Perceptual Processing to FER

Our results suggest that social motivation was a partial mediator of the relationship between N170 and FER. This indicates social motivation may be a pathway between N170 and FER. That is, the benefit of a faster N170, resulting in better recognition of child angry faces, is partially facilitated by lower social motivation.

[3]This study was drawn from the same sample as was used by Lerner et al. [12]. In that study, the correlation between N170 and DANVA-2 was most evident for adult faces, while the current study indicated this relation was most evident for child faces. Due to the focus only on the DANVA-2 faces modules a slightly different participant set than in the previous sample was used (i.e. those who met inclusion criteria for the DANVA-2 faces modules only). The overall pattern of relations between these samples was not substantially different. Please contact the Corresponding Author for further inquiries regarding differences between these subsamples.

We suggest that this unique relationship may be explained by the divergent development of social motivation relative to early-stage face perception and FER. In early childhood, social motivation may be more explicitly linked to face processing, such that interest in, and attention to, social information helps build perceptual efficiency and face specialization [9]. However, as children mature, the facial information processing system may continue to develop detached from social interest and motivation [9]. Specifically, some children with ASD may continue to become skilled at FER, aided by early-stage face perception [i.e., N170; 9, 86]. Yet, this may be due to the use of cognitive strategies or logical methods of processing to solve problems like FER, instead of emotional processing methods [87, 88]. That is, the use of compensatory, effortful cognitive strategies may facilitate FER accuracy. However, this method of processing is thought to be less efficient than more automatic emotion processing, and individuals who employ this may appear atypical in day-today social interactions [87]. Atypical social interactions may thus reinforce decreased social motivation and, as such, may strengthen the use of effortful cognitive processing, resulting in proficiency for FER.

Limitations

There are several limitations to this study that bear mention. First, in order to extend our findings, a larger sample would enable testing of additional FER pathways as well as greater heterogeneity within the ASD group. Our sample was also limited in age and IQ (i.e. cognitively-able adolescents with ASD). As the processes under investigation here almost certainly vary across development, future studies should extend the study of these intertwined variables to younger [40] and older [39] individuals with ASD, as well as those with lower measured IQ. Additionally, this study did not contain a TD control group. Inclusion of other comparison groups would allow us to better assess whether any obtained relations are unique to (or especially strong or weak among) ASD populations.

Second, the sample was limited in the number of female compared to male participants. Development of FER is known to occur differently in males and females [89]. Additionally, there are clear differences in processing of social information between males and females [90], including among those with ASD [91]. Thus, future investigations should recruit more females to better parse out sex differences in FER and differences in the development of processes proposed to underlie FER in ASD.

Third, FER was measured using the DANVA-2, which consists of photographs of emotions and employs the four most commonly-studied basic emotions (happy, sad, anger, fear). As such, follow up studies should consider evaluation of other basic emotions (surprise, disgust). The DANVA-2 uses static images of faces, for which FER may be more difficult (i.e. less naturalistic) compared to viewing dynamic faces [92]. However, assessment of FER when processing faces that may be more challenging may yield greater insight into how these processes work in youth with ASD. That is, evaluation of FER should test not only the bounds of the system but also optimal operation. Accordingly, future studies testing FER should consider utilizing dynamic faces to further explore relations found here.

Fourth, social motivation is a multifaceted and complex concept. Chevallier et al. [12] propose that social motivation is composed of several facets that support the biological and psychological predisposition to orient socially, experience reward from social interaction and maintain social ties. Our study measured social motivation only using the social persistence with peers subsection of the DMQ-SPP, a parent-report questionnaire measure. Thus, the attendant concerns associated with such measures (e.g., covert psychological constructs, reporter bias, context or observer-dependent ratings) are present here. While there is currently no gold standard measure of social motivation, future studies should consider a multimethod approach to addressing this complex construct across levels of analysis.

Fifth, the current study did not have an ERP measure of social motivation. ERP components such as the stimulus preceding negativity (SPN) and feedback related negativity (FRN), would allow measurement of reward anticipation and reward processing [93], which may additionally contribute to social motivation. Recording these ERPs while presenting FER stimuli would allow examination of the relationship between reward-based processing of social stimuli and the accuracy of a behavioral response.

Sixth, in the current study we used the averaged N170 latency across all trials for each participant for each analysis. This limited examination of differences in early-stage face processing per each condition, and instead provided a more trait-like indicator of this construct. Thus, future investigations of this model should employ more trials per condition to also examine individual differences in early-stage face processing across stimulus type (e.g. adult vs. child).

Seventh, as parents of children with ASD may exhibit some of the same social-cognitive differences as their children with ASD [94], this may have affected their answers concerning their child’s behavior on the DMQ-SPP. Future research should examine how parental social-cognitive abilities affect the rating of their child’s behaviors.

Finally, while we conducted a mediation analysis to test a plausible conceptual ordering of the effects under investigation here, it is nonetheless the case that true mediation can only be obtained via temporal ordering of measurement. Future studies aiming to probe this finding must measure these constructs in the order indicated by the mediation model.

Summary

The present study demonstrates the differential roles of social motivation and early-stage face perception to FER in adolescents with ASD. These findings show that social motivation may sometimes negatively relate to FER ability, as well as partially mediate the usually advantageous relationship between N170 latency and FER. Thus, social motivation and N170 may indeed underlie FER in adolescents with ASD [9], though they may do so in unique and complex ways that necessitate further exploration, and indicate caution in presuming such mechanistic processes to be uniformly advantageous in populations with social challenges. Finally, future research aimed at improving FER in ASD should consider approaches designed to assess and target such underlying mechanisms more directly [95].

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Table 1

Descriptive characteristics of participants with ASD (N = 35)

	ASD sample		Age-normed TD standardization sample[1]		
	Mean (SD)	**Range**	**Mean (SD)**	**# Items**	***t***
Age (years)	13.17 (2.12)	9.80–16.67			
Full scale IQ	111.00 (15.36)	74–138			
ADOS	11.14 (3.63)	7–20			
DMQ	15.69 (4.54)	7–26		30	
N170 latency	186.62 (20.59)	159.97–219.96			
DANVA-2 total faces	38.83 (4.02)	30.00–45.00	40 (.97)	48	5.85***
Q1, Q3	36, 42				
DANVA-2 adult faces	18.54 (2.16)	14.00–22.00	19.1 (.70)	24	4.20***
Q1, Q3	17.5, 20				
DANVA-2 child faces	20.29 (2.35)	15.00–24.00	20.78 (.27)	24	6.07***
Q1, Q3	19, 22				
DANVA-2 high intensity	21.63 (1.88)	17.00–24.00		24	
DANVA-2 low intensity	17.20 (2.63)	12.00–22.00		24	

ASD autism spectrum disorder, *TD* typically-developing. Wechsler Intelligence Scale for Children-IV (Full Scale IQ), *ADOS* autism diagnostic observation schedule, *DMQ* dimensions of mastery questionnaire, diagnostic analysis of nonverbal accuracy-2 (*DANVA-2*; # correct); *Q1* quartile 1, *Q3* quartile 3. Independent sample one-tailed *t* tests.

[1] Nowicki (2004)

*** $p < .001$

Table 2

Correlations among DMQ, N170 latencies and DANVA-2 stimulus type (N = 35)

	Total faces	High intensity	Low intensity	Adult faces	Child faces
DMQ	−.404 *	−.224	−.457 **	−.333 +	−.386 *
N170 latency	−.228	−.163	−.231	−.093	−.304 +

DMQ dimensions of mastery questionnaire, *DANVA-2* diagnostic analysis of nonverbal accuracy-2. All DANVA-2 variables are # correct. Pearson *r* correlations, all are 1-tailed

+ $p < .10$;

* $p < .05$;

** $p < .01$

Table 3

Correlations among DMQ, N170 latencies and DAVNA-2 child face stimulus type (N = 35)

	Child faces high intensity	Child faces low intensity	Child faces happy	Child faces sad	Child faces angry	Child faces fearful
DMQ	−.083	−.484**	−.218	−.155	−.277	−.268
N170 latency	−.242	−.276	−.031	−.070	−.336*	−.131

DMQ dimensions of mastery questionnaire, *DANVA-2* diagnostic analysis of nonverbal accuracy-2. All DANVA-2 variables are # correct. Pearson *r* correlations, all are 1-tailed.

+ $p < .10$;

* $p < .05$;

** $p < .01$

Table 4

Hierarchical multiple regression predicting DANVA-2 child angry faces (N = 35)

Variable	Model 1 *B*	Model 2	
		B	**95 % CI**
Constant	−2.72	−3.18	[−7.63 to 1.26]
N170 latency	.03*	.02+	[−.00 to .05]
DMQ		.07	[−.02 to .17]
R^2	.113	.156	
F	4.211	4.256	
ΔR^2		.043	
ΔF		.045	

DMQ dimensions of mastery questionnaire, *DANVA-2* diagnostic analysis of nonverbal accuracy-2. All DANVA-2 variables are # correct

+ $p < .10$;

* $p < .05$