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Late Positive Potential ERP Responses to Social and Nonsocial Stimuli in Youth with Autism Spectrum Disorder

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Abstract We examined the late positive potential (LPP) event related potential in response to social and nonsocial stimuli from youths 9 to 19 years old with ($n = 35$) and without ($n = 34$) ASD. Social stimuli were faces with positive expressions and nonsocial stimuli were related to common restricted interests in ASD (e.g., electronics, vehicles, etc.). The ASD group demonstrated relatively smaller LPP amplitude to social stimuli and relatively larger LPP amplitude to nonsocial stimuli. There were no group differences in subjective ratings of images, and there were no significant correlations between LPP amplitude and ASD symptom severity within the ASD group. LPP results suggest blunted motivational responses to social stimuli and heightened motivational responses to nonsocial stimuli in youth with ASD.

Keywords Autism spectrum disorder · Social · Restricted interests · Late positive potential · Motivation

Introduction

Social communicative impairments are a defining feature of autism spectrum disorder (ASD; APA 2013). These deficits are evident in the domains of social cognition (e.g., theory of mind), social perception, and social attention (Levy et al. 2009). Recently, there has been increased interest in examining the impact of motivational factors on social functioning in ASD. The "social motivation" hypothesis of autism posits that disrupted social motivational mechanisms may constitute a primary deficit in ASD with potential downstream effects on the development of social impairments (Chevallier et al. 2012; Dawson et al. 2005; Kohls et al. 2012). Decreased social motivation is clearly not the only mechanistic account of the full range of social deficits associated with ASD (e.g., some individuals with ASD have social interests and actively seek social interactions but fail to form friendships due to impaired social cognition and pragmatic language). However, even

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during the first year of life, infants who go on to develop ASD demonstrate infrequent orienting to their own name and diminished eye contact (Ozonoff et al. 2010), suggesting that decreased social interest early in life may interfere with the development of social cognition in at least a significant proportion of those with ASD.

Differences in Attention to Social and Non-social Stimuli in ASD

One corollary of the social motivation hypothesis of autism is that individuals with ASD find nonsocial information, rather than social information, to be highly salient (Klin et al. 2002, 2003). This "nonsocial bias" may lead to increased preference for, and in turn interaction with, the nonsocial environment to the detriment of social development, potentially contributing to the emergence of restricted interests. Restricted interests (RIs) are a component of restricted and repetitive behavior symptoms in ASD (APA 2013) and refer to the tendency for nearly all individuals with ASD to develop unusually strong interests, attachments, and preoccupations for idiosyncratic topics or objects (Lam et al. 2008). These interests are more intense and less flexible than interests in typically developing children and often interfere with the development of social relationships (Klin et al. 2007; Turner-Brown et al. 2011).

Additionally, whereas the social motivation theory of ASD suggests that neural systems supporting motivation and attention may be hyporesponsive to social stimuli in ASD (Delmonte et al. 2012; Scott-Van Zeeland et al. 2010; Yirmiya et al. 1989), these same neural systems may be hyperresponsive to certain classes of nonsocial stimuli in ASD (Cascio et al. 2014). This mechanistic account of RIs in ASD explains why individuals with ASD may exhibit positive affect in response to specific nonsocial aspects of the environment (Attwood 2003; Sasson et al. 2012) and may even engage in increased joint attention (Vismara and Lyons 2007) and eye contact (Nadig et al. 2010) when such RIs are incorporated into social interactions. These clinical features suggest that social motivation deficits and RIs in ASD may both be causally linked to abnormal reward-based responses to social and nonsocial information.

ERP Indices of Attention in ASD

Motivational responses to RIs in ASD have been studied using self-report (Sasson et al. 2012), functional neuroimaging (Dichter et al. 2012), and physiological methods (Dichter et al. 2010; Louwerse et al. 2014). However, to date, there have been no published event related potential (ERP) studies of RIs in ASD. This lack of research stands

in contrast to the growing ERP literature addressing responses to social stimuli in ASD, which have mostly focused on the P300 response, reflecting stimulus evaluation, novelty detection, and categorization, and the N170 response that is associated with facial recognition responses (Dawson et al. 2005; Devitt et al. 2015; Luckhardt et al. 2014). These studies have generally found longer N170 latencies to faces (but not objects) in ASD (Cygan et al. 2014; Dalton et al. 2008; McPartland et al. 2011), a lack of N170 modulation by directed attention to faces in ASD (Gunji et al. 2009), diminished N170 amplitude in the right hemisphere to faces and lack of P300 amplitude differences between self and other faces in ASD (Gunji et al. 2009), and greater P100 and N170 amplitude to faces versus houses and lack of differentiation of responses to upright versus inverted faces (Webb et al. 2012). More recent work has found attenuated P3 response during the anticipation of social, but not non-social, rewards in typically developing young adults with high levels of autistic traits (Cox et al. 2015).

One ERP component that has not been evaluated in ASD but that has particular relevance to the social motivation hypothesis of ASD is the late positive potential (LPP) ERP component in response to faces and objects. The LPP is a centro-parietal ERP positive component that initiates around 300 ms after stimulus onset and lasts for several hundred milliseconds (Cuthbert et al. 2000). The LPP response is greater in response to a range of positive and negative affective stimuli relative to neutral stimuli (Fischler and Bradley 2006; Herbert et al. 2008; Schacht and Sommer 2009) and has been suggested to reflect a variety of mechanisms, including sustained attention (Cuthbert et al. 2000; Weinberg et al. 2013), motivational responses (Keil et al. 2002; Schupp et al. 2007), and attentional resources (Citron 2012). The LPP is responsive to both emotionally positive and negative stimuli and thus is considered to reflect the enhanced motivation and arousal that is experienced in response to affective stimuli rather than their emotional valence (i.e., elicited by positive and negative emotions) *per se* (Cuthbert et al. 2000). However, in contexts where only one valence category is presented, the LPP has been interpreted to reflect, at least in part, stimulus valence as well (Bayer and Schacht 2014; Herbert et al. 2006).

Current Study

In the present study, social stimuli (images of faces) and nonsocial stimuli (images of objects related to RIs in ASD) were presented to children and adolescents with ASD to evaluate LPP amplitudes to these two classes of stimuli. Social stimuli were smiling faces. The nonsocial image set

was designed to reflect common RIs in ASD, and a previous report has shown that individuals with ASD rated this image set to be more pleasing than did individuals without ASD (Sasson et al. 2012). The LPP response was examined as an index of positive motivational responses and salience to these two classes of stimuli. Given previous findings of decreased orienting to social stimuli (Dawson et al. 1998; Klin et al. 2009) and increased orienting to the same set of nonsocial stimuli used in the present study (Sasson and Touchstone 2014), we hypothesized that the ASD group would be characterized by decreased LPP amplitude to social stimuli and increased LPP amplitude to nonsocial stimuli. We further hypothesized that LPP amplitude in the ASD group would predict the magnitude of core ASD symptoms.

Method

Participants

A total of 39 participants with ASD (5 female) and 35 control (5 female) participants were recruited for this study. Data were not analyzable from four participants with ASD and one control participant because discomfort with skin abrasion yielded unacceptably high impedances (>30 kΩ). The final ASD sample consisted of 35 children and adolescents with ASD and 34 controls 9–19 years old who participated in the following: (a) a diagnostic and symptom evaluation; (b) an electroencephalogram (EEG) recording session; and (c) a ratings session during which they provided subjective ratings of valence and arousal of the experimental images.

Participants consented to a protocol approved by the local human investigations committee at UNC-Chapel Hill. All ASD participants had clinical diagnoses of ASD that were confirmed through the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al. 2000) administered by trained research staff supervised by a licensed clinical psychologist and using standard cutoffs. Because both Module 3 and Module 4 were used (Module 3: 16 participants, Module 4: 19 participants), calibrated severity scores were calculated from raw ADOS-G scores to obtain a dimensional measure of ASD symptom severity across both modules (Gotham et al. 2009; Hus and Lord 2014). Both groups also completed the Social Responsiveness Scale (Constantino and Gruber 2002), which is a dimensional measure of overall ASD symptom severity. They also completed the Repetitive Behavior Scale-Revised (Bodfish et al. 1999), which is a dimensional measure of repetitive behavior severity in ASD. Control participants scored below the recommended cutoff of 15 on the Social Communication Questionnaire (Mulligan et al. 2009).

Diagnostic groups did not differ in terms of age or intelligence quotient scores (derived from the Kaufman Brief Intelligence Test; (KBIT; Kaufman 1990)), all ps > .05 (see Table 1). Fourteen children in the ASD group were on psychotropic medication, including psychostimulants (Vyvanse, Adderall, Focalin), atypical anti-depressants (Bupropion), antihypertensives/central alpha-2 adrenergic agonists (Tenex, Clonidine, Intuniv), benzodiazepines (Klonopin), selective serotonin reuptake inhibitors (Prozac, Zoloft), mood stabilizers (Depakote), and atypical anti-psychotics (Risperdal, Abilify).

Stimulus Materials

All visual stimuli were presented in color and had a resolution of 1024×768. Each participant viewed one of two possible sets of images, the presentation of which was counter-balanced across participants. Each participant viewed ten social stimuli and ten nonsocial stimuli. Participants were instructed to view each image as they

Table 1 Participant characteristics

Variable	ASD ($n = 35$)	Control ($n = 34$)
Age	13.4 (3.2)	13.3 (2.9)
ADOS total score	15.4 (3.5)	.
ADOS calibrated severity score[a]	8.17 (1.4)	.
SRS		
Total score*	73.8 (7.9)	57.7 (3.7)
Awareness	8.9 (2.6)	10.4 (2.3)
Cognition*	17.0 (4.3)	11.2 (2.3)
Communication*	27.0 (6.4)	17.1 (3.0)
Mannerisms*	17.3 (5.6)	1.7 (1.6)
Social motivation*	13.6 (3.6)	9.4 (2.7)
RBS-R		
Total score*	24.1 (12.5)	0.5 (1.3)
Stereotyped behavior*	3.4 (2.2)	0.1 (0.3)
Self-Injurious behavior*	1.4 (1.5)	0.0 (0.1)
Compulsive behavior*	3.45 (3.7)	0.2 (0.7)
Ritualistic behavior*	5.17 (4.0)	0.0 (0.3)
Sameness behavior*	7.0 (5.9)	0.2 (0.5)
Restricted behavior*	2.7 (1.1)	0.1 (0.2)
Full scale IQ	104.6 (17.5)	113.7 (14.1)
Verbal IQ	103.1 (17.4)	111.3 (14.0)
Performance IQ	104.5 (16.9)	111.9 (12.9)

* $p < .001$. ASD = autism spectrum disorder. [a] Standardized severity scores on a scale of 1–10 calculated from raw Autism Diagnostic Observation Schedule (ADOS) scores (Gotham et al. 2009; Hus and Lord 2014). SRS Social Responsiveness Scale (Constantino and Gruber 2002), RBS-R Repetitive Behavior Scale-Revised (Bodfish et al. 1999), IQ Intelligence Quotient derived from the Kaufman Brief Intelligence Test (KBIT)

normally would and to try to look at the image the entire time it was on the screen.

Social Stimuli

Social stimuli consisted of Happy-Direct Gaze Closed Mouth Female NimStim images (Tottenham et al. 2009), a standardized set of faces. Half of the images depicted White faces. The identifiers of the NimStim images used were: 01, 02, 03, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19 from the "F_HA_C" set.

Nonsocial Stimuli

A set of nonsocial stimuli were used that have been developed to be related to common RIs in ASD. Although the RIs of individuals with ASD are, by definition, idiosyncratic, a standardized image set of images related to common RIs in ASD (e.g., trains and electronics) was used to allow all participants to view the same images (images are presented in the Appendix of Dichter et al. 2012). These images were derived from categories of common RIs in ASD (South et al. 2005). They have been shown to differentially activate brain reward circuitry in ASD (Dichter et al. 2012), elicit great visual attention in children and adults with ASD (Sasson et al. 2011; Sasson and Touchstone 2014), have been rated as more pleasant by individuals with ASD (Sasson et al. 2012), and have been shown to elicit greater valuation by individuals with ASD (Watson et al. 2015).

Procedure

Participants saw 20 images twice each (once for EEG recording and once to provide subjective ratings). Picture presentation was controlled by the E-Prime v1.1 software package (Psychology Software Tools Inc., Pittsburgh, PA). During EEG recording, participants viewed each image for 6 s with an inter-trial interval (ITI) of 10 s, with a fixation cross presented between stimuli. These durations were chosen to be consistent with our previous work on affective startle modulation in autism (Dichter et al. 2010). The mood states induced by neutral images are very brief (Dichter et al. 2002). Thus, there is likely no effect of the inclusion of other images on affective responses given the 10 s ITI. Presentation was pseudo-random such that the same picture category was never repeated more than twice in a row and pictures of each category were equally distributed throughout the session. Pictures were displayed on a 21 inch color monitor approximately 1.0 m in front of the participant, resulting in a visual angle of the monitor of 30°, though images did not fill the entire screen. There were two sets of stimuli that contained non-overlapping images, and image set was counterbalanced across participants. Participants were monitored via infrared camera throughout the recording sessions, and the experimenter ensured that all participants attended to the pictures during the entire ERP recording session.

After EEG was recorded, the EEG cap was removed, the pictures were presented a second time, and participants rated each picture with respect to pleasure and arousal using 9-point scales. During the rating procedures, participants controlled the duration of picture exposure, though viewing time data were not recorded. The range and direction of the ratings for Valence were −4 (extremely unpleasant) to +4 (extremely pleasant) and for Arousal were 0 (not at all aroused) to +8 (extremely aroused).

Electroencephalography Data Recording and Data Reduction

Data were acquired with a Neuroscan (Compumedics, Charlotte, USA) SynAmps^2 64-channel system and were sampled at 2000 Hz with alternating current (AC), with a gain of 2010 and an impedance threshold for recording of 10 kΩ. An online bandpass filter from 0.05 to 500 Hz was used, and data were recorded from 9 channels (F3, Fz, F4, C3, Cz, C4, P3, Pz, P4) using the standard 10–20 international system (Jasper 1958; American Electroencephalographic Society 1994) with a Neuroscan 64 channel Ag–AgCl Electro-Cap. Only nine sites (in addition to mastoid, VEO, and HEO sites) were used to decrease the time required to apply the electrode cap in this initial study, which used a low impedance system that required preparation at each electrode site. Data were referenced to linked mastoids and epoched between 250 ms pre-stimulus to 1550 post stimulus; 50 ms of data on each end of the epoch were included to buffer against filtering artifacts in subsequent processing. Epoched data were analyzed offline after applying a 0.01 Hz high-pass and a 64 Hz low-pass filter at 24 dB/octave. Artifacts from eye movements were corrected using the ARTCOR procedure in SCAN v4.5 based on a 10 % threshold at VEO (see Heritage and Benning 2013). The data were baseline corrected from 200 ms pre-stimulus and analyzed. LPP amplitude was defined as the mean voltage from 800 ms to 1500 ms post-stimulus onset relative to baseline.

Data Analysis

Data from all 20 images viewed by each participant were included in analyses. The omnibus analyses of interest were 2 × 2 repeated measures ANOVAs with Group (ASD, control) as the between-participants factor and stimulus Category (Social, Nonsocial) as the within-

participants factor. This analysis was performed on LPP amplitude, valence ratings, and arousal ratings with effect sizes are reported as partial eta squared (η_p^2). Significant interaction tests were followed by independent samples t tests comparing groups on responses to social and nonsocial stimuli with effect sizes reported as Hedges' g. Finally, relations between LPP amplitude and symptom severity in the ASD sample were evaluated by correlations conducted separately for LPP amplitude in response to social and nonsocial stimuli with SRS and RBS-R total scores.

Results

Gender, Age, and Picture Set Effects on LPP Amplitude

There were no significant main effects or interactions involving gender, age, or picture set on LPP amplitude. Thus, age, gender, and picture set were excluded from all analyses reported below.

Valence and Arousal Ratings

Mean valence and arousal ratings are presented in Fig. 1. Ratings data from four ASD participants indicated inadequate comprehension of the ratings procedure (the same rating was endorsed for every image or valence and arousal ratings were perfectly correlated) so they were excluded from the analysis of ratings data. Regarding valence ratings, there was no main effect of Category, $F(1,63) = 1.04$, $p = .312$, $\eta_p^2 = .02$, no main effect of Group, $F(1,63) = 1.42$, $p = .238$, $\eta_p^2 = .02$, and no interaction effect, $F(1,63) = 0.42$, $p = .519$, $\eta_p^2 = .01$. Likewise, with respect to arousal ratings, there was no main effect of Category, $F(1,63) = 0.40$, $p = .529$, $\eta_p^2 = .01$, no main effect of Group, $F(1,63) = 2.07$, $p = .155$, $\eta_p^2 = .03$, and no interaction effect, $F(1,63) = 0.07$, $p = .792$, $\eta_p^2 = .00$.

LPP Amplitude

LPP amplitudes at all nine electrode sites that were recorded are presented in Fig. 2. Because the LPP is a midline response (Cuthbert et al. 2000), a priori analyses focused on the Fz, Cz, and Pz electrodes. Furthermore, because there was a significant Category x Electrode interaction in a preliminary ANOVA, $F(2, 66) = 6.74$, $p = .002$, $\eta_p^2 = .17$, we analyzed data separately for each electrode. At Cz, there was a Group $\times$ Category interaction, $F(1,67) = 4.00$, $p = .049$, $\eta_p^2 = .06$, which reflected

that Group status moderated LPP amplitude to Social and Nonsocial images. Follow-up between-groups t tests (see Fig. 3) revealed that compared to controls, the ASD group had relatively smaller LPP amplitudes to social images, $t(67) = -3.23$, $p = .002$, $g = -0.32$, and relatively larger LPP amplitudes to nonsocial images, $t(67) = 1.99$, $p = .050$, $g = 0.21$. This interaction substantially qualified the main effect of Category, $F(1,67) = 22.7$, $p < .001$, $\eta_p^2 = .25$, in which social stimuli elicited larger LPP amplitudes than non-social stimuli. There was no main effect of Group, $F(1,67) = 0.01$, $p = .921$. There were no main effects or interactions at Fz or Pz, ps $> .15$.

Relations Between LPP Amplitude and ASD Symptoms

There were no significant correlations between LPP amplitudes at Cz to social or nonsocial stimuli and picture ratings or SRS or RBS-R total or subscale scores either across both groups combined or within both groups (uncorrected rs $< .21$, ps $> .20$). Similarly, there were no significant correlations between LPP amplitudes at Cz to social or nonsocial stimuli and ADOS severity scores within the ASD group (uncorrected ps $> .60$).

Discussion

This study investigated LPP responses in children and adolescents with ASD in response to social and nonsocial stimuli. Social stimuli were pictures of smiling faces and nonsocial stimuli were a set of images previous developed around common RIs in ASD. The LPP ERP response occurs in response to a range of positive and negative affective stimuli (Fischler and Bradley 2006; Herbert et al. 2008; Schacht and Sommer 2009) and has been suggested to reflect enhanced motivation and arousal that is experienced in response to affective stimuli (Cuthbert et al. 2000; Keil et al. 2002; Schupp et al. 2007). Additionally, in contexts where only one valence category is presented (e.g., only pleasant stimuli), the LPP has been interpreted to reflect stimulus valence as well as motivation (Bayer and Schacht 2014; Herbert et al. 2006); thus, in the present context, we interpret the LPP response to reflect motivation responses to social and nonsocial stimuli.

Dissociation of Electrophysiological and Self-report Reactivity to Social and Nonsocial Stimuli

Group status moderated LPP amplitudes at Cz to social and nonsocial stimuli such that the ASD sample demonstrated relatively smaller responses to social stimuli and relatively larger responses to nonsocial stimuli compared to the

Fig. 1 Valence (*left*) and arousal (*right*) ratings of ASD and control groups. *Error bars* represent standard errors of the mean. The range and direction of valence ratings are −4 (extremely unpleasant) to +4 (extremely pleasant). The range and direction of arousal ratings are 0 (not at all aroused) to +8 (extremely aroused)
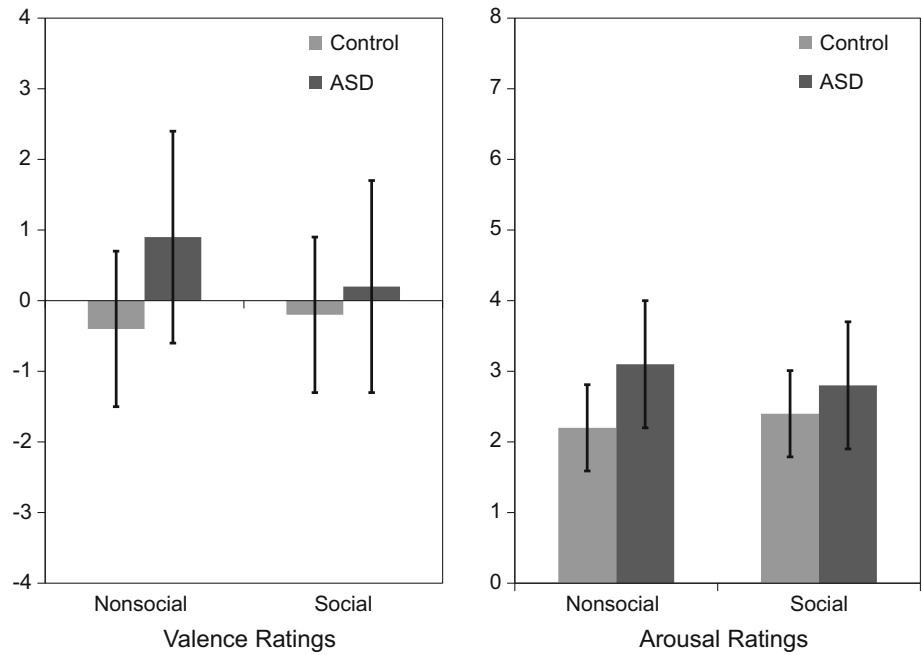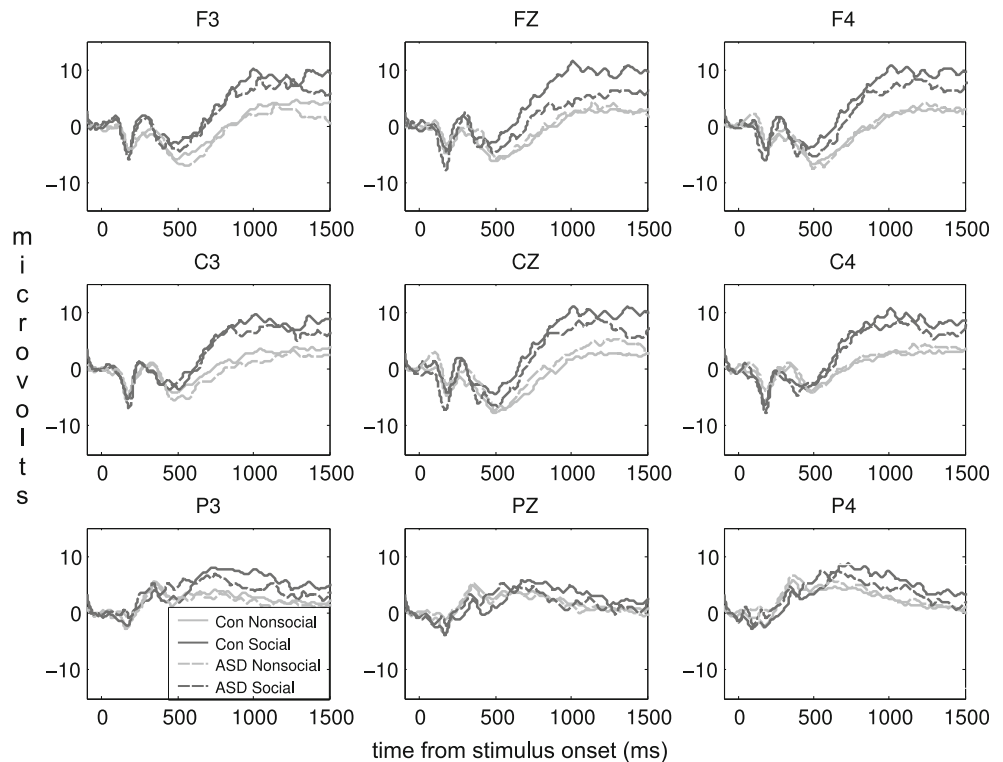
Fig. 2 Grand average waveforms for ASD and control ("Con") groups while viewing social and nonsocial images at the nine electrode locations recorded (F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4)

control group. Because the LPP is an index of motivation and arousal, these findings indicate relatively blunted motivational responses to images of faces in ASD and relatively enhanced motivational responses to nonsocial stimuli related to RI in ASD compared to the control group. More broadly, these findings are consistent with the social motivation hypothesis of autism that posits decreased motivation for social stimuli in ASD. Moreover, these findings extend this account, suggesting that brain systems processing motivational responses may be co-opted in ASD to be hyper-responsive to certain nonsocial stimuli related to RIs in ASD.
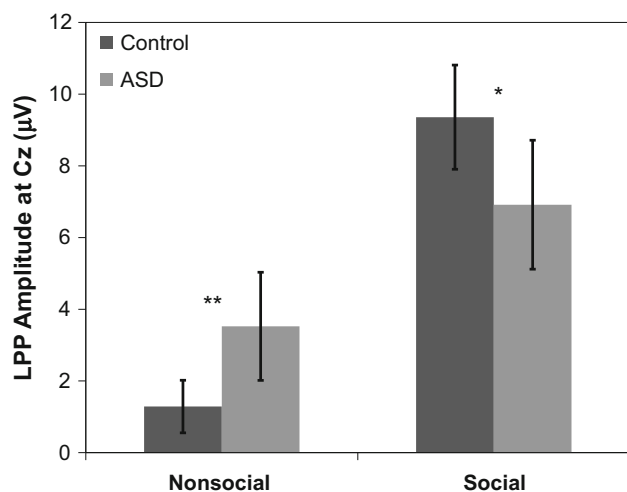
Fig. 3 Average LPP amplitude for ASD and control groups in response to social and nonsocial images. *Error bars* represent standard errors of the mean. $*p < .05$; $**p < .01$

However, the ASD and control groups did not differ in subjective ratings of valence or arousal to the images. This stands in contrast to the findings of Sasson et al. (2012) that reported higher valence ratings of these same nonsocial stimuli by a larger sample of adults self-identifying as having an ASD. In this regard, we note that the present sample included only children and adolescents, and also that the significantly larger sample size in Sasson et al. (2012) (i.e., 213 controls, 56 with ASD) provided more power to find statistically significant effects. Despite these sample differences, the fact that LPP responses showed differential modulation by these nonsocial images in ASD and control groups illustrates that this brain potential response may be a potentially more sensitive indicator of motivational responses to images related to RIs in ASD than subjective self-report. A similar pattern of disconnect between subjective and brain responses was reported in Dichter et al. (2012), a functional magnetic resonance imaging (fMRI) study of responses to this same images set.

Limitations and Future Directions

We opted to use a standard set of nonsocial images related to RIs rather than images of each child's specific RI. RIs are, by definition, idiosyncratic and person-specific, and idiosyncratic RIs have been used in prior ASD studies (Cascio et al. 2014); nonetheless, the use of a standardized set of images allowed for increased internal validity because stimuli viewed by different participants did not differ in semantic content or visual features (e.g., luminance, contrast, etc.) and did not contain any depictions of faces. Importantly, because significant group differences were found in LPP responses using a standard set of

images, these findings may be more pronounced using idiosyncratic and child-specific images. Future research that directly compares responses to child-specific RIs versus a standard set of nonsocial stimuli related to RIs will be needed to evaluate this possibility. Additionally, the use of child-specific RIs may have the potential to reveal subtle brain potential responses that may not be detectable using a standard set of images. We also note that presenting pictures for 6 s each is longer than some other ERP studies (e.g., Eisenbarth et al. 2013), potentially resulting in more artifacts than if images were presented for briefer amounts of time. Finally, we acknowledge that this study had a relatively broad age range and that over half of participants in the ASD group were taking medications, and future studies aimed at replicating and extending this work should focus on a narrower age range of participants who are medication-free.

Despite this potential limitation, the present finding adds to the literature documenting differential motivational responses in ASD to social sources of information (Chevallier et al. 2012; Dichter and Adolphs 2012) by examining an ERP component of motivational responses. Additionally, results are consistent with prior findings that certain types of nonsocial stimuli may be highly salient for individuals with ASD (Klin et al. 2002, 2003). This "nonsocial bias" may be mechanistically related to the development of RIs in ASD and may interfere with social development (Cascio et al. 2014; Klin et al. 2007; Turner-Brown et al. 2011). It may be the case that intensive behavioral interventions for children with ASD should expand their focus from increasing the salience and reward value of social interactions to also targeting the effects of RIs in ASD on social communicative skills (Boyd et al. 2007). To the extent that brain systems processing motivational responses may be co-opted in ASD to be responsive to certain nonsocial stimuli rather than to social stimuli, optimal treatment outcomes may not be achievable until ASD interventions focus on reducing the motivational relevance of RIs.

Consistent with this idea, many early intervention programs for children with or at-risk for ASD teach parents to "follow the child's lead" as a strategy for encouraging the child's development in a variety of domains, including social-communication skills. "Following the child's lead" involves observing the child's behavior, recognizing the child's interests, and joining in the child's activities, rather than redirecting the child. Thus, if a child is demonstrating an RI, the therapist would attempt to engage the child in a social-communication interaction using that RI. Subsequent portions of the intervention may then include increasing the child's interest in their play-partner than the RI (Mahoney and MacDonald 2007). This type of intervention has demonstrated positive parent and child

outcomes, including in the context of Responsive Teaching (Karaaslan et al. 2013; Mahoney and MacDonald 2007; Mahoney and Perales 2005), Adapted Responsive Teaching (Baranek et al. 2015); Focused Playtime Intervention (Kasari 2014; Siller et al. 2013, 2014), and Hanen's More Than Words program (Carter et al. 2011; Venker et al. 2012). The results of the current study support the potential utility of behavioral ASD interventions to leverage nonsocial interests to improve social-communication functioning in children with ASD by gradually expanding the child's interests to include new objects, actions, and people.

Author Contributions SDB implemented the psychophysiological data collection protocols with RVA's assistance and programmed the study while refining its design; he also supervised data reduction and analyses, contributed to the introduction and discussion, and finalized the method and results. GSD and NJS selected stimuli for this study and designed its parameters; GSD also supervised MK's and AC's analyses of the data and drafted the manuscript. SM monitored the collection and integrity of the psychophysiological data under GSD's supervision, while CRD and LT-B monitored participants' clinical characterization. EKH, ASD, and JK provided additional scholarly input throughout the manuscript. All authors reviewed the manuscript and provided scholarly feedback on its contents.

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