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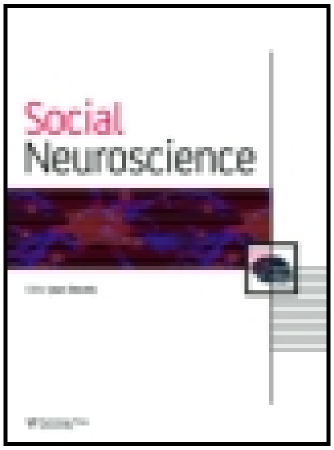

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Interpersonal distance and social anxiety in autistic spectrum disorders: A behavioral and ERP study

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An inherent feature of social interactions is the use of social space or interpersonal distance—the space between one individual and another. Because social deficits are core symptoms of Autistic Spectrum Disorder (ASD), we hypothesized that individuals on this spectrum will exhibit abnormal interpersonal distance preferences. The literature on interpersonal distance in ASD is not conclusive. While some studies show preferences for closer distances among this group, others show preferences for farther distances than controls. A common symptom of ASD that may explain the variance in responses to interpersonal distance in this population is social anxiety (SA), which has been shown to correlate with interpersonal distance preferences. In the current study, we investigated interpersonal distance preferences in a group of individuals with ASD using both behavioral and ERP measures. We found greater variance in interpersonal distance preferences in the ASD group than in the control group. Furthermore, we showed that this variance can be explained by differences in SA level and can be predicted by the N1 amplitude, an early ERP component related to attention and discrimination processes. These results hint at the early sensory and attentional processes that may be affecting higher social behaviors, both in subclinical and in clinical populations.

Keywords: Autism; Interpersonal distance; Personal space; N1 ERP.

An inherent feature of social interactions is the use of social space or interpersonal distance—the space between one individual and another. Both animals and humans use interpersonal distance as a social signal of threat in some situations and of friendship, attraction, or intimacy in others (Hall, 1966; Kaitz, Bar-Haim, Lehrer, & Grossman, 2004; Lloyd, 2009). In fact, interpersonal distance is so basic in our daily lives that we usually do not explicitly notice it until someone stands or sits closer or farther away than we expected. Awareness of interpersonal distance sometimes occurs when traveling or interacting with people from a different culture (Watson, 1970; Watson & Graves, 1966), but it may also occasionally occur within one's own culture, due to personality differences or misinterpretation of a social situation (Carrington & Graham, 2001; Perry, Rubinsten, Peled, & Shamay-Tsoory, 2013).

One clinical population that is especially prone to misunderstanding social situations comprises individuals with ASD, a neurodevelopmental disorder characterized primarily by deficits in communication and impaired social interaction (DSM-V; American Psychiatric Association, 2013). Since communication and social deficits are core symptoms of ASD, we hypothesized that this population would show differences in interpersonal distance preferences. Yet, the literature on interpersonal distance in ASD is controversial. While some studies report that participants with ASD prefer to be farther away from others than did controls (Freitag, 1970), or show high variability in this measure (Miron, 2008), most report that individuals with ASD tend to come closer to others than the norm (e.g., Pedersen, Livoir-Petersen, & Schelde, 1989; Pedersen & Schelde, 1997). Ingram, Mayes,

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Troxell, and Calhoun (2007) used the Playground Observation Checklist to evaluate children who may have special education needs. They compared elementary school children with ASD and no mental retardation, to school children with mental retardation and no diagnosed ASD, and to typical developing children. One of the items that differentiated between children with and without ASD was respecting boundaries and personal space. While personal space was respected by only 50% of the children with ASD, it was respected by 100% of the typical developing children and by 96% of the children with mental retardation. Still, it should be noted, that 50% of the ASD group did respect personal space. Similarly, Parsons, Mitchell, and Leonard (2004) examined participants with ASD and IQ matched controls in a virtual reality café setting. While the use of the environments by the two groups was similar, some participants in the ASD group were significantly more likely to be judged as bumping into, or walking between, other people in the virtual scene. This tendency could not be explained by executive dysfunction or a general motor difficulty. Lastly, there are personal reports of individuals with ASD or their family members that refer to deficits in assessing personal space (Carrington & Graham, 2001; Sperry & Mesibov, 2005).

What may account for the inconsistent findings regarding preferred interpersonal distance among individuals with ASD? One possible explanation for the aberrant social response in ASD may be related to social anxiety (SA), a core characteristic of ASD. Autistic traits are known to be associated with levels of SA (e.g., Bellini, 2004, 2006; Cath, Ran, Smit, Van Balkom, & Comijs, 2008; Gillott, Furniss, & Walter, 2001; Kuusikko et al., 2008; Simonoff et al., 2008). A recent assessment of a large student population (n = 1325) revealed a positive correlation between the Autism-Spectrum Quotient and the Liebowitz Social Anxiety Scale. Students with high levels of autistic traits were more likely to report increased social anxiety than those with average or low levels of autistic traits. In addition, levels of SA were best predicted by autistic traits that are associated with social skills, attention switching, and communication, accounting for 33% of the variance in social anxiety scores (Freeth, Bullock, & Milne, 2013). Furthermore, other studies have found elevated rates of SA among parents and siblings of children with ASD (with SA onset prior to the birth of the child), suggesting that SA and ASD may have shared genetic underpinnings (Kuusikko-Gauffin et al., 2013; Smalley, McCracken, & Tanguay, 1995).

Interestingly, individuals with high levels of SA show abnormal preferences regarding interpersonal distance. In a recent study (Perry et al., 2013) we showed a positive correlation between levels of SA and preferred interpersonal distance. Using a computer-based task we found that individuals with higher SA traits preferred to stay farther away from a stranger avatar compared to those with low SA traits. Furthermore, individuals with high SA levels exhibited attenuated early ERP responses (P1 and N1). In fact, SA level correlated with the N1 component, so that the more socially anxious an individual was, the smaller his or her N1 amplitude in an interpersonal distance paradigm. These early ERP components are affected by early attention and discrimination factors (Luck, Woodman, & Vogel, 2000; Vogel & Luck, 2000) and the smaller amplitudes seen for higher SA individuals suggest fewer attentional resources allocated to social stimuli. These results imply that individuals with high SA levels may feel discomfort earlier than others in social engagement due to early attentional mechanisms, leading them to stand farther away and thus creating a cycle of less communicative social interactions. Nevertheless, it is not clear whether individuals with ASD will show similar interpersonal preference patterns, and whether their preferences will be related to their level of SA.

Only a few studies have examined visual N1 abnormalities in individuals with ASD, and the large diversity of this population makes it difficult to reach clear conclusions. Courchesne, Lincoln, Kilman, and Galambos (1985) published a study in which they used an oddball paradigm and showed, among other ERP abnormalities, a lower N1 amplitude in the ASD group (Courchesne et al., 1985). Yet, other studies failed to find differences between ASD and controls for the N1 component (Kemner, Verbaten, Cuperus, Camfferman, & Van Engeland, 1994) or for other early visual ERP components (for a review, see Jeste & Nelson, 2009). Studies examining the processing of social information have mostly focused on the N170 face-specific effect, in which faces normally elicit larger N170s than objects. These studies reported a smaller, slower, or more left lateralized effect in individuals with ASD (Dawson et al., 2005; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004; O'Connor, Hamm, & Kirk, 2005; but see Wong, Fung, Chua, & McAlonan, 2008).

In the current research, we investigated interpersonal distance preferences in a group of individuals with ASD, using both behavioral and ERP measures. To measure interpersonal distance preferences in the most ecological way, we used the stop-distance paradigm, a realistic behavioral measure of interpersonal distance in which participants choose their preferred distance from a stranger in a live interaction in the laboratory. Following this behavioral study, the same participants participated in an ERP study, in which preferred interpersonal distance was assessed using a modified version of the Comfortable Interpersonal Distance paradigm (CID; Duke & Kiebach, 1974; Duke & Nowicki, 1972). In this paradigm, participants are instructed to imagine themselves in the center of a room visualized on a computer screen and to respond to a virtual person approaching them by indicating where they would like the person to stop (see the Materials and Methods section). Considering the literature described above, it was not clear whether the ASD group would prefer farther or closer distances, or in fact show a greater variability in this measure. We hypothesized that the variance in this measure could be explained by differences in SA level, and could be predicted by visual N1 amplitude in an interpersonal distance task.

MATERIALS AND METHODS

Participants

A total of 13 typical participants (all male; mean age = 24, SEM = 0.46) and 13 participants with ASD (12 male, 1 female; mean age = 25, SEM = 1.24) participated in this study for payment. All participants in the ASD group had a confirmed diagnosis of ASD. One was diagnosed by the Autism Diagnostic Interview-Revised (Lord, Rutter, & Le Couteur, 1994) and two by the Autism Diagnostic Observation Schedule (Lord et al., 2000) as part of previous studies. The remainder provided written confirmation of an independent clinical diagnosis. As their diagnoses were made before the release of DSM V, five were diagnosed with Asperger's Syndrome, three with High Functioning Autism, and the rest with PDD NOS. Three participants with ASD were on anti-depressant medication. None of the control participants had a diagnosis of ASD or any other clinical diagnosis nor were they on any kind of medication. All participants had completed 12 years of compulsory education in Israel. One control participant was left-handed, while all the other participants were right-handed. Experiments 1 and 2 were both approved by the Ethical Review Committee of the University of Haifa and by the Ethical Review Committee of Beit Ekstein, a rehabilitation center for people with autism. All participants provided written informed consent in accordance with the Declaration of Helsinki.

Experiment 1: behavioral experiment

Task and design

In this behavioral experiment, we used a modified version of a highly controlled paradigm to assess preferred interpersonal distances: the stop-distance paradigm (Greenberg, Strube, & Myers, 1980). This procedure is one of the most frequently used paradigms for assessing preferred or tolerated interpersonal distance under varied conditions, with high reliability measures (for reviews, see Aiello, 1987; Hayduk, 1983). The validity of this measure is supported by its association with measures of control, comfort, need for privacy, and other personality attributes that can predict differences in interpersonal distance preferences (e.g., Bar-Haim, Aviezer, Berson, & Sagi, 2002; Greenberg et al., 1980; Kaitz et al., 2004).

Data acquisition and analysis

Two experimenters from a pool of six highly trained undergraduates ran each testing session. One was in charge of greeting the participant, instructing him/her on protocol, and later running the ERP experiment. The other experimenter (always male) only ran the stop-distance trials from which the estimates of interpersonal distance were derived. None of the stop-distance experimenters was acquainted with any of the participants, nor did they have any information about which group the participants belonged to (ASD or control).

Testing began with the participant positioned at one end of the room with his/her toes against a drawn line and the experimenter standing facing the participant from a distance of 2.5 meters. From this position, the experimenter (with eyes open, gazing down, and a neutral facial expression) approached the participant slowly until he/she, as previously instructed, reported feeling "slightly uncomfortable." The experimenter noted the distance in centimeters (Experimenter D1) on a tape measure that lined the approach route between his toes and the participant's toes and committed it to memory. The experimenter then resumed his approach until the participant voiced "considerable discomfort" (Experimenter D2). This distance was noted and, immediately afterwards, both stop-distances were recorded. This procedure was then repeated, but this time the participant was instructed to approach the experimenter and again stop and report once when feeling "slightly uncomfortable" and again when feeling "considerable discomfort" (Participant D1 and D2). The order of who approached first, the experimenter or the participant, was counterbalanced among participants.

In all, four measures were derived from the stop-distance procedure: Experimenter D1 and Participant D1 reflect tolerance of interpersonal proximity or threshold distance for discomfort. This point has been suggested to be the point that marks the border between interpersonal space and personal space (e.g., Bar-Haim et al., 2002). Experimenter D2 reflects individual tolerance to invasion of interpersonal space, while Participant D2 reflects how comfortable an individual feels in invading the personal space of another (while also compromising one's own space).

Experiment 2: ERP

Stimuli task and design

The task in Experiment 2 was identical to that described in a previous paper (Perry et al., 2013) and is a modified version of the Comfortable Interpersonal Distance task (CID; Duke & Nowicki, 1972). In brief, the participant was shown the name of a protagonist (Stranger/Friend) who would enter the room for 1000 ms, a fixation point for 500 ms, and then a still picture (1000 ms) of a circular room with a stick figure at the center and an approaching stick figure depicting the protagonist at one of eight entrances. This was followed by a 3000 ms animation in which the protagonist approached the center of the circle. Participants were instructed to imagine themselves at the center of the room and to respond to the virtual protagonist approaching them along a particular radius by pressing the spacebar indicating where they would want the person to stop. The animation stopped after three seconds when the character and the protagonist collided, or beforehand if the participant pressed the spacebar (Figure 1). In measuring ERPs, the 1000 ms still picture depicting the room with the protagonist ready to approach was the crucial event for ERP analysis. Although not as realistic as the stop-distance paradigm described above, the CID has been validated numerous times and has been shown to be correlated with other interpersonal distance measures (Duke & Nowicki, 1972). In addition, we recently validated this task in our laboratory (unpublished), and found a significant correlation between the four measures of the stop-distance paradigm and the CID measure of a stranger approaching (with Participant D1: r = .595; with Participant D2: r = .521; with Experimenter D1: r = .622; with Experimenter D2: r = .613; all p < .05). In order for there to be enough data for ERP analysis, each of the approaching protagonists appeared 56 times (seven repetitions of the eight radii, collapsed for analysis), yielding a total of 112 trials. There were two breaks during the experiment, enabling participants to rest. The experiment

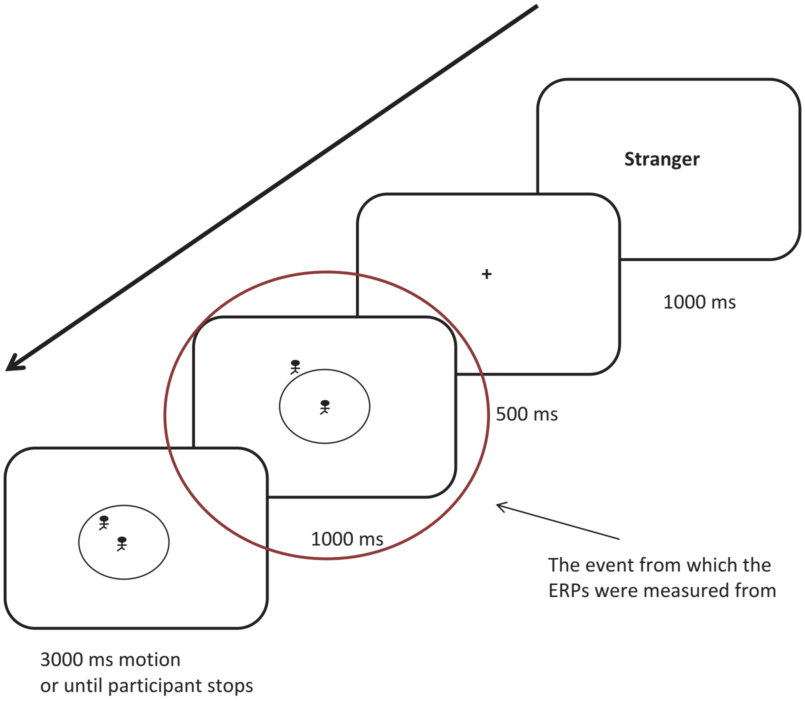

Figure 1. The ERP design (see text). Note that the crucial ERP event was the 1000-ms still picture preceding the figure's motion.

was shown on a CRT monitor 60 cm away from the participant's eyes, with the circle's diameter creating a visual angle of 8.58°. E-Prime (Psychological Software Tools) was used for stimulus presentation.

Data acquisition and analysis

EEG recording. The EEG analog signals were recorded continuously (from DC with a low-pass filter set at 100 Hz) from 32 Ag–AgCl pin-type active electrodes mounted on an elastic cap (Biosemi^{TM}, http://www.biosemi.com/headcap.htm), according to the extended 10–20 system, and from two additional electrodes placed at the right and left mastoids. A 32-electrode cap (rather than 64) was used for all participants in order to make the experiment preparation phase easier for the ASD group. All electrodes were referenced during recording to a common-mode signal (CMS) electrode between POz and PO3 and were subsequently re-referenced digitally (see data processing below). Eye movements as well as blinks were monitored using bipolar horizontal and vertical EOG derivations via two pairs of electrodes, with one pair attached to the external canthi and the other to the infraorbital and supraorbital regions of the right eye. Both EEG and EOG were digitally amplified and sampled at 512 Hz, using a Biosemi Active II system (www.biosemi.com).

Data processing. Data were analyzed using Brain Vision Analyzer software (Brain Products) and Matlab routines. Raw EEG data were initially 0.5 Hz high-pass filtered (24 dB) and re-referenced off-line to the digital average of the 32 electrodes. EEG deflections resulting from eye movements and blinks were corrected using an ICA procedure (Jung et al., 2000). Remaining artifacts exceeding ±100 µV in amplitude were rejected. Between 0–14 trials were rejected for each participant in each condition, with no difference between groups, conditions, or their interaction.

ERP Analysis. ERPs were determined by averaging the 1-s segmented trials separately in each condition (Stranger, Friend). The averaged waveforms were smoothed by applying a low-pass filter of 20 Hz and were baseline corrected according to the 200 ms before stimulus onset. As our previous study focused on the PO7 and PO8 sites not present in the 32 cap, we focused our current analysis on the closest sites, P7 and P8, which are also commonly used for P1 and N1 analyses (e.g., Doesburg, Roggeveen, Kitajo, & Ward, 2008; Wijers, Lange, Mulder, & Mulder, 1997). For each subject, the P1 peak was determined as the most positive peak between 50 and 150 ms, and the N1 peak as the most negative peak between 150 and 250 ms. Subsequent visual scrutiny ensured that these values represented real peaks rather than end points of the epoch.

The Liebowitz Social Anxiety Scale (LSAS)

Following the experiment, participants completed a computerized version of the LSAS (Liebowitz, 1987), one of the most commonly used and validated clinician-administered scales for the assessment of social anxiety (Fresco et al., 2001; Heimberg et al., 1999; Mennin et al., 2002). Two of the ASD participants were too tired to complete the questionnaire at the end of the experiment, and completed it a few days later. In this questionnaire, participants are asked to rate their levels of fear and avoidance of 24 situations on a scale from 0 to 3. The 24 items are divided into two subscales that address social interaction (11 items) and performance (13 items). Thus, the LSAS provides six subscale scores: total fear, fear of social interaction, fear of performance, total avoidance, avoidance of social interaction, and avoidance of performance. An overall total score is often calculated, and this index is the one most commonly used in SA studies (Heimberg et al., 1999).

RESULTS

Experiment 1: behavioral

The four measures derived from this experiment—Participant D1, Participant D2, Experimenter D1, Experimenter D2—were compared between the ASD and the control groups for differences in mean distances using *t*-tests for Equality of Means, and differences in variance using Levene's test for Equality of Variances. The two groups did not differ in the mean preferred distance (in meters) on any of the measures (Participant D1: ASD mean = 0.67, SD = 0.52, CL mean = 0.81, SD = 0.31; Participant D2: ASD mean = 0.40, SD = 0.35, CL mean = 0.40, SD = 0.17; Experimenter D1: ASD mean = 0.70, SD = 0.57, CL mean = 0.87, SD = 0.30; Experimenter D2: ASD mean = 0.37, SD = 0.29, CL mean = 0.43, SD = 0.17). However, the two groups significantly differed in their variance on three of the four measures (Participant D1: $F = 5.50$ $p < .05$; Participant D2: $F = 10.77$, $p < .005$; Experimenter D2: $F = 4.66$, $p < .05$), and the variance approached a

TABLE 1

Distances chosen (in meters) for each participant in the control and ASD groups

Controls					*ASD*				
Subject	*Participant D1*	*Participant D2*	*Experimenter D1*	*Experimenter D2*	*Subject*	*Participant D1*	*Participant D2*	*Experimenter D1*	*Experimenter D2*
1	0.52	0.34	0.54	0.38	1	1.2	0.9	0.54	0
2	0.5	0.25	0.89	0.35	2	0.48	0.3	0.68	0.44
3	0.72	0.38	0.63	0.41	3	0.94	0.66	1.14	0.68
4	0.88	0.64	0.75	0.39	4	0.84	0.34	1.04	0.36
5	0.73	0.33	0.75	0.36	5	1.05	0.22	0.56	0.46
6	0.6	0	1.56	0.8	6	0.92	0.52	0.74	0.4
7	0.78	0.42	0.6	0.24	7	0	0	0	0
8	1.18	0.58	0.92	0.42	8	0.86	0.62	1.98	0.72
9	0.6	0.39	0.5	0.22	9	1.56	0.94	1.2	0.7
10	1.6	0.56	1.18	0.52	10	0.93	0.72	0.99	0.72
11	1.04	0.54	1.13	0.64	11	0	0	0.3	0.3
12	0.93	0.52	1.05	0.61	12	0	0	0	0
13	0.5	0.3	0.83	0.3	13	0	0	0	0

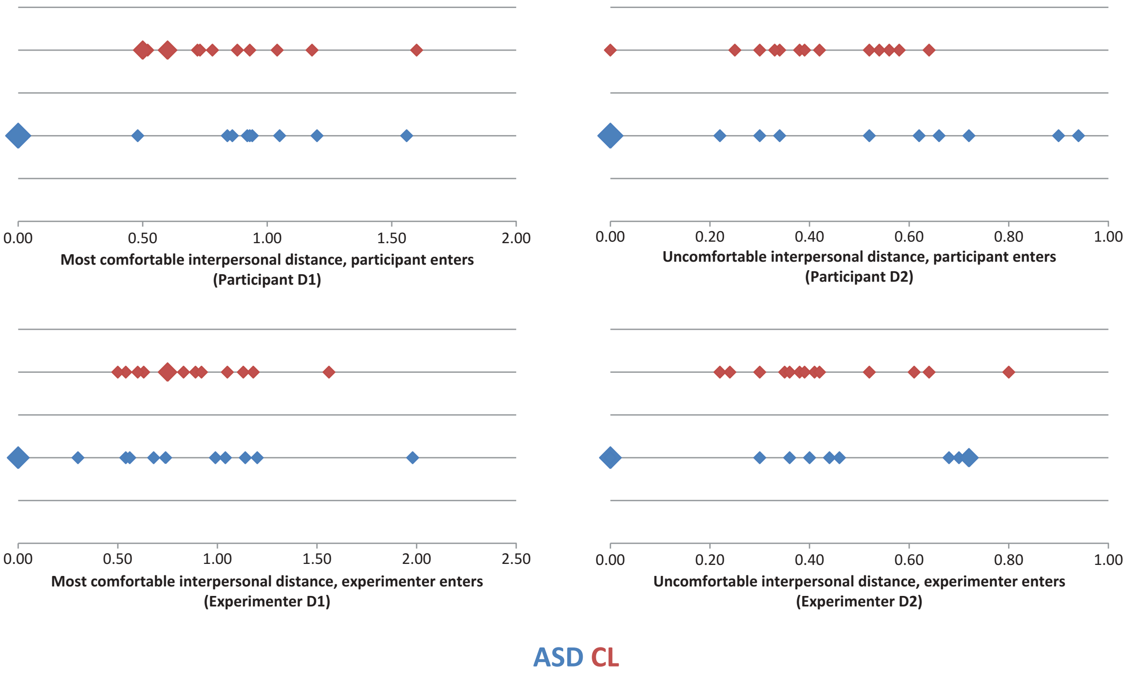

Figure 2. Behavioral results showing greater variance in the ASD group for all four distances.

significant difference in the fourth (Experimenter D1: $F = 3.71$, $p = .06$; Table 1 and Figure 2).

LSAS

There was no significant difference in the LSAS between the two groups [ASD mean = 51.38 (SD = 27.12), CL mean = 42.92 (SD = 19.09); $t(24) = .92$, $p > .3$], and no significant differences between their variances (Levene's test, $F = 1.92$, $p > .2$).

Correlations between SA and interpersonal distance

In order to examine our prediction that levels of SA are correlated with interpersonal distance measures and may explain the variance among individuals with ASD, we computed an average of the four interpersonal distance measures from Experiment 1 and analyzed the correlation between this average measure and the LSAS, for the whole pool of participants ($n = 26$) and separately for each group. This analysis revealed a significant correlation for the whole group (Pearson $r = .45$, $p < .05$). When analyzed separately, the two measures were highly correlated in the ASD group (Pearson $r = .591$, $p < .05$, Figure 4a) but not in the CL group ($p > .5$).

Experiment 2: ERP

The distribution of the P1 and N1 components was posterior temporal (see Figure 3a). The statistical analysis of each peak was based on a mixed ANOVA design (between subjects: ASD and CL groups; within subjects: hemisphere, condition) for the amplitude and latency of each peak.

P1

There was no between-group effect for P1 (ASD = 2.96, CL = 2.66; $F < 1$). Importantly, there was also no variance difference between groups (both SE = 0.48). There was a significant effect for hemisphere, indicating that P1 was greater in the right hemisphere (Left = 2.32, Right = 3.30, $F(1, 24) = 6.25$, $p < .05$)), with no other significant main effects or interactions. There were no significant differences in latencies between groups, conditions, hemispheres, or their interactions.

N1

There was no between-group effect for N1 (ASD = −1.63, CL = −1.7; $F < 1$), once again showing no variance difference between groups (both SE = 0.58). There was an effect approaching significance for Condition, indicating that the N1 was greater for Stranger than for Friend (Stranger = −1.81, Friend = −1.52; $F(1, 24) = 3.95$, $p = .058$; see Figure 3b), with no other significant main effects or interactions. There were no significant differences in latencies between groups, conditions, hemispheres, or their interactions.

Correlations between the N1 amplitude and behavior

Lastly, correlations between the average N1 amplitude in P8 and the behavioral measures of Experiment 1 were examined. The N1 in the right hemisphere was chosen as it was previously shown to correlate with SA level in an interpersonal distance task (Perry et al., 2013). In the current study, the participants' actual interpersonal distance preferences were measured, enabling us to test a stronger claim: that the N1 was correlated with interpersonal distance behavior. There was no significant correlation between the N1 and behavior for the whole pool of participants (n = 26,

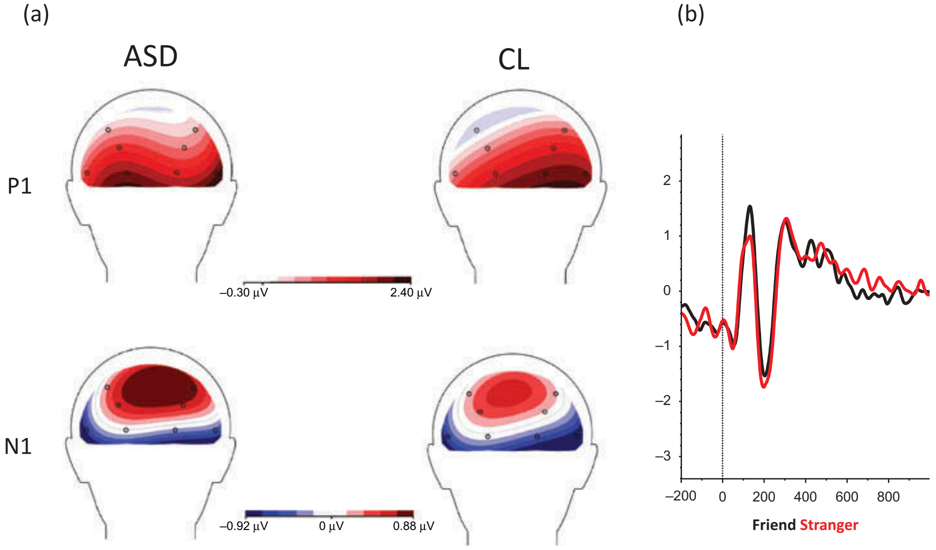

Figure 3. (a) Scalp distributions of the P1 and N1, for the ASD and CL groups; (b) the N1 condition effect in electrode P8: Conditions in which a stranger who entered the room elicited a more negative N1 compared to friend conditions ($p = .058$).

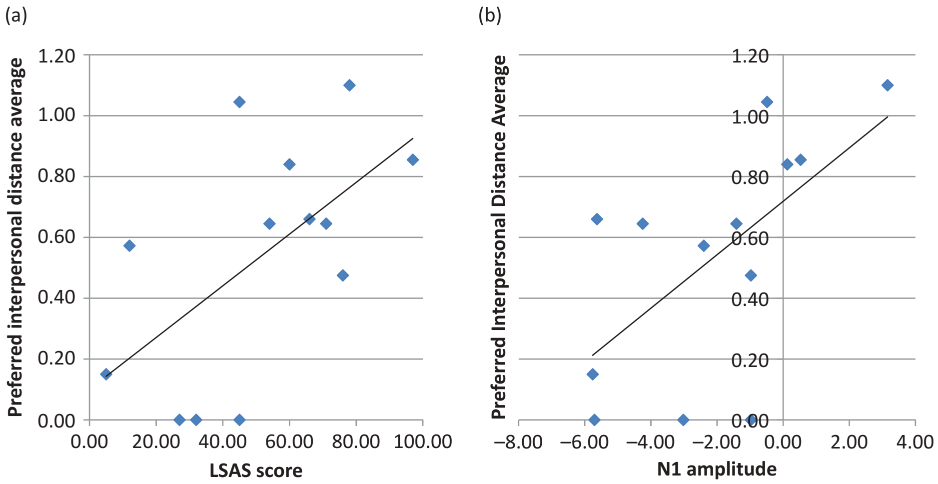

Figure 4. The correlation between the average preferred distances and (a) the LSAS score (r = .591, p < .05); (b) the N1 ERP amplitude (r = .620, p < .05) for the ASD group.

p = .12). However, there was a significant and strong correlation in the ASD group (Pearson r = .620, p < .05, Figure 4b), with no correlation in the CL group (p > .5).

DISCUSSION

The aim of the present study was to investigate interpersonal distance preferences among individuals with ASD using behavioral and ERP measures. Individuals in the ASD group did not differ from the control group on mean preferred distances; however, their preferred distances on three of the four measures showed greater variance than the control group (with the fourth approaching significance). Some of the ASD group participants preferred greater distances than controls, stopping more than 1 meter away from the experimenter. On the other hand, 4 of the 13 ASD group participants actually walked right into the experimenter when asked to stop when they felt uncomfortable. Even after debriefing and making sure they understood the task, the participants insisted they do not feel uncomfortable at close distances. It should be noted that one of these participants was the female participant. More research should be done in an attempt to compare the two sexes on interpersonal distances preferences. These findings are in line with others who found diverse reactions among individuals with ASD on interpersonal distance tasks (e.g., Miron, 2008). Subtle individual differences in interpersonal distance may lead to a vicious cycle in which an individual's distance from another may be interpreted as a less communicative, social, or comfortable interaction, and may in turn strengthen that individual's discomfort in social situations. Closeness promotes intimacy and allows better eye contact and closer attention to subtle interpersonal cues. People standing far away from one another are unlikely to disclose personal information (Hall, 1966; Kaitz et al., 2004). At the other extreme, people standing too close may be perceived as threatening, causing the other to withdraw, both physically and socially (i.e., share less information, avoid eye contact).

It may be the case that as part of their social deficits, individuals with ASD do not know how to assess the expected distance in an interpersonal situation. But why do we see greater variance in the ASD population, and what can help differentiate between those who prefer closer and those who prefer farther distances? One answer we wish to propose here is that differences in SA level can predict preferred interpersonal distance among individuals with ASD. In an earlier study we showed that SA level is correlated with interpersonal distance, such that people with higher levels of SA prefer farther distances than those who have low SA traits (Perry et al., 2013) (see also Scheele et al., 2012) . In the present study, we show that the same correlation exists in a clinical population of individuals with ASD: the greater their SA, the farther away they prefer to stand. This does not explain, however, the closer proximity chosen by some of the participants with ASD. It is possible that apart from SA levels, one needs an understanding of the other's need for personal space. Individuals with ASD who lack this understanding, and do not suffer from SA, choose very close distances from the other. It is important to note that we did not ask about what the participants thought was comfortable for the other, so we could not assess this aspect of social understanding.

On the neural level, as in the behavioral study, we found no significant (mean) differences between groups on the P1 and N1 components. Across both groups, we found significant differences between Stranger and Friend, thus validating the participants' discrimination between the two (visually identical) stimuli, with no differences between the groups. In the current study the N1 component not only correlated with SA (as reported in Perry et al., 2013), but actually with real behavior, outside the EEG, specifically for individuals with ASD. It should be noted that this was true for the female participant with ASD as well, and her ERP measures did not differ from that of her group. This correlation was not found in the CL group, perhaps because of the low variance in the control group's behavioral measures (Perry et al., 2013; see also Scheele et al., 2012).

The visual N1 component has been linked to attention and discrimination processes, with a larger N1 corresponding to attended stimuli compared to unattended stimuli (see also Kleinhans et al., 2010 for a study showing SA as explaining variance in ASD). The visual N1 has also been shown to be modulated by the valence of the stimuli, with a larger N1 seen for more positive or negative stimuli compared to neutral ones (Vogel & Luck, 2000). A smaller N1, in the context of SA and interpersonal distance, may therefore be related to avoidance mechanisms, i.e., to not devoting enough attention to the social situation. In the normal population, this may lead to subtle differences in interpersonal distance. However, in the population of individuals with ASD, who may have trouble understanding the implicit norms of interpersonal distance in the first place, preferred interpersonal distance may be determined mostly by these early attentional mechanisms.

An additional explanation for the greater variance in preferred interpersonal distance in the ASD population may be related to levels of sensory sensitivity. Individuals with ASD are often diagnosed with Sensory Modulation Disorder (SMD), demonstrating either hypersensitivity or hyposensitivity on some or all senses. Sensory sensitivity has also been shown to correlate with social functioning in ASD (hence the differences for Stranger and Friend in the current study; see also Foti, Hajcak, & Dien, 2009). It is easy to imagine why an individual would prefer to be farther away from others if that individual is more sensitive to touch, voice, or smell, as well as why an individual who is less sensitive to these senses would stand closer. However, from a post hoc sample of 11 of the 13 participants with ASD, who were willing to answer a validated SMD questionnaire a few weeks following the initial experiments (Hilton, Graver, & LaVesser, 2007), SMD did not seem to explain the preferred distances. For example, from the three participants who continued walking straight to the experimenter on all four behavioral measures, one showed hypersensitivity, one hyposensitivity, and one was within the normal range. Nevertheless, as these results were obtained only from a portion of the ASD group and not at all from the control group, this hypothesis should be further examined in future studies. Note that the two explanations are not necessarily mutually exclusive: hypersensory sensitivity is assumed to be a heritable vulnerability factor for shyness and may cause greater social avoidance and SA in general (The Sensory Responsiveness Questionnaire, SRQ; Bar-Shalita, Seltzer, Vatine, Yochman, & Parush, 2009). Indeed, a genetic, biochemical, and/or anatomic difference might explain the differences in interpersonal distance preferences, and could be a common factor relating also to sensory sensitivity and social anxiety. Testing this hypothesis requires a much larger sample, and would be interesting to test in both clinical and healthy populations.

Several limitations of this study should be acknowledged. The first is the relatively small number of participants in each group. The second is the fact that our sample was restricted to individuals with high-functioning ASD, making it unclear as to whether these results would also generalize to the broader spectrum of autism, i.e., individuals with low functioning abilities. Given the heterogeneous nature of ASD, further research is needed to address this issue. Third, we did not find a significant correlation between the N1 component and behavioral preferences in the laboratory for our control group. A larger and more heterogeneous group of participants is needed in order to investigate whether such a correlation also exists in nonclinical populations. Lastly, it should be acknowledged that although the measuring tape was not mentioned, and the recording of the distances was done after the task, participants might have noticed it and this may have altered their typical distance behavior.

To conclude, this study examined interpersonal distance preferences in an ASD group, using both behavioral and ERP measures. On four behavioral measures, interpersonal distance preferences showed greater variance in the ASD group compared to controls, with participants with ASD preferring closer, farther, or similar distances compared to controls. Differences in interpersonal distance preferences in the ASD group were correlated with SA measures, such that individuals who preferred farther distances in the behavioral study had higher SA traits, replicating previous results. Moreover, the participants' behavioral preferences also correlated with the N1 ERP component, measured independently in a different experiment. A smaller N1, in the context of interpersonal distance, may be related to avoidance mechanisms, i.e., to paying less attention to the social situation. These results hint at the early sensory and attentional processes that may be affecting higher social behaviors, in both subclinical and clinical populations. Apart from the scientific significance of understanding differences in interpersonal distance, these ERP differences may also serve as diagnostic tools for evaluating SA severity in ASD and treatment efficiency in both clinical and subclinical populations.

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