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Don't stand so close to me: A behavioral and ERP study of preferred interpersonal distance

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ABSTRACT

The space between people, or *interpersonal distance*, creates and defines the dynamics of social interactions. Given that invasion of one's interpersonal space may trigger threat and anxiety, a critical question is if high vulnerability to social anxiety (SA) is associated with avoidance and attentional biases when anticipating invasion to one's interpersonal space. Therefore, the current study sought to examine the behavioral mechanisms, time course and neural correlates underlying the threat of interpersonal distance invasion with a focus on different SA levels, using both a behavioral and an ERP experiment. Preferred interpersonal distance was assessed using a paradigm that involves responding to different virtual protagonists (friend or stranger) approaching the participant by indicating where one would like the protagonist to stop. In addition, participants' level of social anxiety was measured. The behavioral experiment indicated that levels of SA predicted one's preferred interpersonal distance such that higher SA individuals preferred further distance from a stranger. At the neural level, across groups, early (N1) but not late (LPP) differences were found between stranger and friend conditions. Importantly, SA individuals were characterized by attenuated early ERP responses, suggesting less attentional resources allocated to social stimuli. The results suggest that high SA individuals feel discomfort earlier than others in social engagement, which may lead them to stand further away, thus creating less communicative social interactions.

Introduction

The space between people, or *interpersonal distance*, creates and defines the dynamics of social interactions (Lloyd, 2009), and is a salient cue signaling responsiveness and a feeling of being comfortable (Birtchnell, 1996; Feeney, 1999; Meisels and Guardo, 1969; Roberts, 1997). The space around the body has been defined as the 'area individuals maintain around themselves into which others cannot intrude without arousing discomfort or even withdrawal' (Hayduk, 1978, 1983; Sommer, 1969). Once intruded, the person may experience threat, emphasizing the important influence that emotional and motivational factors can have on the use of space between people (Horowitz et al., 1964; Lloyd, 2009). The use of social space by both animals and humans is an inherent feature of social interactions and can be empirically mapped through measures of proximity and observation. For example, following observational studies, Hall introduced four zones of spatial distance as a way of placing spatial boundaries on interpersonal behavior: intimate distance, used in very close relationships only where all senses are involved but vision is limited; personal distance, used in the near space of the other, where one can see, touch and hear but not smell the other person; social distance used in more formal interactions (eye gaze, a loud voice and body movements are often present) and public distance which is the distance kept from public figures (e.g. a lecturer, focus on load voice and body movements, Hall, 1966). Although different between cultures, within each culture interpersonal distance is implicit but clearly felt, especially if one stands or sits nearer or further than expected. The physical distance between interacting people plays a significant role in shaping the quality and tone of their encounter and helps maintain a level of intimacy that is comfortable, appropriate, and safe (Kaitz et al., 2004). Perceived threat from others in terms of personal space may be one of the most salient factors in mediating the equilibrium between interpersonal distance and social interaction (Lloyd, 2009).

In line with this, it has been shown that lesions in the amygdala, which have been associated with diminished experience of social threat and anxiety (Broks et al., 1998; Feinstein et al., 2011; Hurlemann et al., 2009; Sprengelmeyer et al., 1999) may dramatically reduce the need for interpersonal distance, and that amygdala activity in an fMRI setting is correlated with one's uncomfortable feeling at a close interpersonal distance (Kennedy et al., 2009). Also using fMRI, Lloyd and Morrison (2008) presented female participants with real-life scenes of male and female actors in an either threatening or non-threatening social context. Their results suggest that the neural encoding of interpersonal spatial behavior involves a network of areas modulated both by the distance between the interactants and by the nature of the interaction.

Given that invasion of one's interpersonal space may trigger threat and anxiety, people suffering from different levels of social anxiety (SA) should be especially sensitive to manipulations of interpersonal

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distance. SA disorder is characterized by a marked and persistent fear of inspection and examination by others, with sufferers experiencing excessive anxiety about being humiliated or judged negatively in social situations (American Psychiatric Association, 1994). As a result, social situations are either avoided or endured with distress. Importantly, current literature suggests that SA is a spectrum ranging from moderate distress in some social situations (i.e. shyness) to a clinical diagnosis of Social Anxiety Disorder. In the moderate cases, individuals may be able to endure social interactions but with a degree of discomfort and distress; at the extreme end, the fears may be sufficiently powerful to induce active behavioral avoidance of almost all social encounters, resulting in marked disability. Interestingly, a functional perspective suggests that the extreme manifestations of SA represent maladaptation of a behavioral system that evolved as a means of regulating social behaviors in complex primate societies (Miskovic and Schmidt, 2012a, 2012b). Indeed, information processing biases are key factors in the development and maintenance of SA (Amir et al., 2001; Musa and Lepine, 2000), leading individuals with SA to interpret social situations as more threatening than they actually are (Hirsch and Clark, 2004), and to respond faster to probes that replaced threat stimuli, rather than neutral stimuli (e.g. Mogg et al., 1997). However, while some studies report heightened awareness and increased attention to negative cues in SA (e.g. Miskovic and Schmidt, 2012a, 2012b; Mogg et al., 1997, 2004b; Perowne and Mansell, 2002; Veljaca and Rapee, 1998) and enhanced detection of social signs in general (Gilboa-Schechtman et al., 1999, 2005), others suggest that SA individuals shift their attention *away* from social cues (Chen et al., 2002; Horley et al., 2004; Morrison and Heimberg, 2013), and generally exhibit reduced processing of the external social environment under social threat conditions (Musa et al., 2003). In line with the avoidance hypothesis, two recent studies used a virtual reality environment to investigate preferred interpersonal distance and the direction of eye gaze toward or away from an avatar, and showed greater preferred distance, and averted eye gaze in high SA individuals (Rinck et al., 2010; Wieser et al., 2010). Lastly, it has been suggested that initial orienting of attention toward threat may be followed by subsequent avoidance at more protracted stimulus exposure durations (Mogg et al., 2004a), or that symptom severity may distinguish between the two biases. For example, Waters et al. showed increased attention to threatening stimuli in a group of children with high SA, but increased avoidance to these stimuli in a group of children with lower levels of symptom severity (Waters et al., 2011).

In line with these attentional biases, studies of Event Related Potentials (ERPs) in individuals with varying degrees of SA have highlighted both early ERP components, such as the attention-related P1 and N1 (Luck et al., 2000; Vogel and Luck, 2000), and late ERP components, such as the Late Positive Potential (LPP), which is thought to reflect a more high-level elaborate analysis of emotional content (Schupp et al., 2003). While some studies found that in comparison to non-SA individuals, those with SA exhibit larger early ERP amplitudes in response to threatening stimuli (e.g. Kolassa and Miltner, 2006; Mühlberger et al., 2009), other studies reported decreased amplitudes in socially anxious individuals relative to non-anxious controls (Rossignol et al., 2007; see also Frenkel and Bar-Haim, 2011 in general anxiety; Jetha et al., 2012). Using a dot-probe task, Mueller et al. (2009) reported elevated P1 amplitudes in socially anxious participants in response to emotionally neutral face pairs, but decreased P1 amplitudes in response to emotional faces. Mixed findings were also found for the LPP, as some studies revealed threat-related augmentation of LPP amplitudes in SA individuals (Moser et al., 2008), whereas others found a reduction in subtle differentiations between conditions in the SA group (Mühlberger et al., 2009).

Collectively, the behavioral and electrophysiological evidence points to two contrasting possible potential attentional biases in SA: intensified awareness to social cues associated with larger early and late ERP amplitudes in response to threatening stimuli cues vs. diminished attention to social cues associated with attenuated early and late amplitudes in socially anxious individuals relative to non-anxious controls.

While behavioral and neuroimaging studies to date have been increasingly capable of characterizing the neural networks involved in processing of social stimuli in SA (Freitas-Ferrari et al., 2010a, 2010b), only ERP studies can examine directly differences in early and late processing of social information. Considering that no study to date has investigated the relation between preferred interpersonal distance and levels of social anxiety, or the differences in neural correlates related to preferred interpersonal distance using ERPs, the current study sought to characterize the behavioral and electrophysiological bases of social distance, and their relation to levels of SA. The goal of the first experiment was to investigate the relationship between one's level of SA, as measured by the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987) and preferred interpersonal distance. The latter was assessed using a modified version of the comfortable interpersonal distance paradigm (CID; Duke and Nowicki, 1972), in which 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 methods). In line with the cognitive biases observed in SA, the goal of the second experiment was to examine the time course and neural correlates of anticipating interpersonal distance from a friend or stranger, and to examine the differences between low and high SA individuals, by examining early and late ERP components in a similar CID paradigm.

Based on the above evidence we hypothesized that that the level of SA would predict the preferred distance from another person entering the room. Furthermore, we hypothesized that different protagonists entering the room would elicit different degrees of the N1 and LPP components, as both have been shown to be modulated by level of threat or emotional stimuli (Carretié et al., 2004; Foti et al., 2009; Schupp et al., 2003). Considering the avoidance hypothesis, and the recent findings of averted eye gaze in high SA individuals, we expected to find attenuation in early ERPs in high SA individuals, as both the P1 and N1 components have been shown to correlate with attentional mechanisms.

Materials and methods

Both experiments 1 and 2 were approved by The Ethical Review Committee of the University of Haifa.

Experiment 1

Participants were 100 undergraduate Hebrew speaking students from the University of Haifa, Israel, who received course credit or payment for participating in the experiment. Participants were equally divided between males and females and ranged in age from 18 to 60 (mean 25.66, SD = 6.9). Twelve participants were left-handed. All participants reported normal or corrected to normal visual acuity and had no history of psychiatric or neurological disorders, as confirmed by a screening interview.

Stimuli task and design

The stimuli used were a modified version of a paper-and-pencil validated measure of comfortable interpersonal distance (CID; Duke and Kiebach, 1974; Duke and Nowicki, 1972). In the original version, in eight different trials, a circle was presented and participants were instructed to imagine themselves in the center of the room and to respond to an imaginary protagonist approaching them along one of eight radii by making a mark on the radius indicating where they would want the person to stop. The radii corresponded to 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. In the current study, we transformed the test to a computerized animated version (using E-Prime), in which the participant saw a fixation point for 0.5 s, followed by a circular room on the screen, with a line-figure protagonist in the center and in one of the entrances to the room. The participant was asked to mark with the computer mouse where s/he would start feeling uncomfortable if the figure was approaching him/her on the dotted radius (see Fig. 1).

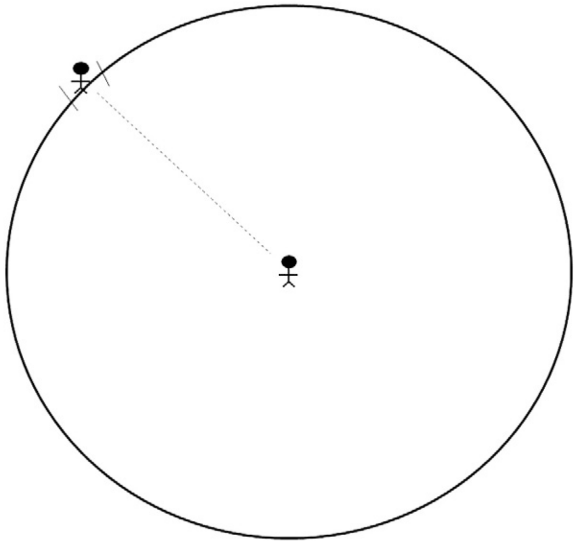

Fig. 1. An example of the comfortable interpersonal distance stimuli: participants were instructed to imagine themselves in the center of the room and to respond to an imaginary person approaching them along a particular radius by making a mark on the radius indicating where they would want the person to stop.

The radius between the room's center and an entrance was 90 mm, and the line figure's length was 12 mm. This was repeated eight times, once for each radius.

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). Participants were asked to rate their levels of fear and avoidance of 24 situations on a 0–3 scale. The 24 items were 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).

Data acquisition and analysis

An average of the eight preferred distances was calculated for each participant, thus forming a CID score. A Pearson correlation was calculated between the CID scores and the total LSAS scores, and between the CID scores and each of the four LSAS subscale scores. Results of three participants were not used for analysis, as their CID distances were more than three standard deviations from the average score and their distance was actually outside the circular room. Results were thus computed for 97 participants.

Experiment 2

Participants were 48 undergraduate students from the University of Haifa, Israel, who received course credit or payment for participating in the EEG experiment. Participants were equally divided between males and females and ranged in age from 23 to 39 (mean 27.5, SD = 2.9). Eight participants were left-handed. All participants reported normal or corrected to normal visual acuity and had no history of psychiatric or neurological disorders, as confirmed by a screening interview. Three participants were excluded from the data analysis due to excessive noise in the raw data, and one participant was excluded when she reported not following the task at debriefing. Hence, the reported results are based on 44 participants (21 female). After the EEG experiment, participants completed the LSAS questionnaire (see above). According to their total LSAS score, participants were further divided by the median score (37) into low SA (LSAS < 35; 22 participants, 12 female; mean LSAS score = 22.36, SD = 8.1) and high SA (LSAS > 39; 22 participants, 10 female; mean LSAS score = 54.86, SD = 14.72) groups for purposes of analysis.

Stimuli task and design

In this modified computerized version of the CID, we further defined the protagonist entering the room to be either a close friend or a stranger. The participant saw the type of the 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 the circular room with a character in the center and the approaching protagonist in one of the eight entrances. This was followed by a 3000 ms animation in which each different protagonist approached the center of the circle. As in the original version, the participants were instructed to imagine themselves in the center of the room and to respond to the virtual protagonist approaching them along a particular radius, this time 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 at the press of the spacebar (Fig. 2). In order to measure ERPs, the 1000 ms still picture, depicting the room with the protagonist ready to approach, was the crucial 'event' for ERP analysis.

Responses were computed as the percentage of the remaining distance from the total distance. In contrast to the previous behavioral experiment, where the responses were spontaneous and fast, the responses in this experiment were less spontaneous, as they were elicited a few seconds after the name of the figure appeared in order to measure the ERPs without motor interference. In order to enable enough data for ERP analysis, each of the approaching protagonists appeared 56 times (7 repetitions of the 8 radii, collapsed for analysis), giving a total of 112 trials. There were two breaks during the experiment, enabling participants to rest. In order to avoid eye movements, the stimuli size was reduced such that the radius of the circle was 45 mm, and the line figure's length was 6 mm. The experiment was presented 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 64 Ag-AgCl pin-type active electrodes mounted on an elastic cap (Biosemi™, 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. 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 64 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 and 24 trials were rejected for each subject, with no difference between groups, conditions or their interaction (Trials rejected for high SA Stranger: mean = 5.68, SD = 6.32; high SA Friend: mean = 6.41, SD = 6.89; low SA Stranger: mean = 7.36,

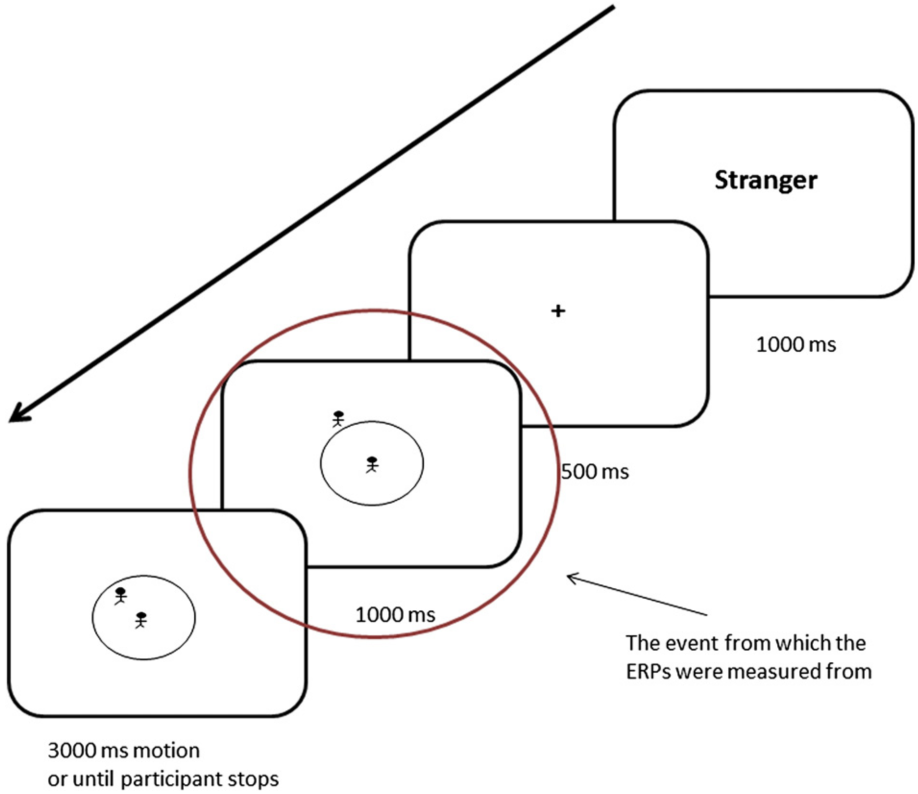

Fig. 2. The ERP design (see text). Note that the crucial ERP 'event' was the 1000 ms still picture, preceding the motion of the figure.

SD = 6.36; low SA Friend: mean = 7.00, SD = 5.63; Group effect p = 0.545; Condition effect p = 0.658; Group × Condition p = 0.188).

Behavioral and ERP analysis

Behavioral analysis. Similar to experiment 1, separately for stranger and friend protagonists.

ERP analysis. ERPs were determined by averaging the one-second segmented trials separately in each condition (Stranger, Friend). The averaged waveforms were smoothed by applying a low-pass filter of 17 Hz (Falkenstein et al., 1991) and were baseline corrected according to the 500 ms before stimulus onset. Based on previous studies and on scrutiny of the present distributions, the statistical analysis of the P1 and N1 components was restricted to the occipito-parietal sites PO7 and PO8. For each subject, the peak of P1 was determined as the most positive peak between 50 and 150 ms, and the peak of N1 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. Finally, LPP amplitude was scored as the mean amplitude in the time interval from 400 to 800 ms following stimulus onset (Frenkel and Bar-Haim, 2011) at the vertex electrodes (Pz, Cz and Fz; Schupp et al., 2003) and at Centro-Parietal Sites (using the mean amplitude of C3, C1, PO3, PO1, P3, P1 and the corresponding right hemisphere sites; e.g. Frenkel and Bar-Haim, 2011).

Results

Experiment 1

A positive correlation was found between the CID scores and the total LSAS score, such that the higher one's LSAS score, the further the distance one would want from the person entering the room (N = 97; r = 0.44, p < 0.001; see Fig. 3). Positive correlations were also significant between the CID scores and all four subscale scores (anxiety of performance: r = 0.49, p < 0.001; anxiety of social interaction: r = 0.46, p < 0.001; avoidance of performance: r = 0.37, p < 0.001; and avoidance of social interaction: r = 0.25, p ≤ 0.014). After correcting for multiple comparisons using the Bonferroni correction, all but the last correlation remained significant.

Experiment 2: ERP

Behavioral results of the ERP experiment

A repeated measures analysis indicated a significant protagonist (Stranger/Friend) effect, such that Stranger was stopped before Friend

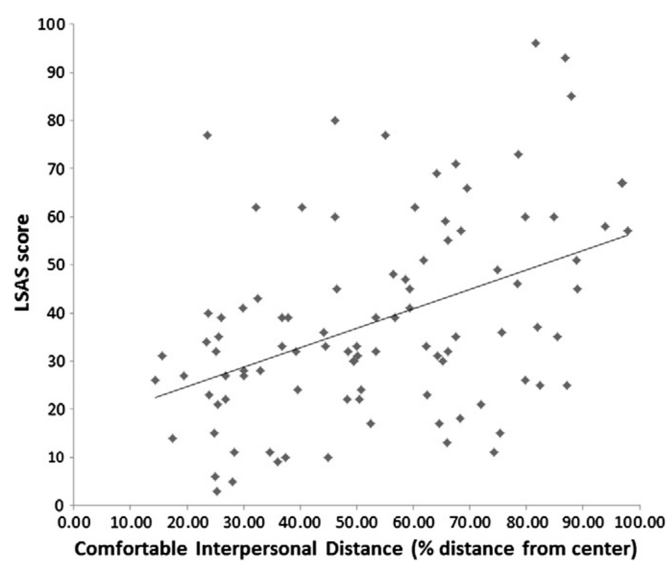

Fig. 3. The correlation between the LSAS and the CID (r = 0.44, p < 0.001).

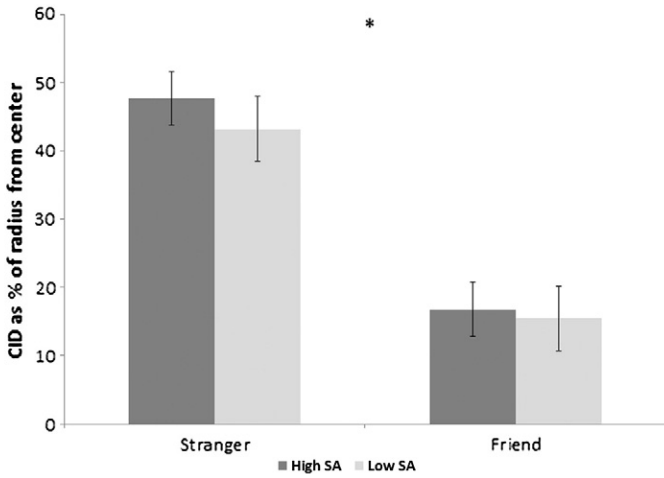

Fig. 4. Behavioral results of the ERP experiment. A significant difference was found between the preferred distances from Stranger and Friend, with no significant difference between the groups.

[$F(1,42) = 100$, $p < 0.001$]. However, although distance for Stranger was further from the center for the high SA group than for the low SA group, there was no significant group difference or interaction (both Fs < 1; see Fig. 4). The correlation between the behavioral results and the LSAS was not significant ($p > 0.5$).

ERPs

The distribution of the P1 and N1 components was posterior temporal (see Fig. 5). One participant had no recordings from PO8 due to a bad signal at recording time, so the ERP data are from 43 participants (21 from the low SA group, 22 from the high SA group). The statistical analysis of each peak was based on a mixed ANOVA design (between subjects: SA groups; within subject: Hemisphere, Condition) for the amplitude and latency of each peak.

P1. There was a significant between-group effect for P1, such that the high SA group exhibited attenuated P1 amplitudes relative to the low SA group (high = 1.57, low = 3.26; $F(1,41) = 4.66$, $p < 0.05$, $p^2 = 0.1$; see Fig. 6). There were no other significant main effects or interactions. There were no significant differences in latencies between groups, conditions, hemispheres, or their interactions.

N1. Similar to the P1, there was a significant between-group effect for N1, such that the high SA group exhibited attenuated N1 amplitudes relative to the low SA group [high = −2.76, low = −4.15; $F(1,41) = 4.29$, $p < 0.05$, $p^2 = 0.095$; see Fig. 6). In addition, there was a significant main effect for Condition [$F(1,41) = 5.76$, $p < 0.05$, $p^2 = 0.123$], revealing that N1 was greater for the Stranger (−3.54) than for the Friend condition (−3.19; see Fig. 7). There was also a significant main effect for Hemisphere [$F(1,41) = 6.29$, $p < 0.05$, $p^2 = 0.133$; right N1 greater than left], attenuated by a Group × Hemisphere interaction [$F(1,41) = 9.30$, $p < 0.001$, $p^2 = 0.185$]. Post-hoc t-tests revealed that the hemispheric differences were driven by differences in the low SA group only (low SA: $t(20) = 4.33$, $p < 0.001$, right = −4.89, left = −3.2; high SA: $t(21) = -0.35$, $p = 0.7$, right = −2.76, Left = −2.59). There were no significant differences in latencies between groups, conditions, hemispheres, or their interactions.

Following the large difference between the two groups in N1 amplitude, a correlation was computed between the average N1 amplitude of the two conditions in PO8 and the LSAS scores. The results revealed a significant correlation between the two, such that the higher one's LSAS score, the smaller the right N1 amplitude ($r = 0.35$, $p < 0.05$, see Fig. 8). No such correlation was found between the N1 and the behavioral results, indicating that the significant correlation was not an artifact derived from the participants' subsequent motor reactions.

LPP. Following the LPP literature and the parieto-central distribution of the LPP in the current study, we conducted a similar ANOVA analysis for both the vertex electrodes (Pz, Cz and Fz; Schupp et al., 2003) and for Centro-Parietal Sites (using the mean amplitude of C3, C1, PO3, PO1, P3, P1 and the corresponding right hemisphere sites; e.g. Frenkel

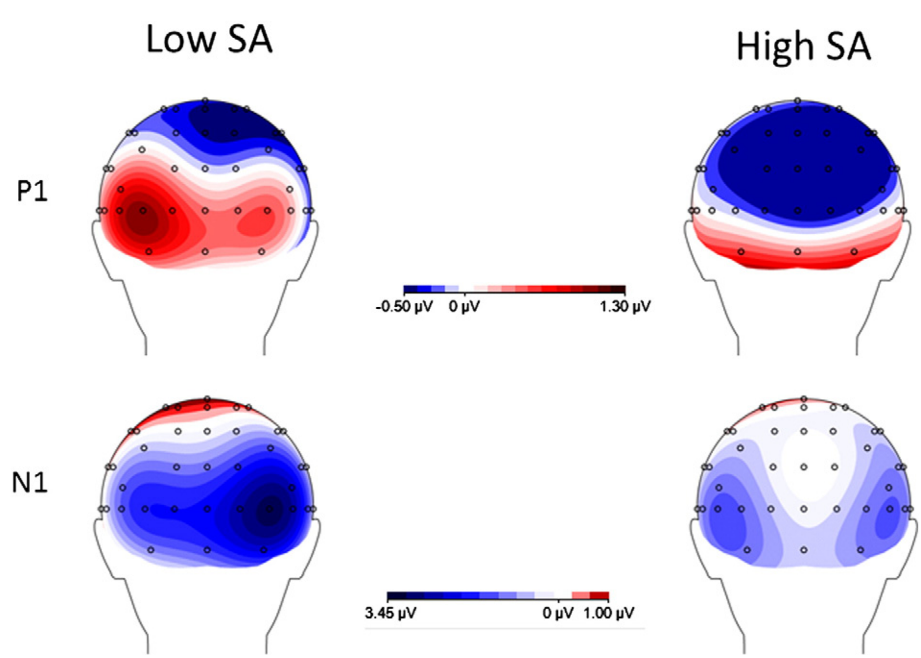

Fig. 5. Scalp distributions of the P1 and N1, for the low and high SA groups.

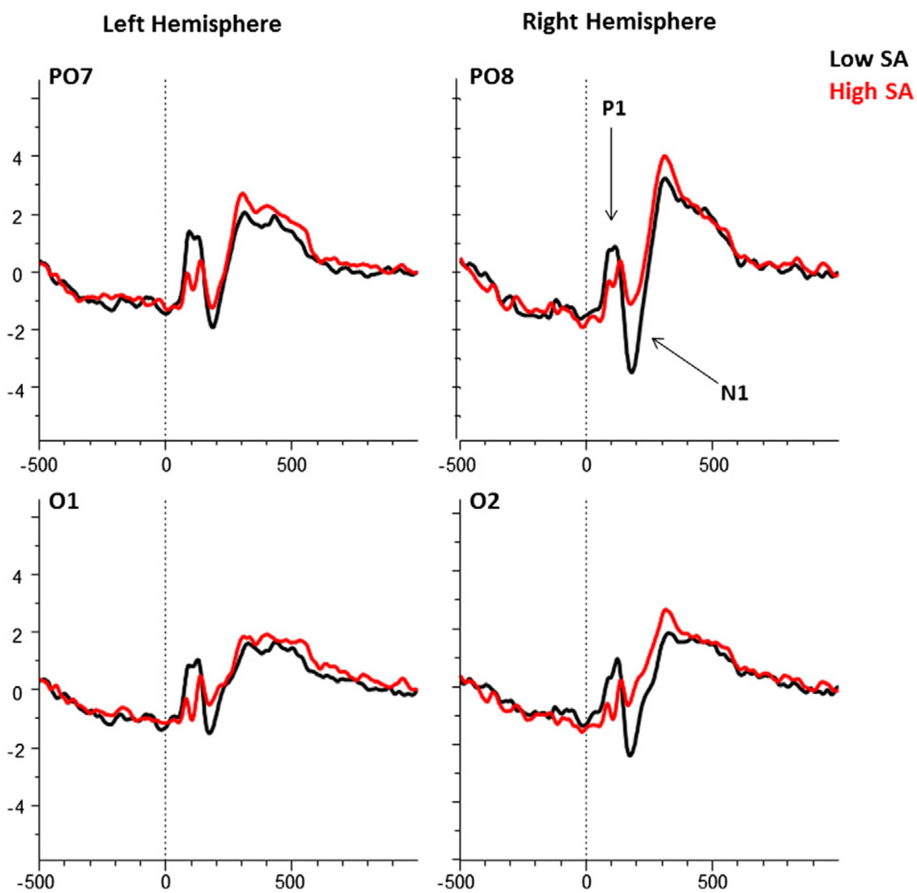

Fig. 6. Early ERP differences between the high and low SA groups, both at the P1 and the N1 components. Occipital electrodes O1 and O2 are shown in addition to PO7 and PO8, showing the same general effect.

and Bar-Haim, 2011). These analyses indicated no significant effects for Condition, Group or their interaction (all ps > 0.2).[1]

Discussion

The aim of the present study was to investigate the relationship between SA and interpersonal distance preferences. Several findings relevant to the initial hypotheses emerged. First, behaviorally, levels of SA were found to be highly correlated with preferred interpersonal distance. This finding is in line with others (Kaitz et al., 2004), who found that fearful-avoidant attachment style, which has been previously related to social anxiety (e.g. Eng et al., 2001), is associated with sitting further away from a stranger. These results are also in line with Scheele (Scheele et al., 2012) who recently reported that participants with higher SA scores maintained larger distances from a female experimenter, and with Wieser et al. (2010) and Rinck et al. (2010) who used virtual reality to show greater preferred distance and averted eye gaze in high SA individuals. Our study thus provides additional support for the strong link between SA traits and preferred interpersonal distance across sex and methodologies. Preferring further interpersonal distance from strangers seems to be a symptom even of non-clinical SA individuals and may serve as a subtle form of social withdrawal. This strong correlation has not been highlighted in the SA literature and may be of clinical as well as diagnostic value. Furthermore, our study revealed that neural differences between high and low SA groups performing an interpersonal distance task are evident from as early as 100 ms. Attenuated P1s and the following N1s were evident in high, relative to low, SA individuals. In addition, while the low SA group showed a laterality effect, with a greater N1 in the right hemisphere, the high SA group did not.

This attenuation in early attention-related components supports the proposed avoidance hypothesis, i.e. that SA individuals orient their attention away from social information, resulting behaviorally in greater interpersonal distance from others (Frenkel et al., 2009; Simonian et al., 2001). Importantly, attenuation of the P1 has been recently related to participants' reports of drifted attention at a given task (Kam et al., 2011). The visual N1 component has also been linked to attentional processes, with a greater N1 corresponding to attended compared to unattended stimuli (Vogel and Luck, 2000). The visual N1 has also been shown to be modulated by the valence of the stimuli, with a greater N1 correlated with positive or negative valance, compared to neutral valance (Foti et al., 2009). The greater N1 found for Stranger as compared to Friend in the current study, is in line with these results and validates the participants' discrimination of the two (visually identical) stimuli. However, although the N1 was modulated both by group and by condition, there was no interaction between the two, perhaps because the differences between the conditions were small and required the participants' ongoing cooperation and imagination (see limitations of the study below).

Interestingly, fMRI studies consistently show hyper-excitability of the amygdala and insula regions in socially anxious individuals (Etkin and Wager, 2007; Freitas-Ferrari et al., 2010a, 2010b; Miskovic and Schmidt, 2012a, 2012b). Amygdala activation was also found to be prominent in situations of discomfort with interpersonal distance (Kennedy et al., 2009). Finally, a recent fMRI study found that SA individuals exhibit an increased influence of the amygdala on the visual

[1] As suggested by a reviewer, we have also analyzed the LPPs for the preceding words "Friend" versus "Stranger" in both SA groups, but found no significant differences between the conditions, groups or their interaction.

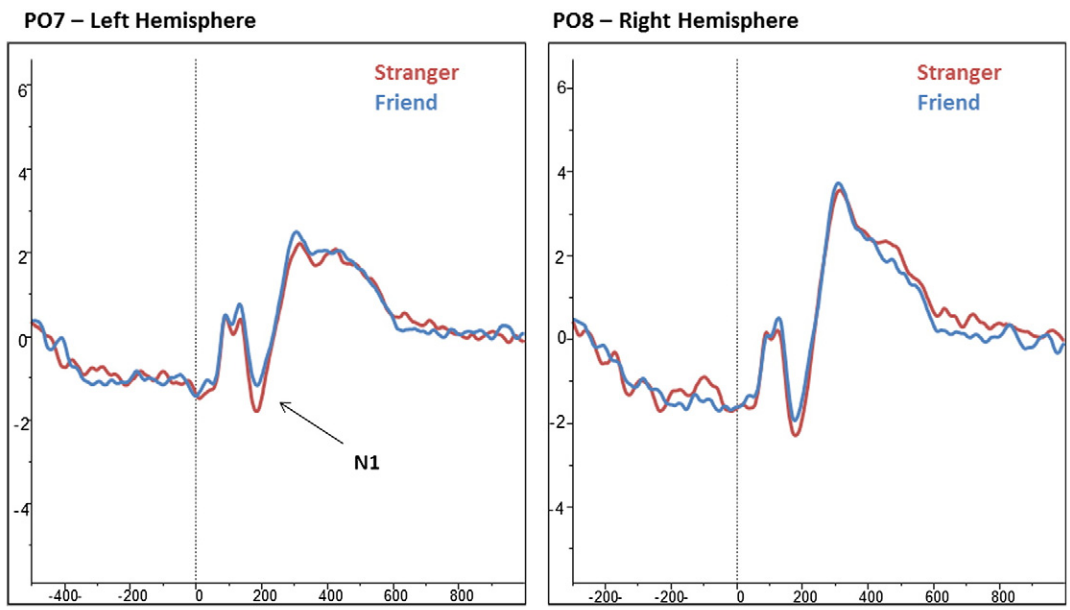

Fig. 7. ERP differences for the different conditions (Stranger, Friend).

cortices (Liao et al., 2010). Thus, a possible hypothesis is that hyper-amygdala activation in social situations inhibits normative attentional-visual processing resulting in greater preferred interpersonal distance from others (see similar interpretations in Jetha et al., 2012; Mueller et al., 2009). Nonetheless, it should be noted that the present study cannot provide direct support to this hypothesis as no source localization analyses were carried out (see different possible interpretation by Sabatinelli et al., 2005). Future studies, combining EEG and fMRI, are needed in order to better understand the possible link between amygdala hyperactivation and the attenuated early ERPs described in this study.

Discrepancies between studies showing heightened versus attenuated early attentional ERPs in SA populations may be explained by differences between the study populations, tasks and designs. It may be the case that our sub-clinical SA group exhibited avoidance mechanisms, but that a group with higher SA traits would have shown hyper vigilance (pronounced by elevated ERPs), as seen behaviorally in Waters et al.'s study (2011). Similarly to Frenkel and Bar-Haim (2011), the current paradigm explicitly focused on a threatening situation, in this case a socially threatening one. Perhaps this scenario biased the more anxious participants to be continuously looking for threatening stimuli, resulting in reduced stimulus-driven effects in these participants (Frenkel and Bar-Haim, 2011). Alternatively, the lack of specific interactions of social threat cues (Friend, Stranger) and SA may imply that the P1 and N1 differences convey general differences in early visuocortical processing between the two groups, not related specifically to interpersonal distance. Unfortunately, this hypothesis could not be measured in the current study, and calls for future investigation. An alternative explanation to the findings of the present study is that there was an elevated differential response in high SA participants already in response to the words preceding the stimuli. As 'Friend' and 'Stranger' may both be threatening stimuli for the social anxious observer, the words themselves may have captured the attention away from the subsequent stimuli. To rule out this possibility we carried out an ERP analysis of the words stimuli and did not find evidence for this hypothesis in ERP analysis of the words stimuli.

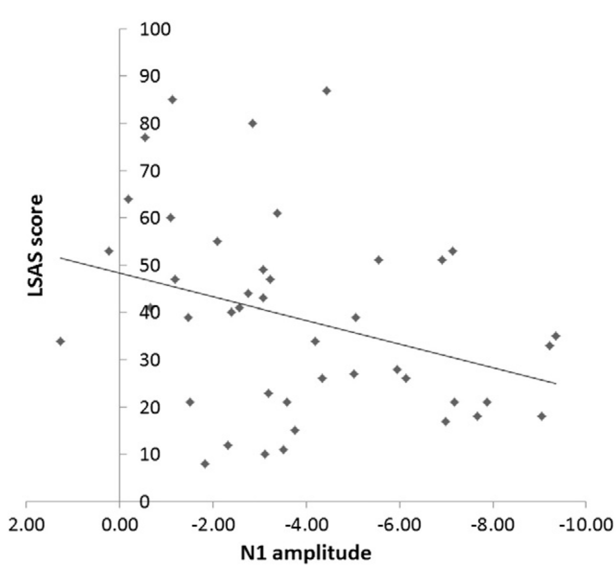

Fig. 8. The correlation between the N1 amplitude at PO8 and the LSAS score ($r = 0.33$, $p < 0.05$).

In addition, the current study shows that the N1 amplitude not only differs between the two groups, but also actually correlates with the level of SA. Since differences in N1 amplitude have not been reported in other SA studies, we do not believe that this is a global marker of SA. However, at least in the context of social distance, it may serve as a marker of SA severity. Notably, Mueller et al. (2009) did not directly analyze N1 differences time-locked to their face pairs, but their figures do seem to show a remarkable difference between the two groups at the same PO8 site. The results presented here may be clinically relevant insofar as attention to social distance may provide a novel viable target for future psychotherapeutic interventions. Subtle individual differences in interpersonal distance may lead to a vicious cycle in which one's distance may be interpreted as a less communicative, social, or comfortable interaction. This in turn may strengthen one's discomfort in social situations. Closeness promotes intimacy, and allows better eye contact and closer attention to subtle interpersonal cues. People standing at far distances from one another are unlikely to disclose personal information (Hall, 1966; Kaitz et al., 2004). Indeed, Donald et al. (2012) showed that attention training for social anxiety had a positive effect on SA. Thus, one of the most effective ways to reduce SA may be to improve attention to social cues from an early age, turning the cycle of failure–fear–failure to one of success–confidence–success. A neural marker for SA level may have future clinical implications, serving as an additional diagnostic tool for screening or for evaluating treatment efficacy (for a similar approach see Miskovic, Miskovic et al., 2011; Moscovitch et al., 2011).

Importantly, although these results reveal a close link between SA and preferred interpersonal distance, we do not claim that one's SA level is the only factor determining his or her preferred distance from another. Other personality traits, such as one's social awareness or interest in others may play a role, in addition to cultural differences and situational factors, such as intimacy level, attraction or smell. However, this study reveals the central, and early, role SA level plays in determining one's comfortable interpersonal distance, both behaviorally and at the neural level.

The uniqueness of the current study lies in the fact that at a perceptual level, the stimuli of the stranger and the friend figures were exactly identical, differing only in the participant's knowledge (depicted by a previous word) of what the figure symbolized. The fact that the stimuli were identical, and that the line figures were not considered highly emotional on their own, may explain the lack of an LPP difference between conditions. Further studies are needed to evaluate the effects of interpersonal distance on the LPP, perhaps using more realistic approaching figures or pictures of actual friends versus strangers.

Several limitations of this study should be acknowledged: first, it should be noted that in our second experiment, no significant behavioral differences were found between the high and low SA groups, and we did not replicate the correlation between the CID results and the LSAS seen in Experiment 1. Besides the group size differences, we believe that the main reason for this discrepancy was the delay in the time of response. In contrast to Experiment 1, where the responses were spontaneous and fast, the responses in Experiment 2 were less spontaneous, as they were elicited a few seconds after the name of the figure appeared in order to measure the ERPs without motor interference. In addition, ERP analysis requires many repetitions of the stimuli, which may further diminish the behavioral effect. However, taking into consideration similar results from our lab with a different group of participants (in preparation), as well as recently published similar results from a different group of researchers (Scheele et al., 2012), further confirms that the strong correlation between SA and preferred interpersonal distance found in Experiment 1 is genuine. Importantly, these results strengthen the notion that the correlation between the N1 component and the SA level was actually derived from variance in the SA levels and was not an artifact of the behavioral results. A second limitation is the non-clinical SA group, making implications for clinical SA disorder more difficult. Notably, our high SA group included eight individuals with considerable levels of SA, namely with LSAS scores above 55, which is already considered to be moderate social anxiety. Of those, two scored above 80, which is considered severe social anxiety (Heimberg et al., 1999). Nevertheless, as differences in behavior between groups of different SA levels have been reported (e.g. Waters et al, 2011), further research is needed in order to establish a relationship between interpersonal distance and clinical SA disorder. Lastly, there are strengths and weaknesses in using a simple line drawing paradigm — on the one hand, it can be easily replicated in different experimental settings (e.g. EEG, fMRI) and effects between conditions cannot be attributed to low level visual differences; on the other hand, this paradigm strongly relies on the participants' ability and willingness to imagine a friend/stranger time and again, trial after trial. The use of more realistic stimuli, for example, depicting real pictures of the participant's friends (and those of strangers) may result in stronger effects, such as an LPP effect or an interaction between group and condition.

Lastly, questions regarding social perceptions in social phobia may arise from the current findings. For example, a recent study demonstrated that stimuli that were perceived as threatening were experienced by participants as physically closer than stimuli that emitted affective signals of disgust or no affective signal (Cole et al., 2013). These results along with our findings, lead to an interesting question: do people with greater SA prefer further interpersonal distance, or do they perceive others as physically closer than they actually are? Future studies are needed in order to answer this question.

Conclusions

To conclude, this study revealed a strong relationship between SA level and preferred interpersonal distance, using both behavioral and neural measures. Behaviorally, higher SA individuals preferred further distance from a stranger, which may be associated with social deficits and withdrawal. Furthermore, the current study indicates that individuals with higher levels of SA exhibit more attenuated early ERPs, which may be a sign of diminished attention toward social cues, in line with an avoidance bias. In addition, this study revealed early neural differences in response to protagonists of a different threatening nature, even when these were perceptually identical. That the findings are seen in sub-clinical populations strengthens the notion that SA represents a spectrum, ranging from moderate distress in some social situations to a clinical diagnosis of Social Anxiety Disorder. Apart from the scientific significance in understanding differences in interpersonal distance, these ERP differences may also serve as diagnostic tools for evaluating SA severity and treatment efficiency in both clinical and sub-clinical populations.

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