Changes in interpersonal distance modulate social attention engagement: Evidence from EEG alpha band suppression

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Abstract

Interpersonal space is regulated carefully and updated dynamically during social interactions to maintain comfort. We investigated the naturalistic processing of interpersonal distance in real time and space using a powerful implicit neurophysiological measure of attentional engagement. In a sample of 37 young adults recruited at a UK university, we found greater EEG alpha band suppression when a person *occupies* or *moves into* near personal space than for a person occupying or moving into public space. In the dynamic condition only, the differences attenuated over the course of the experiment, and were sensitive to individual differences in social anxiety. These data show, for the first time, neurophysiological correlates of interpersonal distance coding in a naturalistic setting. Critically, while veridical distance is important for attentional response to the presence of a person in one's space, the behavioural relevance of their movement through public and personal space takes primacy.

Keywords: social cognition, interpersonal interactions, interpersonal space, attention, social anxiety, alpha band suppression.

Research Transparency Statement

Conflicts of interest: All authors declare no conflicts of interest.

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Data: Anonymised primary and ready-to-analyse data are publicly available (https://doi.org/10.17605/OSF.IO/E62YG). Analysis scripts: All analysis scripts are publicly available (https://doi.org/10.17605/OSF.IO/E62YG).

Changes in interpersonal distance modulate social attention engagement: Evidence from EEG alpha band suppression

Representing the spatial aspects of sensory input is critical for human cognition and behaviour. How far something is from oneself is key to identifying its behavioural relevance, determining its reachability, estimating threat value, and so on. Our social interactions typically occupy physical space, and the mutual maintenance of comfortable interpersonal distance is very important in dyadic and group interactions. When others get too close, feelings of discomfort or fear can be evoked, prompting action to re-establish a preferred distance (Candini et al., 2021; Hall, 1963; Hayduk, 1983; Perry et al., 2013). The functions of interpersonal space maintenance are manifold. We act to keep potential threats to our safety distal, and signals of safety more proximal (Cole et al., 2013; Givon-Benjio & Okon-Singer, 2020; Vieira et al., 2020). Interpersonal space regulation can also be a social signal: approaching others indicates an interest in further contact and interaction. The construct has proven challenging to understand because studies investigating the perceptual and social cognitive mechanisms underpinning interpersonal distance must grapple with challenges associated with balancing ecological validity with measurement precision, and the difficulty of capturing processes that can vary across time and can be sensitive to a wide range of characteristics in the observer and the observed.

The current study aimed to elegantly manage these issues and contribute to the understanding of interpersonal distance perception. We did so by using an electrophysiological index of visual attentional processing – suppression of EEG alpha oscillatory activity. Activity in the alpha (8-12Hz) reflects coherent oscillatory neural activity and is thought to reflect attentional processing amongst other factors (e.g. Foster et al., 2017). Specifically, alpha band power is strong at rest and is suppressed during attention engagement. Attentional processing is important for social cognition; for example, we know that socially relevant stimuli such as faces can powerfully capture attention (e.g. Theeuwes & Van der Stigchel, 2006), As a robust and relatively straightforward measure to extract, we felt that alpha suppression was an ideal approach to deploy to study attention engagement where participants experienced real-life social interactions in real space. We measured changes in alpha suppression in response to the presence of another individual appearing in proximal or distal physical space, and we manipulated whether they were static or moving towards or away from the observer. To our knowledge, previous research has not examined interpersonal distance with live person to person interactions using the continuous neurophysiological insights that EEG recording affords. This approach allows for real-time online neural activity to be indirectly recorded in social interactions. For the first time, we will be able to discover how the brain codes changes in interpersonal distance in real space and time.

Interpersonal distance has been investigated extensively in social psychology. A seminal proxemics work by Hall (1963) carves it into intimate (>46cm), personal (46-122cm), social (122-210cm), and public (>210cm) space. A recent large study has re-confirmed these boundaries for Western samples while noting important cross-cultural differences (Sorokowska et al., 2017). These boundaries are highly sensitive to context. For example, perception of likelihood of threat modulate interpersonal distance tolerances (Ruggiero et al., 2021). Similarly, studies show changes of space perception during and after the recent COVID-19 pandemic indicating that perception of interpersonal distance can be sensitive to risk-related broad social context (Givon-Benjio et al., 2024; Welsch et al., 2021).Where people are free to maintain what is termed 'comfort distance' from others, they tend to manage proximity in step with psychological closeness (e.g., we sit or stand closest to our intimate partners, further for friends, and more distal still for strangers; Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013). It currently remains unclear whether there are also predictable neural responses associated with proxemics in real space and time, which align with such preferences for social stimuli.

We have also learned a great deal from experiments varying static distances. For example, Martin et al. (2021) showed that emotional face images within personal space attract more attention than those presented outside it. To examine changes in interpersonal space, some researchers have presented dynamic stimuli (Holt et al., 2014). For example, Candini et al. (2021) found that approaching confederates induced higher arousal than those receding. Greater arousal was also found with approaching fearful face avatars in virtual reality (Ellena et al., 2020). Participant trait-level factors such as social anxiety also seem critical; people with high social anxiety tend to feel comfortable at relatively greater interpersonal distances (Givon-Benjio & Okon-Singer, 2020), and can deploy attentional disengagement or avoidance strategies when social stimuli are proximal. Such work indicates that not only interpersonal distance per se but heading direction of potential interactants may be critical for understanding how social perception operates as a function of interpersonal space.

The mechanisms that underpin the representation and regulation of interpersonal space are not yet well characterised but are likely to be multivarious. Domain-general distance perception processes are of clear importance (e.g., Holway & Boring, 1952; Sperandio et al., 2012), as are social psychological processes relating to person perception (e.g., Lampinen et al., 2014), and emotional processes (Bogdanova et al., 2022; Dureux et al., 2021). Demonstrating the importance of arousal/alerting elements of attentional processing, the previously-discussed Candini et al. (2021) also showed stronger skin conductance response to approaching vs. receding confederates (see also Ellena et al., 2020). Further, an fMRI study reported increased amygdala activation when an individual is standing close to participants in the scanner (Kennedy et al., 2009; see also Mobbs et al., 2010). Using EEG, Perry et al. (2016) found stronger alpha band suppression - a reduction or attenuation of alpha wave activity in the EEG, thought to index attentional engagement - to imagined human approaches compared with those of inanimate objects, which is consistent with a distance-related processing system tuned to behavioural relevance of the 'other' individual sharing our space.

Integrating the classical social psychological work with more recent behavioural and neural approaches, the aim of this study was to utilise neurophysiological indices of attentional processing for a fine-grained measure of how we process the position of other humans in our personal and public space. Utilizing an implicit measure of attention is one way of indexing the registration of behavioural relevance of a stimulus, which encompasses both orienting and alerting processes (Posner, 1980). It is worthy of note that only a few of the studies cited herein measured responses to varying interpersonal distance with humans in physical space; many instead present images and/or use stimulus size as a proxy for distance as appropriate for their research questions. Nevertheless, a challenge for the field is to leverage ecological validity of classical in-person studies while utilizing the rich and precise data afforded by experimental psychology and cognitive neuroscience (see Huang & Izumi, 2021). Addressing this, Huang et al. (2022) explored neural responses to interpersonal distance during real-time interactions with individuals of varying social status with functional near-infrared spectroscopy. Their findings suggest that both the prefrontal cortex (PFC) and Broca's area are involved in regulating interpersonal space, highlighting the brain's dynamic adaptation to social hierarchies during face-to-face interactions. Here we aimed to contribute to this potential advance with a 'real world' study directly tracking changes in an implicit, neural measure of participants' attention (alpha band oscillations) while observing someone occupy or move through their own near and far personal space. We hypothesised that, in this ecological setting, the behavioural relevance of a stimulus determines distance-related processing, predicting greater alpha suppression (heightened attention) when an individual appears near compared with far in static conditions. Moreover, under dynamic conditions, we predicted greater alpha suppression when the confederate was approaching the participants compared with receding. Note that we make this prediction based on the behavioural relevance of the approach action rather than mere distance since the approximate mean interpersonal distance in both receding and approaching trials is similar to one another over the recording epochs. We conducted secondary exploratory analyses to investigate changes in preferred comfort distance and alpha suppression across time (first half vs second half of the experiment), and individual differences in trait social anxiety.

Method

Participants

We calculated *a priori* power analysis with G*Power 3.1.9.4 (Faul et al., 2007). To provide sufficient statistical power ($\alpha > .95$) to detect a medium-sized effect ($f = 0.25$) in the present design, we required 28 participants. We over-sampled to accommodate anticipated attrition and collected data from a total of 44 participants, a convenience sample drawn from the local undergraduate research participation pool. Technical challenges and poor data quality (e.g. movement artefacts) led to the exclusion of five participants and two further participants did not meet a preregistered inclusion criterion threshold of having 75% or more trials survive the EEG artifact detection procedure. One participants' questionnaire data was lost due to a technical error. Our final sample comprised 37 psychology undergraduates, aged 18 to 31 years (M = 19.7 years, SD = 2.7 years; 31 women, 7 men) who received course credit for their participation.

Apparatus and Materials

Data collection was conducted in a spacious laboratory (L: 6m H: 3m W: 2m) with the same Experimenter (author KV) a white European female (age 29 years, height 165cm), wearing black trousers and t-shirt. A dressmaking mannequin (a torso on a stand with no head or legs) was used in a 'non-human' control condition (as a non-social reference point) in the Comfort Distance measurement task (165cm tall). This was done to enable the comparison of comfort distances to a person with a non-person object that shared some stimulus features of a person. Comfort distance preferences were measured chest-to-chest at the sternum level with a laser measuring tool (RockSeed meter, accuracy ±0.16cm). Participants were fitted for a nylon EEG cap and PLATO Visual Occlusion Spectacles (Translucent Technologies; constructed with liquid crystal cells that can change rapidly from transparent to luminance-equivalent opaque). EEG was continuously recorded with a Brain Products 32-channel active electrode system (10-10 system extended) using Brain Vision Recorder version 1.25.0202 (Brain Products GmbH). The EEG signal was acquired at a 500 Hz sampling rate using an FCz reference, with impedance kept below 50 kΩ. Participants also completed a Brief Fear of

Negative Evaluation Scale (FNEB; Leary, 1983), a well validated measure of social anxiety (Collins et al., 2005).

Design and Procedure

Comfort Distance (behavioural task)

The experiment started with three comfort distance measurements, which were recorded relative to the Experimenter and a dressmaking mannequin (order randomised across participants; see Supplemental Fig. S1 for image). We included these measures to test whether participants' comfort distances would change over the course of the experimental session. Active and passive comfort distances (Experimenter, mannequin) were recorded after introducing participants to comfort distance as a construct (i.e., the minimum distance at which people feel comfortable standing from others). In the active tasks we asked them to approach each stimulus from 2.5m and stop just before they would start feeling uncomfortable. Passive comfort distance was measured similarly, but here their task was to stop the approaching experimenter, who commenced from the same 2.5m starting point. In both conditions participants were asked to make eye contact with the experimenter during the approach.

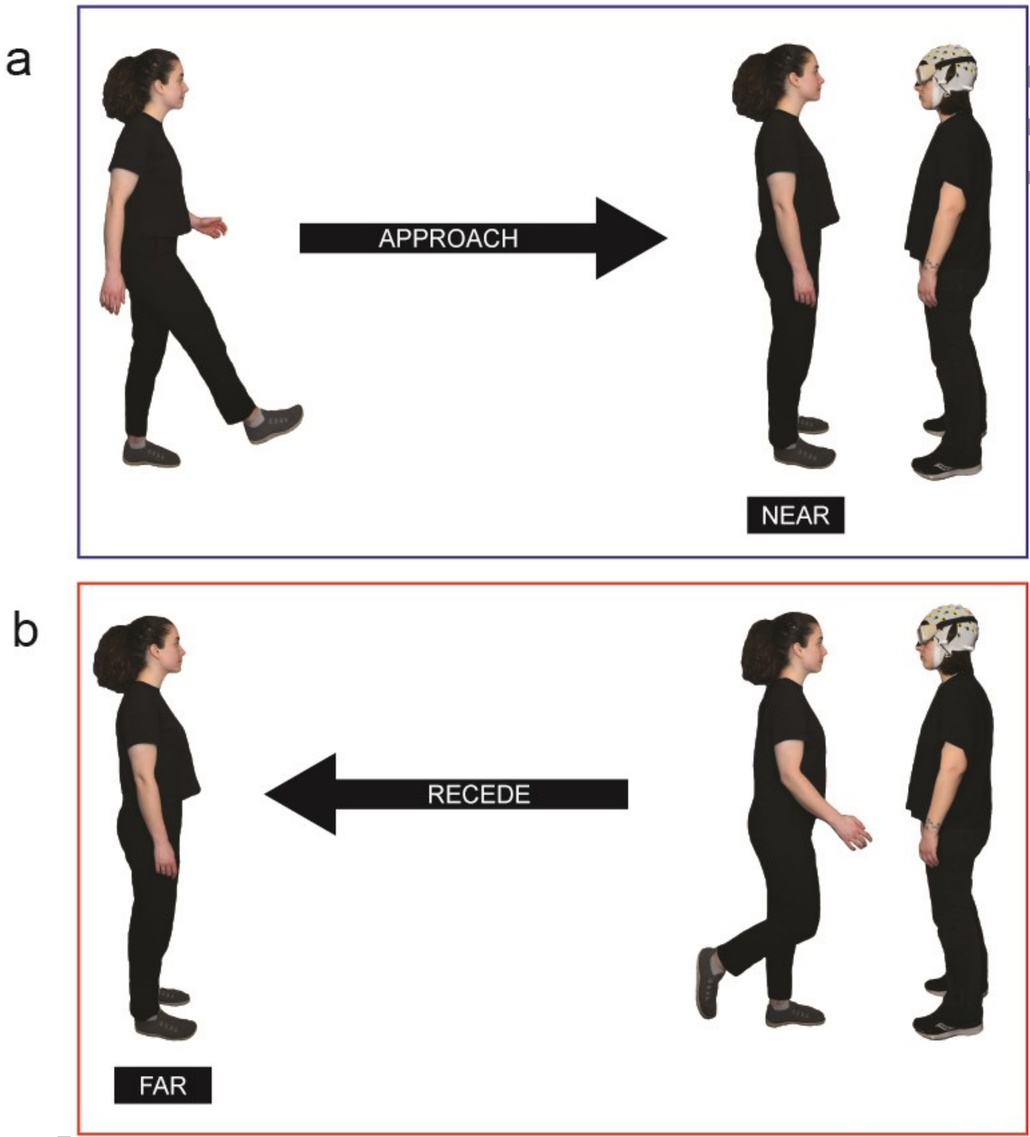
Interpersonal Distance Observation Task (EEG meaures)

Participants were then briefed about the EEG tasks. They were told the experimenter would be standing and walking towards/away from them. Their task was to stand in a comfortable position, directly facing the experimenter, maintaining eye contact and remaining as still as possible throughout each trial. Regular breaks were scheduled and also made available as needed.

Each trial commenced with the spectacles 'opening' (becoming transparent) to reveal the confederate standing in a 'Far' position (public space, 4.5m distance) or a 'near' position (personal space, 0.5m), from which they would slowly approach or recede respectively from the participant for 8s. The experimenter was trained to walk at a steady pace in time with acoustic pace cues delivered through an earpiece. Floor tape marked 0.5m steps to ensure consistent temporal-spatial correspondence across the trial epoch (i.e.,1 second=0.5m; 2=1m;3=1.5m;4=2m; 5=2.5m;6=3m;7=3.5m,8=4m; 9=4.5m). After the Experimenter reached their near/far destination, the glasses became opaque for 6s after which a 4s Static trial occurred (Experimenter remained standing at the end position of the Dynamic trial: 0.5m or 4.5m). There was a total of 192 trials: 48 Approach, 48 Recede, 48 Near, 48 Far, with the order of yoked trial pairs (Approach+Near, Recede+Far) randomised for each participant (See Fig. 1).

Fig. 1.

Representation of (a) Approach+Near and (b) Recede+Far trial pairs. Dynamic trials (divided into eight 1s Distance windows) were followed by Static trials (divided into three 1s Time windows). Static trial was the ending position of the Dynamic one. EEG was recorded throughout, stimulus onset and offset was controlled by occlusion goggles. For a more detailed figure see Supplemental Fig. S2 and trial example video.



At the end of the testing session, the three comfort distance measurements were repeated (active, passive, control), order randomised. Participants also completed the Brief Fear of Negative Evaluation Scale (FNEB; Leary, 1983).

EEG preprocessing and analysis

EEG data preprocessing was performed using EEGLAB 2024.0 and 2022.1 (Delorme & Makeig, 2004), ERPLAB 9.00 (Lopez-Calderon & Luck, 2014) and FieldTrip 20230707

(Oostenveld et al., 2011). The horizontal EOG was computed as the difference between the electrodes F8 and F7, and the vertical EOG was computed as the difference between the electrode below the left eye and the Fp1 electrode. Data were bandpass filtered using a second-order, bidirectional IIR Butterworth filter (0.1–40Hz). Channels and trials containing excessive noise were removed based on visual inspection. Blinks and eye movement artefacts were removed using independent component analysis and visual inspection of the resulting components (see Supplemental Materials Section 3 for details). Data was re-referenced to the mean of both mastoids. Time-frequency analysis was performed on 6s and 12s EEG epochs for the static and dynamic conditions that began 1s prior to spectacles opening and ended 2s after the spectacles closed. The first second of Dynamic and Static trials following the opening of the glasses, the data were not analysed to allow for the participant to reorient to the Experimenter following the visual transition, making the trial length analysed 3s for Static and 8s for Dynamic trials.

Changes in the alpha band power (8–13Hz) induced by Static and Dynamic trials were expressed in terms of change scores from baseline (activity from -700ms to -200ms served as the baseline period, using similar rationale as Bacigalupo & Luck, 2022) and were calculated broadly over parieto-occipital electrode sites (Pz, P3, P4, P7, P8, O1, O2, and Oz; similar to Perry et al., 2016, who used a broadly similar design). The frequency representation of the EEG data was obtained through convolution in the time domain using Morlet wavelets from 2 to 30Hz (in steps of 1Hz) and a Gaussian taper, with analysis windows centred every 50ms, using 5-cycle wavelets (Spaak et al., 2014). The data at each time point for a given frequency were normalized to the baseline power for that frequency on a dB scale, i.e., the normalized value at a given time point represented the change in power relative to the mean baseline power on a log scale. Normalisation was performed separately for each combination of trial, channel average, frequency, and participant.

All statistical analyses were conducted using R studio 2023.06.1 (RStudio Team, 2020; with packages: haven (Wickham & Miller, 2023), ggplot2 (Wickham, 2016), psych (Revelle, 2023), dplyr (Wickham et al., 2023), tidyverse (Wickham, 2023), ez (Lawrence, 2016), readr (Wickham et al., 2023), tidyr (Wickham, 2023)) and IMB SPSS Statistics (Version 25). To be able to compare the distance related power changes of the Dynamic conditions the time course of the Recede condition was flipped (1-9s) for the graphic alpha difference presentations and statistical analyses. To reduce the influence of outliers and enhance the robustness of the statistical analysis, we applied a winsorization technique with 1st and 99th percentiles as cutoff points. Greenhouse-Geisser corrected degrees of freedom are reported for repeated measures ANOVA where the assumption of sphericity was violated. When the assumptions of normality were violated, correlations were calculated using the non-parametric Kendall's Tau.

Results

Comfort Distance (behavioural task)

Participants' mean pre-experiment comfort distance (57cm) was slightly further from the confederate than our chosen "Static Near" distance (50cm), and their post-experiment comfort distance reduced to fall within this distance (M = 42cm). These values indicate that our "Near" boundary aligned closely with what was considered proximal/personal space, and also highlights increasing comfort with the experimenter over the course of the experiment (see Supplemental Table S2). A 2 (Time of Measurement: Pre-, Post-Experiment) x 3 (Comfort Distance Task: Active, Passive, Control) repeated measures ANOVA on these comfort distance estimates showed a significant main effect of Time, $F(1, 36) = 25.32, p < .001$, $\eta_p^2 = .413$, with post-experiment comfort distances smaller than when measured pre-experiment. The main effect of Task was also significant, $F(1.93, 69.49) = 17.37$, $p < .001$, $\eta_p^2 = .325$, with participants comfortable closer to the mannequin (control condition; M = 55.24, SD = 28.80) than the experimenter (active condition; M = 40.97, SD = 21.38) $t(36) = -5.04$, $p < .001$. There was no significant difference between passive (M = 59.03, SD = 27.41) and active (M = 55.24, SD = 28.80) comfort distance, $t(36) = 1.44$, $p = .159$. The interaction was also significant, $F(1.77, 63.65) = 9.92$, $p < .001$, $\eta_p^2 = .216$, because the effect of Time was observed less strongly in the control condition (mean change 6cm) compared to the Active (13cm) and Passive (17cm) conditions. Surprisingly, we did not find significant correlations between Fear of Negative Evaluation scores and any of the comfort distance measures (all τ_bs > -.18, all ps > .140).

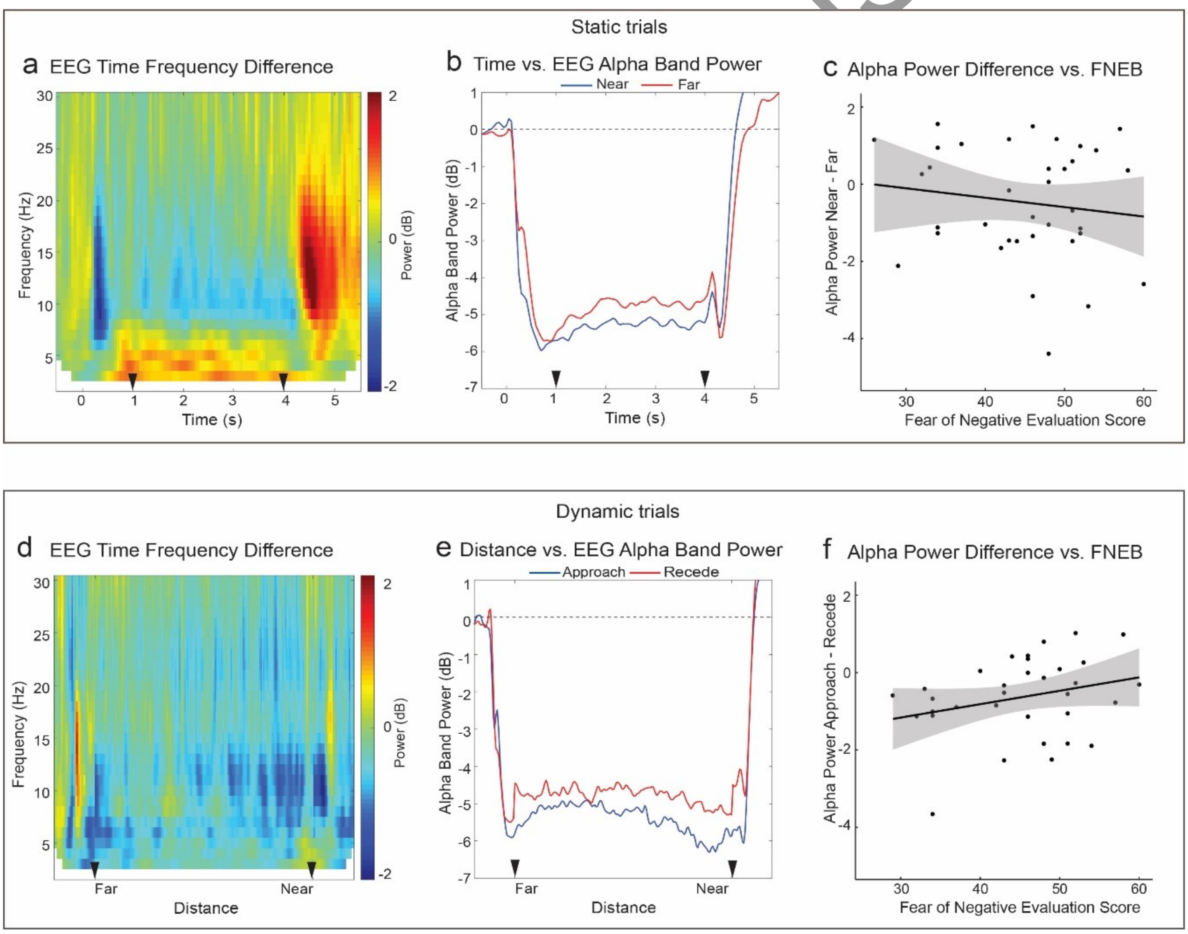
Interpersonal Distance Observation Task (EEG meaures)

Static trials

EEG alpha suppression occurred for both Proximity conditions (Near, Far; see Fig. 2a; for descriptive statistics, see Supplemental Table S3). A repeated measures ANOVA investigated the effects of Proximity (Near, Far) x Time (windows 1 - 3) on levels of alpha suppression (see Fig. 2b). There was a significant main effect of Proximity, $F(1,36) = 5.06$, $p = .031$, $\eta_p^2 = .123$, with greater alpha suppression when the confederate stood at the near than far proximity (-5.35 [-6.44, -4.26]dB vs. -4.81[-5.84, -3.78]dB). Alpha suppression also significantly reduced over Time, $F(1.56, 56.41) = 8.44$, $p = .002$, $\eta_p^2 = .190$. The interaction was non-significant, $F(2, 72) = .53$, $p = .593$, $\eta_p^2 = .014$.

Fig. 2.

Graphic representation of results. Top panel: Static trial plots (differences calculated as Near minus Far): a) EEG Time Frequency difference plot shows the Static differences across the time of the trial and different frequencies (2–30Hz); b) EEG alpha-band (8–13Hz) power over time for Near and Far; c) Scatterplot of association between participants' Fear of Negative Evaluation scores and the alpha power Static differences (all time windows averaged); Bottom panel: Dynamic trial plots (differences calculated as Approach minus Recede): d) Time Frequency difference plot shows the Dynamic differences across the distance of the trial and different frequencies (2–30Hz); e) EEG alpha-band (8–13 Hz) power over distance for Approach and Recede; e) Scatterplots of association between participants' Fear of Negative Evaluation score and the alpha power Dynamic differences (all distance windows averaged). Analyses windows marked by black arrows.



Dynamic trials

Fig. 2d represents the differences in power at frequencies ranging from 2 to 30 Hz between movement direction conditions (Approach and Recede) over distance (for descriptive statistics, see Supplemental Table S4). Fig. 2e shows alpha power changes across distance. To be able to compare the *distance related* power changes of the movement direction, the trial *time course* of the Recede condition was flipped (1-9s). Repeated-measures ANOVA looking at the effects of Movement Direction (Approach, Recede) x Distance (windows: 1-8) on levels of alpha suppression revealed a significant main effect of Movement Direction, $F(1,36) = 8.72$, $p = .006$, $\eta_p^2 = .195$. There was more alpha suppression when the confederate was approaching vs receding (-5.43[-6.49, -4.37]dB vs. -4.78[-5.72, -3.84]dB). There was also a significant main effect of Distance, $F(2.14, 77.20) = 13.78$, $p < .001$, $\eta_p^2 = .277$. There was a significant interaction between Movement Direction and Distance, $F(3.94, 141.82) = 3.79$, $p = .006$, $\eta_p^2 = .095$, which could be explained by a significant linear contrast, $F(1,36) = 5.00$, $p = .032$, $\eta_p^2 = .122$, because while the Recede condition remained stable across distances, in the Approach condition alpha decreased with proximity.

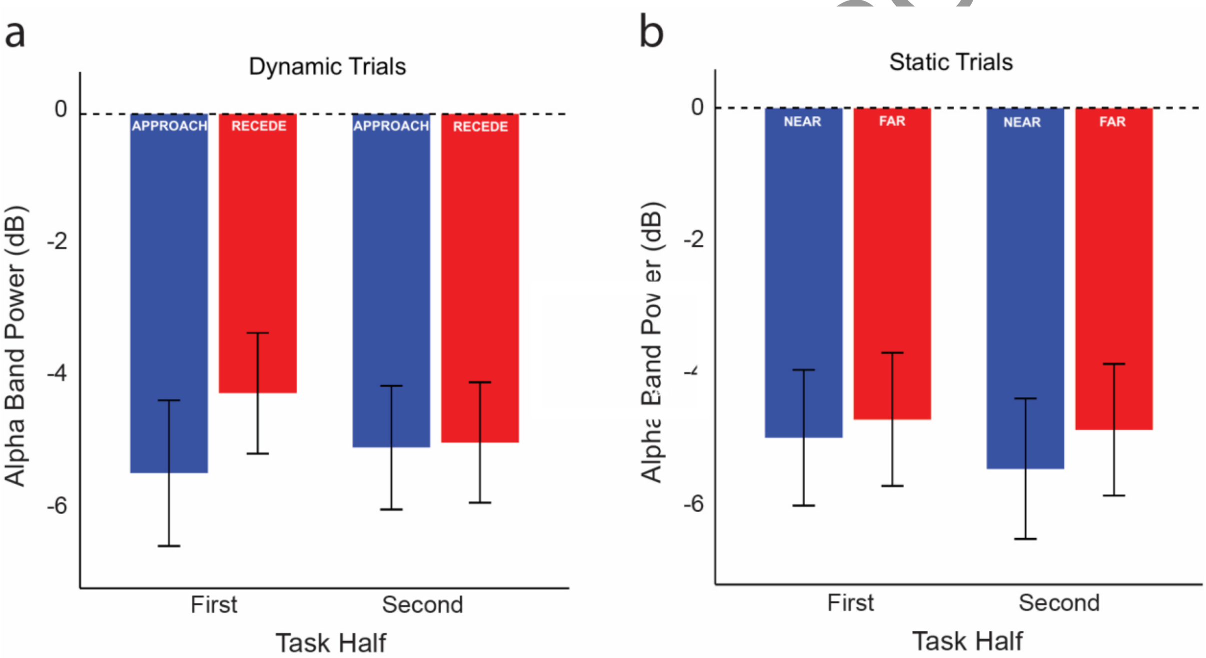
Exploratory follow-up analyses

Alpha suppression and increasing familiarity

Given the observed changes in participants' preferred comfort distance across the course of the testing session we conducted an exploratory analysis to examine if there was also a change in alpha suppression sensitivity to distance over the course of the EEG experiment. Thus, we compared the effects observed during the first and the last 20 trials of each condition (see Fig. 3 and Table S6).

For the Dynamic trials the interaction between Movement Direction and Experiment-Half was significant, $F(1, 36) = 4.52$, $p = .041$, $\eta_p^2 = .111$. This was because the alpha suppression decreased in the Recede condition but not in the Approach condition over time. For the Static Trials, the interaction between Distance and Experiment-Half was non-significant, $F(1, 36) = 1.30$, $p = .261$ $\eta_p^2 = .035$. That is, the effect of interpersonal distance on alpha suppression was stable over the course of the experiment.

Fig. 3. Alpha power in Experiment-Half for (a) Dynamic and (b) Static trials. In each graph, the pair of bars on the left show alpha suppression during the first half of the xperiment, and the bars on the right show alpha suppression in the second half of the experiment for approach/recede (dynamic) and near/far (static).



Individual differences in social anxiety

To explore potential individual differences in participants' sensitivity to these distance-related effects, social anxiety levels (scores on the Brief Fear of Negative Evaluation Scale) were correlated with the differences between conditions (Static: Near minus Far; Dynamic: Approach minus Recede, see Fig. 2c, f). Non-parametric Kendall's Tau was used due to non-normal distribution of FNE scores, though parametric correlations yielded comparable outcomes. We found a significant positive correlation in Dynamic trials, $\tau_b(34) = .26$, p = .028, because relatively more socially anxious individuals showed less attention-related neural differentiation between Approach and Recede conditions. In contrast, this relationship was not found in the Static condition, $\tau_b(34) = -0.05$, p = .672.

General Discussion

In real space and time, the current study identified a neural metric sensitive to the presence of another individual occupying and moving through personal and public space. We identified greater attention-related EEG alpha band power suppression when participants observed a person standing in near vs. far space. This neural distinction aligns with differences in the behavioural relevance of someone appearing proximal vs distal to us: those closer to us warrant greater attentional engagement and deeper processing. Critically, we also observed distinct patterns of neural activity when the experimenter dynamically changed their position relative to the participant. Alpha suppression was stronger in trials where the experimenter appeared at a far distance and approached the participant (i.e., moving into personal space), compared with when the experimenter appeared near to them and then receded (i.e., moving into social and public space). Given that the mean aggregate stimulus distance (and size) experienced is very similar over the course of the approach and recede trials, this finding crucially demonstrates that the data patterns are not best explained by physical aspects of the stimulus, but by higher-level processes related to social behavioural inference. Together these findings are in line with previous research which showed greater attention and arousal with proximity (e.g. Candini et al., 2021; Kennedy et al., 2009; Martin et al., 2021; Mobbs et al., 2010).

Further, the difference between alpha suppression associated with the experimenter moving through personal vs. public space was smaller in the second half of the experiment compared with the first half. We interpret this change as evidence of attenuation of differential allocation of attentional resources based on stimulus proxemics after extended contact with the experimenter and experimental context. We note that the neural change tracked behavioural changes in comfort distance measured at the start vs. end of the experiment, which implies that participants became more comfortable with the experimenter sharing their personal (or even intimate) space (Sorokowska et al., 2017). Broadly in line with previous research (e.g., Iachini et al., 2014), we observed that active distances - where participants controlled the approach, were numerically smaller than passive distances (though this was not statistically reliable in the present study). A dressmaking mannequin served as a control condition against which we could compare the comfort distances maintained towards people. As expected, participants maintained smaller distances to the mannequin, suggesting greater comfort standing closer to an object than a person. This behaviour may be influenced by perceived threat or situational appropriateness.

Finally, we showed an intriguing effect of social anxiety, whereby participants scoring higher on the Fear of Negative Evaluation Scale showed relatively less sensitivity to the different dynamic testing conditions. We interpret this reduced attentional sensitivity to the social qualities of the stimuli as potential evidence of an avoidance strategy, operating to manage their relatively higher levels of anxiety associated with an individual approaching or receding from them (see also Perry et al., 2013). This effect was not detected in the static condition, where the differences between near and far social presence were stable over the course of the experiment and across social anxiety trait levels. This result therefore further suggests that the extent to which social processing is engaged depends upon the behavioural relevance of the stimulus. Specifically, it reinforces the general notion that biological motion is a highly salient environmental cue, with motion that is directed towards being afforded very high weighting in perceptual processing relative to absolute proximity or physical stimulus properties (e.g. Heenan & Troje, 2015). Our neural findings are in line with previous studies which found disrupted perception and regulation of interpersonal distances with greater social anxiety (e.g., Givon-Benjio & Okon-Singer, 2020). This is despite that in our sample we did not find the relation between social anxiety and behavioural measures of comfort distances that was detected by Givon-Benjio and Okon-Singer.

Taken together we show, for the first time, that a key neurophysiological measure of attention is highly sensitive to interpersonal distance in an ecological setting. This sensitivity is much greater for dynamic than static stimuli, is greater prior to familiarisation with a social partner, and is weaker for individuals who find social situations challenging. Critically, these contextually-driven differences are present only where people are moving through space rather than merely 'occupying' a location. It is under these conditions only that familiarity and social competence is relevant to how social perceptual mechanisms for interpersonal space regulation are fully engaged. Beyond the immediate scope of this research, we can foresee utility in neural measures across personal space as informative for clinical practice as it pertains to social anxiety. For example, such findings could feed into the design of spaces which afford incidental interpersonal interactions in a way that allow people to better manage their interpersonal space.

We acknowledge some limitations of our work. First, our sample characteristics were limited as we drew from a primary female undergraduate psychology participant pool in a western industrialised, democratic nation with limited diversity, and levels of social anxiety (44.83 ± 8.52) greater than norms (35.7 ± 8.1; Leary, 1983). In our efforts to maintain high levels of experimental control in this naturalistic testing context our social stimulus set was necessarily restricted to one individual (the Experimenter). Determining the replicability and generalisability of these findings will be important for future work. A key advantage of our study was the retention of a great deal of ecological validity, utilising (albeit carefully controlled) real-life interactions. Future work could examine further the effects of familiarity of interactive partners more closely and explore alternative methods of delivering stimuli. A particularly fruitful avenue will be to have studies that take individual differences as a primary variable of interest to gain more direct evidence for avoidance or hypervigilance for behaviourally relevant stimuli. Similarly, individual differences in comfort distances could be taken into account to spatially arrange stimuli in a personalised manner for participants to attempt to hold constant implied comfort while varying other social factors. Finally, while alpha suppression can indicate attentional engagement, it is not a direct or the only way to measure attention and is sensitive to arousal and cognitive load (e.g. Kardan et al., 2020). To gain a more comprehensive understanding of attentional processes and behavioural relevance during changes of proximity, further research is needed to explore these constructs using other methods that contribute to a broader picture of attentional processes, for example eyetracking could be used to assess overt attention deployment and eye contact regulation (e.g. Birmingham & Kingstone, 2003).

In conclusion, we showed here remarkably clear patterns of data that demonstrate how sensitive alpha suppression is to interpersonal proximity. Our findings highlight variability in intensity of attentional engagement associated with social stimuli as a function of distance, heading (approach/recede), familiarity, and individual differences. We find ourselves in a world of contradictions with social contact. For example, we have experienced challenging periods of forbidden space-sharing through the COVID-19 restrictions, in parallel with widening opportunities to share real and virtual space with others, along with both the need for, and anxiety about social interactions. Understanding the complex operations involved in what is often the first social processing to occur when meeting another person, is key to appreciating person perception and social cognition in functional and dysfunctional social behaviour.

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