Too Close for Comfort: Behavioural and Neural Investigations of Interpersonal Distance

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Abstract

Interpersonal distance is a ubiquitous factor of everyday human interactions. As such it communicates a wealth of information, such as our intentions, personal preferences, and relation to the other person. The space between us and another person affects how socially and behaviourally relevant they are to us and the quality and quantity of sensory information available. This thesis explores interpersonal distance across 9 experiments. Experiments reported in Chapter 2 investigated how physical distance (Experiment 2) and distance proxies (Experiments 3 and 4) between a person and a life-sized whole-person image impacted the ratings of various trait impressions and how isolated faces and bodies were rated at different distances (Experiment 5). These experiments revealed amplification of judgements with proximity and showed important differences of distance modulation of different traits. Chapter 3 explores the role of context on trait ratings and how different contexts interact with distance. We found that both social (Experiment 6) and non-social (Experiment 7) contexts affected all rated traits and a selective interaction between social context and distance on trustworthiness ratings, where context had a bigger effect at further distances. Chapter 4 investigates the individual differences in explicit estimations of distance preferences and is used to validate the experimental projector design used in Chapters 2 and 3, by revealing people kept similar comfort distances towards strangers and their life-sized projected images. Subtle distance modulations of person perception informed Experiment 9 (Chapter 5), where we used a confederate to understand whether real interpersonal distance would have a systematic effect on the neural correlates of attention and arousal. We found greater alpha band suppression in conditions with greater behavioural relevance – near more than far and approaching more than receding. Together, these findings contribute to our understanding of the underlying mechanisms of proximity and its effects on social interactions.

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Author's Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the School of Psychology Ethics Committee at the University of East Anglia.

Some of the research presented here was communicated to the scientific community. Experiments 2, 3, and 4 have been presented at the EPS conference in Plymouth in April 2023 and at invited seminars in Paris Nanterre University in July 2023 and Nottingham Trent University in October 2023. In Nottingham Experiments 6 and 7 were also presented. Experiment 9 has been presented at Social Affective Neuroscience Society conference in Toronto in April 2024 and EPS conference in York in July 2023. Experiments 1, 2, 3, 4, and 6 have been submitted to British Journal of Psychology on 25.7.2024. Experiment 9 has been submitted to the Social Cognitive and Affective Neuroscience on 16.7.2024.

Thesis outline

The thesis is divided in 6 Chapters: Introduction, 4 Research chapters and Discussion. In Chapter 1, Introduction, aims and objectives of the thesis are presented and literature review outlines past research, defines and relates the relevant concepts related to the following studies. The following chapters explore how interpersonal distance and distance related visual cues affect trait impressions (Chapter 2) and how background context interacts with distance (Chapter 3). Chapter 4 explores the relationships between comfort distances and different individual measures, and also validates the experimental design used in experiments from Chapters 2 and 3. The last research chapter (Chapter 5) investigates the neural correlates of proximity. Finally, the findings of all experiments are discussed in Chapter 6.

Chapter 1: Introduction

Summary of the chapter

In Chapter 1, the literature review outlines past research relevant to the studies presented in the thesis, defines the key concepts (see also Appendix A for glossary of key terms) and establishes the relationships between these concepts.

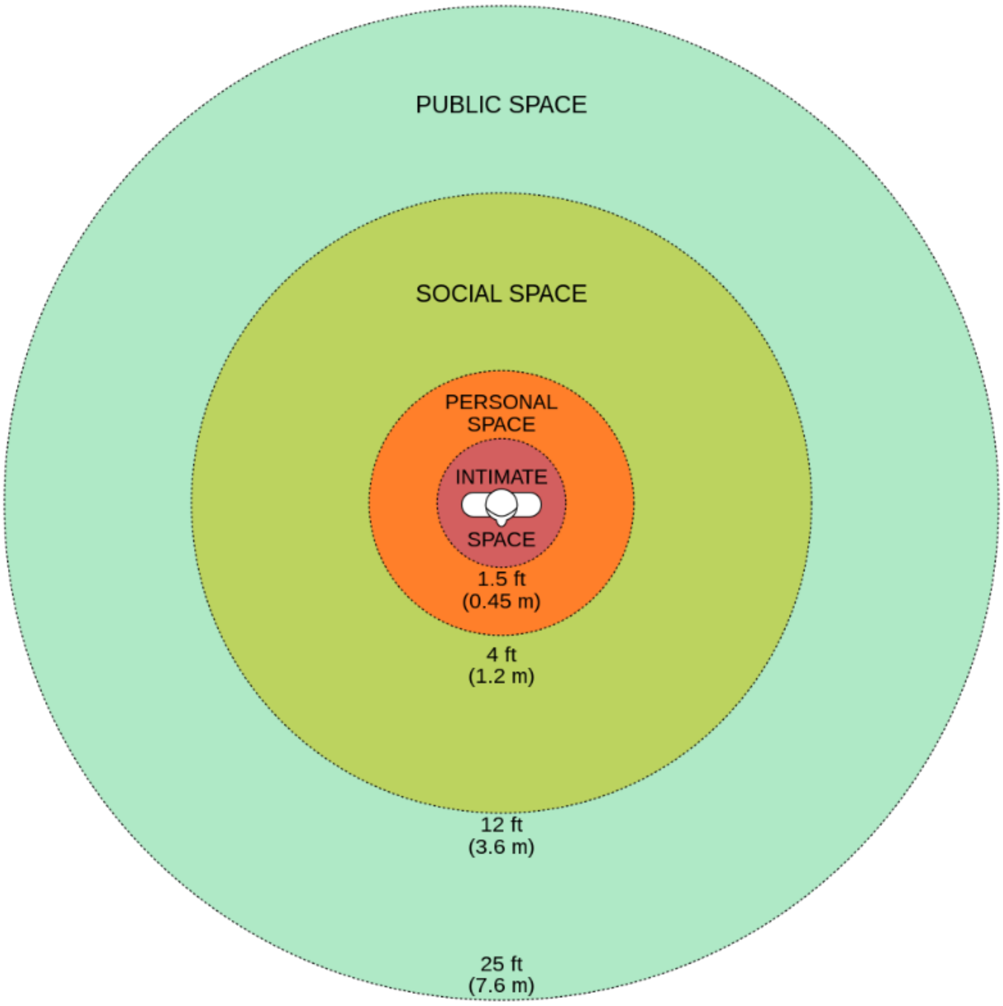
Literature review

Interpersonal space

Interpersonal space is the distance we keep from each other during social interactions (Hall, 1963). It is typically assessed by asking participants to evaluate the distances at which they would be most comfortable to have social interactions with another person (e.g., Kennedy et al., 2009; Perry et al., 2016; Sorokowska et al., 2017). Its function is presumably to maintain appropriate distances during interactions. Closely related to interpersonal space is personal space, which is the minimum distance we keep to another person, beyond which that person becomes uncomfortably close (e.g., Cartaud et al., 2022; Iachini et al., 2014, 2015). Its presumed function is to maintain a margin of safety around the body, and it is determined by participants assessing distances beyond which the proximity becomes uncomfortable. Both interpersonal and personal comfort distances are assessed through tasks where a confederate approaches or is approached by the participant and stops at the desired distance, either for comfortable interaction or minimum comfortable distance, respectively. Studies revealed that people maintain larger distances in passive tasks (being approached by a confederate) compared with active tasks (approaching the confederate) (Candini et al., 2021; Hecht et al., 2019; Iachini et al., 2014). Comfort distances to people are often compared to distances to inanimate objects used as non-social references (e.g., mannequins). Terms and measurements of interpersonal and personal distance have been found to be closely related and are often used interchangeably (Geers & Coello, 2023).

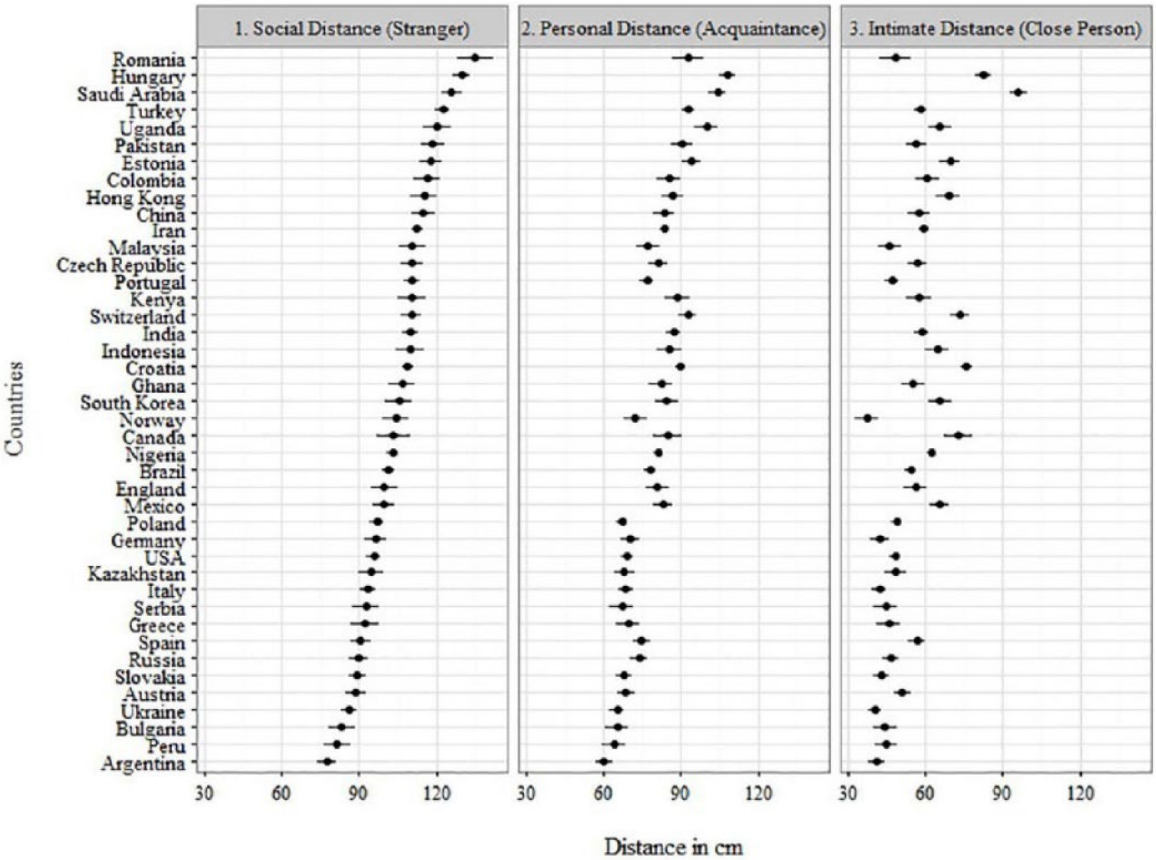
Interpersonal distance is a ubiquitous part of everyday social interactions – either real or virtual, we all interact at some distance from each other. Interpersonal distance has been widely explored in social psychology research; a seminal work by Hall (1966) carves it into intimate (<46 cm), personal (46-122 cm), social (122-210 cm), and public (>210 cm) space (Hall, 1966; see Figure 1.1). These buffer zones help individuals manage intimacy in social settings by regulating their sensory exposure, as there is a higher likelihood of visual, tactile, auditory, and olfactory stimulation at closer distances. At a public distance people speak at higher volumes, and reduce eye contact; social distance is maintained for more formal interactions, at this distance sensory information is limited to auditory and visual sensory information; personal distances are maintained between interactions with friends, all senses are present at these distances, apart from heat; intimate distance is characterized by poor and blurred vision, there is increased perception of heat and smell, while speaking volume is lower (Hall, 1966). In a more recent study, Sorokowska et al., (2017; see Figure 1.2) conducted a cross-cultural study across 42 countries with 8,943 participants and found that on average intimate distance was 31.9 cm, personal 91.7 cm, and social 135.1 cm, broadly aligning with those described by Hall (1966).

Figure 1.1. Schematic representation of distinct distance buffer zones



Note. Hall (1966)

Figure 1.2. Figure representing comfort distances people keep from different people (Stranger, Acquaintanence, Close person) across different countries



Note. Sorokowska et al. (2017)

Our perception and regulation of comfortable interpersonal distances are influenced by a range of factors:

a) *personal factors*, like personality (e.g., people high on extraversion and openness prefer closer distances; Hebel & Rentzsch, 2022), age and gender (e.g., women and older people keep larger distances; Silvestri et al., 2022; Sorokowska et al., 2017), height (e.g., larger distances are kept from taller men; Pazhoohi et al., 2019), culture (e.g., higher annual temperatures predicted closer preferred distances to strangers; Sorokowska et al., 2017; see also Hall, 1963; Wei et al., 2024), personality disorders (e.g., greater preferred distances of people with borderline personality disorder; Fineberg et al., 2018), social anxiety (people with higher social anxiety prefer larger distances; Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013), attachment styles (e.g., avoidantly attached prefer greater distances; Kaitz et al., 2004), psychopathologies (e.g., impaired interpersonal distance regulation with people with schizophrenia, for review see Kraus et al. (2024) and autism, for review see Candini et al. (2020)),

b) *the relationship with the interactant* (i.e., psychological closeness) e.g., we sit or stand closest to our intimate partners, then friends, and then strangers (Hall, 1963; Hayduk, 1983; Sommer, 1959; Sorokowska et al., 2017; Wei et al., 2024), and

c) various *contextual factors* (e.g., crowdedness (Evans & Wener, 2007), room size (White, 1975), threat likelihood (Ruggiero et al., 2021).

These distances also constitute an important social signalling mechanism (e.g., via approaching vs avoiding; Candini et al., 2021; Iachini et al., 2016; Perry et al., 2013).

In our experiments we measured participants' individual differences in social anxiety and empathy, which we wanted to relate to the estimates of comfort distances. While research has consistently found greater preferred distances are kept by highly socially anxious people, the relation between empathy and interpersonal distances have produced mixed results. Our participants completed Brief Fear of Negative Evaluation Scale (Leary, 1983) a validated measure of social anxiety (Collins et al., 2005) and Interpersonal Reactivity Index (Davis, 1983), a validated measure of empathy (Grevenstein, 2020).

Social Anxiety. Comfort distances have been linked to measures of social anxiety (Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013). Social anxiety is characterized by a pronounced tendency to avoid social interactions, which manifests as a preference for increased interpersonal distances, particularly in the presence of strangers (Cohen & Shamay-Tsoory, 2018; Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013). Individuals with high social anxiety often employ attention strategies related to disengagement or avoidance when social stimuli are proximal (Perry et al., 2013; Rinck et al., 2010; Wieser et al., 2010). Additionally, they tend to estimate distances from strangers as shorter than they actually are (Givon-Benjio & Okon-Singer, 2020). This makes social anxiety a good predictor of comfortable interpersonal distances.

Empathy. Empathy has also been linked to perceptions of personal space (Gherri et al., 2022; Perry et al., 2015; Schiano Lomoriello et al., 2023; Vieira & Marsh, 2014; Welsch et al., 2018). For example, Perry et al. (2015) found that after the administration of oxytocin, which enhances the perception of social cues and increases social approach behaviours, highly empathic individuals reduced their preferred interpersonal distance, while those with lower empathy increased theirs. Another link between empathy and interpersonal space was found by Vieira & Marsh (2014), who discovered that individuals with higher psychopathy scores, who typically exhibit lower empathy, maintained shorter distances from others. Welsch et al. (2018) expanded on this by finding that psychopathic traits altered the regulation of interpersonal distance, such that individuals with higher psychopathic traits exhibited smaller changes in their distance preferences when responding to happy vs. angry facial expressions. These results suggested a complex relationship between interpersonal distance and empathy.

Together these findings highlight that social anxiety and empathy significantly influence how individuals perceive and regulate interpersonal space. People with high social anxiety prefer larger personal spaces due to heightened sensitivity to social threats, while higher empathy might increase personal space preferences, because they might want to ensure the other person feels comfortable.

Interpersonal distance and person perception

Despite its crucial role in social perception and interpersonal interactions, interpersonal distance has rarely been considered in person perception research, especially by those investigating social attributions. Many person perception studies asked people to judge people based on small-size photographs shown on a computer screen, which imply a larger distance than is typical in everyday social interactions. A non-systematic review of the literature (based on person perception research with the following key words: first impressions OR trait attributions OR trait judgements OR attractiveness OR competence OR dominance OR trustworthiness OR personality judgements OR facial traits OR trait inferences, resulted in 146 research papers) revealed 32 papers reported information (visual angle or viewing distance and stimulus size) that provided sufficient information to calculate the simulated distance of their presented stimuli. Assuming an average whole person height 170cm, height of the face 20cm, and height of the body 150cm, the experiments using whole person stimuli simulated an average distance of 11.7m (range: 4.9-17.2m), using face stimuli simulated an average distance of 3.5m (range: 0.5-19.5m), using body stimuli simulated an average distance of 9.4m (range: 1.3-18.2m). According to Hall’s distance buffer zones (Hall, 1966), the face stimuli would fall in the far zone of social space (1.2-3.7m), while the body and whole person stimuli within the public space (3.7m<; Hall, 1966). All fall far beyond social space according to Sorokowska et al. (2017), who found distances kept from strangers to be on average 135cm. This discrepancy is meaningful because the quality of social interactions differs dramatically between the implied distances in these studies and the distances at which most every day in-person social interactions occur.

The larger simulated distances likely result in lower social motivation and relevance and provide impoverished visual information about a person. On one hand, social and behavioural relevance is much higher at closer distances, evidenced by the involvement of the neural systems evaluating behavioural relevance (amygdala and insula), which have higher activations when processing events in near space (e.g., Kennedy et al., 2008; Mobbs et al., 2010). Furthermore, at near distances studies noted physiological arousal responses (increased heart rate and greater skin conductance response) in reaction to relevance – closeness and direction of approach (Candini et al., 2021; Evans & Wener, 2007; McBride et al., 1965). When someone is near us or approaching us, the possibility of interaction is much higher compared with when they are far or going away from us. This proximity increases the potential for meaningful social engagement, as closer distances inherently demand more immediate attention and response. On the other hand, the space between people constrains the type and quality of sensory information that is available for different social judgments. Visual inputs, for example, can differ substantially when we are talking to someone close to us versus farther away (e.g., spatial frequency information, proportion of the body visible). As distance increases, the visual information available decreases, which means people must rely on information available with lower spatial frequencies (Lampinen et al., 2014; Loftus & Harley, 2005) and consequently person and emotion recognition worsens over distances (Goffaux & Rossion, 2006; Lampinen et al., 2014; Smith & Schyns, 2009). Thus, a comprehensive understanding of the mechanisms underlying social evaluation warrants targeted consideration of how such spatial information affects social interaction. This question motivated the experiments in Chapters 2 and 3, where we were looking to investigate how distance impacts trait judgements and what is behind this relation.

Trait impressions

Trait impressions are fast spontaneous judgements that people make about others based on their appearance, which often remain stable over time (Oosterhof & Todorov, 2008; Rule et al., 2012; Sutherland et al., 2013, 2018; Willis & Todorov, 2006; Zebrowitz & Montepare, 2008). There is high consensus among individuals regarding first impressions (Sutherland et al., 2020), which has been observed cross-culturally (Sutherland et al., 2018; Zebrowitz et al., 2012) and with young children (3–4-year-olds) who show similar levels of consensus as adults (Cogsdill et al., 2014). Research by Todorov et al. (2009) demonstrated that the agreement among raters on an impression is above chance after 34 milliseconds of exposure to a stimulus, which improved and stabilized within the first 167 milliseconds, indicating these judgements are predominantly based on lower-level perceptual rather than higher level cognitive processing (Todorov et al., 2015). Using data-driven approaches, several studies have identified four key dimensions underlying trait impressions that explain most of the variance: trustworthiness, dominance, competence, and youthful-attractiveness (Oosterhof & Todorov, 2008; South Palomares et al., 2018; Sutherland et al., 2013).

Some studies suggest that these judgements about other's appearance can contain a kernel of truth about the actual traits (e.g., Bond et al., 1994; Bonnefon et al., 2015; Boshyan et al., 2014), however they are generally shown to be highly inaccurate (Rule et al., 2012; Todorov et al., 2015; Zebrowitz & Rhodes, 2004). Zebrowitz et al. (2003) proposed an overgeneralization theory that identifies several overgeneralization effects, which contribute to the formation of first impressions:

1. *Babyface Overgeneralization*: people attribute child-like characteristics to those with baby-like facial features (e.g., large eyes, round face), which leads them to be perceived as warm, not competent and not dominant (Montepare & Zebrowitz, 1998; Zebrowitz et al., 2003);
2. *Familiar Face Overgeneralization*: people judge strangers based on their resemblance to known individuals, which can lead them to undue trust or mistrust (Lewicki, 1985); additionally, familiar faces are treated more favourably (Zebrowitz et al., 2007);
3. *Unfit Face Overgeneralization*: people associate unattractive looking faces with poor health, which elicits impressions of lower warmth, power, and competence compared with attractive faces (Zebrowitz et al., 2003);
4. *Emotion Face Overgeneralization*: people's neutral faces that resemble specific emotional expressions (e.g., anger, happiness) are influenced by the perceived emotions (Montepare & Dobish, 2003).

These studies demonstrate trait judgements based on others appearance have limited accuracy, while they also have high social consequences, such as election outcomes (Antonakis & Dalgas, 2009; Castelli et al., 2009; Todorov et al., 2005), hiring decisions (Rule & Ambady, 2010; 2008), consumer behaviour (Ert et al., 2016), and criminal sentencing (Wilson & Rule, 2015). This highlights the critical importance of studying trait impressions, given their profound impact on various societal and individual outcomes.

Distance and trait impressions

Previous research on trait impressions suggests that high-level socio-cognitive processes are linked to sensorimotor-spatial processes and that there may be an inherent link between spatial and social cognition. It has been shown that personality affects how people maintain and perceive distances from others in social interactions. For example, people high in trait dominance and social class keep smaller distances to others in social interactions (Hall et al., 2005). The context of social interactions also affects how people regulate interpersonal distances. For instance, from an evolutionary perspective it is advantageous for people to keep greater distances when perceived threat is higher (e.g., individuals with angry or disgusted expressions), when encountering approaching individuals, (Ruggiero et al., 2017; Vieira et al., 2017) or when others act unfairly or immorally (McCall & Singer, 2015). Furthermore, more intense emotional and behavioural responses are more likely close, either negative because of the reduced ability to take evasive action, or positive because of the increased chance of an intimate encounter.

The limited extant work on this topic suggests that space information is relevant for the processing of trait attributes. For instance, Patterson & Sechrest (1970) asked participants to form impressions (aggressiveness, friendliness, extraversion, dominance) of confederates sitting at set distances from them (60cm, 120cm, 180cm, 240cm) during an interview and found that trait ratings generally decreased with distance, with the exception of somewhat lower ratings at the closest distance; ratings were highest at 120cm and lowest at 240cm, they were similar at 60cm and 180cm. They attributed the negative linear trend to people appearing more ‘socially active’ at closer distances. Bryan et al. (2012) presented photographs of the same face identities taken at 46cm vs. 137cm distance (i.e., within versus outside their estimated personal space, respectively). They observed lower ratings of social traits (trustworthiness, competence, and attractiveness) for the images captured within the estimated personal space. Across a series of online experiments a recent study by Trifonova et al. (2024) investigated judgements of trustworthiness and dominance with videos of avatars standing near/far, approaching/receding, camera moving towards/away from the avatars. They found higher ratings of both traits when avatars were approaching cf. standing still, however no differences were found between close and distant images. They also found that ratings of dominance were higher when avatars were approaching or when the camera approached them; meanwhile trustworthiness ratings were higher during the movement of the avatars compared with when they stood still, even when the camera was moving towards them. They concluded movement of the avatars looks more naturalistic compared with stillness and that toward motion increases ratings of dominance. They speculated distance and dynamic cues might have interacted when forming these impressions. These studies suggest that physical or implied interpersonal distance affects trait judgements.

Role of faces and bodies in social judgements

Research has shown that both bodies and faces contribute independent and related information to the perception of a person. Bodies and faces share visual information about the person, such as sex, age, race, body shape, body weight, and height (Holzleitner et al., 2014; Schneider et al., 2012) and also ratings of physical attractiveness (Honekopp et al., 2007; Thornhill & Grammer, 1999). The integration and contribution of each body part has been extensively studied in the context of emotional expressions and identity processing and to a lesser extent trait attributions (see Hu et al., 2020 for review). Emotional expression research found that the perception of bodies influences the perception of faces and vice versa (Kret et al., 2013; Lecker et al., 2020), and demonstrated that bodies and faces are processed in an integrated manner (Aviezer et al., 2008). Identity processing research has shown that people tend to rely more on faces than bodies and that the influence of bodies increases in dynamic conditions (Hahn et al., 2016; O'Toole et al., 2011) and in suboptimal conditions, such as images with reduced identity information (Rice et al., 2013) and depicted at far distances (Hahn et al., 2016). For example, Hahn et al. (2016) studied the contribution of the face and body to person recognition across distances. They found that as the distance decreases, the reliance on the body decreases while reliance on the face increases when both are present. Overall, these studies indicate that both faces and bodies provide independent and related information that is integrated when processing emotion and identity, while their contribution also depends on the quality of visual cues.

Body shapes and postures have also been found to be important sources of information for making social attributions about others (Hu et al., 2018; Hu & O'Toole, 2022; McElvaney et al., 2021; Tzschaschel et al., 2022). For example, Tzschaschel et al. (2022) identified the principal components of trait impressions from body shapes and found that these impressions are best described by two dimensions: trustworthiness and dominance, similar to those made from faces. Hu & O'Toole (2022) had participants evaluate photographs of people, sometimes with obscured faces or bodies, on a range of different personality traits. Their results indicated that some evaluations appear to be made primarily from face-based information (e.g., trustworthiness), while other social judgments are based on body information (e.g., self-discipline). Most social inferences, however, reflect the integration of facial and bodily information. McElvaney et al. (2021) found that bodily appearance, specifically body mass and musculature, predicted ratings of perceived threat in others. They also found that when bodies were shown together with faces, faces had a greater influence on the final ratings. These findings show that like judgements of identity and emotion, judgements of trait impressions rely on both the bodily and facial information.

In daily life, one's consideration of socially relevant information available in the face and body is critically dependent on interpersonal distance. At substantial distances, the relatively low spatial frequency of a face on the retina will interfere with a detailed examination of features that is easier when it is close enough to be fully resolved. By contrast, whole-person information is not visually available at very close distances (i.e., the lower half of the body falls within/beyond peripheral vision). Conversely, the body is a larger, coarser stimulus for which fine-grained detail is less perceptually useful. Impressions derived from the body are therefore likely to be more resilient to the loss of high spatial frequencies at further distances (Yovel & O'Toole, 2016). Although the body seems to make an important independent contribution to person perception most past research has focused on face perception.

Role of context in social judgements

Outside of the laboratory, we rarely encounter people in isolation. Rather they appear in unconstrained environments, which can themselves be very informative about the social dynamics and contextual factors influencing behaviour. These environments provide additional cues that help us interpret interactions, such as group dynamics, cultural norms, situational context, and nonverbal signals. When we observe people at varying distances and contexts, this can interact with their appearance and alter our perception of them. Previous studies have found that our perception of others' appearance is highly affected by the background environment (Aviezer et al., 2008; Righart & De Gelder, 2008), especially when the context is attributable to the person's actions or their personality (Mattavelli et al., 2023). Extensive research has investigated the impact of background context on emotional expressions, revealing facilitated response times when the emotional context of the scene and face are congruent (Aviezer et al., 2008; Barrett & Kensinger, 2010; Kret & de Gelder, 2010; Mumenthaler & Sander, 2015; Righart & De Gelder, 2008). Some studies investigated the effects of ambient context (Aviezer et al., 2008; Barrett & Kensinger, 2010; Righart & De Gelder, 2008), these studies added affective scene as a background of a person, while others added background figures and explore the influence of social contexts (Ito et al., 2013; Kret & de Gelder, 2010; Mumenthaler & Sander, 2015). Beyond faces, Kret & de Gelder (2010) demonstrated that context affected body expression recognition, showing better recognition when bodily expressions were congruent with the emotional context of the scene. Moreover, Reschke et al. (2018) found that emotional postures and scenes impacted emotional facial expressions, with posture-scene combinations resulting in shorter response times. While the effects of context on emotional expressions are well-documented, few studies have explored the role of context in trait impressions. Recent studies highlighted the importance of face-context integration in making trustworthiness judgements (Brambilla et al., 2018; Mattavelli et al., 2021, 2022, 2023). For example, Brambilla et al. (2018) found that visual scenes influence trustworthiness categorization of faces. In threatening environments, people's faces were perceived as less trustworthy than in non-threatening background scenes. Moreover, Mattavelli et al. (2021) found that threatening contexts decreased trustworthiness attributions more when threatening stimuli were attributable to the perceived person's actions (e.g., smiling face in front of a bloody axe). These studies revealed that background context affects the person perception and threat related judgements. To the best of our knowledge, no study investigated how context affects other trait judgements (apart from trustworthiness) and how distance interacts with social and ambient background context when people are making trait impressions.

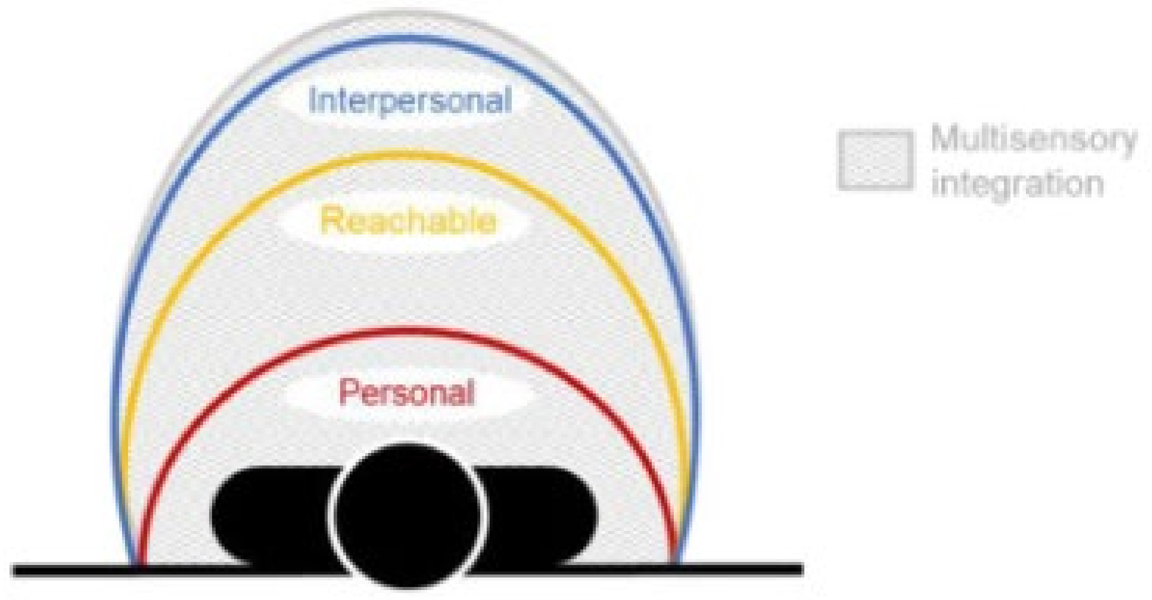
Multiple space representations

While social psychology research mainly focused on interpersonal and personal space representations with ecologically valid designs, cognitive neuroscience investigated space perception through neural representations of action spaces and divided space into peripersonal (within reach) and extrapersonal (beyond reach) mostly within highly controlled laboratory settings. Both approaches greatly contributed to the understanding of human representation of space, however this division between the two approaches has left a gap between what we know about interpersonal distance, studied in real space and cognitive and neural investigations of distance conducted in highly controlled laboratory settings, where size is often used as a proxy for distance and static isolated faces appear as the social stimuli.

Research has shown that the space surrounding the body is represented by a distinct neural network, which involves parietal and frontal brain regions. Using single cell recordings in primates they discovered many neurons within this area respond to objects presented within this space and have multisensory properties (Graziano & Cooke, 2006; Graziano & Gross, 1993; Rizzolatti et al., 1981). Additionally, some of these neurons respond preferentially to objects moving towards the body (Colby et al., 1993). In humans, this research was primarily conducted using functional magnetic resonance imaging (fMRI). These studies confirmed the frontoparietal network is responsible for creating a multisensory representation of the reachable space around the body, known as peripersonal space, crucial for interacting with the environment, allowing objects to be grasped and manipulated (Bartolo et al., 2014; Ferri et al., 2015; Grivaz et al., 2017; Holt et al., 2014). For example, Vieira et al. (2020) conducted an fMRI study where participants viewed images of faces with 'threatening' and 'non-threatening' emotional expressions, as well as images of 'non-threatening' insects and 'threatening' arachnids, either looming or receding. The findings revealed that regardless of the threat levels, both social and non-social stimuli activated the frontoparietal regions. Additionally, they found greater activations in the midbrain periaqueductal grey (PAG), which indicated the involvement of defensive mechanisms as a response to space intrusion. They also found that the functional connectivity of the midbrain areas differentiated between social and non-social stimuli and that the connectivity between midbrain and premotor cortex was stronger for approaching social stimuli and that the strength of connectivity between the midbrain and the premotor cortex was linked to preferred interpersonal distance. Holt et al. (2014) investigated responses to approaching/receding objects (faces, cars, spheres) and the connectivity between dorsal intraparietal sulcus (dIPS) and the ventral premotor cortex (PMv). They found that both areas responded more strongly to images of faces that were looming (vs receding), the response that was not observed with objects. Furthermore, they found that the two regions were functionally connected, and that the strength of their connection was related with participants' preferred personal distance and level of social activity. A recent study by Nejati et al. (2023) used transcranial direct current stimulation (tDCS) to investigate the role of the temporoparietal junction (TPJ), an area involved in social cognition processes such as self-awareness, evaluation of social norms, perspective-taking, and interpretation of social cues, in regulating the distance between self and others. They found that stimulating the right TPJ increased the perceived distance between self and others, revealing its crucial role in regulating interpersonal space. Together these studies demonstrate that distance is processed by the network that integrates sensory and social information and coordinates appropriate behavioural and autonomic responses to objects and people that are or are predicted to be in the space where interaction is likely.

Recent studies explored the links between various representations of space – interpersonal, personal, and peripersonal (Geers & Coello, 2023; Iachini et al., 2014; Zanini et al., 2021). Geers and Coello (2023) found that multisensory integration extends beyond both reachable and interpersonal spaces, potentially fulfilling the need for sensory integration during social interactions (see Figure 1.3 for a schematic representation of different spaces). Additionally, several studies suggested that reachable space serves as a spatial reference for defining social spaces (Geers & Coello, 2023; Iachini et al., 2014, 2016; Quesque et al., 2017). Previous research has shown that these spatial representations share many common characteristics, such as being modulated by threat perception (larger distances are kept from more threatening social stimuli; Ruggiero et al., 2017), individual characteristics (e.g., larger distances preferred by highly anxious individuals; Iachini et al., 2015), and various social factors (e.g., larger distances kept to the uncooperative others (Teneggi et al., 2013) and people that are perceived as immoral (Pellencin et al., 2018)).

Figure 1.3. Schematic representation of distinct spatial representations



Note. Geers & Coello (2023)

Role of attention and arousal in distance perception

Distance does not only affect visual cues, but also determines the intensity and relevance of social interactions, affecting attention and arousal. We attend most closely to those individuals that are near to us (cf. far) and therefore most likely to be behaviourally relevant: as a potential friend or foe (e.g., Martin et al., 2021; Pilz et al., 2011). Studies investigating the underlying physiological mechanisms of proximity found responses indicative of stress and arousal. These serve as markers of autonomic nervous system activation in reaction to relevance – closeness and direction of approach (Candini et al., 2021; Evans & Wener, 2007; McBride, 1965), and prolonged eye contact (Rinck et al., 2010; Wieser et al., 2010), underscoring the body's arousal response to relevant events in social contexts. For example, Candini et al. (2021) investigated skin conductance responses (SCR) when a confederate was approaching or receding and when they were standing near or far, and found greater levels of arousal in the more relevant conditions (approaching compared with receding and near compared with far). Furthermore, studying event related potentials (ERPs), Martin et al. (2021) found that fearful faces capture attention more effectively when presented within reachable space as opposed to farther away and that attention is greater for faces that appear to be looming compared to those receding (Martin et al., 2021). All these studies have shown proximity is related to attention and arousal and that people near us or directed towards us are more behaviourally relevant to us.

The amygdala and insula brain regions related to regulating arousal and vigilance, become more active with proximity, arousal, and threat intensity (Kennedy et al., 2009; Mobbs et al., 2010; Schienle et al., 2015, 2017; Vieira et al., 2017, 2020). Investigating proximity-related threat responses using fMRI, Mobbs et al. (2010) found that the PAG, amygdala and insula were more activated when a tarantula was near or approaching participants' feet compared with when it was far or receding. In a study using real social distance, Kennedy et al. (2009) identified increased amygdala activation in response to when individuals were standing near a participant in the scanner, compared with further away. They also reported disrupted personal space processing in a patient with amygdala damage, who felt no discomfort with others' proximity. Using images of faces, studies found increased amygdala and insula activation in response to approaching versus static and receding faces (Schienle et al., 2015, 2017; Vieira et al., 2017). A recent study by Dureux et al. (2022) investigated space perception in patients with lesions in the medial temporal lobe (MTL), those with and without damage to amygdala. They found similarly altered perceptions of interpersonal space in all patients, regardless of whether the amygdala was lesioned. This indicates a broader involvement of the MTL in regulation of interpersonal space. Together these findings indicate that proximity engages a system, which evaluates the behavioural relevance of a social stimulus, and prepares people for appropriate defensive actions to avoid or minimize harm (Lloyd, 2009).

Another measure of attentional engagement and allocation of attention to relevant stimuli is the suppression of the electroencephalographical (EEG) activity (i.e., decreased activity) in the alpha band (8-13 Hz of the frequency spectrum; Bacigalupo & Luck, 2022; Perry et al., 2016). This metric is therefore a potential correlate of attention allocation during interpersonal interactions, that may vary with distance. Early investigations (Adrian & Matthews, 1934; Berger, 1929) revealed the dynamic nature of EEG amplitude in the alpha-band, with increases observed during introspective or unfocused states and decreases when attention is directed externally (see also Gallotto et al., 2020; Heyselaar et al., 2018). Furthermore, a recent study by Starita et al. (2023) found a negative correlation between skin conductance response and alpha power for threatening stimuli. Using the dynamics of alpha suppression Perry et al. (2016) found a stronger suppression response to imagined human approaches compared with inanimate objects and stronger suppression among individuals with heightened sensory sensitivity. Additionally, a study by Heyselaar et al. (2018) revealed greater alpha suppression with familiar (i.e., previously interacted with) avatars. Together these studies underscore the utility of alpha suppression when exploring the nuanced dynamics of behaviourally relevant events, such as interpersonal distance and similar social constructs.

Concluding remarks

Interpersonal space is a ubiquitous component of all social interactions. It powerfully influences and interacts with social cognitive processes through different low-level and high-level mechanisms. People that are closer are more behaviourally and socially relevant to us, i.e., their actions have higher consequences for us and are more likely directed towards us. At the same time distances affect the type and quality of sensory information that is available to us, e.g., spatial frequency information, proportion of the body visible. Despite this, distance is frequently overlooked in lab-based research.

Aims and objectives

Understanding the mechanisms of interpersonal space and how it relates to social interactions is especially important in the current climate, with increasing population density in urban areas and reduced opportunities for physical and social interactions due to technological advancements, particularly since the COVID-19 pandemic. Similarly, it is crucial to investigate the mechanisms of trait impressions as these judgements have the power to shape the dynamics of our social interactions with others both positively and negatively (e.g., encouraging trust and cooperation vs. stereotyping and discrimination).

With the research presented in this thesis I sought to improve our understanding of the role played by physical space in our perception of, and responses to trait attributions (e.g., first impressions) and underlying neural mechanisms of interpersonal distance. I aimed to use relatively ecologically valid methods to capture the cognitive processes underpinning realistic social interactions, in real time and space. I aimed for these designs to enhance the understanding of how distance influences social and cognitive processes and offer new avenues for exploration in social cognition research.

Chapter 2: The role of interpersonal distance in formation of trait impressions

Chapter summary

Across a series of 5 experiments, this chapter investigates the role played by interpersonal distance in a variety of trait and aesthetic judgements to better understand the contextual factors that affect person perception in the real world. Our social appraisals of other people reflect the rapid integration of available visual information with broader contextually driven information (e.g., intentions). Interpersonal distance often affects both information availability and social context, yet how it changes trait impressions is less understood. Here we addressed this question by developing and validating a new experimental paradigm that allowed us to manipulate perceived interpersonal distance from life-size images of people in a highly controlled manner (Experiment 1; see also Chapter 5) while assessing the impact of distance on the emotional arousal ratings elicited by life-sized images of people. Next, we assessed participants' attributions of attractiveness, competence, dominance, and trustworthiness of people when they appeared at near (1m) and far (4m) distances (Experiment 2). We found that proximity amplified the magnitude of all impressions, but this was significantly weaker for aesthetic attractiveness judgements. We then investigated the roles of two visual cues of distance (stimulus size in Experiment 3; spatial frequency composition in Experiment 4) in trait attribution while holding observer-target distance at 1m. We found that manipulating stimuli size and spatial frequency produced broadly similar results to the distance manipulation, suggesting that the role of interpersonal distance was mediated by perceptual factors (e.g., size, spatial frequency). Finally, we conducted an experiment (Experiment 5) where participants rated images of people with either their faces or bodies covered to investigate the individual contribution of each body part to the whole person perception. Our findings revealed that ratings for images of bodies, faces, and whole persons were highly correlated across all four traits and at both near and far distances. This indicates that people could make reliable trait judgments from both the body and the face, regardless of distance. Furthermore, the effects of distance on trait evaluations for both body-only and face-only images were similar to those for whole-person images. Together, these results demonstrated the crucial role of interpersonal distance in impression formation and underscored the limitation of conventional paradigms of impression studies. Presenting other people as small size images on a computer screen often implies an interpersonal distance beyond space in which most real-life social interactions occur.

Introduction

Given that encounters with others at near vs far distances contain different sensory information and afford different types of social interactions, we hypothesised that reliable differences may exist when people form their impressions of others appearing at relatively near and far interpersonal distances. To test this hypothesis, we conducted five experiments to systematically investigate how interpersonal distance contributes to social perception of others in a controlled, but also relatively ecologically valid setting.

To characterise appraisals of a wide range of realistic social stimuli, while maintaining high levels of experimental control, we displayed life-sized, whole-person photographs of people on a projector screen to be rated at two interpersonal distances. 'Near' stimuli were presented at a distance of 1m from participants. This distance reflects the average space that the local (English) population prefers to keep from strangers (Sorokowska et al., 2017) and corresponds to the region of 'personal space' where the majority of most relevant social interactions are likely to occur (Hall, 1966). Furthermore, we were looking for a distance at which the body would still be visible and could play a role. By contrast 'far' stimuli appeared 4m away. At this range, the social relevance of an individual is much lower and they are considered to be in public space (Hall, 1966).

We focussed on four trait dimensions commonly associated with first impressions: trustworthiness, attractiveness, competence, and dominance. We broadly hypothesised that ratings of all these traits would differ between the near and far distances, but also that there might be variability in the magnitude of effects observed across traits. For example, we reasoned that evaluations of dominance and competence might be particularly amplified for individuals at relatively closer distances, because that is where/when they are most critically considered as potential assailants or assistants. By contrast, evaluations of someone's trustworthiness or attractiveness might be important across a larger spatial range, because they are important for our safety (trustworthiness) and mate-seeking behaviour (attractiveness), which are both relevant to consider near and far to the extent that they may impact upon our decision to stay close or move away from an individual. If this is the case, then we would expect relatively weaker distance-related modulation of these trait impressions.

Research questions

Does physical interpersonal distance affect how people are rated on trait impression dimensions (attractiveness, competence, dominance, trustworthiness)?

Is the modulation of real/physical distance similar to that associated with distance proxies (size and spatial frequency)?

How do bodies (with covered faces) and faces (with covered bodies) contribute independently to impression formation?

Are there differences in the levels of perceived emotional arousal at near and far distances?

Research considerations

The primary aim of this experiment was to present whole-person images of individuals and examine the effects of distance on various trait dimensions. To achieve this, we aimed to design an experiment that would allow for the presentation of large/life-sized images and the variation of real physical distance. The first consideration was the size of the room, because the design of some of our experiments required participant-stimulus distances of 8 meters. Given that room size affects space perception (White, 1975), we worked with Estates and our technical team at UEA to identify (and hold on to) a room large enough to accommodate the maximum required length, for all the linked studies in the chapter.

Another challenge associated with the studies in this chapter was presenting life-sized images of people. We considered several options for this. Virtual Reality would allow us to manipulate distance, include dynamic stimuli, and immerse participants in the environment with the ability to interact with avatars. However, developing such an environment is time-consuming and costly. Additionally, we preferred presenting a widely varying set of real people rather than avatars, due to the limitations of current technology in achieving realistic avatar appearances. Using a large monitor was another option, but the costs of such monitors were too great for the use of a single project. We decided to use a projector and projector screen. To allow participants to stand very near and unobstructed to the images they were rating, we opted for rear projection. This decision further restricted our room options. The room needed to be even larger and had to be dark enough for the projection to have sufficient contrast and brightness.

We found it important for participants to stand during the experiments for several reasons. First, we believed standing would enhance their engagement with the images and more closely mimic real social interactions, as they would be at their normal height and at a similar eye level. This setup could facilitate more natural engagement with the images of people. Second, we wanted to avoid any obstructions between participants and the stimuli. A desk or another object could create a sense of separation, impacting participants' space perceptions and potentially altering the experimental results.

Another consideration was the choice of distances in our research. We aimed to select distances that allowed participants to observe the whole person (both body and face) while minimizing the general lack of visual cues at farther distances. We also wanted the participants to feel like they could exhibit approach or avoidance behaviours, ensuring they felt unobstructed in moving towards or away from the stimuli. The near distance was set at 1m, an approximate conversational distance, representing the average distance at which most everyday interactions occur. We assumed this distance would be more socially relevant compared with 4m, which was chosen as the far distance. The differences in emotional arousal at these distances were also verified in Experiment 1.

Another challenge was finding an appropriate stimulus set. Since we wanted to present life-sized, whole-person images, we required very high-resolution colour photographs that did not suffer from being presented at that large scale. This proved difficult, because most research typically uses small images of people (suitable for computer screens) or isolated images of faces. Fortunately, we identified a stimulus set in the literature that seemed appropriate and contacted the lead author (Dr Ian Stephen), who kindly provided us access (and joined some of the work as a collaborator). These images were originally created to study body perception in individuals with body image distortion. The set was large enough to allow the presentation of non-overlapping images for each trait dimension and varied in body shapes and ethnicities. However, these stimuli had an unusual (uniform) posture, with arms away from the body and palms upturned, to allow visibility of arm thickness. Despite the potential influence these postures could have had on trait perception, our focus was on how different people are rated at various distances, not on how a specific person was rated. Therefore, we believed it was appropriate to use them in our studies.

When considering the ecological validity of a study investigating social inferences, we recognize that making explicit ratings is not a typical everyday behaviour. However, the trait impression dimensions that we used in our study are grounded in research that employed more naturalistic methods (Oosterhof & Todorov, 2008). In these studies, participants were asked to generate unconstrained descriptions of faces, which were then categorized into trait dimensions. Therefore, although people rarely make explicit judgments in everyday life, we found this approach to be acceptable for our experiments because it aligns with established methodologies in the field.

Finally, in one of our follow-up studies in this chapter (Experiment 3b) we sought to investigate the effect of distance-related differences in spatial frequency on trait impressions. To that end we sought to manipulate the appearance of our images to simulate the exact spatial frequency of images at 4m. However, we were unable to find an exact formula to convert broadband spatial frequency to the frequency of a coloured image at that distance. As a result, we used an approximation by applying Gaussian smoothing in Photoshop.

Experiment 1: Emotional arousal and interpersonal distance

In our first experiment we sought evidence of variability in the social salience of our projected person images when viewed at specific near versus far distances, (i.e., those used in Experiments 2 and 3: 1m and 4m). Levels of arousal are typically higher when standing close to a (real) person compared with further away (e.g., Candini et al., 2021; Evans & Wener, 2007). We sought to replicate this pattern with participants' ratings of emotional arousal in response to our *projected* stimuli and chosen distances.

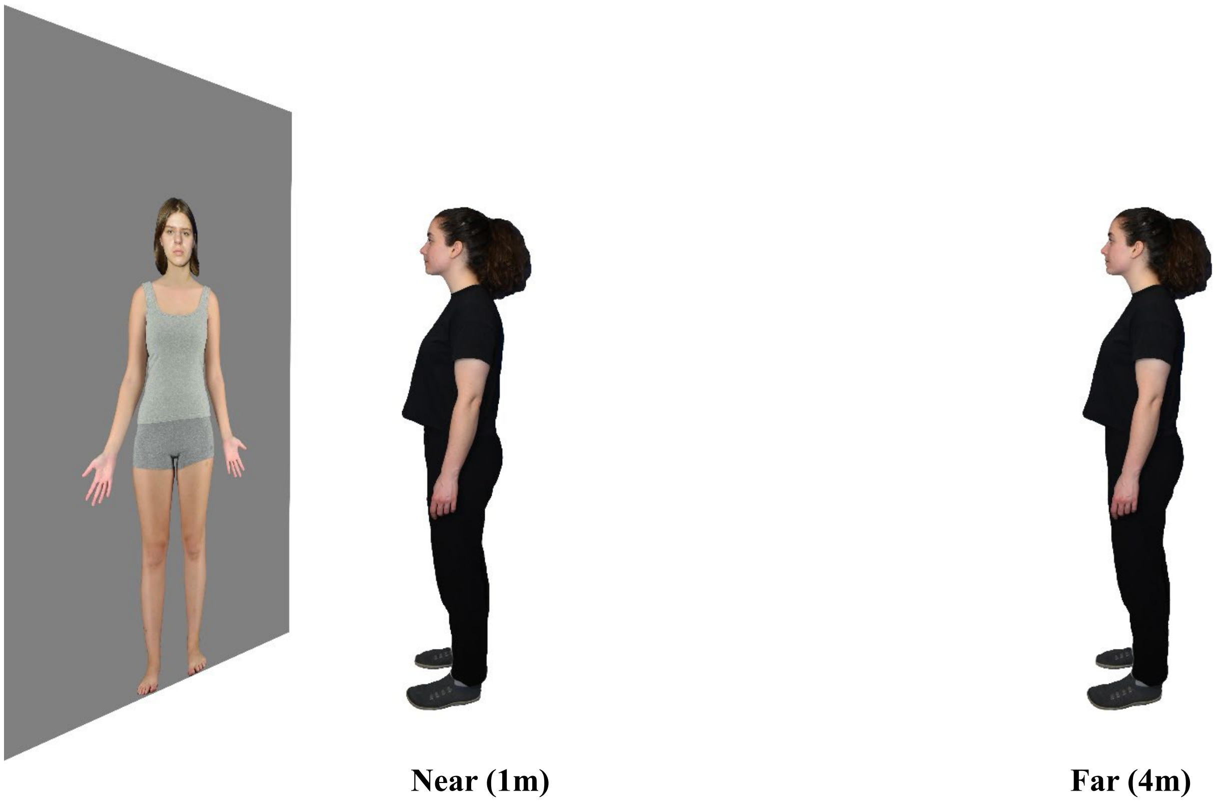
Methods

Participants. Twenty-four participants (M = 19.3 years, SD = 1.2, range from 18 to 22 years; 19 female, 5 male, 0 non-binary) completed the study. We collected data from participants in March 2023, after taking part in the Experiment 4 reported here (reported first to improve the clarity of the logic of our studies). The procedure of all experiments reported in this chapter was approved by the local Ethics Committee (reference code: ETH2324-0775).

Stimuli and Apparatus. This and subsequent experiments reported here were programmed using Gorilla Experiment Builder (gorilla.sc).

Figure 2.1. Schematic representation of the experimental apparatus

Participants were standing at 2 distances (1 and 4m) from the projector screen, onto which images of people were projected.



The stimuli consisted of high resolution (1794 x 4494 pixels) images of 96 adults of different ages and ethnic backgrounds from an existing database (for more detail see Stephen et al., 2016). Individuals are pictured wearing standard close-fitting grey singlets and shorts and facing forward in a standard posture - with their arms by their side - and a neutral facial expression. Each image was positioned on a grey background, so that the individual appeared to be approximately standing on the same ground plane. They appeared at realistic life sizes: males at a standard UK average height of 175cm, and females 160cm (NHS, 2019). These images were projected onto a 2.3m (height) × 1.5m (width) white screen (Optoma GT1080 projector, 2800 Lumens (ANSI), working resolution of 1080 x 1920 pixels). This projector frame and set up was the same for all experiments reported here. Near-distance images subtended vertically 84° of visual angle, and far-distance images 25° when participants stood at 1 and 4 meters away respectively (for schematic representation of the experiment, see Figure 2.1).

Design & Procedure. Participants were asked to rate their emotional arousal while viewing images of people on a screen. They assessed their arousal at 1 meter (near) and 4 meters (far) from the screen. Images appeared for 2500ms; as soon as the image appeared, the participants could take as long as they needed to make their rating using a Likert scale (ranging from 1, meaning bored/calm – 7, meaning excited/alert), which was presented at the top of the image (descriptive labels were positioned on both side of the scale). They were asked to use the whole range of the scale. Their rating was followed by a 500ms interstimulus interval (ISI). Responses were made using a mouse, which rested on a platform that was moved with them to the different rating locations. Each stimulus identity was presented at the near and far distance, a new random order for each participant and condition. Order of standing distances was counterbalanced across participants.

Results & Discussion

We conducted item-level and subject-level analyses to understand both how participants rated the stimuli at different distances, and how the identities of the stimuli were rated at different distances, for consistency with the logic of subsequent analyses. Both analyses indicated that participants' emotional arousal ratings were significantly higher when the projected images appeared at the near (item level: 3.13 [95% CI: 2.99, 3.26]; subject level: 3.13 [95% CI: 2.86, 3.39]) compared with the far distance (item level: 2.88 [95% CI: 2.76, 3.00]; subject level: 2.88 [95% CI: 2.59, 3.18]), item analysis: $t(95) = 6.03$, $p < .001$, $d = .62$ [95% CI: -1.36, 2.60], subject analysis: $t(23) = 2.67$, $p < .014$, $d = .56$ [95% CI: -1.49, 2.61]. This result was consistent with distance-related modulation of arousal responses to real people (Candini et al., 2021; Evans & Wener, 2007; Ferri et al., 2013), providing further evidence that space information plays a critical role in social perception of other people. People closer to us are perceived as more behaviourally relevant because we are more likely to interact with them and their actions bare more consequences for us. This finding also demonstrated that, just like seeing people in real life, viewing life-sized images of people could elicit higher arousal when they appeared at a near than at a far distance.

Experiment 2: Interpersonal distance modulation of trait impressions

Experiment 1 established that similarly to real people, whole-person images were associated with higher level of arousal of our participants and stimuli when these images appeared to be close by compared with far away. In Experiment 2, we further investigated how interpersonal distance modulates high-level social perception of other people. We presented life-size images of people and asked participants to rate attractiveness, competence, dominance, and trustworthiness when standing at a near (1m) versus far (4m) interpersonal distance. We hypothesised that varying proximity would modulate impressions – and that effects might vary between different traits. Specifically, we considered that impressions of competence and dominance might be particularly affected by changes in distance, because these attributes are related to other people performing tasks which often requires proximity – at closer distance the perception of others might be amplified. By contrast, we anticipated that trustworthiness (how helpful or harmful someone may be) and attractiveness (related to mate seeking behaviour) might be relevant across a greater range of distances, so they would hold more stable.

Methods

Participants. Sixty participants (M = 30.4 years, SD = 17.3 years, range from 18 to 47 years; 42 female, 16 male, 2 non-binary) completed this task. One participant was excluded from the data analysis due to poor engagement. In the follow up experiments the sample size of 31 participants is used, due to evidence that that number is sufficient to obtain stable averages for the targeted traits (95% confidence at +/- 0.50 values on a 1-7 Likert scale) (see Hehman et al., 2018). This experiment was pre-registered (https://aspredicted.org/937s7.pdf), however we deviated from the pre-registered analyses to better address our research questions. Data was collected June – October 2022.

Stimuli & Apparatus. Drawing from the same image set used in Experiment 1 we selected high and low-rated exemplars for attractiveness, competence, dominance, and trustworthiness based on pre-ratings collected online. Seventy-two participants aged 18 to 26 years (M = 20.7 years, SD = 3.7; 64 female, 8 male, 0 non-binary) pre-rated 159 images for attractiveness, competence, dominance, or trustworthiness (between subjects). The selected images were four, non-overlapping stimulus sets (one for each trait), each comprising 12 male and 12 female stimuli (96 images in total), choosing the 6 highest and 6 lowest rated on each trait for each gender.

Design & Procedure. Participants were asked to stand at near (1m) and far (4m) locations (marked on the floor) from a projector screen onto which life-sized images (same height and visual angles as Experiment 1) of people were projected (for schematic representation of the design see Figure 2.1). Detailed descriptions of characteristics were given just before the block started. Images appeared for 2500ms; as soon as the image appeared, the participants could take as long as they needed to make their rating using a Likert scale (ranging from 1, meaning low on a trait to 7, meaning high on a trait). They were asked to use the whole range of the scale. Their rating was followed by a 500ms intertrial interval (ITI). Each participant rated all four traits in separate blocks (order randomised, with a new order for each distance block; order of gender was randomised within each trait).

Data Analysis. Initial tests revealed there was no main effect of distance for any of the traits (see Table 2.1). This led us to additional exploratory analyses, in which we correlated the baseline rating of people (choosing ratings at far distance) with the effect of distance (the difference between the ratings at near and far) on the item level to observe the subtle variations of different stimuli with distance. We treated ratings at far distance as baseline and tested how getting closer to people changed impressions. These analyses revealed that the ratings of different stimuli changed differently with distance. To take into account the variation of stimuli and participants, data from mixed effect models are presented, which include our fixed effects of interest along with the participants and stimuli as random factors. Readers may wonder whether the necessary yoking of the baseline measure (i.e., far) with the effect of distance (i.e., near minus far) might contaminate our effect measure and yield possibility of voodoo correlations. See Appendix D for extended discussion why we believe this is not an issue.

Initially the mixed effects model used ANOVAs to examine the effects of *trait* (attractiveness, competence, dominance, and trustworthiness), '*baseline stimulus ratings'*, which served to index impressions of each stimulus identity at one of the distances (we opted to use far distance ratings, given that these are most comparable to extant research in terms of stimulus size/implied distance), along with their *interaction* on distance-related modulation of impressions (calculated as a difference score: far ratings minus near ratings for each item/stimulus). We examined these factors in a single model to estimate their overall contribution to distance related modulation of impressions. To account for potential variability associated with individual stimuli and participants they were specified as random factors in the model.

To examine how the distance would impact individual traits and to be able to compare them (whether some traits would change more with distance than others), linear mixed effects models were produced for each trait, with distance-related modulation of impressions (i.e., difference between near and far ratings) serving as the outcome variable and baseline stimulus ratings (i.e., far rating) serving as the predictor variable. Participant and stimulus were again specified as random factors in the model. We then ran linear mixed effects models for each trait separately, to compare the relationships between baseline stimulus ratings and the distance-related modulation of impressions between traits. Once again, distance-related modulation of impressions (i.e., difference between near and far ratings) served as the outcome variable and baseline stimulus ratings (i.e., far rating) served as the predictor variable. Participants and stimuli were again specified as random factors in the model. Confidence intervals were compared to establish whether the traits were different between each other (non-overlapping 84% confidence intervals can be considered equivalent to significance at the 5% level; Payton et al., 2003). The 84% confidence intervals of the coefficients of the slopes were estimated using 1,000 bootstraps (bias-corrected accelerated method). Statistical analyses reported in this chapter were carried out using RStudio 2023.06.1 (RStudio Team, 2020), using packages *tidyr* (Wickham, 2023), *lme4* (Bates et al., 2015), *dplyr* (Wickham et al., 2023), *ggplot2* (Wickham, 2016), *lmeresampler* (Lloyd, 2023), and *emmeans* (Lenth, 2023) and IMB SPSS Statistics (Version 25).

Results

Table 2.1 provides descriptive statistics detailing the stimulus ratings on each of the four targeted traits. No main effects of distance were found for the four traits.

Table 2.1. Means and 95% confidence intervals of the four traits at Near and Far distance

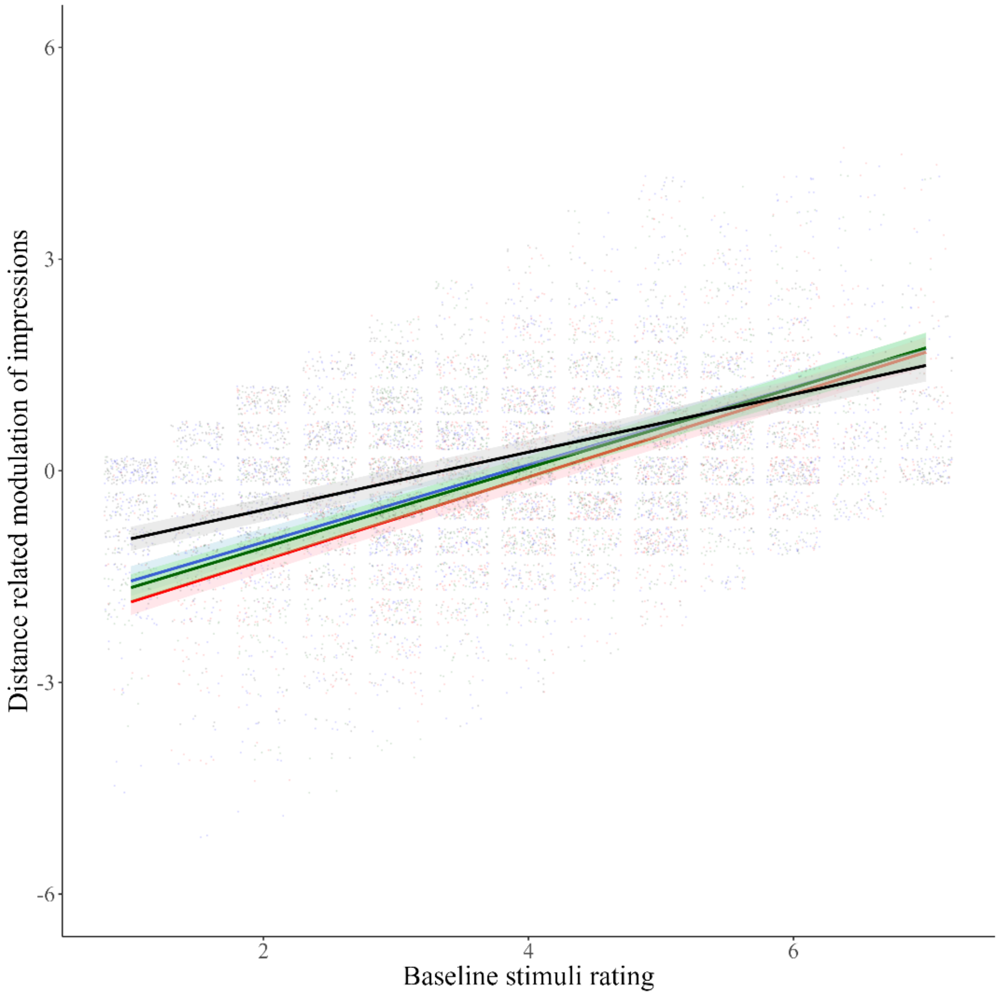
	Near	Far	Paired t-tests
Attractiveness	3.51 [3.43, 3.60]	3.57 [3.49, 3.66]	$t(58) = .91$, $p = .364$, $d = .12$ [-1.88, 2.11]
Competence	4.15 [4.07, 4.22]	4.11 [4.04, 4.18]	$t(58) = -.55$, $p = .582$, $d = -.07$ [-2.06, 1.92]
Dominance	3.83 [3.75, 3.91]	3.80 [3.72, 3.89]	$t(58) = -.34$, $p = .737$, $d = -.04$ [-2.04, 1.95]
Trustworthiness	3.94 [3.86, 4.01]	3.92 [3.85, 3.99]	$t(58) = -.30$, $p = .765$, $d = -.04$ [-2.03, 1.95]

Note. Values in square brackets represent 95% confidence intervals.

Both the overall model and the separate models for each of the traits indicated that as baseline stimulus ratings increased (i.e., higher ratings), the distance-related modulation was increased for all traits. People's baseline ratings of all traits were amplified at close distances. Modelling of the different traits separately revealed that attractiveness ratings were significantly different to all the other traits. The estimate of attractiveness was less positive than the other traits, which means that people's impressions of attractiveness were more stable across distances than their impressions of the other three traits. The mixed effects modelling analysis revealed significant effects of trait, $F(3, 83.88) = 9.15$, $p < .001$, $\eta_p^2 = .25$ [95% CI: .14, .37], baseline stimulus ratings, $F(1, 96.68) = 704.56$, $p < .001$, $\eta_p^2 = .88$ [95% CI: .76, .94] and their interaction, $F(3, 78.19) = 8.01$, $p < .001$, $\eta_p^2 = .24$ [95% CI: .13, .36]. The model showed that distance-related modulation of impressions was significantly predicted by trait (i.e., whether someone was considering attractiveness, trustworthiness, competence, or dominance), baseline stimulus ratings (i.e., the extent to which an individual stimulus had high or low ratings on the given trait irrespective of distance) and their interaction.

Figure 2.2 shows the ratings of each participant of each stimulus for the four traits. It depicts the relationship between distance related modulation of impressions and baseline stimuli ratings. The relationships for individual traits are presented numerically in Table 2.2. The positive slopes (β) indicated positive relationships between distance related modulation of impressions and baseline stimuli ratings. T-tests showed that the slopes were significantly different from zero. Together, these results showed a substantial increase in the distance-related modulation of impressions as baseline ratings increased. This means that – perhaps unsurprisingly - increasing interpersonal proximity amplified first impressions (e.g., trustworthy looking people seemed even more trustworthy near, untrustworthy looking people seemed even less trustworthy near). This effect was qualified by the interaction between trait and distance related modulation of impressions, showing that attractiveness was less affected by distance than all the other traits.

Figure 2.2. Relationship of distance-related modulation of impressions and baseline ratings for the four traits



Note. Black line = attractiveness; Red line = competence; Blue line = dominance; Green line = trustworthiness.

Comparing the confidence intervals of the traits, we found the distance-related modulation was different for attractiveness compared with the other traits – people's ratings of attractiveness were more similar at near and far distance compared with the other three traits. The positive relationship observed was significantly less steep for attractiveness compared with the other three traits.

Table 2.2. Distance related modulation of the four traits

Trait	β	SE	84% CI		One sample t-tests
			LL	UL	
Attractiveness	.41	.02	.36	.45	t(25.59) = 18.23, p < .001, d = 3.51 [3.13, 3.89]
Competence	.59	.03	.53	.64	t(27.02) = 21.48, p < .001, d = 4.06 [3.69, 4.43]
Dominance	.55	.02	.50	.59	t(28.09) = 22.49, p < .001, d = 4.18 [3.81, 4.54]
Trustworthiness	.57	.03	.52	.61	t(27.19) = 20.55, p < .001, d = 3.88 [3.51, 4.25]

Note. β and SE represent the mean and standard error of the slope for each trait. Confidence intervals (CI) are used to compare differences in the slopes, where non-overlapping 84% CIs indicate a significant difference at p < .05. T-tests are used to determine if the slope is significantly different from 0. Values in square brackets represent 95% confidence intervals of the effect size.

Discussion

The results of this experiment revealed that impressions of others were systematically amplified with increased proximity. Crucially, this modulatory effect of distance operated differently across traits. For example, ratings of attractiveness were relatively more similar (i.e., less amplified) across distances compared with ratings of competence, dominance, and trustworthiness. This finding could indicate that relatively more social (cf. aesthetic) judgements were more affected by distance. One possibility is that judgements on more social aspects (e.g., competence, dominance and trustworthiness) are more sensitive to distance (i.e., when unfamiliar people are approaching us) than that on more aesthetic judgements of other people (e.g., attractiveness), for which distance might make less of a difference. Alternatively, people may rely more on facial information to make judgements of competence, dominance, and trustworthiness, which is less visible from afar, while attractiveness is also powerfully influenced by cues in the body (Hu & O'Toole, 2022; Honekopp et al., 2007; Thornhill & Grammer, 1999).

Experiment 3: Size modulation of trait impressions

In the following two experiments (Experiment 3 and 4), we tested whether the effect of interpersonal distance on trait attribution is driven by two perceptual cues to distance perception: visual size and spatial frequency information.

Firstly, we manipulated stimulus size as a proxy for distance manipulation and examined whether the effect of size change mirrors that observed in Experiment 2. To this end, we kept viewing distances constant at near (1m) and simulated the visual appearance of a stimulus at the far distance (contrasted with near distance) by presenting stimuli at a smaller size: matching the visual angle of the far stimuli in Experiment 2. If the effect of distance on trait perception is mediated by perceptual information like stimulus size, then we should expect a similar pattern of response as in Experiment 2. In contrast, if the effect of distance is purely social in nature, changing stimuli size would not have the same influence on impression as physically moving close or away from other people.

Methods

Participants. Thirty-two participants (M = 24.38 years, SD = 6.04, aged from 18 to 33 years; 23 female, 9 male, 0 non-binary) completed the task. Here and for Experiment 4, this sample size was targeted given evidence that data from 31 participants is sufficient to obtain stable averages for the targeted traits (95% confidence at +/- 0.50 values on a 1-7 Likert scale) (see Hehman et al., 2018). Data was collected May – November 2023.

Apparatus & Stimuli. The stimulus set was the same as described in Experiments 1b and 2. Here the ‘large size’ images matched the life-size images used in Experiment 2. The ‘small size’ images were reduced to match the visual angle of images presented at the far distance in Experiment 2 – heights 26° for men (46cm) and 22° for women (38cm; for stimuli examples see Figure 2.3).

Figure 2.3. Representative examples of Large and Small stimuli

Note. Representative examples were not used in the study.

Procedure. Participants stood 1m from the projector screen and rated the same four traits on images of people when presented with the large and small sizes in separate blocks. All other aspects of the procedure were the same as in Experiment 2.

Results

We conducted the same data analyses as reported for Experiment 2, using image size (large, small) as a proxy for distance (near, far) and using rating of small-size stimuli as the baseline condition. Table 2.3 details the descriptive statistics associated with ratings of large versus small images on the four targeted traits. No main effects of size were found for the four traits.

Table 2.3. Means and 95% confidence intervals of the four traits with Large and Small image sizes

	Large	Small	Paired t-tests
Attractiveness	3.44 [3.33, 3.56]	3.46 [3.35, 3.58]	t(31) = -.22, *p* = .828, d = -.04 [-.39, .31]
Competence	3.93 [3.83, 4.03]	4.02 [3.93, 4.11]	t(31) = -1.44, *p* = .161, d = -.25 [-.60, .09]
Dominance	3.75 [3.64, 3.86]	3.59 [3.48, 3.69]	t(31) =1.85, *p* = .074, d = .33 [-.02, .67]
Trustworthiness	3.65 [3.56, 3.75]	3.69 [3.59, 3.79]	t(31) = -.42, *p* = .680, d = -.07 [-.42, .27]

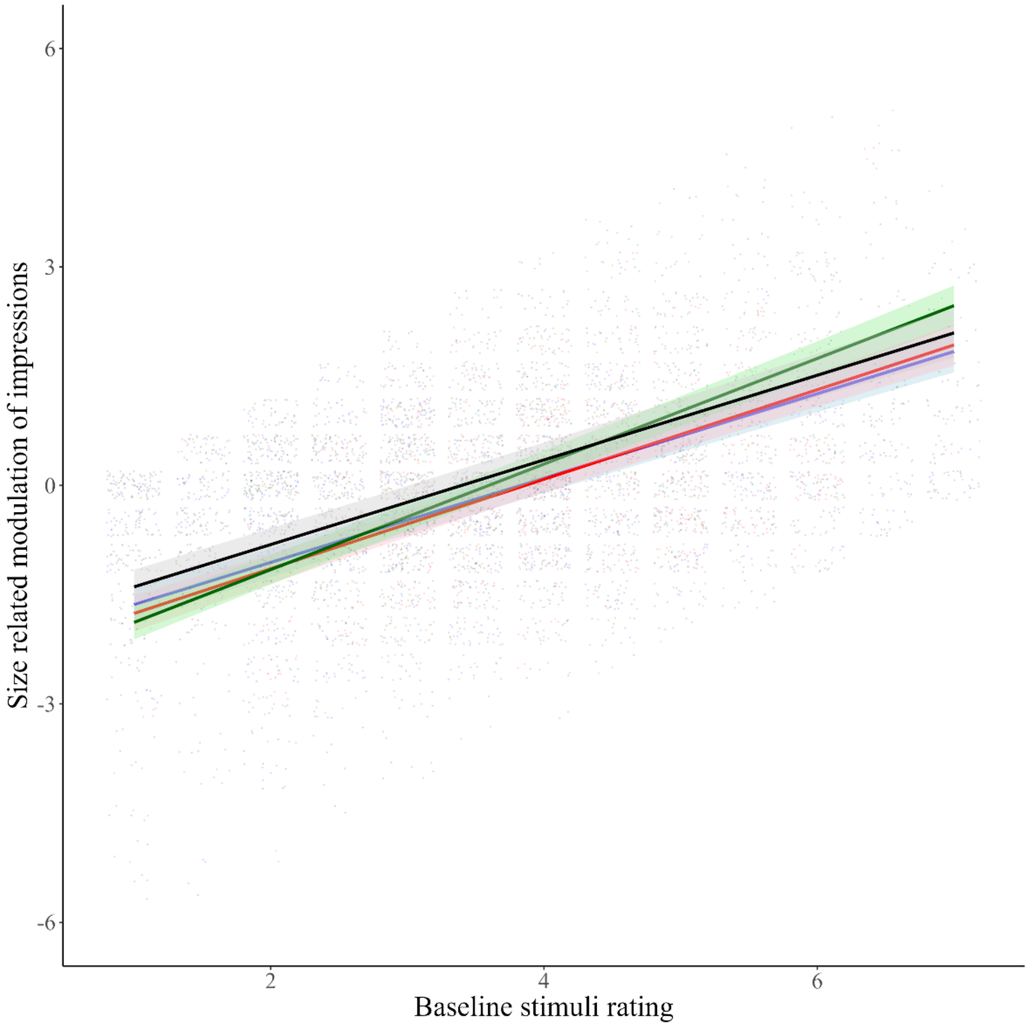
Note. Values in square brackets represent 95% confidence intervals of the effect size.

Both the overall model and the separate models for each of the traits indicated that as baseline stimulus ratings increased the size-related modulation is increased. People's baseline ratings of all traits were amplified with large images. Modelling of different traits separately revealed that trustworthiness ratings were significantly different to all the other traits. The estimate of the slope of trustworthiness was more positive than the slopes of the other traits, which means that people's impressions of trustworthiness were relatively more amplified with larger images.

The linear mixed effects modelling analysis revealed significant effects of trait, $F(3, 75.30) = 3.52$, $p = .018$, $\eta_p^2 = .12$ [95% CI: .05, .20], baseline stimulus ratings; $F(1, 51.14) = 488.26$, $p < .001$, $\eta_p^2 = .91$ [95% CI: .83, .98]; and their interaction, $F(3, 68.26) = 4.89$, $p = .004$, $\eta_p^2 = .18$ [95% CI: .09, .26]. The model showed that size-related modulation of impressions was significantly predicted by trait (i.e., if someone was considering attractiveness, trustworthiness, competence, or dominance), baseline stimulus ratings (i.e., the extent to which an individual stimulus had high or low ratings on the given trait irrespective of size) and their interaction.

Figure 2.4 shows the ratings of each participant of each stimulus for the four traits. It depicts the relationship between size-related modulation of impressions and baseline stimuli ratings. These relationships are presented in Table 2.4. The positive slopes (β) indicated a positive relationship between size related modulation of impressions and baseline stimuli ratings. T-tests showed that the slope was significantly different from zero. Together, these results have shown a substantial increase in the size-related modulation of impressions as baseline ratings increased. This means that increasing image size amplified first impressions (e.g., trustworthy looking people appeared even more trustworthy when large, untrustworthy looking people appeared even less trustworthy when large). This effect was again qualified by the interaction between trait and size related modulation of impressions, showing that trustworthiness was more affected by size than all the other traits.

Figure 2.4. Relationship of size-related modulation of impressions and baseline ratings for the four traits



Note. Black line = attractiveness; Red line = competence; Blue line = dominance; Green line = trustworthiness.

Comparing the confidence intervals of the traits, we found the size-related modulation was significantly stronger for trustworthiness compared with the other traits. This means that people's ratings of trustworthiness were more amplified with larger images compared with the other three traits.

Table 2.4. Size related modulation of the four traits

Trait	β	SE	84% CI		One sample t-test
			LL	UL	
Attractiveness	.58	.04	.52	.63	t(25.47) = 15.31, p < .001, d = 3.00 [2.62, 3.39]
Competence	.62	.04	.55	.67	t(24.53) = 13.70, p < .001, d = 2.69 [2.30, 3.07]
Dominance	.58	.03	.53	.62	t(27.65) = 16.71, p < .001, d = 3.10 [2.74, 3.47]
Trustworthiness	.72	.04	.67	.77	t(26.52) = 18.15, p < .001, d = 3.43 [3.06, 3.80]

Note. β and SE represent the mean and standard error of the slope for each trait. Confidence intervals (CI) are used to compare differences in the slopes, where non-overlapping 84% CIs indicate a significant difference at p < .05. T-tests are used to determine if the slope is significantly different from 0. Values in square brackets represent 95% confidence intervals of the effect size.

Discussion

Changing stimulus size produced a similar effect to the changes of physical inter-personal distance. Trait attributions of other people were amplified when tested with larger-size images. Trait ratings for trustworthiness were even more amplified than the other traits with larger sizes. With larger images, people were rated even more trustworthy than with smaller images. These results indicated that size and distance had a similar modulation of trait impressions, although they affected some traits slightly differently. This could mean that some of the effects of distance were partially driven by perceptual information such as stimulus size.

Experiment 4: Spatial frequency modulation of trait impressions

As distance from a target increases, visual information at high spatial frequencies is less likely to be available (Lampinen et al., 2014; Loftus & Harley, 2005; McKone, 2009). As a result, people must rely more on information at lower spatial frequencies for impression formation. To investigate the potential contribution of differences in available visual information to the results observed in Experiment 2, we contrasted trait ratings of stimuli containing low spatial frequency (LSF) information with those of standard stimuli which include full frequency spectrum or broad spatial frequency (BSF) information. We kept both distance and size constant (1m, large) but varied spatial frequency information by blurring the images (Gaussian blur, radius 5px) in the LSF condition. If available spatial frequency information plays a role in the effect of distance on impression formation, we would expect to observe a similar pattern of responses to that in Experiment 2. If the effect of interpersonal distance is more socially determined and is not mediated by spatial frequency information, our manipulation would not change trait attribution.

Methods

Participants. Thirty-three participants (M = 19.6 years, SD = 2.6, range from 18 to 33 years; 23 female, 8 male, 2 non-binary) completed this task. Data was collected between March and November 2023.

Apparatus & Stimuli. The stimulus set was the same as used in Experiments 2 and 3. The LSF images were created with Adobe Photoshop: applying the Gaussian blur function with radius of 5px. The research team eyeballed the projected stimuli and made a judgement call (for examples of stimuli see Figure 2.5).

Figure 2.5. Representative examples of Broad (BSF) and Low Spatial Frequency (LSF) stimuli

Note. Representative examples were not used in the study.

Design & Procedure. Participants stood 1m from the projector screen and rated the test stimuli when presented as BSF images and LSF images in separate blocks. All other aspects of the procedure matched Experiment 2.

Results

We repeated the analyses reported for Experiment 2 using image spatial frequency (BSF, LSF) as proxy for distance (near and far respectively). Table 2.5 details the descriptive statistics associated with these ratings for the four targeted traits. Interestingly, we found that people on LSF (blurred) images were perceived as more competent than on BSF (not-blurred) images, while no main effects of spatial frequency were found for the other traits.

Table 2.5. Means and 95% confidence intervals of the four traits with broad (BSF) and low (LSF) spatial frequency images

	BSF	LSF	Paired t-tests
Attractiveness	3.38 [3.26, 3.50]	3.36 [3.24, 3.47]	$t(32) = .34$, $p = .734$, $d = .06$ [-.28, .40]
Competence	3.86 [3.75, 3.96]	4.00 [3.90, 4.10]	$t(32) = -2.05$, $p = .049$, $d = -.36$ [-.70, -.02]
Dominance	3.71 [3.59, 3.82]	3.67 [3.56, 3.79]	$t(32) = .50$, $p = .618$, $d = .09$ [-.25, .43]
Trustworthiness	3.67 [3.56, 3.78]	3.76 [3.65, 3.86]	$t(32) = -.79$, $p = .436$, $d = -.14$ [-.48, .20]

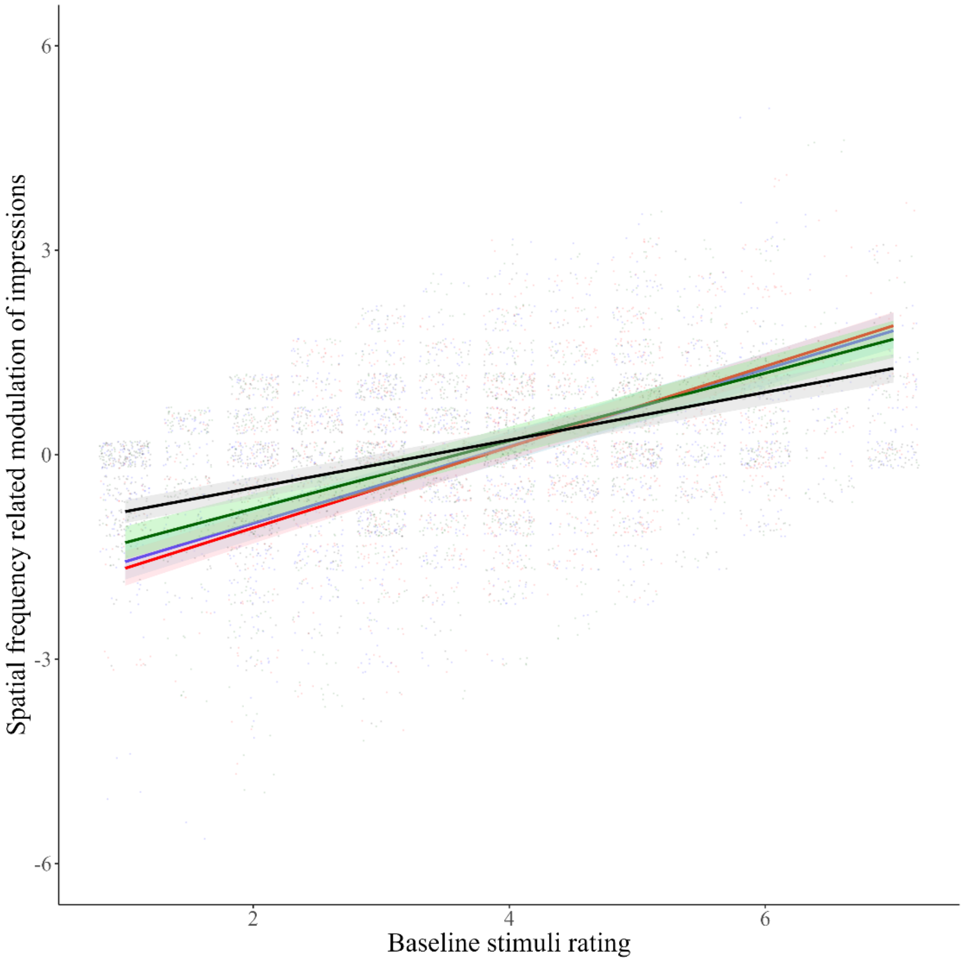
Note. Values in square brackets represent 95% confidence intervals of the effect size.

Both the overall model and the separate models for each of the traits indicated that as baseline stimulus ratings increased (i.e., higher ratings), the spatial frequency-related modulation was increased for all traits. People's baseline ratings of all traits were amplified for the BSF images. Modelling of different traits separately revealed that attractiveness ratings were significantly different to all the other traits. The estimate of attractiveness was less positive than the other traits, which means that in comparison people's impressions of attractiveness were more stable with different spatial frequencies.

The linear mixed effects modelling analysis revealed significant fixed effects of trait, $F(3, 79.83) = 11.25$, $p < .001$, $\eta_p^2 = .30$ [95% CI: .20, .39], baseline stimulus ratings; $F(1, 51.49) = 535.12$, $p < .001$, $\eta_p^2 = .91$ [95% CI: .84, .99]; and their interaction, $F(3, 69.96) = 16.26$, $p < .001$, $\eta_p^2 = .41$ [95% CI: .30, .52]. The model showed that spatial frequency-related modulation of impressions was significantly predicted by trait (i.e., if someone was considering attractiveness, trustworthiness, competence, or dominance), baseline stimulus ratings (i.e., the extent to which an individual stimulus had high or low ratings on the given trait irrespective of spatial frequency) and their interaction.

Figure 2.6 shows the ratings of each participant of each stimulus for the four traits. It depicts the relationship between spatial frequency related modulation of impressions and baseline stimuli ratings. These relationships are presented numerically in Table 2.6. The positive slopes (β) indicated positive relationships between spatial frequency related modulation of impressions and baseline stimuli ratings. T-tests showed that the slopes were significantly different from zero. Together, these analyses indicated a substantial increase in the spatial frequency-related modulation of impressions as baseline ratings increased. This means that adding high spatial frequencies to images amplified first impressions (e.g., trustworthy looking people appeared relatively more trustworthy with BSF images, untrustworthy looking people seemed relatively less trustworthy with BSF images). This effect was again qualified by the interaction between trait and spatial frequency related modulation of impressions, showing that attractiveness was less affected by spatial frequency than all the other traits. Additionally, trustworthiness was less strongly affected by spatial frequency than competence.

Figure 2.6. Relationship of spatial frequency related modulation of impressions and baseline ratings for the four traits



Note. Black line = attractiveness; Red line = competence; Blue line = dominance; Green line = trustworthiness.

Comparing the confidence intervals of the traits, we found that spatial frequency-related modulation was different for attractiveness than for the other traits – people's ratings of attractiveness were more similar with LSF and BSF images compared with the other three traits. The positive relationship observed broadly was significantly less steep for attractiveness compared with the three other traits. Furthermore, trustworthiness was less strongly affected by spatial frequency than competence.

Table 2.6. Spatial frequency related modulation of the four traits

Trait	β	SE	84% CI		One-sample t-test
			LL	UL	
Attractiveness	.35	.02	.31	.38	t(25.59) = 15.17, p < .001, d = 2.92 [2.54, 3.30]
Competence	.59	.02	.55	.62	t(24.02) = 20.76, p < .001, d = 4.15 [3.76, 4.54]
Dominance	.57	.03	.52	.60	t(24.38) = 17.42, p < .001, d = 3.48 [3.09, 3.88]
Trustworthiness	.50	.04	.43	.54	t(27.84) = 14.31, p < .001, d = 2.66 [2.29, 3.02]

Note. β and SE represent the mean and standard error of the slope for each trait. Confidence intervals (CI) are used to compare differences in the slopes, where non-overlapping 84% CIs indicate a significant difference at p < .05. T-tests are used to determine if the slope is significantly different from 0. Values in brackets represent 95% confidence intervals of the effect size.

Discussion

When spatial frequency information was manipulated as a proxy for distance, we found that people's impressions of others were amplified from low to broad spatial frequency images. This effect was similar to that observed with the manipulation of physical interpersonal distance in Experiment 2. Furthermore, as with our physical distance manipulation, we observed that ratings of attractiveness were more similar (i.e., relatively less amplified) between low and broad spatial frequency images compared with the ratings of competence, dominance, and trustworthiness. Surprisingly, we also found that competence was more amplified from low to broad spatial frequency images. Distance and spatial frequency seemed to share a more similar pattern than size when it came to the modulation of attractiveness compared with the other three traits. However, the perception of competence and trustworthiness seemed to be different between distance and spatial frequency, showing that distance and spatial frequency perhaps selectively affected these judgements. Overall results indicated that changes in spatial frequency information modulated trait impressions in a broadly similar way to changes in real/physical distance.

Experiment 5: Trait impressions from bodies and faces

Experiment 5 explored the relationship between independent ratings of faces and bodies of stimuli identities and how they compare to whole person ratings. In a previous study, Hu and O'Toole (2022) asked participants to evaluate photographs of people on various personality traits, based on whole person images or those with faces or bodies obscured. Their analysis indicated that some inferences appeared to be made primarily from face-based information (e.g., judgments of trustworthiness) and others from body-based information (e.g., self-discipline). However, most inferences reflected the integration of information from both the body and the face. Tzschaschel et al. (2022) showed that trait judgements made from bodies are best summarized by the trustworthiness and dominance dimensions, which means that the two trait dimensions underlie the perception of the whole person, not only the perception of the face.

Here we aimed to understand whether ratings of the four trait dimensions in our experiments would be similar when made from bodies and faces in isolation at both near and far distances. Additionally, we wanted to see if these ratings would correspond to ratings of whole persons at near and far distance (i.e., collected in Experiment 2).

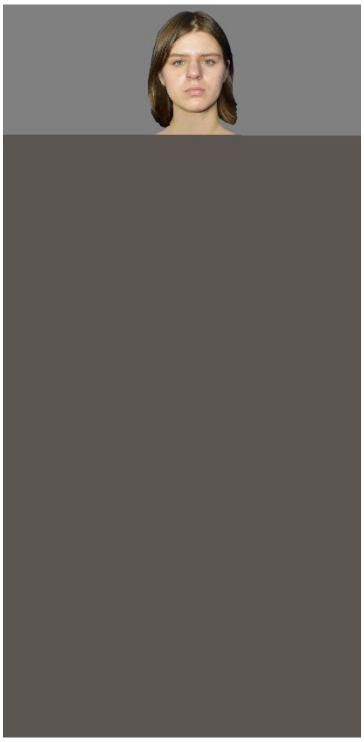
To address these questions, we repeated the design from Experiment 2 (projecting life-sized images of people to be rated from our near and far distances) but this time we selectively obscured the faces or bodies. Participants rated all stimuli identities with covered faces and bodies. For comparison, we used the ratings of the whole person images from Experiment 2 in the analyses.

Methods

Participants. Twenty-seven participants (M = 19.0 years, SD = 1.7, range from 18 to 27 years; 20 female, 6 male, 1 non-binary) completed this task. Data was collected between November and December 2023.

Apparatus & Stimuli. The stimulus set was the same as used in Experiments 2, 3, and 4. To the images of people a grey cover over the face or the body was added in Adobe Photoshop (see Figure 2.7).

Figure 2.7. Representative examples of Face-only and Body-only stimuli



Note. Representative examples were not used in the study.

Design & Procedure. Participants were rating images of people with covered faces and bodies. The images of faces and bodies were presented together within the same trait blocks. All other aspects of the procedure matched Experiment 2.

Data analyses. To investigate how the images were rated when they contained whole-person, body-only, and face-only images, we conducted items-based correlation analyses. Ratings of whole person images were taken from Experiment 2 and were correlated to body-only and face-only image ratings for each of the four trait dimensions at near and far distance.

To understand whether the distance had a similar effect on different traits, we repeated the analyses from Experiment 2 for the body-only and face-only images separately.

Results

Descriptive statistics of ratings of Body-only, Face-only, and Whole-person at Near and Far distances of four trait dimensions are presented in Table 2.7.

Table 2.7. Means and 95% confidence intervals of the four traits with Whole-person, Body-only and Face-only images

Trait	Body part	Near	Far
Attractiveness	Body-only	3.90 [3.51, 4.30]	3.78 [3.36, 4.21]
	Face-only	3.48 [2.97, 3.98]	3.59 [3.07, 4.12]
	Whole-person	3.44 [2.90, 3.98]	3.50 [2.96, 4.05]
Competence	Body-only	4.14 [3.93, 4.35]	3.98 [3.75, 4.21]
	Face-only	4.28 [3.94, 4.63]	4.20 [3.90, 4.50]
	Whole-person	4.02 [3.69, 4.36]	4.04 [3.73, 4.35]
Dominance	Body-only	3.76 [3.53, 3.98]	3.64 [3.45, 3.83]
	Face-only	4.20 [3.71, 4.68]	4.13 [3.66, 4.60]
	Whole-person	3.76 [3.33, 4.18]	3.78 [3.36, 4.20]
Trustworthiness	Body-only	4.16 [3.95, 4.36]	4.10 [3.89, 4.32]
	Face-only	3.54 [3.16, 3.92]	3.54 [3.16, 3.92]
	Whole-person	3.87 [3.51, 4.23]	3.89 [3.62, 4.16]

To explore the relationships between ratings of the whole-person, body-only, and face-only images, we correlated all combinations for each of the four trait dimensions at both near and far distances (Table 2.8). For all traits at both distances, the ratings of body-only and face-only images were highly correlated with the whole-person image ratings (all τ_bs > .38, all ps < .009). This means that ratings of the body-only and face-only images were related to the whole-person ratings, indicating both the body and the face contributed significantly to the whole person ratings, suggesting that these traits could be reliably determined from either the body or the face.

Furthermore, the ratings of the body-only and the face-only were significantly correlated at all distances for Attractiveness, Dominance, and Trustworthiness and for the Competence ratings at Near (all τ_bs > .30, ps < .039), while the Competence ratings at Far were not significant (τ_b = .27, p = .085). This indicates that both the face and body independently provided substantial and comparable information for trait evaluation. This suggests that people synthesized cues from both sources when they formed an overall impression of a person.

Table 2.8. Correlations of Whole-person, Body-only, and Face-only combinations for each of the four traits

Trait		Near	Far
Attractiveness	Body*Face	τ_b = .46, p = .003	τ_b = .40, p = .009
	Person*Body	τ_b = .62, p < .001	τ_b = .51, p = .001
	Person*Face	τ_b = .80, p < .001	τ_b = .87, p < .001
Competence	Body*Face	τ_b = .39, p =.012	τ_b = .27, p = .085
	Person*Body	τ_b = .46, p = .003	τ_b = .56, p < .001
	Person*Face	τ_b = .63, p < .001	τ_b = .59, p < .001
Dominance	Body*Face	τ_b = .62, p < .001	τ_b = .74, p < .001
	Person*Body	τ_b = .54, p < .001	τ_b = .66, p < .001
	Person*Face	τ_b = .75, p < .001	τ_b = .76, p < .001
Trustworthiness	Body*Face	τ_b = .30, p = .039	τ_b = .45, p = .002
	Person*Body	τ_b = .38, p = .009	τ_b = .46, p = .002
	Person*Face	τ_b = .60, p < .001	τ_b = .64, p < .001

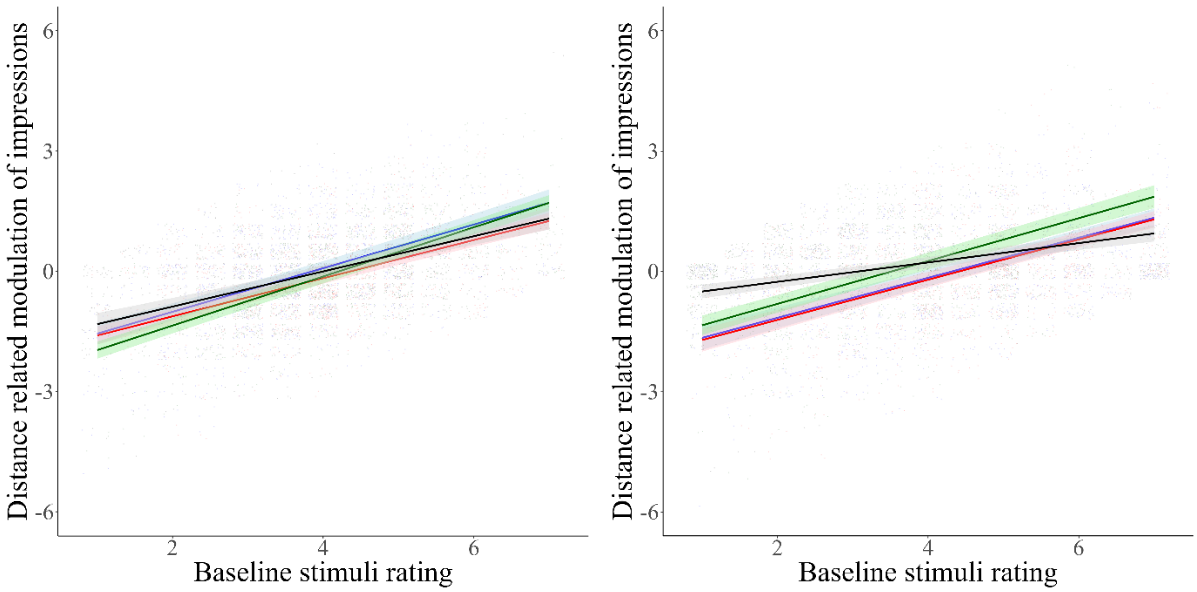
Note. Kendal Tau (τ_b) is reported due to small number of stimuli identities and some deviations from normality.

Furthermore, we ran the analyses used in the Experiment 2 separately on the body-only data and the face-only data to see how the distance modulated different trait ratings of the body parts compared with those of the whole-person images. The mixed effects modelling analysis for the body-only revealed significant effects of trait, $F(3, 78.32) = 31.81$, $p < .001$, $\eta_p^2 = .55$ [95% CI: .44, .66], baseline stimulus ratings; $F(1, 38.81) = 482.17$, $p < .001$, $\eta_p^2 = .93$ [95% CI: .84, 1.00]; and their interaction, $F(3, 77.67) = 29.90$, $p < .001$, $\eta_p^2 = .54$ [95% CI: .43, .64]. Similarly, the mixed effects modelling analysis for the face-only revealed significant effects of trait, $F(3, 53.56) = 7.50$, $p < .001$, $\eta_p^2 = .30$ [95% CI: .18, .41], baseline stimulus ratings, $F(1, 45.12) = 426.26$, $p < .001$, $\eta_p^2 = .90$ [95% CI: .82, .99], and their interaction, $F(3, 47.70) = 7.11$, $p < .001$, $\eta_p^2 = .31$ [95% CI: .18, .43].

Figure 2.8 shows each participant's ratings of each stimulus for the four traits for body-only (A) and face-only (B) images. It depicts the relationship between distance related modulation of impressions and baseline stimuli ratings. The relationships for individual traits are presented numerically in the Table 2.9. As with the whole-person stimuli (Experiment 2) we found positive relationships between distance related modulation of impressions and baseline stimuli ratings for both the body-only and face-only images. This effect was qualified by the interaction between trait and distance related modulation of impressions, showing that distance had a different effect on different traits.

Figure 2.8. Relationship of distance-related modulation of impressions and baseline ratings for the four traits for Body-only (A) and Face-only (B) images

A) Body-only images B) Face-only images



Note. Black line = attractiveness; Red line = competence; Blue line = dominance; Green line = trustworthiness.

The analysis of the body-only data revealed that attractiveness ratings were less affected by distance than trustworthiness ratings, with no significant differences observed among the other traits. Meanwhile, the face-only data revealed that attractiveness was less modulated by distance compared with all the other traits, a finding that closely mirrored the differences between traits in the whole person data (Experiment 2). This indicates that the distance had a similar trait rating modulation pattern when evaluating face-only and whole-person images. To a lesser extent this modulation was also similar to body-based ratings.

Overall, whole-person, body-only and face-only images were similarly modulated by distance.

Table 2.9. Distance related modulation of the four traits for Body-only (A) and Face-only (B) images

	Trait	β	SE	84% CI		One sample t-test
				LL	UL	
A)	Attractiveness	.44	.05	.36	.49	t(24.06) = 8.29, p < .001, d =1.66 [1.27, 2.05]
	Competence	.48	.04	.39	.54	t(33.14) = 12.44, p < .001, d = 2.13 [1.80, 2.47]
	Dominance	.54	.06	.45	.63	t(24.90) = 9.53, p < .001, d = 1.87 [1.48, 2.25]
	Trustworthiness	.61	.03	.56	.66	t(39.91) = 24.02, p < .001, d = 3.75 [3.45, 4.06]
B)	Attractiveness	.24	.03	.18	.28	t(28.76) = 8.20, p < .001, d = 1.50 [1.14, 1.85]
	Competence	.50	.04	.44	.55	t(26.15) = 13.99, p < .001, d = 2.69 [2.32, 3.07]
	Dominance	.50	.04	.44	.54	t(24.92) = 13.37, p < .001, d = 2.62 [2.24, 3.01]
	Trustworthiness	.53	.04	.47	.58	t(28.22) = 14.38, p < .001, d = 2.67 [2.31, 3.03]

Note. β and SE represent the mean and standard error of the slope for each trait. Confidence intervals (CI) are used to compare differences in the slopes, where non-overlapping 84% CIs indicate a significant difference at p < .05. T-tests are used to determine if the slope is significantly different from 0. Values in square brackets represent 95% confidence intervals of the effect size.

Discussion

Results of Experiment 5 indicated that people were able to make reliable trait impression judgements from both body-only and face-only stimuli. Interestingly we did not find a significant correlation between body and face Competence ratings at Far distances. We also found differences between attractiveness and the rest of the traits in the face-only experiment, similarly as with the whole-person data collected during Experiment 2. Analysis of the body-only data revealed that in this stimulus format attractiveness was more stable across distances only compared with trustworthiness. This result could indicate whole-person ratings were more similar to the face-only ratings cf. body-only ratings.

General discussion

The current study investigated how social perception is affected by interpersonal distance - a crucial perceptual and social cue in our social interactions. Across five experiments, we have shown that life-size presentation of whole person stimuli elicited higher levels of arousal at near than far interpersonal distances (Experiment 1). We have shown that both *physical* (Experiment 2) and *implied* interpersonal distance based on image size and visual spatial frequency information (Experiments 3 and 4) modulated how people attribute high-level social traits to others. Finally, we have shown that people were able to make reliable trait impression judgements at near and far distances from both the body and the face (Experiment 5). These results provide evidence for the pivotal role of interpersonal space information in social perception and also highlight the dynamic nature of trait attribution to other people.

Given that perceptual information and social importance of a given target changes with distance, we hypothesised that social attributions (i.e., trait ratings) might vary predictably when an individual appears near vs far. Furthermore, we reasoned that the magnitude of these effects might depend on the specific characteristic under consideration. Trustworthiness, competence, and dominance are traits that are related to how beneficial or harmful someone can and will be for an individual (e.g., Oosterhof & Todorov, 2008; Sutherland et al., 2013). When people make these judgements, it follows that they are considering another's potential utility and harm. Proximity might be a more salient influence upon these traits because collaboration and threat are most relevant at close distances. Greater physical distance might be psychologically associated with less familiarity and reduced social engagement, affecting trustworthiness more significantly than attractiveness, which might be perceived as a more inherent and less context-dependent trait. Furthermore, at further distances we have less detail and might make our judgements more cautiously. For these reasons people might prefer to rate others closer to the average at far distances.

The results of our main study (Experiment 2) revealed that trait ratings tend to be amplified with proximity. That is, images of individuals who were rated relatively low in dominance (for example) were considered even less dominant at near distances. This pattern of relatively amplified responses at a near distance was true for all traits, but distance had relatively stronger effects on trustworthiness, competence, and dominance compared with attractiveness judgements. This distinction may highlight differences in the distance-related stability of the critical cues that influence more 'social' vs 'aesthetic' judgments.

While all three studies on the topic of distance and trait impressions supported the influence of interpersonal distance and relevant perceptual cues on trait ratings, our results also differed from previous findings. Patterson & Sechrest (1970) observed a negative linear trend of trait ratings decreasing from the second closest distance just outside the personal space (120cm) to the furthest distance (240cm). Our results broadly followed this pattern, with numerically lower ratings at further distances. Yet the effects we observed were more nuanced, i.e., proximity amplified the perception of trait judgements. In line with this finding, people presented/photographed within personal space in the previous two studies (46cm (Bryan et al., 2012) and 60cm (Patterson & Sechrest, 1970)) were rated lower than those just outside it (137cm and 120cm respectively). Contrary to these findings, a recent study by Trifonova et al. (2024), which studied distance with variations in size of avatars on a screen, did not find differences in ratings of dominance and trustworthiness with large and small avatars. The differences between our study and the previous studies could be due to various reasons. The study by Patterson & Sechrest (1970) used a very different task (ratings of traits were made after an interview) and a small number of confederates prevented them from a more detailed stimuli based analyses. It is also possible that the images with distance-distorted faces in Bryan et al. (2012) were perceived differently compared with a real distance manipulation. Meanwhile the study by Trifonova et al. (2024) was conducted online and therefore the simulated distances could not be reported and might have represented distances too far away to induce differences in judgements.

In our experiments we also observed the modulation of trait judgements by physical distance with our perceptual visual distance proxies – manipulation of stimulus size and spatial frequency information. That is, all trait ratings were consistently enhanced when stimulus conditions were analogous to being closer to the participants (i.e., presented with BSF or in large stimulus size). Moreover, while manipulation of spatial frequency has shown a similar distinction between its effects on attractiveness versus other traits, size modulation has only shown a difference between attractiveness and trustworthiness ratings. These results suggest that the effect of interpersonal distance on impression formation may be mediated by differences in spatial frequency and to a lesser extent by stimuli size. With these experiments we have shown that distance related modulation of traits was also observed with modulation of stimulus spatial frequency and size. This indicates that the observed effects were at least in part perceptual in nature.

The results of Experiment 5 have shown that body-only and face-only images provided sufficient information for people to have made reliable judgements of all studied traits, at near and far distances. It has previously been established that bodies and faces share information about gender, age, race, body shape, weight and height (Holzleitner et al., 2014;

Schneider et al., 2012), and attractiveness (Honekopp et al., 2007; Thornhill et al., 1999), which people might be using when making trait impressions. These results were also in line with previous studies which found that body-based trait impressions were best summarised by the trustworthiness and dominance dimensions (Tzschaschel et al., 2022), and found significant contribution of the body mass and musculature to higher perception of threat (McElvaney et al., 2021) and dominance (Hu et al., 2018). We also found greater differences between the distance modulation of traits for whole-person and body-only images compared with whole-person and face-only images. This could indicate that people may generally rely more on the facial information at both distances. In line with this notion, previous literature has demonstrated that people rely more on facial information cf. bodily information when making most trait judgements (Hu et al., 2020; McElvaney et al., 2021). Together, these results showed that people's trait impressions from bodies and faces can be summarised by similar dimensions and that people's judgements were likely integrating the cues from both. However, despite being able to make reliable judgements from both faces and bodies, people might be predisposed to rely more on the facial information when they are free to do so.

The differences we found between ratings of the four traits could also be due to the involvement of different higher-level cognitive mechanisms. Closer distances and their proxies are more behaviourally and socially relevant to the observer as they simulate scenarios where detailed social evaluation is crucial. This difference in relevance between the two distances was indicated by Experiment 1, in which we found greater self-reported levels of emotional arousal with near compared with far life-sized images (when no particular traits were highlighted for consideration in the pictured individuals). This relevance could heighten sensitivity to social cues, leading to stronger trait judgments across the board. Our social perception systems seem to prioritize and intensify evaluations when interaction is imminent or socially significant (e.g., Pilz et al., 2011), whether this significance is conveyed by actual/physical proximity or by visual cues mimicking proximity. From an evolutionary standpoint, closer distances or more detailed visual information might signal immediate social or environmental interaction, requiring more accurate and rapid judgments for survival and social cohesion. The similarity in effects between physical distance and visual distance proxies could reflect an adaptive mechanism where the brain enhances social trait evaluations in contexts suggesting imminent interaction, whether these contexts are real or simulated.

We also observed a noteworthy main effect of spatial frequency on competence ratings. That is, people were perceived as more competent in blurred images compared with unaltered/BSF images. One possible explanation for main effect of distance on competence could be that blurred images reduced the visibility of fine details and imperfections, leading to a more favourable perception of competence, because the absence of detailed information allowed for a more idealized and less critical evaluation. It is interesting that we did not observe these effects with a trait like attractiveness, the ratings of which have been shown to increase in conditions with lower visibility (such as briefly glimpsed images of faces; Vaughn & Eagleman, 2016). This effect might not have been observed because we presented whole-person images. When rating attractiveness people seemed to be considering both bodies and faces equally, while they were attending more to faces for their competence judgements, leading them to higher ratings. However, it is not clear why the effects observed here were present only for spatial frequency and not for distance or size. Since we did not perfectly simulate the spatial frequencies associated with a viewing distance of 4m, it is possible that our level of blurring reflected a greater implied distance, where this effect became more pronounced.

In Experiment 1 we were interested in whether life-sized images of people are valid social stimuli to investigate social distance. We found that the arousal differences between different distances correspond to the previous findings of arousal changes with real people (Candini et al., 2021) with higher levels of arousal near cf. far. Finding these associations, we demonstrated that projected whole-person life-sized images were appropriate to study proxemic behaviour. Furthermore, we were interested in whether the specific test distances we selected in the experiment would be perceived as different enough in social saliency to have the potential to lead to different social perception. The observed pattern of differences in arousal ratings confirmed that the two chosen distances were significantly different from some aspect of social cognition.

Limitations and future research

Our study was not without limitations. Our experimental design was limited to two specific distances (1m and 4m). Since social interactions occur at various distances, our findings might not distinguish between effects specific to other interpersonal distances (see Patterson & Sechrest, 1970). It would also be interesting to run an experiment with individualized distances, i.e., calibrated to align with participants' personal and interpersonal comfort distances.

Our study design, sample size, and the number of stimuli prevented us from developing a more complex model that could compare the effects of distance, size, and spatial frequency, as well as differences between whole-person, body-only, and face-only conditions. As a result, our comparisons were limited. Furthermore, it is important to note that the limited number of stimuli reduced the power of the t-tests and might have prevented us from detecting reliable effects.

Additionally, our study was conducted on a sample of convenience, which was a non-representative WEIRD (Western, Educated, Industrialized, Rich, Democratic) sample. It is well established that distance perception varies across cultures and societies, which is why this sampling bias could have limited the generalizability of our findings to the broader population. Furthermore, despite having diverse set of stimuli, many ethnicities and ages were underrepresented, and the research could benefit from an even more varied stimuli set.

To further elucidate the differences and similarities between perceptions of distance and distance proxies, arousal levels could be estimated for images with variations in size and spatial frequency. Moreover, our research focused on two distance proxies and did not investigate others, such as contrast and colour saturation, which might reveal how these other visual factors impact the modulation of trait impressions related to distance perception. It would also be interesting to investigate other sensory inputs affecting trait impression. For example, voice perception has been found to be a rich source of trait impression information (see Schweinberger et al., 2014 for review) and would be interesting to investigate across distances.

It would also be interesting to determine which cues people naturally base their judgments on when looking at whole-person, body-only, and face-only images at various distances. That is, when these cues are not artificially isolated with a design such as ours. This could be achieved with eye tracking where participants would be presented with whole body stimuli, and by analysing the visual features (e.g., shoulder width, height, chin width) of our stimuli that were rated higher and lower on specific traits at the two distances.

Furthermore, the static nature of the images presented during the current study did not account for the potential contribution of movement to the perception of trait impressions. Such cues might particularly affect body perception. Previous research has shown that body dynamics carry crucial information for emotion and person recognition, making judgments more precise (e.g., Ambady & Rosenthal, 1993; O'Toole et al., 2011). Combining whole-person presentations with dynamic stimuli could enhance the understanding of person perception and potentially offer a more accessible alternative to virtual reality.

Conclusions

While real-life social interactions occur in space and are shaped by interpersonal spatial information, the impact of interpersonal distance on social perception of others is not well investigated. Here, we addressed this question by employing a validated and ecological paradigm using life-size images of people in trait attribution tasks. We found that at closer distances the ratings of all impressions were amplified, i.e., people rated high/low on a trait far away were rated even higher/lower when near. This was also found for the proxies of distance – size and spatial frequency.

Our results indicate that the cues used to determine a consensus about trustworthiness, competence and dominance at close distance were weighted differently compared with further away. That was less true for attractiveness. We found that distance shares these effects with low-level visual properties associated with changes in distance (i.e., size and spatial frequency). From the present study we can conclude that people were indeed rated differently at different distances and when modified with distance related cues. Finding a similar pattern of results across Experiments 2, 3 and 4 indicates that the effect was at least in part perceptual. The finding that people were able to make reliable judgements from both faces and bodies at both distances, indicates the involvement of higher lever social mechanisms.

Chapter 3, The role of background context and interpersonal distance on trait impression formation

Summary of the chapter

The two experiments reported in this chapter build on the experiments in Chapter 2, targeting the role of background context as well as physical space on trait impression judgments of life-sized, whole person images of people. Participants again rated images on the trait dimensions attractiveness, competence, dominance, and trustworthiness, at 2 distances (1 and 4 m). We wanted to understand whether the ratings of different trait dimensions would differ in positive cf. negative background contexts when evaluated at near cf. far interpersonal distances. In Experiment 6 we added a social background context – people in the background with happy or disgusted facial expressions. In Experiment 7 we added an ambient background context – a sunny beach or a roaring fire. We expected that adding a positive background would affect the ratings differently than negative background and that the background would have more of an effect at further distances where people are relatively less able to distinguish the facial features which makes them more reliant on other cues (body and context) to make a judgement. Results revealed that context had an effect on ratings of all traits, across all distances. In the social context condition, we also observed elevated perception of dominance at near distances. Crucially, we also found an interaction effect between social context and distance on the perception of trustworthiness. Only with ratings of trustworthiness with a social background we found the expected interaction with distance: at far distances target stimuli were rated relatively less trustworthy when surrounded by disgusted people and more trustworthy when surrounded by happy background people. This indicates a highly specialized interaction between social context and distance, highlighting the complex ways in which these factors influence trustworthiness perceptions.

Introduction

In everyday life, person perception relies on both facial and bodily appearances, which interact with the situational context in which we observe them. While most studies have focused on trait impressions from isolated faces (Oosterhof & Todorov, 2008; Sutherland & Young, 2022; Zebrowitz, 2017), recent research underscores the significance of body shapes and postures in social attributions (Hu et al., 2018; Hu & O'Toole, 2022; Tzschaschel et al., 2022). Additionally, context plays a crucial role in our perception of others. Background environments influence emotional expression judgments, with better recognition of emotional expressions when the scene and facial emotions are congruent (Aviezer et al., 2008; Barrett & Kensinger, 2010; Righart & De Gelder, 2008). Recent studies highlight the importance of integrating facial cues with contextual information for trustworthiness judgments (Brambilla et al., 2018; Mattavelli et al., 2021, 2022, 2023), whereas other trait impressions remain underexplored.

There is scope for context to have a greater effect at further distances, where the surrounding context is more visible and the relatively small size of the image of a person (particularly the face) on the retina makes their features harder to visually resolve. We hypothesised that such scenario would prompt observers to rely more on the background context when making trait judgments. We expected that positive social contexts (compared with negative ones) would increase the ratings of all traits. Similarly, we anticipated that a beach/positive ambient setting (compared with a fire/negative ambient setting) would elevate ratings of an individual’s trustworthiness, competence, and attractiveness. For dominance, we anticipated the people might be rated lower in the beach context compared with the fire context, because fire could be associated with power and beach with leisure.

Research considerations

When designing this study, we considered a variety of context options. The choice of social context was based primarily in the study by Smith & Schyns (2009) which found that grimacing and smiling faces are well recognised emotional expressions over longer distances. For the ambient context we wanted to select backgrounds which would represent actual environment (rather than schematic, such as blood drops in the background, as in Mattavelli et al., 2022). We also wanted the oppositely valanced contexts to have similar ratings of arousal to ensure that any differences could not be attributed to some scenarios being more stimulating than others.

Though including multiple backgrounds would have benefited the generalisability of our findings, we chose to include only two. This design choice allowed us to keep the length of the experiment brief. It also allowed for a more straightforward interpretation of data, making it easier to isolate the effects of the backgrounds on trait impressions. Finally, it ensured a high level of experimental control, which also made the comparisons between conditions more meaningful.

We also attempted to run a large multilevel model on the data, similar to the experiments presented in Chapter 2. However, we encountered issues with convergence and singularity due to the model's complexity relative to the amount of data available. These issues raised concerns about the reliability of the results of such an analysis. Thus, while a larger multilevel model could potentially provide additional insights, we came to the pragmatic conclusion that the critical questions being targeted in these experiments can be sufficiently and clearly answered using a simple factorial ANOVA.

Experiment 6: Role of social context and distance on trait impression judgements

Methods

Participants. Sixty-one adults (M = 21.00 years, SD = 5.06, range from 18 to 44, 51 female, 9 male, 1 non-binary) participants completed this experiment. 10 participants were excluded from the analysis due to poor engagement, as indicated by repetitive and non-variable response patterns on the Likert scale. The procedure of both experiments reported here were approved by the local Ethics Committee (reference code: ETH2324-0775). All participants were naive as to the purpose of the study and provided informed written consent to participation after being informed about the procedure of the study. Participants in our studies were Psychology undergraduate students and received course credits for participation. This experiment was pre-registered (https://aspredicted.org/zn9qq.pdf). The deviation from the pre-registration was in that we decided to run the analyses on the item level, following the findings of Experiment 2. Data was collected between September 2022 and February 2023.

Stimuli & Apparatus. The experimental design was very similar to that of Experiment 2. This and the subsequent experiment reported in this chapter were programmed using Gorilla Experiment Builder (gorilla.sc). High-resolution life-sized stimuli were projected onto a 2.3m (height) × 1.5m (width) white screen (Optoma GT1080 projector, 2800 Lumens (ANSI), working resolution of 1080 x 1920 pixels; see Figure 2.1). The stimuli consisted of high resolution (1794 x 4494 pixels) images of 96 adults of different ages and ethnic backgrounds from an existing database (for more detail see Stephen et al., 2016). Individuals are pictured wearing standard close-fitting grey singlets and shorts and facing forward in a standard posture - with their arms by their side - and a neutral facial expression (Figure 3.1). Each image was positioned on a grey background, so that the individual appeared to be approximately standing on the same ground plane. They appeared at realistic life sizes. Near-distance images subtended vertically 84° of visual angle, and far-distance images 25° when participants stood 1 and 4 meters away respectively. For our experiments we selected high and low-rated exemplars for trustworthiness, dominance, competence and attractiveness based on pre-ratings collected online (see Chapter 2, page 38). Assuming a standard viewing distance (60cm) images appeared at an average 17° visual angle. The selected images made up four, non-overlapping stimulus sets (one for each trait), each comprising 12 male and 12 female stimuli (96 images in total), choosing the 6 highest and 6 lowest rated on each trait for each gender. Due to an error in the code, 8 stimuli identities were excluded from analysis, leaving 20 identities for attractiveness, 22 for competence, 22 for dominance and 24 for trustworthiness.

For the Social context manipulation, we used Adobe Photoshop to add two background figures (a male and a female) with either both disgusted or both happy facial expressions (see Figure 3.1 for stimuli examples). These positively and negatively valanced expressions were chosen because both disgust and happiness have been found to be well recognisable across a range of distances (Smith & Schyns, 2008). We edited the heads of the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998) dataset onto the bodies of exemplars from our primary stimulus set. The height of the central identities was adjusted to be proportionally comparable to the background figures. The same stimulus identities appeared in the positive and negative social context conditions. We mirror reversed the sides on which each gender of the background figures was presented, with each stimulus identity appearing 4 times in total.

Figure 3.1. Representative examples of Happy and Disgusted social context stimuli

Note. Representative examples were not used in the experiment.

Design & Procedure. Participants were asked to rate images of people on their characteristics, based on their appearance, when standing at 1m (near distance) and 4m (far distance) from the screen. Detailed descriptions of characteristics to be rated were given just before the block started. Images appeared for 2500ms; from as soon as the image appeared, the participants could take as long as they needed to make their rating using a Likert scale (ranging from 1, meaning low on a trait – 7, meaning high on a trait). They were asked to use the whole range of the scale. Their rating was followed by a 500ms intertrial interval (ITI). Responses were made using a mouse, which rested on a platform that was moved with participants to the different rating locations. Order of standing distances was counterbalanced across participants.

Data analysis. Statistical analyses reported in this chapter were carried out using IBM SPSS Statistics (Version 25). Because we were interested in how the stimuli were rated rather than how participants were rating them, we conducted an items-based analysis. We ran a repeated measures ANOVA on ratings for each trait dimension separately, with distance (near, far), and context (disgusted, happy) as within-subjects factors. 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 cut-off points.

Results

Table 3.1 contains descriptive statistics for all conditions of Experiment 6.

Table 3.1. Means and 95% confidence intervals of Social Context experiment conditions

Trait	Disgust Social Context		Happy Social Context	
	Near	Far	Near	Far
Attractiveness	3.50 [2.92, 4.08]	3.47 [2.90, 4.04]	3.58 [3.00, 4.16]	3.58 [2.98, 4.17]
Competence	3.84 [3.50, 4.17]	3.79 [3.48, 4.11]	3.97 [3.61, 4.32]	3.97 [3.63, 4.31]
Dominance	3.91 [3.48, 4.35]	3.84 [3.38, 4.30]	3.97 [3.52, 4.42]	3.88 [3.42, 4.33]
Trustworthiness	3.43 [3.09, 3.77]	3.42 [3.13, 3.72]	3.63 [3.30, 3.96]	3.73 [3.41, 4.04]

Table 3.2 contains results of 4 repeated measures ANOVAs for each of the trait judgements. Results showed that when target/central figures were surrounded by people with happy facial expressions, they were rated relatively higher on all traits compared with when they were surrounded by people with disgusted facial expressions (all Fs > 7.71, all ps < .011). This means that trait impressions ratings were highly sensitive to the social environment. Furthermore, we found a significant main effect of Distance on Dominance ratings, $F(1, 21) = 5.63$, $p = .027$, $\eta_p^2 = .21$ [95% CI: .02, .41], indicating that target stimuli were consistently perceived as more dominant when viewed at Near cf. Far distances. Crucially, we found an interaction effect between Context and Distance on Trustworthiness ratings, $F(1, 23) = 9.98$, $p = .004$, $\eta_p^2 = .30$ [95% CI: .09, .53], when happy people surrounded the central figure on the images, ratings increased with distance, however when they were surrounded by disgusted ratings decreased with distance. All other main effects and interactions were not significant.

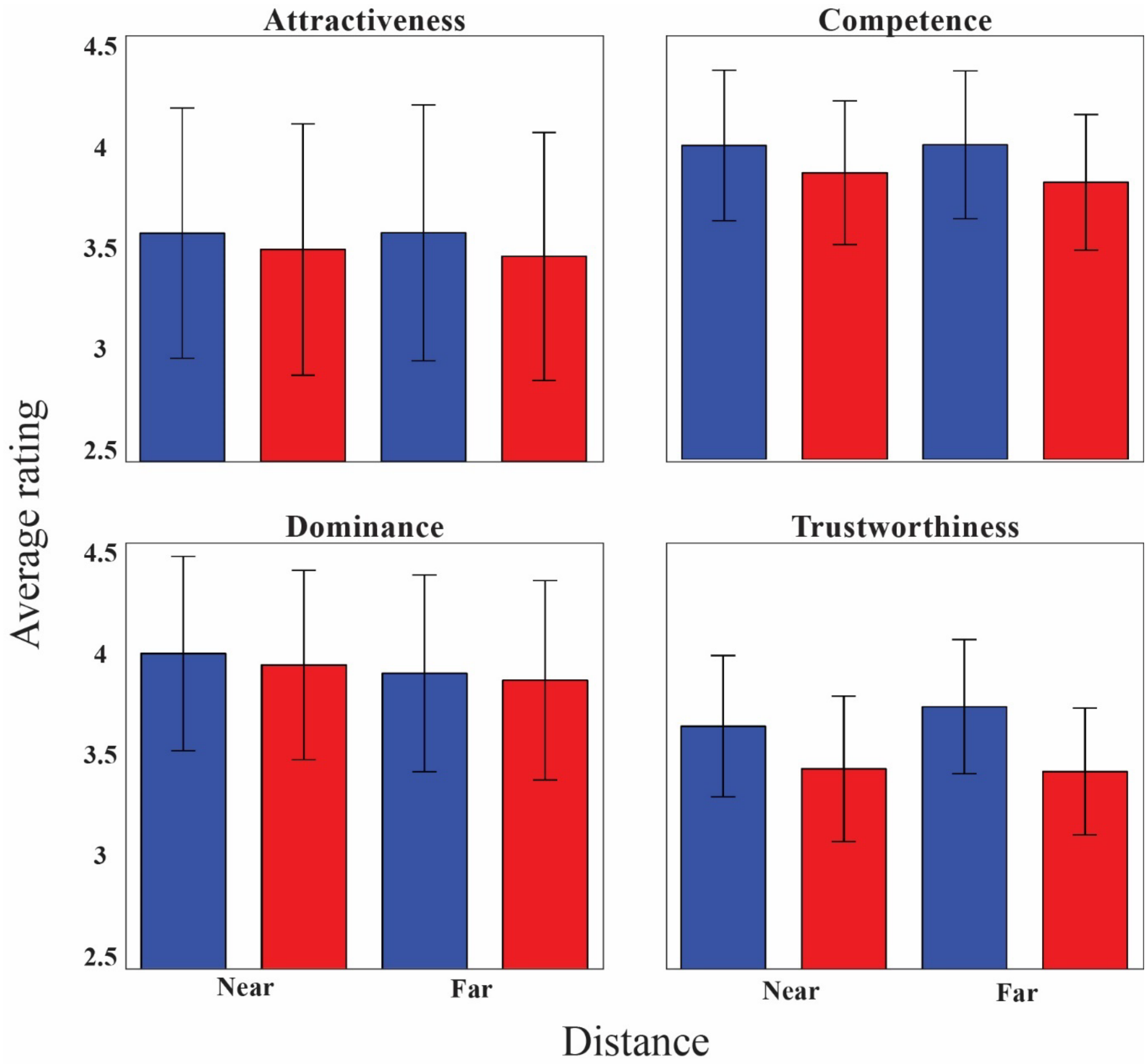
Table 3.2. Results of Social Context (Happy, Disgusted) x Distance (Near, Far) repeated measures ANOVAs for the four traits

Trait	Factor	ANOVA
Attractiveness	**Context**	**$F(1, 19) = 35.13$, $p = <.001$, $\eta_p^2 = .63$ [.44, .86]**
	Distance	$F(1, 19) = .55$, $p = .465$, $\eta_p^2 = .03$ [.00, .10]
	Interaction	$F(1, 19) = .68$, $p = .417$, $\eta_p^2 = .03$ [.00, .11]
Competence	**Context**	**$F(1, 21) = 51.03$, $p = <.001$, $\eta_p^2 = .71$ [.52, .90]**
	Distance	$F(1, 21) = .27$, $p = .607$, $\eta_p^2 = .01$ [.00, .06]
	Interaction	$F(1, 21) = 1.25$, $p = .276$, $\eta_p^2 = .06$ [.00, .15]
Dominance	**Context**	**$F(1, 21) = 7.43$, $p = .013$, $\eta_p^2 = .26$ [.08, .44]**
	Distance	**$F(1, 21) = 5.52$, $p = .029$, $\eta_p^2 = .21$ [.04, .38]**
	Interaction	$F(1, 21) = .28$, $p = .601$, $\eta_p^2 = .01$ [.00, .06]
Trustworthiness	**Context**	**$F(1, 23) = 230.35$, $p = <.001$, $\eta_p^2 = .91$ [.79, 1.00]**
	Distance	$F(1, 23) = 1.01$, $p = .325$, $\eta_p^2 = .04$ [.00, .12]
	Interaction	**$F(1, 23) = 10.19$, $p = .004$, $\eta_p^2 = .31$ [.12, .49]**

Note. Significant effects ($p<.05$) in bold. Values in square brackets represent 95% confidence intervals of the of the effect size.

Figure 3.2 depicts the interactions of Distance and Social Context of the four trait dimensions.

Figure 3.2. Plots of the Social Context (Happy, Disgusted) x Distance (Near, Far) repeated measures ANOVAs for the four traits



Note. Blue bars = Happy context, Red bars = Disgust context. Error bars represent 95% confidence intervals of the mean.

Discussion

We found that when a person was surrounded by happy looking people, their ratings of all the targeted traits increased. This result indicated clearly that the background figures had an effect on the perception of the target/central stimulus. Furthermore, we found that overall people were perceived as more dominant when they appeared closer to the participant, compared with further away. This result could be because a group of three people looked intimidating at near distances. Crucially, we found an interaction between context and distance in ratings of trustworthiness. When happy people surrounded the target figure, this individual was rated as *more* trustworthy with increased distance, however when they were surrounded by disgusted people, they were rated as *less* trustworthy with increased distance. This result suggests that at greater distances, observers relied more on the surrounding people's expressions to judge the target figure's trustworthiness. This reliance on contextual cues at further distances likely occurred because detailed facial information, which is crucial for assessing trustworthiness, became less available (Hu & O'Toole, 2022). Therefore, in the absence of clear facial details, people depended more on the emotional expressions of those around the target to make their judgments.

Experiment 7: Role of ambient context and distance on trait impression judgements

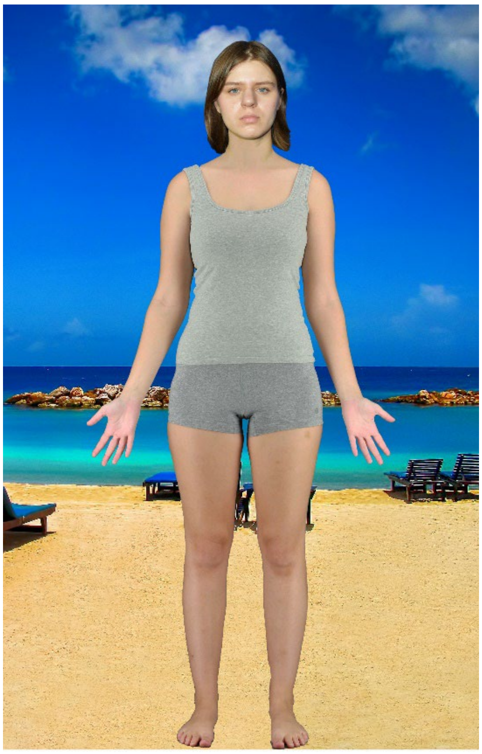
Methods

Participants. Sixty adults (M = 20.14 years, SD = 3.80, range from 18 to 44, 48 female, 8 male, 0 non-binary) completed this experiment. Four participants were excluded from the analysis due to poor engagement as indicated by repetitive and non-variable response patterns on the Likert scale.

The procedure of both experiments reported here were approved by the local Ethics Committee (reference code: ETH2324-0775). All participants were naive as to the purpose of the study and provided informed written consent to participation after being informed about the procedure of the study. Participants in our studies were Psychology undergraduate students and received course credits for participation. This experiment was pre-registered (https://aspredicted.org/wd9is.pdf). The deviation from the pre-registration was in that we decided to run the analyses on the item level, following the findings of Experiment 2. Data was collected between September 2022 and February 2023.

Stimuli & Apparatus. The stimuli and apparatus were as in the Experiment 6, the only difference was the background. In Adobe Photoshop we added two background images of either roaring fire (I59) or sunny beach (I322; see Figure 3.3 for stimuli examples). The background images were from the OASIS (Open Affective Standardized Image Set), chosen to have similar ratings of arousal (Fire = 4.74 ± 1.69; Beach = 5.29 ± 1.82) and opposite valance (Fire = 6.37 ± .85; Beach = 1.74 ± .98).

Figure 3.3. Representative examples of Beach and Fire ambient context stimuli



Note. Representative examples were not used in the experiment.

Procedure. The procedure was the same as in the Experiment 6.

Data analysis. Again, we used an items-based analysis for the repeated measures ANOVA, with Distance (Near, Far) and Context (Beach, Fire) as within-subjects factors.

Results

Table 3.3 contains descriptive statistics for all the conditions of Experiment 6.

Table 3.3. Means and 95% confidence intervals of Ambient Context experiment conditions

Trait	Fire Ambient Context		Beach Ambient Context	
	Near	Far	Near	Far
Attractiveness	3.39 [2.82, 3.96]	3.35 [2.79, 3.91]	3.50 [2.93, 4.06]	3.47 [2.89, 4.05]
Competence	3.95 [3.61, 4.29]	3.91 [3.60, 4.22]	3.99 [3.66, 4.33]	3.97 [3.67, 4.28]
Dominance	3.77 [3.31, 4.24]	3.75 [3.29, 4.22]	3.64 [3.18, 4.09]	3.63 [3.15, 4.12]
Trustworthiness	3.48 [3.18, 3.78]	3.42 [3.15, 3.68]	3.79 [3.48, 4.10]	3.73 [3.43, 4.02]

Table 3.4 contains results of 4 repeated measures ANOVAs of all four trait judgements. In all the experiments we observed a significant main effect of Context (all Fs > 13.42, all ps < .001). When the target individual was presented centrally on a beach/positive background people's rating of attractiveness, trustworthiness, and competence were higher compared to when they appeared on a fire/negative background. Perhaps unsurprisingly, people were also rated as more dominant when in front of the fire cf. on the beach. We did not observe any significant effects of Distance or interactions between Distance and Context.

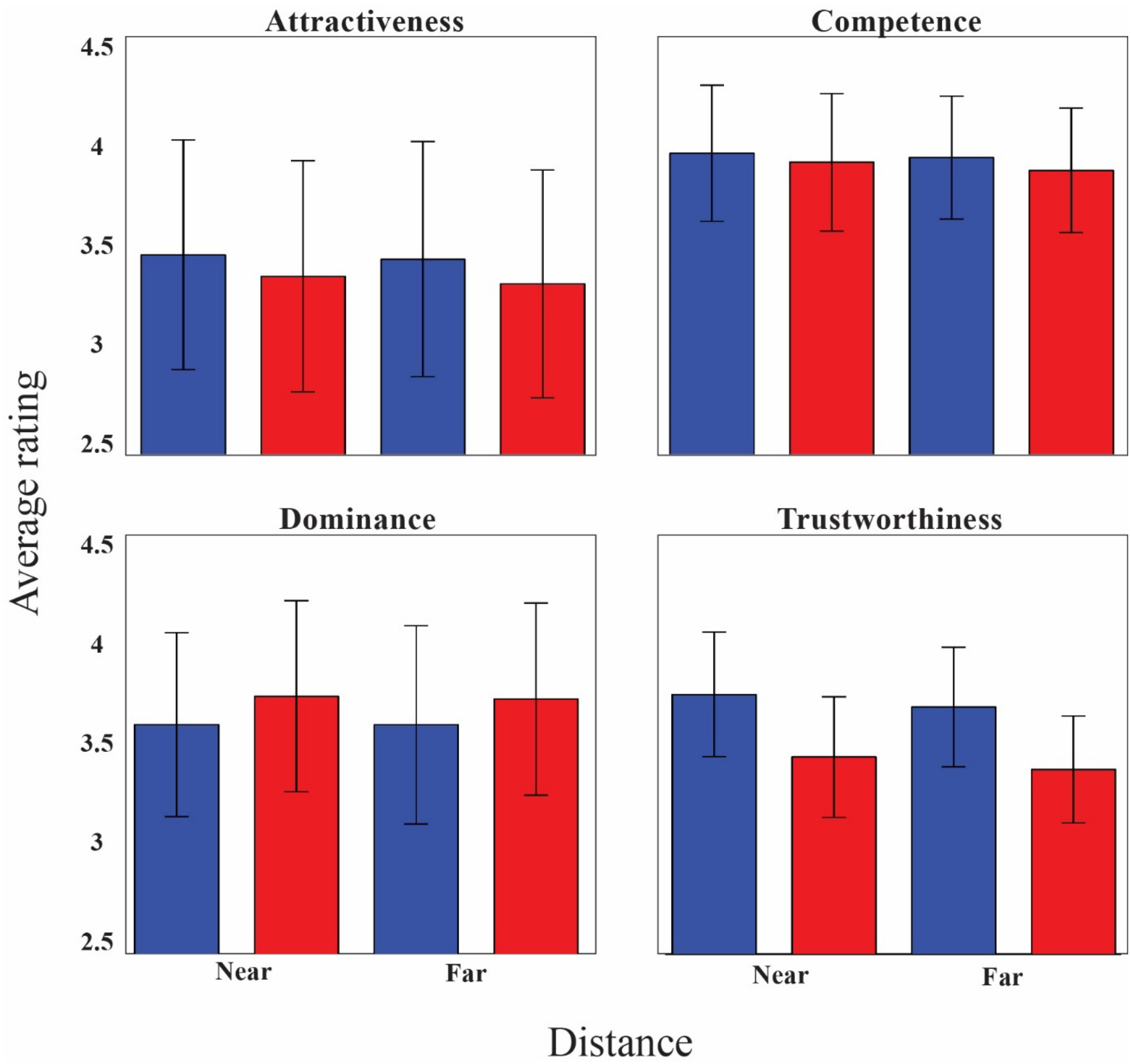
Table 3.4. Results of Ambient Context (Beach, Fire) x Distance (Near, Far) repeated measures ANOVAs for the four traits

Trait	Factor	ANOVA
Attractiveness	**Context**	**$F(1, 19) = 53.13, p <.001, \eta_p^2 = .74$ [.54, .93]**
	Distance	$F(1, 19) = .85, p = .368, \eta_p^2 = .04$ [.00, .13]
	Interaction	$F(1, 19) = .08, p = .786, \eta_p^2 = .00$ [.00, .03]
Competence	**Context**	**$F(1, 21) = 14.81, p <.001, \eta_p^2 = .41$ [.21, .62]**
	Distance	$F(1, 21) = .86, p = .364, \eta_p^2 = .04$ [.00, .12]
	Interaction	$F(1, 21) = .42, p = .522, \eta_p^2 = .02$ [(.00, .08]
Dominance	**Context**	**$F(1, 21) = 50.62, p <.001, \eta_p^2 = .71$ [.52, .90]**
	Distance	$F(1, 21) = .06, p = .810, \eta_p^2 = .00$ [.00, .03]
	Interaction	$F(1, 21) = .21, p = .651, \eta_p^2 = .01$ [.00, .05]
Trustworthiness	**Context**	**$F(1, 23) = 205.76, p <.001, \eta_p^2 = .90$ [.78, 1.00]**
	Distance	$F(1, 23) = 2.69, p = .114, \eta_p^2 = .11$ [.00, .23]
	Interaction	$F(1, 23) = .00, p = .992, \eta_p^2 < .01$ [.00, .00]

Note. Significant effects (p<.05) in bold. Values in square brackets represent 95% confidence intervals of the effect size.

Figure 3.4 depicts the interactions of Distance, Social Context, and Trait judgements.

Figure 3.4. Plots of the Ambient Context (Beach, Fire) x Distance (Near, Far) repeated measures ANOVAs for the four traits



Note. Red bars = Beach context, Blue bars = Fire context Error bars represent 95% confidence intervals of the mean.

Discussion

Results revealed that, similar to the social context manipulations in Experiment 6, ambient context significantly influenced how people were rated across distances. Individuals surrounded by a beach context were perceived as more attractive, trustworthy, and competent, and less dominant compared with those appearing in front of a fire. However, we found no interactions between ambient context and distance, unlike the social background in Experiment 6. This suggested that when a positive or negative background is not social in nature, the context's valence does not impact perceptions differently at varying distances. This finding further underscored the specificity of the interaction effect on trustworthiness judgments observed with social backgrounds.

General discussion

Across two experiments, we investigated the relationship between trait judgments, physical distance, and context. As distance increases, the availability and importance of information in person perception is known to change (e.g., person recognition; Hahn et al., 2016; see also Chapter 2). Additionally, past evidence indicated that background context impacted person perception, such as judgments of emotional expressions (e.g., Reschke et al., 2018) and trustworthiness (e.g., Mattavelli et al., 2022). Building upon this research, we aimed to examine how context and distance influenced different trait dimensions using life-sized images of people presented at various physical distances from participants, as in Chapter 2.

We added social and ambient/non-social backgrounds to images of the same stimuli identities presented during Chapter 2. Our primary goal was to determine the extent to which people use social and non-social referencing at different distances when rating others on various traits. To explore this, we incorporated social contexts where the background figures had either positive expressions (happy and smiling) or negative expressions (grimacing in disgust). Additionally, we investigated whether similar interaction effects of context would be observed when images of people were presented within differently valanced affective environments (roaring fire and sunny beach). This aspect of the design allowed us to distinguish between the effects of context valence broadly and social effects more specifically.

As expected, we found that both social and ambient contexts significantly influenced all trait judgments in the anticipated direction. Negative valanced backgrounds decreased judgments, and positive valence increased them, except for ratings of perceived dominance, which increased with the fire background. In the social context experiment, we also found a main effect of distance on dominance ratings, with selectively higher ratings at near distances compared with far. Crucially, we observed an interaction effect of social context and distance on trustworthiness ratings. Emotionally-valanced background figures had a greater impact on trustworthiness ratings at further distances. While context influenced the perception of all traits at all distances, the effect of social context on trustworthiness ratings became stronger with distance – decreasing ratings in negative contexts and increasing them in positive contexts. These results demonstrated a highly specialized interaction effect of social context and distance on trustworthiness, suggesting that this effect was driven by increased social referencing when making trustworthiness judgments at greater distances, rather than by the mere valence of the background.

Limitations and future studies

Apart from some of the limitations already discussed in Chapter 2, this study faced additional challenges. Our experiments were limited in scope to two specific distances and two contextual settings per experiment. This means that other potentially significant variations in distance and context were not explored. There may be certain distance-related nuances that were not captured by the limited selection of distances we used. Additionally, the variation in social contexts was restricted to two emotional expressions of the background figures, who were facing towards the participant. To gain a more comprehensive understanding of the effects of social referencing, it would be interesting to vary the orientation of these figures, e.g., angling them both towards and away from the target. This would help indicate the directedness of their expressions, potentially providing deeper insights into how social context influences trait judgments. Expanding the range of distances and contextual settings could reveal more intricate patterns and interactions, thereby enhancing the robustness and generalizability of the findings. Similarly, using different ambient contexts might yield varying results. Mattavelli et al. (2022) found that people's ratings of targets changed based on the attributability of the context to the target's actions (e.g., a person standing in the room with blood splatters on the walls). This suggests that different environmental settings could influence trait judgments in distinct ways. Exploring a broader range of ambient contexts, especially those that can be attributed directly or indirectly to the target's behaviour, might reveal different patterns of perception and provide a deeper understanding of how context shapes social evaluations.

Using a sample of convenience, specifically psychology undergraduate students from a UK university, poses challenges regarding the representativeness of our sample and the generalizability of our findings to a broader population. There could be important differences between different cultures in visual and social perception. For example, it has been shown that East Asian participants incorporated more information from the social environment (Masuda, Ellsworth, et al., 2008) and other contextual information (Masuda, Gonzalez, et al., 2008) compared with Western participants. It would therefore be interesting and important to investigate these effects while making trait judgements at various distances.

Conclusions

This experiment demonstrated the valance of the context impacted trait ratings across distances. More importantly it revealed a highly specialized interaction effect of distance and social context on trustworthiness ratings, such that context had greater effect at further distances. This result indicates that at greater distances, individuals relied more on the surrounding social cues to make judgments about trustworthiness, highlighting the importance of integrating both distance and social context in understanding interpersonal perceptions.

Chapter 4, Linking individual differences to comfort distances

Summary of the chapter

From the start of this PhD project, we were interested in collecting data on individual differences related to people's interpersonal space perception. Given that any such individual differences study requires a large sample size (Schönbrodt & Perugini, 2013) we decided to include a short theoretically motivated 'easter egg' experiment at the end of each experiment for which participants came into the lab (such as those reported in Chapters 2 and 3). Participants included in these analyses are therefore overlapping with the ones collected for Chapters 2 and 3 and other experiments that were conducted as part of the PhD and are not included in this thesis.

We were particularly interested in how individual differences in comfort distance preferences relate to other personality characteristics (social anxiety and empathy). We were also interested to confirm how comfort distance preferences associated with real people relate to those associated with life-sized *images of people*, projected onto the screen. We used comfort distance estimation tasks in which participants were asked to indicate the distances at which they would feel comfortable standing from the experimenter, a mannequin and an image of the experimenter projected onto the projector screen. In these approach- (active) and stop- (passive) distance protocols, the participant approaches or stops the experimenter respectively at a comfortable distance. We found that all the comfort distances correlated between each other and that the comfort distances to the real-person and the image of a person also correlated with social anxiety and empathy scores. The second aim of these experiments was to validate the use of our experimental setup using a projector, a central feature of the design of the experiments presented in Chapters 2 and 3.

Introduction

In this experiment, we investigated people's estimation of comfort distances, defined as the distance beyond which another person becomes uncomfortably close (see Introduction), and whether this distance varies between real-life people and life-size projections of their whole-person images. We employed a classic 'comfort distance estimation' task, where participants were asked to determine the distance at which they would feel comfortable standing from a target (Candini et al., 2021; Hecht et al., 2019; Iachini et al., 2014; Sorokowska et al., 2017). Furthermore, we aimed to relate these distances to measures of social anxiety and empathy.

Our goal was to determine whether participants would estimate similar comfort distances towards a real person (the experimenter), a life-sized image projection of the experimenter on a screen, and a non-social reference: a dressmaking mannequin. Additionally, this experiment aimed to validate our projector design used in Chapters 2 and 3, by showing whether the distances towards the projected images are similar to those to the real people.

Social anxiety has been shown to positively correlate with preferred comfort distance (Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013). People with high social anxiety tend to feel comfortable at relatively greater interpersonal distances (Givon-Benjio & Okon-Singer, 2020). They often employ attention strategies related to disengagement or avoidance when social stimuli are proximal (Perry et al., 2013; Rinck et al., 2010; Wieser et al., 2010) and estimate distances from strangers as shorter than less socially anxious individuals (Givon-Benjio & Okon-Singer, 2020). We hypothesized that social anxiety would be positively correlated with the distances participants maintain from the experimenter. To validate the use of the projector screen, social anxiety measures should also be positively correlated with the distances participants keep from the screen, demonstrating that the participants perceive the images as valid social objects.

In addition to social anxiety, empathy has been linked to people's perception of social space (Gherri et al., 2022; Perry et al., 2015; Schiano Lomoriello et al., 2023; Vieira & Marsh, 2014), which we aimed to explore further in our study. For example, Perry et al. (2015) revealed that after the administration of oxytocin, which has been shown to facilitate pro-social (Striepens et al., 2011 for review) and approach behaviours (Kemp & Guastella, 2011), highly empathic individuals reduced their interpersonal distance preferences, while those lower in empathy increased them. Furthermore, Schiano Lomoriello et al. (2023) found that participants exhibited lower levels of empathy for images of people seen as separate – presented beyond the reachable action space using plexiglass as a barrier – compared with those within the action space without such separation. Another link between empathy and interpersonal space perception was identified by Vieira & Marsh (2014), who examined the relationship between comfort distance and psychopathic traits, which include a lack of empathy. They discovered that individuals high in psychopathy maintained shorter distances from others, suggesting a potential link between interpersonal space and empathy. Together, these findings suggest a relationship between empathy and comfort space. In contrast to individuals with psychopathic traits, who tend to disregard other’s boundaries and invade their personal space, it is possible that empathy will be positively correlated with comfort distances

– people with higher empathy would prefer maintaining larger distances, because they might be more sensitive to other's discomfort at closer distances.

Research considerations

We decided that our protocol would measure the minimum distance at which participants feel comfortable. We believed that this "margin of safety" might be more informative and relatable to the individual differences we were measuring, particularly social anxiety. Similarly, we decided to use the directed gaze to increase the perceived intensity of the social approach. During piloting, we also found that these distances were more reliable and that participants were more confident in their estimations compared with when they were asked to estimate the distances at which they would prefer to stand during social interactions.

Experiment 8, Individual differences related to space perception

Methods

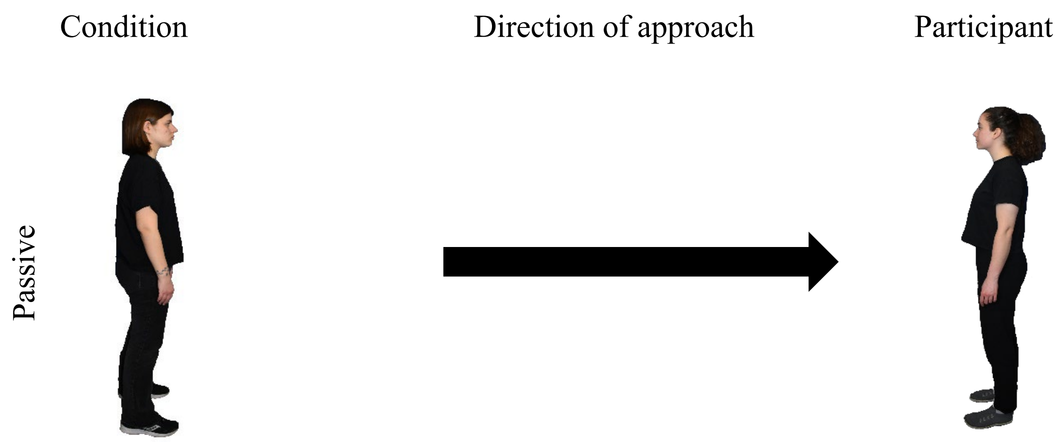
Participants. Two hundred and nine adults (M = 20.9 years, SD = 4.8 years, range from 18 to 47 years; 40 male, 3 non-binary) completed this experiment. Participants reported normal or corrected-to-normal vision. These participants completed the experiments detailed in Chapters 2 and 3. Data was collected between February 2022 and March 2023. For this experiment, the procedure of the study was approved by the local Ethics Committee (reference code: ETH2324-0775). All participants were naive as to the purpose of the study and provided informed written consent to participation after being informed about the procedure of the study. Participants in our studies received course credits or a small monetary compensation for participation. Most of the participants were Psychology undergraduate students, the remainder from the local community.

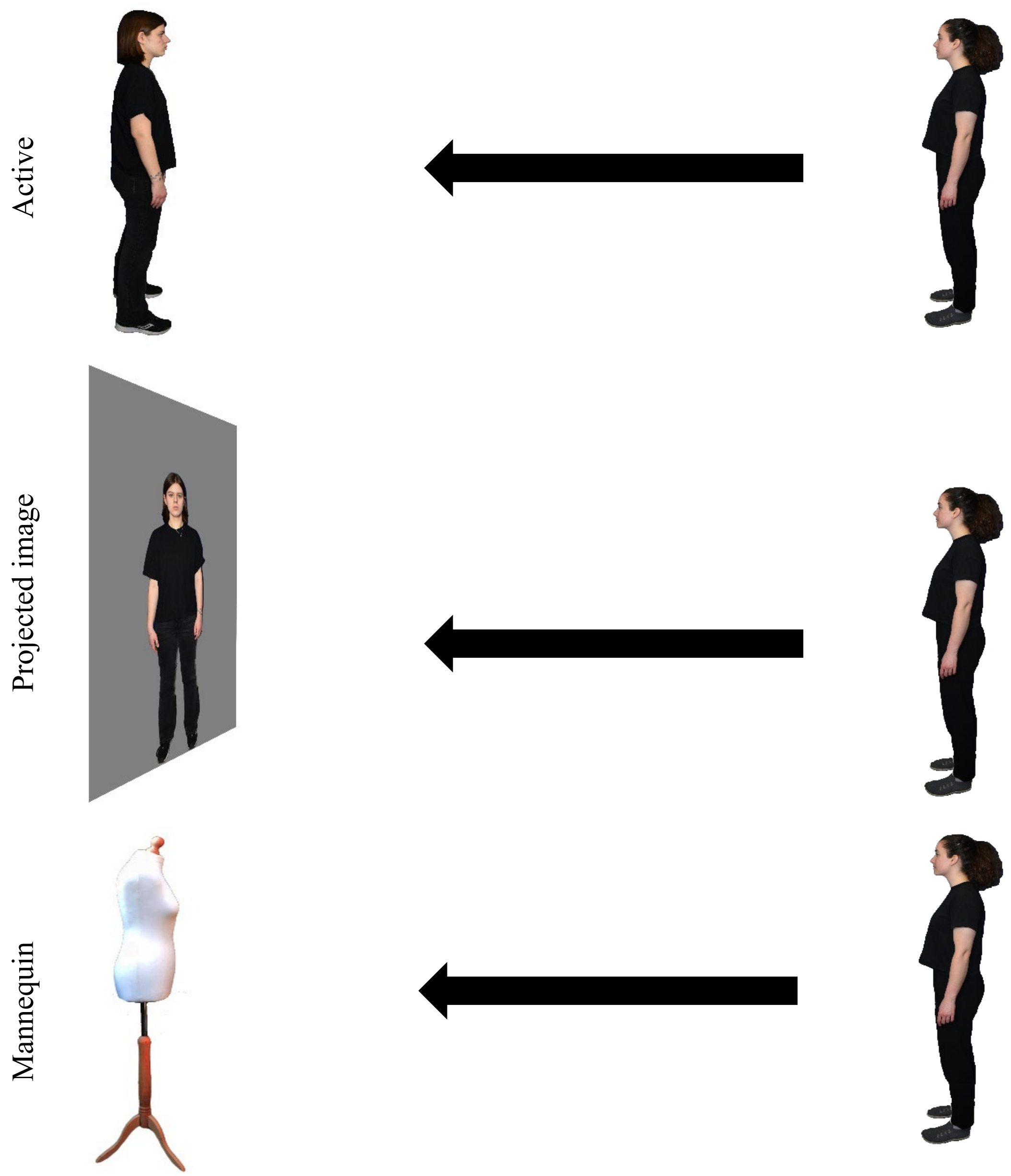
Apparatus & stimuli. The experiment started with four comfort distance measurements, which were recorded relative to a female confederate, an image of that experimenter, and a dressmaking mannequin (order randomised). Active comfort distances (confederate, image, mannequin) were recorded by introducing participants to comfort distance as a construct (i.e., the distance at which people feel comfortable standing from others) and asked 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 confederate conditions participants were asked to make eye contact during the approach.

A high-resolution life-sized image of the experimenter was projected onto a 2.3m (height) × 1.5m (width) white screen (Optoma GT1080 projector, 2800 Lumens (ANSI), working resolution of 1080 x 1920 pixels). The dressmaking mannequin comprised a female torso with no head, arms, or legs. The projected image was a life-sized image of the experimenter. The mannequin, image and the female experimenter were all 165cm tall. All experiments were conducted in a large room (11.7m x 7.5m x 3.8m) with low lighting. Chest-to-chest comfort distance at the sternum level were measured with a laser measuring tool (RockSeed meter, measuring range 50m, accuracy ±0.16cm). For schematic representation of comfort distance tasks see Figure 4.1.

Questionnaires. We measured social anxiety with the *Brief Fear of Negative Evaluation Scale* (FNEB; Leary, 1983) a validated measure (Collins et al., 2005) where participants self-report apprehension of being negatively evaluated by others. We measured empathy with the *Interpersonal reactivity index* (IRI; Davis, 1983) a validated measure (Grevenstein, 2020) where participants self-report reactions of one individual to the observed experiences of another.

Figure 4.1. Schematic representations of comfort distance tasks





Design & Procedure. At the end of a projector experiment (those described in Chapter 2 and 3 or similar) participants took part in four comfort distance approach tasks (stopping the approaching experimenter, approaching the experimenter, an image of the experimenter and a mannequin) and then completed the two questionnaires. Participants were introduced to comfort distance as a construct (i.e., the distance at which people feel comfortable standing from others) and told they would be asked to identify their comfort distance from the experimenter, a mannequin, and an image of the experimenter. They approached each stimulus from 2.5 m and were asked to stop when they felt comfortable to be standing in relation to the person/mannequin/image, just before they would start feeling uncomfortable. Statistical analyses reported in this chapter were carried out using IMB SPSS Statistics (Version 25).

Results & Discussion

We found the comfort distances kept to experimenter, screen, and mannequin to be highly correlated (all rs > .40, all ps < .001, see Table 4.1 and Appendix G). In addition, we observed significant positive correlations between social anxiety and mean comfort distances kept from the real person (r = .19, p = .006) and from the projected life-sized image of the person (r = .21, p = .004). These results suggested that participants responded to these life-sized projections in a similar manner to real person targets. That is, those more fearful of negative evaluation keep larger distances from both real and projected people. Critically, social anxiety levels were not significantly associated with comfort distances from the mannequin (r = .09, p = .189), suggesting that such association was specific to interpersonal distances rather than a generic effect associated with distance preferences.

Interestingly, we found that empathy was highly correlated with all other measures, including mannequin distance preferences (all rs > .25, all ps < .001, see Table 4.1 for numerical representation of results and Figure A.5 in Appendix G for scatterplots). This result might indicate that highly empathic individuals possessed a heightened sensitivity to social cues, leading them to attribute human-like qualities to inanimate objects, such as the mannequin, and consequently applied similar comfort distance preferences as they would with actual people. These findings also laid a sound foundation for our working hypothesis that life-sized projected images act as a valid proxy for investigating proxemic behaviour.

Table 4.1. Means, 95% confidence intervals, and correlations of individual differences

Variable	M [95% CI]	1	2	3	4	5
1. IRI	56.95 [54.39, 59.51]					
2. FNES	41.25 [39.83, 42.68]	0.57***				
3. Image CD	84 [78, 89]	0.39***	0.20**			
4. Active CD	73 [69, 76]	0.27***	0.22**	0.49***		
5. Passive CD	75 [71, 79]	0.36***	0.23***	0.54***	0.74***	
6. Control CD	59 [54, 63]	0.25***	0.09	0.67***	0.40***	0.47***

Note. * indicates p < .05; ** indicates p < .01; *** indicates p <.001. M, CI, FNES, IRI, and CD are used to represent mean, confidence interval, Fear of Negative Evaluation Scale, Interpersonal Reactivity Index, and Comfort Distance respectively. Distances reported in cm; rounded to cm to account for laser measuring tool accuracy (±16cm).

Limitations and future research. Personal comfort distances vary greatly depending on the nature of the interaction. Despite the confederate following a consistent experimental protocol, different participants might have perceived the confederate and their interaction differently, particularly because the experiment was conducted over an extended period of time. Furthermore, both the questionnaires and comfort distance estimations rely on self-reported data, which can be inaccurate because of things like social desirability bias, lack of self-awareness, misinterpreting the questions and tasks.

Presented data were specific to comfort distance preference from a ‘single’ target. It would be interesting to explore how comfort distances are estimated towards a group of people and how these relate to the distances to an individual. Such experiments could be conducted with either projected images or in a virtual environment, where it would be possible to present diverse targets, manipulate the distance between them, whether they are facing towards or away from each other, their emotional expressions. It would also be interesting to relate this to other self-reported measures and their impressions of the targets. Furthermore, there is a great scope for such an experiment to be conducted cross-culturally because important differences have been observed in space perception among various cultures and societies.

Conclusions

This experiment has identified variables that were associated with individual differences in comfort distance preferences. For example, those with higher levels of self-reported social anxiety and empathy preferred keeping larger distances to others. Crucially, it also demonstrated that images of people projected onto the screen were valid social stimuli to investigate interpersonal distance, validating the experimental setup used in Chapters 2 and 3.

Chapter 5, Neural responses related to interpersonal space

Summary of the chapter

This final study sought to identify a specific neural correlate of interpersonal space by measuring participants electroencephalogram (EEG) activity associated with being at different real world interpersonal distances from a confederate. Specifically, we measured alpha-band suppression, an established marker of attentional engagement, during static (near, far) and dynamic (approaching, receding) manipulations of interpersonal distance. Results confirm empirically that alpha power decreases with proxemic-related changes in the behavioural relevance of the confederate (e.g., associated with being near, particularly when an individual is approaching cf. receding). Furthermore, evidence that these neural effects varied predictably across the course of the testing session (i.e., changing as participants became more familiar with the confederate) and correlated at the individual level with social anxiety strongly signal they are the product of socially selective rather than generic attentional processes.

Introduction

Interpersonal distance is closely linked to attention. We focus more on those near us, because they are more likely to be behaviourally relevant to us (Martin et al., 2021; Pilz et al., 2011). Physiological responses, such as stress and arousal, indicate autonomic nervous system activation in response to proximity and approach direction (Candini et al., 2021; Evans & Wener, 2007; McBride, 1965), and prolonged eye contact (Rinck, 2010; Wieser, 2010). Candini et al. (2021) found higher skin conductance responses in more relevant conditions (approaching vs. receding, near vs. far). ERP studies show that fearful faces capture more attention within reachable space and that looming faces draw more attention than receding ones (Martin et al., 2021). fMRI research indicates that the amygdala, which regulates arousal and vigilance, is more active with proximity (Kennedy et al., 2009; Mobbs et al., 2010). Kennedy et al. (2009) also found disrupted personal space processing in a patient with amygdala damage. These findings are consistent with increased attention being paid more to relevant, closer stimuli.

In the current study we used alpha band (8-13 Hz) EEG activity suppression as an index of attentional engagement to study proximity. Early studies (Adrian & Matthews, 1934; Berger, 1929) found that alpha amplitude increases during introspection and decreases with external attention (Gallotto et al., 2020; Heyselaar et al., 2018). Perry et al. (2016) found stronger alpha suppression to imagined human approaches than to inanimate objects, especially in individuals with heightened sensory sensitivity. As such we used alpha suppression for examining behaviourally relevant events like interpersonal distance. Attention effects related to interpersonal distance may be particularly pronounced in those with social anxiety.

The aims of the present study were twofold, investigating a) the relationship between social proximity and neural correlates of attention/arousal and b) to understand the social selectivity of the attentional effects by investigating whether the observed effects are predictably associated with things like individual differences in social anxiety, comfort distance preferences, and changes in familiarity with the experimenter over the course of the study. In our experiment we wanted to investigate a real interpersonal distance, rather than implied distance as has been the focus of past research, i.e., varying the size of stimuli or having participants imagine the interpersonal distance. We wanted to study the effects of distance in an ecologically valid way, because we believe interpersonal distance employs specific mechanisms which vary with certain individual differences, that might be different to those observed when varying proxies for distance, such as stimulus size. We assessed participants' responses to a live confederate that stood and moved across veridical/real-life space and time.

If attention is tied to behavioural relevance and interpersonal distance, then we anticipated that participants' alpha suppression levels should be selectively higher when confederates are near (cf. far). By additionally measuring responses to dynamic stimuli, we were able to target *behavioural relevance* over and above the contribution of differences in stimuli appearance associated with distance alone (i.e., size, spatial frequency, contrast, illumination), which could be held equivalent in the approach vs recede conditions. We predicted more alpha suppression when the confederate was approaching the participants compared with receding. The choice of distances - 4.5 m for far and 0.5 m for near were chosen to cover all the distinct distance buffer zones according to the proxemics research (public, social, personal and intimate distance; Hall, 1966).

Research questions

Does proximity have a systematic effect on alpha band power?

Do individual differences in social anxiety, empathy, and personal comfort distances relate to alpha band power?

Do comfort distances change over the course of the experiment?

Does familiarity affect alpha band power across different conditions?

Research considerations

We wanted to run the experiment in real time and space which is why EEG was chosen. It allows a great temporal resolution, which enabled us to track changes in proximity in real time, which is why we preferred it over a measure such as fNIRS. We had to slightly adapt the setup to conduct the experiment in a room with sufficient length to accommodate the far distances required for our study. This however meant that the experiment was run in a room that was not empty and we attempted to minimize scene distractions. Since the room remained constant for all participants and our design involved comparing the confederate at the same distances, we decided it was appropriate for the experiment.

To occlude participants vision between trials, we considered several options. We decided against asking participants to open or close their eyes, because any kind of signal for them to do so could bias the results. We decided to use Plato occlusion goggles, which can rapidly change from transparent to occluded without changing the environment luminance. This was important to reduce the delay between participants' adaptation to the light, so that we could start the trial as soon as the glasses opened. These goggles use electric current, which is why we suspected there might be some interference between the glasses and EEG electrodes. To assess this, we conducted several pilot tests. We discovered that electrical interference was present only in the frontal channels, while the posterior and occipital channels, which we planned to analyse, were unaffected. Furthermore, we found the original glasses have very tight temple arms, which would make the one-hour experiment very uncomfortable. We found it was possible to modify them to have an elastic band instead, which also fit well with the EEG cap.

We also considered how to cue the participants to the position of the confederate's eyes. To address this, we added an additional second at the start of the dynamic trials to give participants time to orient themselves and locate the confederate's eyes. Since the study was designed so that static trials followed dynamic ones, with the position of the static trials always being the ending position of the dynamic trials (separated by an intertrial period with glasses closed), we did not deem it necessary to add extra time for participants to orient themselves at the start of the static trials.

We also needed to carefully consider the speed and length of movement during the dynamic conditions of the task: approach and recede. We reasoned that a fast speed of movement would likely elicit stronger arousal responses but could also make it difficult to distinguish between responses associated with specific distances. Therefore, we selected the speed that we believed would best balance these factors. The duration of the dynamic conditions was chosen to be twice as long as trials in the static condition, to allow for scope to potentially compare the dynamic at far and near with the static far and near (note that we later understood this comparison would not be the most appropriate for our analysis).

Experiment 9, Neural correlates of interpersonal distance

Methods

Participants. An a priori power analysis was conducted using G*Power 3.1.9.4 (Faul et al., 2007) to determine the required sample size for detecting main effects and interactions in a 2x4 within-subject repeated measures ANOVA. The analysis was based on a medium effect size ($f = 0.2$), which corresponds to a partial eta squared (η^2_p) of approximately 0.10. This effect size was chosen based on findings from prior EEG alpha band research (Perry et al., 2016), which reported medium-sized effects of attention on alpha power. To ensure the validity of the analysis, we assumed a non-sphericity correction (ε) of 1.0, based on prior studies using similar experimental designs that did not report significant violations of sphericity (Bacigalupo & Luck, 2022; Perry et al., 2016). A moderate correlation between repeated measures ($r = 0.5$) was assumed to account for both expecting systematic variation of alpha power across conditions and individual differences observed with alpha power (e.g., Metzen et al., 2022). Based on these assumptions, and to achieve a power of 0.95 (with $\alpha = 0.05$), the analysis determined that a minimum of 36 participants was required to detect main effects. However, as G*Power does not support power calculations for within-subject * within-subject interactions, the power analysis primarily focused on the main effects, while recognizing that detecting interaction effects typically requires larger sample sizes due to the smaller effect sizes often associated with interactions (Durand, 2013). As such, while the study was well-powered to detect medium-sized main effects, we acknowledge that it may have been underpowered to detect smaller interaction effects.

We over-sampled to accommodate anticipated attrition and collected data from a total of 44 participants. Technical challenges and poor data quality led to the exclusion of 7 participants. Our final sample comprised 37 psychology undergraduates, aged 18 to 31 years

(M = 19.7 years, SD = 2.7 years; 31 women, 6 men) who received course credit for their participation. One participants' questionnaire data was lost due to a technical error. Ethical approval was provided by the Ethics Committee of the School of Psychology of the University of East Anglia (reference code: ETH2324-0059). All participants were naive as to the purpose of the study and provided informed written consent to participation after being informed about the procedure of the study. The experiment was pre-registered (deviations from the pre-registration presented in Appendix E). Data was collected between October 2023 and December 2023.

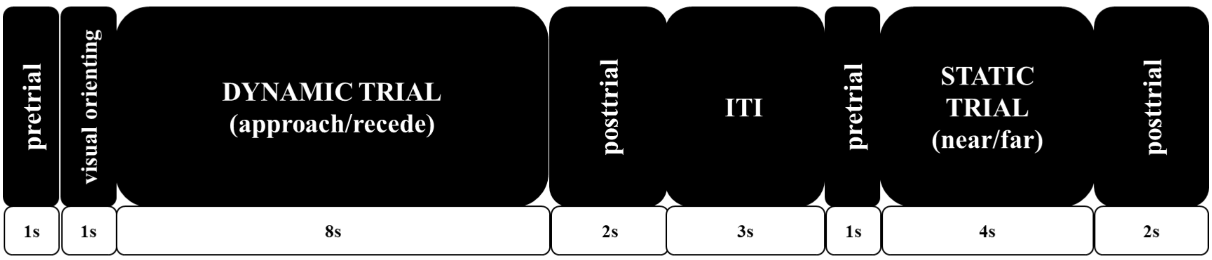
Experimental procedure. The experiment started with three comfort distance measurements, which were recorded relative to a confederate and a dressmaking mannequin (order randomised). Active comfort distances (confederate, mannequin) were recorded by introducing participants to comfort distance as a construct (i.e., the distance at which people feel comfortable standing from others) and asked 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 confederate conditions participants were asked to make eye contact during the approach. A white European experimenter (female, age 29, height 165cm) served as the confederate for all tasks and participants, wearing a standard outfit (black trousers and t-shirt). The mannequin was 165cm tall and comprised a torso with no head or legs. Chest-to-chest comfort distance at the sternum level were measured with a laser measuring tool (RockSeed meter, measuring range 50m, accuracy ±0.16cm; for schematic representation see Figure 4.1).

Participants were then briefed for the main experimental task and fitted for a 32 channel EEG cap and PLATO Visual Occlusion Spectacles (constructed with specially designed liquid crystal cells that can change rapidly from transparent to light scattering/opaque). They were told that during the experiment, the confederate would be standing and walking towards/away from them in the large testing room (D:6m x H:3m x W:2m). Their task was to stand naturally in a comfortable position, directly facing the confederate, maintain eye contact and remain as still as possible throughout each trial (regular breaks were scheduled and also made available as needed). For the experiment we used a standard EEG system with the participant tethered to the amplifiers, which were placed on a desk next to the standing participant. Active cap control box was used to check for impedances after which the raw data was visually inspected to ensure low impedance of the electrodes.

Each trial commenced with the spectacles ‘opening’ (becoming transparent) to reveal the confederate standing in a ‘far’ position (at a 4.5m distance) or a ‘near’ position (0.5m) (50% of each, randomised order for each participant) from which they would slowly approach or recede from the participant for 8 seconds. They were trained to walk at a steady pace and also had acoustic pace cues delivered through an earpiece. Acoustic cues were automatized with a custom-made script in MATLAB as well as the trigger signal in EEG for trials onset and occlusion goggles opening/closing mechanism. Floor tape marked 0.5m steps to ensure consistent temporal-spatial correspondence across the trial epoch (i.e., 1 second = 0.5m; 2s = 1m; 3s = 1.5m; 4s = 2m; 5s = 2.5m; 6s = 3m; 7s = 3.5m, 8s = 4m; 9s = 4.5m). The first second after the glasses opened was not part of the trial, because the confederate was standing still, giving the time to participant to find confederate’s eyes, i.e., visual orienting in the Figure 5.1). After the confederate reached their near/far destination, a 4 second static trial occurred (standing at the ending position: 0.5m or 4.5m; Figure 5.2). There was a total of 192 trials, 96 for the dynamic and 96 for the static part).

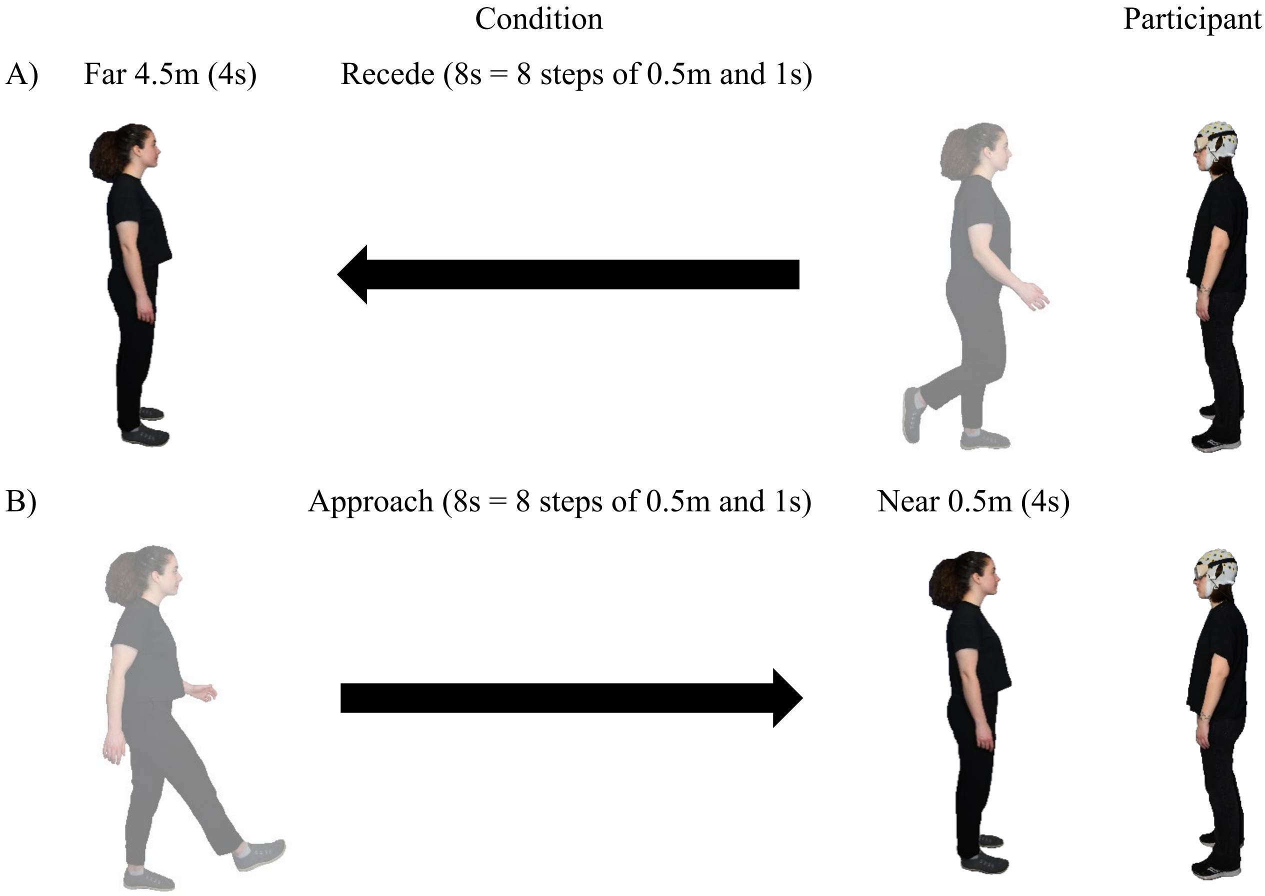
Figure 5.1. Temporal progression of Dynamic and Static trials

Each Dynamic trial was followed by a Static trial. Confederate was in position between trials. The pretrial was used to calculate the baseline. Visual orienting signifies the time for participants to orient gaze towards the confederate and was discarded from the analyses.



At the end of the testing session, the three comfort distance measures were completed again, along with the *Brief Fear of Negative Evaluation Scale* (FNEB; Leary, 1983) a validated measure (Collins et al., 2005) where participants self-report apprehension of being negatively evaluated by others. We measured empathy with the *Interpersonal reactivity index* (IRI; Davis, 1983) a validated measure (Grevenstein, 2020) where participants self-report their reactions to the observed experiences of another.

Figure 5.2. Approach with Near condition (A) and Recede with Far condition (B)



EEG preprocessing & data 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. 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 data for the first second of the Dynamic trials following the opening of the glasses were not analysed to allow for the participant to reorient to the

Experimenter following the visual transition, making the trial length analysed 4s 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

Individual differences. Table 5.1 contains all the descriptive statistics of the measured variables.

Table 5.1. Means and 95% confidence intervals of the individual difference measures

Measure	M [95% CI]
Brief Fear of Negative Evaluation Scale scores	44.83 [41.96, 47.71]
Interpersonal Reactivity Index scores	57.98 [56.19, 59.77]
Near - Far alpha power difference	-0.50 [-0.93, -0.06]
Approach - Recede alpha power difference	-0.62 [-1.09, -0.16]
Comfort Distance Passive Pre - Post difference	16.71 [9.91, 23.51]
Comfort Distance Active Pre - Post difference	13.20 [7.40, 19.00]

Comfort distances. As might be expected, given that familiarity with the confederate increased over the course of the testing session, we also observed a consistent decrease in participants' preferred comfort distances (See Table 5.2). A 2 (Time of Measurement: Pre-, Post-Experiment) x 3 (Comfort Distance Task: Active, Passive, Control) repeated measures ANOVA on these comfort distance estimates confirmed a significant main effect of Time, $F(1, 36) = 25.32$, $p < .001$, $\eta_p^2 = .413$ [95% CI: .25, .57], with post-experiment comfort distances smaller than when measured pre-experiment. The main effect of Task was also significant, $F(1.93, 69.49) = 17.37$, $p < .001$, $\eta_p^2 = .325$ [95% CI: .22, .43], with participants comfortable closer to the mannequin (control condition) than the experimenter (active, passive). The interaction was also significant, $F(1.77, 63.65) = 9.92$, $p < .001$, $\eta_p^2 = .216$ [95% CI: .12, .32], because the effect of Time was observed less strongly in the control condition (mean change 6cm) compared with the Active (13cm) and Passive (17cm) conditions.

We did not find correlations between any of the comfort distance measures (passive, active, pre-experiment, post-experiment) and social anxiety (all τ_bs<.15, all ps > .140), and empathy (all τ_bs<.05, all ps > .691; for scatterplots see Figure A.5 in Appendix H). We did find a significant correlation between empathy and social anxiety $\tau_b(34) = .24$, $p = .048$.

Table 5.2. Means and 95% confidence intervals of comfort distances (in cm) for each comfort distance task

Comfort Distance Task	Pre-Experiment Measure	Post-Experiment Measure

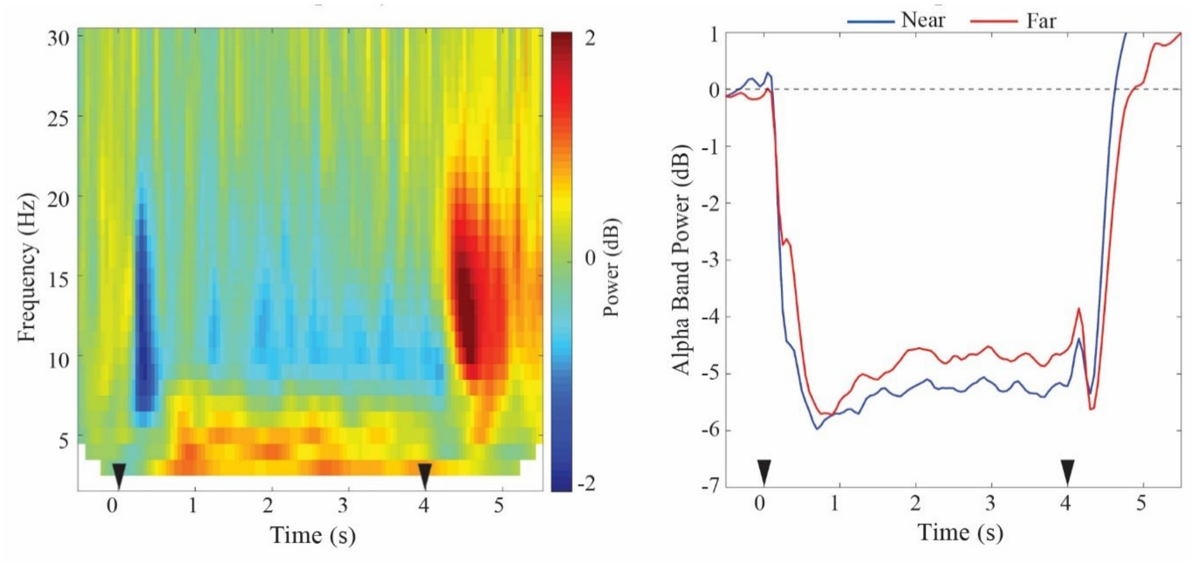
Active	55 [46, 64]	42 [35, 49]
Passive	59 [50, 68]	42 [36, 49]
Control	42 [34, 49]	36 [30, 42]

EEG static trials. Figure 5.3A shows the time frequency plots of the power difference between the Near and Far conditions. Figure 5.3B shows the average alpha band power difference in the Near and Far conditions and the difference between them. From these graphs it is clear that suppression of alpha occurred for both conditions but was larger in the Near trials. Alpha power remained relatively stable over the time of the trial. These results indicate higher attentional engagement when the confederate was standing near, which is consistent with the confederate having higher behavioural relevance for participants at near (cf. far) distances.

Figure 5.3. Graphic representation of results of the Static trials

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; analysis windows marked by black arrows

A) EEG Time Frequency difference B) Time vs. EEG Alpha Band Power



2 (Proximity: Near, Far) x 4 (Time window: 0-4) ANOVA. A repeated measures ANOVA investigated the effects of Proximity and Time on levels of alpha suppression. There was a significant main effect of Distance, $F(1,36) = 6.15$, $p = .018$, $\eta_p^2 = .15$ [95% CI: .03, .26], with greater alpha suppression when the confederate stood at the Near than Far distance

(-5.01 [-6.09, -3.92] dB vs. -4.51 [-5.53, -3.49] dB). Alpha suppression also significantly reduced over Time, $F(1,36) = 21.39$, $p < .001$, $\eta_p^2 = .37$ [95% CI: .22, .53]. The interaction was non-significant, $F(3, 108) = .26$, $p = .852$, $\eta_p^2 = .01$ [95% CI: .00, .02].

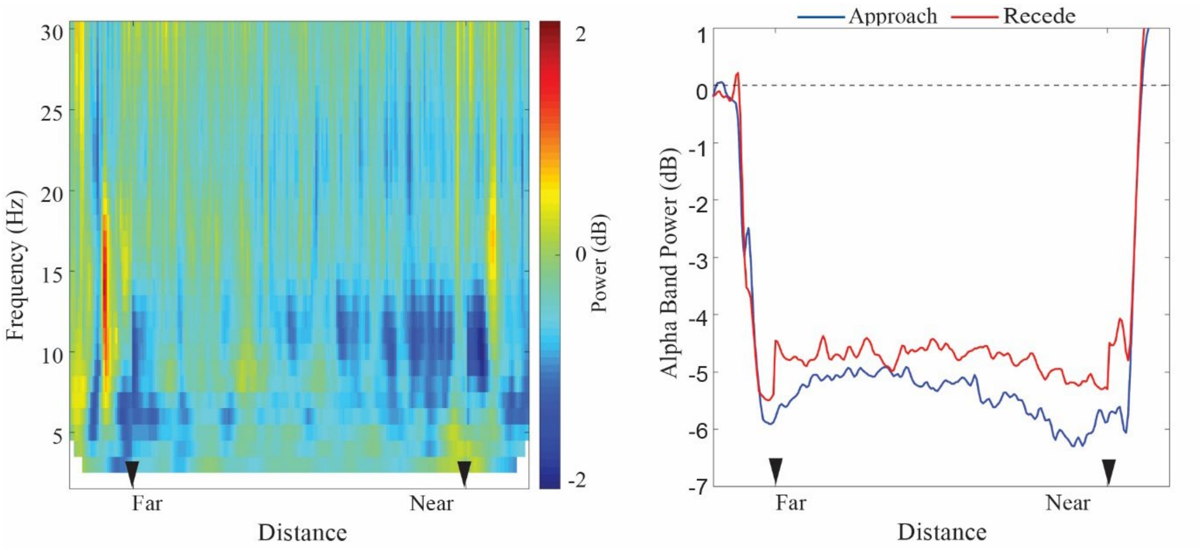
Together these results indicate that alpha suppression may indeed serve as a reliable neural marker of attention-related differences in the processing of interpersonal distance. In line with predictions, we identified significantly more alpha band suppression when the confederate appeared near vs. far from participants. Moreover, this effect was fairly stable temporally, other than for a brief period at the start of the trial that was likely associated with stimulus onset.

EEG dynamic trials. Figure 5.4A represents differences in power at frequencies ranging from 2 to 30 Hz between Approach and Recede conditions over distance. Figure 5.4B shows alpha power changes across the distance. To be able to compare the distance related power changes of the conditions, the trial time course of the Recede condition was flipped (1-9s). The figures show alpha band suppression was larger in the Approach condition overall, while this difference becomes most pronounced at the near distances. While the alpha power remained stable in the Recede condition, it became stronger in the Approach condition at the near distances. Showing the alpha suppression differences at the same distances, in the two conditions in which we varied the behavioural relevance, strongly indicates that the effects were not due to the visual differences of the stimulus, but the differences in attention and the stimulus relevance.

Figure 5.4. Graphic representation of results of the Dynamic trials

A) Time Frequency difference plot shows the Dynamic differences across the distance of the trial and different frequencies (2–30Hz); B) EEG alpha-band (8–13 Hz) power over distance for Approach and Recede; analysis windows marked by black arrows

A) EEG Time Frequency Difference B) Distance vs. EEG Alpha Band Power



2 (Movement Direction: Approach, Recede) x 8 (Distance window: 1-9) ANOVA. Repeated-measures ANOVA looking at the effects of Movement Direction (Approach, Recede) x Distance (windows: 1-9) on levels of alpha suppression revealed a significant main effect of Movement Direction, $F(1,36) = 8.72$, $p = .006$, $\eta_p^2 = .20$ [95% CI: .07, .32]. There was more alpha suppression when the confederate was approaching vs receding (-5.40 [-6.49, -4.31] dB vs. -4.78 [-5.75, -3.80] dB). There was also a significant main effect of Distance, $F(2.14, 77.20) = 13.78$, $p < .001$, $\eta_p^2 = .28$ [95% CI: .18, .38]. There was a significant interaction between Movement Direction and Distance, $F(3.94, 141.82) = 3.79$, $p = .006$, $\eta_p^2 = .10$ [95% CI: .05, .14], which could be described by a linear contrast, $F(1, 36) = 5.00$, $p = .032$, $\eta_p^2 = .12$ [95% CI: .02, .23] because while the Recede condition remained stable across distances, in the Approach condition alpha decreased with proximity.

These results showed that in the condition with higher behavioural relevance – when someone was approaching, the interaction with that person was more likely and reacting to their actions might be required, the alpha power was lower, indicating greater attentional engagement.

Relation between individual differences and alpha power. We were interested in establishing whether alpha suppression levels were also informative about participants' sensitivity to interpersonal distance at the individual level. To this end we correlated the alpha power averages (average of Dynamic and Average of Static trials) and the differences between conditions (Static: Near minus Far; Dynamic: Approach minus Recede) with social anxiety levels (as indicated via scores on the Brief Fear of Negative Evaluation Scale) and empathy levels (via scores on the Interpersonal reactivity Index), and estimations of personal comfort distances, for descriptive statistics see Table 5.1, for correlations see Table 5.3 (for scatterplots see Figure A.6 in Appendix H). We found positive correlations between social anxiety scores and average alpha power in Dynamic trials (approaching significance) and between social anxiety scores and differences in alpha power between Dynamic conditions. This means that higher social anxiety was related with overall increased levels of alpha power and that perhaps counter-intuitively, as levels of social anxiety increased, participants showed *relatively less* alpha suppression in the Approach compared with the Recede conditions (i.e., were less sensitive to the behavioural relevance of these two types of stimuli). We also found positive correlations between empathy scores and average alpha power in Dynamic trials, which means that highly empathic people had reduced overall alpha suppression in the Dynamic trials. We did not find any significant correlations between average or difference values of alpha power and any of the comfort distance estimations (all τ_bs > .157, all ps < 173).

Table 5.3. Correlations Between alpha power and individual difference measures

Measure	Condition	Correlations
FNEB	Dynamic trials average alpha power	$\tau_b(34) = .23$, p = .054
	Static trials average alpha power	$\tau_b(34) = .11$, p = .360
	Dynamic trials difference alpha power	$\tau_b(34) = .26$, p = .028
	Static trials difference alpha power	$\tau_b(34) = -.05$, p = .672
IRI	Dynamic trials average alpha power	$\tau_b(34) = .32$, p = .008
	Static trials average alpha power	$\tau_b(34) = .11$, p = .228
	Dynamic trials difference alpha power	$\tau_b(34) = .08$, p = .529
	Static trials difference alpha power	$\tau_b(34) = .05$, p = .661

Note. FNEB = Brief Fear of Negative Evaluation Scale, IRI = Interpersonal Reactivity Index; correlations were calculated using the non-parametric Kendall's Tau, because assumptions of normality were violated.

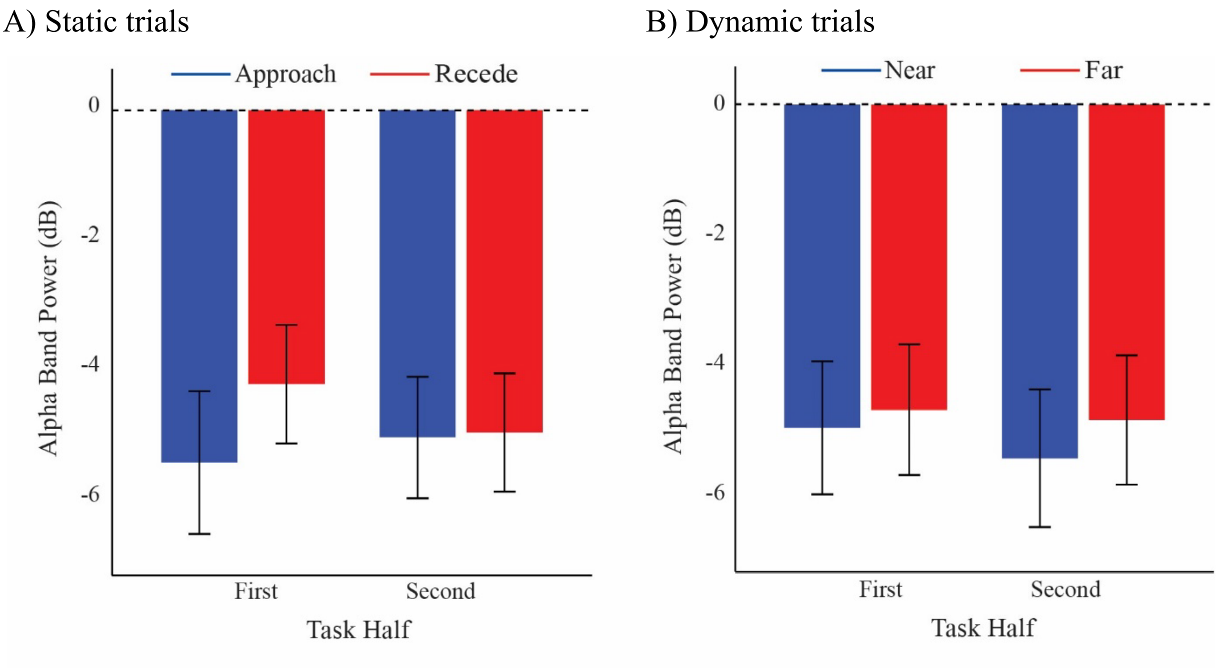
Changes in alpha suppression with increasing familiarity. The significant decreases in the Comfort Distances support a change in participants' social response to the confederate over the course of the experiment. We therefore contrasted the start with the end of the experiment to explore whether these differences might also be observed in patterns of neural activity (i.e., alpha suppression). We selected/extracted the first and the last 20 trials of the static and dynamic conditions (minimum 40 trials were retained per task after trial rejection in the preprocessing), representing the First and Second Half of the experiment respectively (for descriptive statistics see Table 5.4).

Table 5.4. Means and 95% confidence intervals alpha band power for Static and Dynamic trials during the First and Second half of the experiment

Condition		First Half	Second Half
Static	Near	-4.51 [-5.56, -3.46]	-4.71 [-5.71, -3.70]
	Far	-4.77 [-5.83, -3.72]	-5.35 [-6.42, -4.27]
Dynamic	Approach	-5.61 [-6.78, -4.43]	-5.21 [-6.21, -4.20]
	Recede	-4.36 [-5.33, -3.39]	-5.13 [-6.10, -4.16]

For the Static Trials, Experiment-Half was significant, $F(1, 36) = 6.96$, $p = .012$, $\eta_p^2 = .16$ [95% CI: .04, .28], with increased alpha suppression in the Second half of the experiment, the effect of Proximity was approaching significance, $F(1, 36) = 3.72$, $p = .062$, $\eta_p^2 = 0.09$ [95% CI: .00, .19)], while the interaction between Distance and Experiment-Half was non-significant, $F(1, 36) = 2.01$, $p = .165$, $\eta_p^2 = .05$ [95% CI: .00, .12]. That is, the effect of interpersonal distance alpha suppression was stable over the course of the experiment. For the Dynamic trials the main effect of Experiment-Half was non-significant, $F(1, 36) = .95$, $p = .336$, $\eta_p^2 = .03$ [95% CI: .00, .08], and the effect of Movement Direction was significant, $F(1, 36) = 8.11$, $p = .007$, $\eta_p^2 = .18$ [95% CI: .06, .31], while the interaction between Movement Direction and Experiment-Half was significant, $F(1,36) = 4.52$, $p = .041$, $\eta_p^2 = .11$ [95% CI: .01, .21]. This was because the alpha suppression difference between Approach and Recede trials was smaller in the Second-Half of the experiment compared with the First-Half. While alpha power decreased in the Recede condition during the second half of the experiment ($t(36) = 2.44$, $p = .019$, $d = .40$ [95% CI: .08, .72]), the Approaching condition maintained consistent levels of alpha suppression throughout the experiment ($t(36) = -1.17$, $p = .250$, $d = -.19$ [-.51, .13]). See Figure 5.5 for graphical representation of these results.

Figure 5.5. Graphical representation Task-Half x Condition repeated measures ANOVA for Static (A) and Dynamic (B) trials



Note. Error bars represent 95% confidence intervals of the mean.

Discussion

This study aimed to investigate the relationship between social proximity and neural correlates of attention/arousal in an ecologically valid context, with a real interpersonal distance variation. We further wanted to understand whether these changes correlate with social anxiety and comfort distance preferences. We showed that conditions with higher behavioural relevance (Near and Approach) evoked greater alpha band suppression compared with conditions with lower behavioural relevance (Far and Recede). This showed the intricate link between interpersonal distance and attentional engagement in social contexts. Furthermore, we found a relationship between social anxiety and the alpha power difference between dynamic conditions, which indicates the observed effects could in part be social.

With the Static task, we showed larger alpha suppression in the Near cf. Far condition and that the alpha power remained relatively stable over the time course of the trial. The Dynamic task showed overall larger alpha suppression in the Approach cf. Recede condition and these differences were more pronounced at near distances. Together these differences in both tasks could be attributed to behavioural relevance. When someone is nearer, it is more likely that their actions will have a greater impact on us. The same is true when we see someone approaching us (especially when they keep their gaze). The approach shows their attention is on us and their potential intent to interact with us. With this it becomes more likely we will have to react to their actions, which makes them more behaviourally relevant for us.

Our experiment showed that the events we perceive as more behaviourally relevant (like approaching people and people standing near), induce greater alpha suppression. The observed increase in alpha suppression in Near compared with Far and Approaching compared with Receding conditions supports the notion that proximity heightens attentional engagement which aligns with evidence from fMRI (Kennedy et al., 2009; Mobbs, 2010) and SCR studies (Candini et al., 2021; McBride, 1965), showing increased amygdala activation and greater arousal respectively with proximity. These results suggest that our brain prioritizes the processing of stimuli that approach us or are near our personal space. Our findings contribute to the understanding of how the brain processes interpersonal distance within our social environment, while also emphasizing the importance of anticipatory mechanisms in social interactions.

Investigating individual differences, we found a relationship between participants' social anxiety scores and average alpha power in the dynamic conditions and alpha power differences of the dynamic conditions (calculated Approach - Recede). Individuals with greater social anxiety have less alpha suppression overall and lower differences between the Dynamic conditions than those with lower social anxiety. This finding is in line with research showing that individuals with higher social anxiety engage in avoidance behaviours (i.e., they have lower processing of social situations they perceive as threatening), to mitigate their feelings of discomfort associated with an individual approaching or receding from them (see Perry et al., 2013 for a similar interpretation). Furthermore, we found a correlation between empathy and average alpha power in the dynamic trials. This means, that people with higher empathy have less alpha suppression overall. This could be explained either by the fact that highly empathetic people focus more on others than themselves in social situations or that they have better emotion regulation than those with lower empathy. Either of these mechanisms could lead them to consequently experience less arousal and less alpha suppression in dynamic conditions. Compared with social anxiety, empathy was not correlated with the differences between dynamic conditions, which means that people of all empathy levels make a similar differentiation between dynamic conditions. Finding these effects only with the dynamic and not static condition averages might point to the higher potency of the conditions featuring movement of the confederate. Surprisingly, we found that social anxiety and empathy were not correlated to the estimates of comfort distance. By showing that our conditions were processed differently by the groups of people (i.e., those with high vs. low social anxiety) known to have different perceptions of social situations, these findings suggest that our attentional and arousal systems are closely linked to social mechanisms in interpersonal interactions.

We also found that participants' comfort distances decreased over the course of the experimental session. That is people became more comfortable with shorter interpersonal distances from the experimenter over the time course of the experiment. This prompted us to investigate whether there were any differences in alpha power at the start compared with the end of the experiment. In the Static condition we found that alpha suppression was greater at the end compared with the start of the experiment. A recent study by Heyselaar et al. (2018) found more alpha suppression associated with viewing faces of avatars with whom participants previously interacted compared with not-interacted-with avatars, showing familiarity induced greater alpha suppression. We believe our results (i.e., more alpha suppression in the second- cf. first-half) could be driven by a similar mechanism. More alpha suppression from the first-half to the second-half of the experiment was also found with the Recede condition while the alpha band remained relatively stable in the Approach condition. In their study Pilz et al. (2011) showed a greater facilitating effect of identity processing when a person was approaching a participant cf. when they were receding or remained stationary. They concluded that our visual system must have mechanisms that assist with encoding of behaviourally-relevant and familiar dynamic events (Pilz et al., 2011). Approaching might prompt a basic, instinctual readiness in our behaviour, preparing us for action and social interaction, a mechanism, which remains unchanged with familiarity.

Limitations and future research. Due to the experimental design, we were unable to collect a larger sample, which would increase the statistical power of correlation and interaction analyses. While the study was adequately powered to detect medium-sized main effects of a main effects of the within subjects ANOVA, we acknowledge that detecting smaller effects, particularly interactions, may have been limited by the sample size. Future studies with larger samples could more robustly investigate interaction effects. Our design also restricted the possibilities of a diverse stimuli set, i.e., all participants completed the task with one confederate/experimenter, who they were also necessarily exposed to before the experiment.

In the interest of participants' comfort, we designed the experiment to be as short as possible, which led us to interleave the two task conditions. Because the dynamic trials were followed by the associated static ones, the latter were predictable, potentially affecting the results. The predictability of the static trials might have reduced the observed differences between the two static conditions. Furthermore, the alpha power recorded during the dynamic trials might have influenced the alpha power observed in the subsequent static trials. However, the sustained alpha power levels in the static trials suggest that the results still accurately reflected the intended conditions. Similarly, despite occluding the participants' vision between trials, they could hear the confederate repositioning. This auditory cue might have influenced the initial moments of each trial, potentially weakening the differences between the "recede near" and "approach far" conditions. Nevertheless, the sustained response to distance observed in the static trials showed that the alpha power response to proximity was not transitory and remained relatively stable over time. This indicates that the results are robust despite the potential confounds.

Future studies could bypass these limitations by conducting the experiment in Virtual Reality, where they could present a larger stimuli sample size and separate the two conditions. Furthermore, it would allow the presentation of objects with different levels of human appearance (i.e., cylinder, robot, mannequin) to further explore the extent to which the observed effects are indeed social. This approach would also allow us to further explore the effects of familiarity on neural correlates of distance, by testing the differences between avatars which were interacted with (e.g., through an economic game, learning about them through priming vignettes) and those not interacted with.

Future research could also use fNIRS to further understand the underlying neural mechanisms of interpersonal distance. Compared with EEG, it has higher spatial resolution, which could allow the exploration of activations and functional connectivity between cortical regions related to interpersonal space, such as the dorsolateral prefrontal cortex, premotor cortex, and temporoparietal junction during social interactions at different distances.

Conclusions

Our results provide EEG based evidence concerning interpersonal space perception in a naturalistic and ecological social environment. Our study highlights the complex interplay between interpersonal distance, attentional engagement, and social anxiety. By exploring the neural correlates of these processes, we contribute to a deeper understanding of the fundamental mechanisms underpinning spatial cognition in human social interactions.

Chapter 6: Discussion

Summary and aims of the thesis

In this thesis, I explore the concept of interpersonal space – the distance we maintain from others to feel comfortable during social interactions. This space is influenced by factors such as safety, personal preferences, psychological closeness to the interactant, and situational context. It is a fundamental aspect of in-person social interactions, and it influences how we communicate, perceive, and relate to others. Despite its ubiquitous presence in interpersonal interactions, interpersonal space is often overlooked in social cognition research, as highlighted by the non-systematic literature review in the Introduction. Because interpersonal distance is a pervasive factor in social interactions and influences both low-level visual cues and high-level attentional and social processes, it is crucial to understand the mechanisms underlying proxemics behaviour and how we perceive others at varying distances.

Traditionally, cognitive neuroscience and visual perception studies have emphasized highly controlled research environments. This approach has also been adopted by social cognition studies, resulting in research on interpersonal interactions using controlled experimental designs (e.g., static, small, isolated images, mainly of faces (without bodies), disregarding distance). While this method has been highly productive, it has created a gap between discoveries and their applicability to everyday interactions. Meanwhile, seminal work in social psychology has used highly ecologically valid approaches, which despite their high applicability to everyday situations, often lack stringency and produce less reliable results due to methodological limitations. Our studies aimed to bridge these two approaches and address the gaps left by this separation.

The primary aim of this project was to explore less investigated areas of interpersonal distance. Chapter 2 focused on how trait judgments were influenced by distance and distance-related visual factors, assessing how people's judgements changed when varying the distance between the rater and the life-sized images of targets. Chapter 3 additionally looked at the effects of background context and how it interacted with distance. In parallel, Chapter 4 examined participants' comfort distances in relation to individual differences (empathy and social anxiety) and together with Experiment 1 validated the experimental designs used in Chapters 2 and 3. Chapter 5 investigated neural responses to changes in interpersonal distance, implemented without any specific task to capture participants' implicit reactions, which were then related to various individual differences.

Distance and person perception

Role of distance in trait impression formation

In Chapter 2, we explored how distance and distance-related visual cues – such as spatial frequency and size – affected the formation of trait judgments. We also examined emotional arousal ratings at the selected distances and how people were perceived when only the body or the face were visible. Our findings revealed that impressions were amplified with proximity and its proxies (images with broad spatial frequency and large image sizes). These visual details contained most of the pertinent information and were most behaviourally and socially relevant for raters. Importantly, we observed differences between aesthetic judgments (attractiveness) and other, more social traits (competence, dominance, trustworthiness) in the distance experiment. Across other experiments using distance proxies, we consistently noted differences between trustworthiness and attractiveness ratings. This indicates that distance and distance-related visual cues similarly affected these two traits.

Overall, the similarity in effects of physical distance and distance proxies suggests that the brain processes visual information similarly, whether altered by physical distance or by changes in image size and resolution. The amplification of trait judgments with increased visual detail implies a direct link between visual clarity and the perceived intensity of social traits. A possible explanation is that closer distances and detailed images reduced the cognitive load for processing visual information, allowing for more nuanced and confident trait judgments, enhancing the certainty and extremity of these judgments.

At further distances, people might not be able to rely as much on facial cues, which is why it could be that trustworthiness, a predominantly face-based rating (Hu & O'Toole, 2022), was amplified when the faces were more visible at near distances, while attractiveness is similarly determinable from both the face and body (Saxton et al., 2009). However, our final experiment revealed that people could make reliable trait judgments from both the body and the face, regardless of distance. These results indicate that information about all traits was available from bodies and faces. Interestingly, we found that the difference between attractiveness and trustworthiness was similar when people were rating face-only and body-only images, suggesting different mechanisms were at play when making these judgments. The fact that trustworthiness changed more across distances than attractiveness may be less about the specific reliance on facial features for trustworthiness judgments and more about higher-level factors like increased social motivation and relevance at closer distances.

The experiments of Chapter 2 also informed our subsequent experiments. In Chapter 3 we looked at how people's surroundings affected ratings at near and far distances. We reasoned that people are more able to take in the surroundings further away, where we also might want to rely more on additional information from the surroundings to improve the confidence of our judgements. Finding these nuanced effects with distances and higher arousal ratings near compared with far also informed our EEG study (Chapter 5). There we investigated whether proximity had systematic effects on neural correlates of attention, arousal and relevance.

Distance in future research

In Chapter 2, we discovered that life-sized stimuli of people presented nearby provided richer data than when isolated faces were presented. However, the differences in person perception across distances were subtle. Therefore, this finding does not invalidate previous designs that presented isolated faces or small stimuli, nor does it imply that researchers must investigate person perception exclusively with life-sized photographs of people presented nearby. Instead, it highlights an opportunity for researchers to gain additional layers of data when such details are necessary. Consequently, the usefulness of these designs will depend on the specific research questions being addressed.

The Role of Background Context in Trait Judgments Across Distances

In Chapter 3, we investigated how adding social and non-social background context alters ratings of trait judgments and whether this context interacts with distance. We predicted that context would matter more at further distances because 1) context would be more visible and noticeable at greater distances and 2) people might seek additional information from the surroundings to increase their confidence in their judgments when further away. Our findings showed that both types of contexts tested (social and non-social) significantly affected the ratings of all traits. Additionally, we discovered an interaction between social context and distance for trustworthiness ratings. We observed that background figures had a greater impact on trustworthiness ratings at farther distances compared with nearer distances. Happy people in the background increased trustworthiness ratings of the targets, while disgusted people in the background decreased them. This interaction effect, specialized to trustworthiness, suggests that trustworthiness is highly modulated by distance compared with other traits. This finding closely aligned to findings from Chapter 2, where trustworthiness was often the most modulated trait by distance or distance-related cues compared with the other traits. One explanation for this is that judgments of a person's trustworthiness are closely related to decisions about whether they represent an opportunity or a threat (see Ames et al., 2011; Brambilla & Leach, 2014 for review). This evaluation might be more relevant at closer distances, where immediate interaction is more likely, compared with other traits, especially attractiveness, for which distance seems less relevant.

Trustworthiness: threat related trait dimension most modulated by distance

Our findings indicate that trustworthiness is the trait most modulated by distance in the experiments presented in Chapter 2 and the social context experiment in Chapter 3. The body vs. face results from Experiment 5 demonstrate that information about all traits is available from both bodies and faces. Therefore, the observed distance modulation effect in trustworthiness compared with attractiveness may not be due to trustworthiness depending more on facial information (Hu & O'Toole, 2022) and attractiveness relying on both body and face (Saxton et al., 2009). Instead, this effect could be more related to higher-level factors such as increased social motivation and social relevance at closer distances.

Judgments of another person's trustworthiness are closely tied to decisions about whether they represent opportunity or threat, which carry significant consequences, as assessing another person's threat level is crucial for survival (Ames et al., 2011; Brambilla & Leach, 2014). In contrast, judgments of attractiveness could be less affected by distance, as the importance of finding someone attractive remains equally important and therefore constant near or far. The primary goal of seeking a partner drives actions like moving towards/remaining near or moving away/remaining far from someone, and these actions are equally relevant regardless of distance. Overall, these results indicate that trustworthiness is a trait dimension highly modulated by distance, influenced by high-level social factors such as social motivation and relevance rather than merely low-level visual cues.

Neural Correlates of Interpersonal Distance

The final experimental chapter explored the neural correlates of interpersonal distance using EEG alpha band suppression, which is a good index of attentional engagement and allocation of attention to relevant stimuli (Bacigalupo & Luck, 2022; Perry et al., 2016). The findings from Chapters 2, 3, and 4 informed this experiment in several ways. Results from Chapter 2 demonstrated differences in person perception between near and far distances and suggested that these differences could partly stem from variations in social relevance and motivation. Additionally, we found that perceived trustworthiness, which is closely related to threat perception, was the trait most modulated by distance. These insights, combined with prior research, guided our use of EEG alpha suppression to investigate proximity-related changes. Furthermore, we showed differences in explicit ratings of emotional arousal between distances, further validating our choice to focus on EEG alpha suppression. The experiments in Chapter 4 revealed that people's explicit estimations of comfortable distances were related to various individual differences. This finding prompted us to explore the relationship between these explicit estimations and the implicit processing of interpersonal distance with EEG, and to examine whether perceived comfort distances would change over the course of the experiment. In summary, the integration of findings from earlier chapters and previous research informed our approach to use EEG alpha suppression to study the neural correlates of interpersonal distance, highlighting the role of attentional engagement and social relevance in modulating person perception across different distances.

We found greater suppression of alpha band activity in the conditions with higher behavioural relevance: near more than far and approaching more than receding. The dynamic condition allowed us to compare distance related alpha changes across conditions in which the relevance varied. Thus, we could confirm that the alpha suppression was indeed related to behavioural relevance, not just low-level visual differences, like size or spatial frequency. In the second half of the experiment, alpha power in the static and recede conditions became more suppressed, while it remained relatively stable in the approach condition. We believe that the greater suppression in the static and recede conditions was due to increased familiarity with the experimenter. This observation is in line with the findings of Heyselaar et al. (2018), who reported that increased familiarity with an avatar enhances alpha suppression. Meanwhile, the stability of the alpha levels in the approach condition could be attributed to the inherently potent nature of directedness of the approaching behaviour. Approaching consistently prepares us for action and interaction, resulting in the constant levels of alpha suppression.

Results from the dynamic conditions also indicated that people with higher levels of social anxiety had less alpha suppression overall, and less differentiation between the dynamic conditions. This could be because people with higher social anxiety engaged in avoidance behaviours and had consequently reduced processing of the social environment. This result is interesting, because it demonstrates that our conditions were processed differently by groups of people known to process social environments differently. This supports social mechanisms having an effect on our results. The fact that we only found these effects with dynamic and not static stimuli, indicates higher potency of the movement trials.

The role of the dynamic stimuli in social cognition research

Our EEG experiment highlighted the importance of studying interpersonal interactions using dynamic stimuli. In many cases, dynamic stimuli more accurately represent real-life situations where individuals continuously interpret and respond to the movements of others. Movements provide additional information to person perception, such as gait, posture, and other body movements, which can reveal personality traits, trait impressions, emotional states, and intentions, contributing to a more comprehensive understanding of social cues (Atkinson et al., 2004; Dobs et al., 2014; Hahn et al., 2016; Pilz et al., 2011; Thoresen et al., 2012; Trifonova et al., 2024). Movements unfold over time and this temporal context is crucial for understanding certain behaviours and actions (Dittrich et al., 1996; Hahn et al., 2016). Moreover, dynamic stimuli naturally attract more attention than static images. This increased attentional engagement can lead to better processing and interpretation of social information (Pilz et al., 2011). However, as with the use of life-sized whole person images, dynamic stimuli have limitations and can present numerous challenges, such as technical complexity, standardization issues, participant fatigue. Overall, dynamic stimuli enhance both the quality and quantity of perceived information. However, their usefulness must be carefully evaluated based on the specific research question.

The role of the ecological validity in social cognition research

The experiments described in this thesis aimed for greater ecological validity by manipulating distance in real space and time, by presenting life-sized whole-person images, and using a confederate. Such studies, more representative and applicable to real-world settings, are essential for advancing the field, particularly in the study of interpersonal interactions. Generally, ecological validity seeks to ensure that the findings from studies possess greater external validity, making them representative and applicable to everyday life situations (Hammond, 1998; Kihlstrom, 2021; Sbordone & Long, 1996; Zaki & Ochsner, 2009). When research is conducted in naturalistic settings or simulates real-life conditions, the results are more likely to reflect genuine human behaviour, thereby reducing the risk of biases that can be introduced by controlled, artificial environments. This is crucial for making valid inferences about human behaviour, as findings are more generalizable beyond the specific conditions in which they were studied. Therefore, some of the most important considerations when studying interpersonal interactions are the environmental and social contexts in which investigated behaviours occur, rich representative stimuli sets (e.g., diverse, dynamic, multimodal) and using representative participant samples (Henrich et al., 2010; Schmuckler, 2001; Zaki & Ochsner, 2009). However, studies with higher ecological validity present various challenges that must be considered when designing experiments. High ecological validity often means less control over extraneous variables, reducing internal validity and potentially introducing noise and confounding results (Lewkowicz, 2001). Real-world settings are inherently more complex, making it challenging to isolate specific variables and draw clear causal inferences. This requires several careful considerations when designing such experiments, especially regarding replicability, research ethics, and resources. Therefore, social cognition research must find a balance between ecological validity and methodological rigor. Designing systematic and representative experiments can produce results that are both accurate and meaningful contributing valuable insights to the field that are practically applicable.

Practical applications

Clinical applications

Research on interpersonal distance has significant clinical applications, especially in understanding and addressing neuropsychiatric conditions characterized by impairments in social functioning. Abnormalities in personal space regulation are commonly observed in conditions such as schizophrenia (Kraus et al, 2024), autism (Candini et al., 2020), and different anxiety disorders (Givon-Benjio & Okon-Singer, 2020; Perry et al., 2013) and can be good indicators of unhealthy attachment styles (Kaitz et al., 2004). Measuring personal space and related behaviours during social interactions can aid clinicians in early detection of abnormalities in social functioning. Integrating these findings into clinical practice, alongside other diagnostic techniques, can enhance detection, diagnosis, and treatment of social impairments.

Architecture and design applications

Interpersonal distance research can also provide insights for design and architecture, influencing the creation of spaces that increase comfort, efficiency, and social interaction. Understanding how people perceive and use personal and social space, can help designers and architects create environments that accommodate various psychological and social needs, which can improve living standards and overall well-being. Studies on crowding can inform design of public transport and other urban areas to manage crowd flow and reduce stress (Evans & Wener, 2007), while the finding that open tall spaces promote creativity while lower ceilings encourage concrete thinking (Meyers-Levy & Zhu, 2007) can inform the design of environments tailored to specific cognitive purposes. Additionally, research on personal space can contribute to the development of public spaces that incorporate people's need for privacy and territoriality on one hand and collaboration and engagement of the community on the other.

Thesis summary

In our experiments, we investigated various aspects of interpersonal distance. Specifically, its role in person perception and its processing both implicitly and explicitly. From the experiments assessing person perception, we concluded that both low-level visual factors, such as stimulus size and resolution, and higher-level factors, such as social relevance and motivation, contributed to the formation of trait judgments. We also observed individual differences in explicit estimations of comfort distances. These findings motivated us to design a study aimed at assessing implicit distance processing, while distinguishing between lower-level effects and higher-level attentional and social factors. This study revealed that social and attentional mechanisms indeed contributed to the implicit processing of distance. Taken together, the findings of this project suggest that interpersonal distance serves as an important visual, attentional, and social cue and should therefore be carefully considered when designing experiments in the field of social cognition.

This project broadens the scope of research into interpersonal space by demonstrating the extensive impact interpersonal distance has on human perception and functioning. It introduces diverse methodological designs that are broadly applicable to studies of interpersonal interactions and offer new avenues for exploration in social cognition research. Ultimately, this research aims to contribute to the general understanding of interpersonal distance, thereby improving societal functioning by providing insights that can inform policies and practices in areas such as clinical practices, architecture and design and general social dynamics

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Appendices

Appendix A: Term glossary

Definitions of key concepts	
Personal distance	Minimum distance people keep from others to remain comfortable.
Interpersonal distance	Distances people keep from others during social interactions.
Peripersonal/reachable space	Space through which people interact with their environment.
Proxemics	The study of personal space and the degree of separation that individuals maintain between each other in social situations.
Trait impressions	Fast spontaneous judgements people make about others based on their appearance.

Appendix B: Brief Fear of Negative Evaluation scale (FNEB; Leary, 1983)

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate number on the scale with the mouse. Answer as honestly as you can.

Does not describe me well (1) - Describes me well (5)

1. I worry about what other people will think of me even when I know it doesn't make any difference.
2. I am unconcerned even if I know people are forming an unfavourable impression of me.
3. I am frequently afraid of other people noticing my shortcomings.
4. I rarely worry about what kind of impression I am making on someone.
5. I am afraid others will not approve of me.
6. I am afraid that people will find fault with me.
7. Other people's opinions of me do not bother me.
8. When I am talking to someone, I worry about what they may be thinking about me.
9. I am usually worried about what kind of impression I make.
10. If I know someone is judging me, it has little effect on me.
11. Sometimes I think I am too concerned with what other people think of me.
12. often worry that I will say or do the wrong things.

Appendix C: Interpersonal Reactivity Index (IRI; Davis, 1983)

Read each of the following statements carefully and indicate how characteristic it is of you using the mouse.

Does not describe me well (1) - Describes me well (5)

1. I daydream and fantasize, with some regularity, about things that might happen to me.
2. I often have tender, concerned feelings for people less fortunate than me.
3. I sometimes find it difficult to see things from the "other guy's" point of view.
4. Sometimes I don't feel very sorry for other people when they are having problems.
5. I really get involved with the feelings of the characters in a novel.
6. In emergency situations, I feel apprehensive and ill-at-ease.
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it.
8. I try to look at everybody's side of a disagreement before I make a decision.
9. When I see someone being taken advantage of, I feel kind of protective towards them.
10. I sometimes feel helpless when I am in the middle of a very emotional situation.
11. I sometimes try to understand my friends better by imagining how things look from their perspective.
12. Becoming extremely involved in a good book or movie is somewhat rare for me.
13. When I see someone get hurt, I tend to remain calm.
14. Other people's misfortunes do not usually disturb me a great deal.
15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments.
16. After seeing a play or movie, I have felt as though I were one of the characters.

17. Being in a tense emotional situation scares me.

18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them.

19. I am usually pretty effective in dealing with emergencies.

20. I am often quite touched by things that I see happen.

21. I believe that there are two sides to every question and try to look at them both.

22. I would describe myself as a pretty soft-hearted person.

23. When I watch a good movie, I can very easily put myself in the place of a leading character.

24. I tend to lose control during emergencies.

25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while.

26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me.

27. When I see someone who badly needs help in an emergency, I go to pieces.

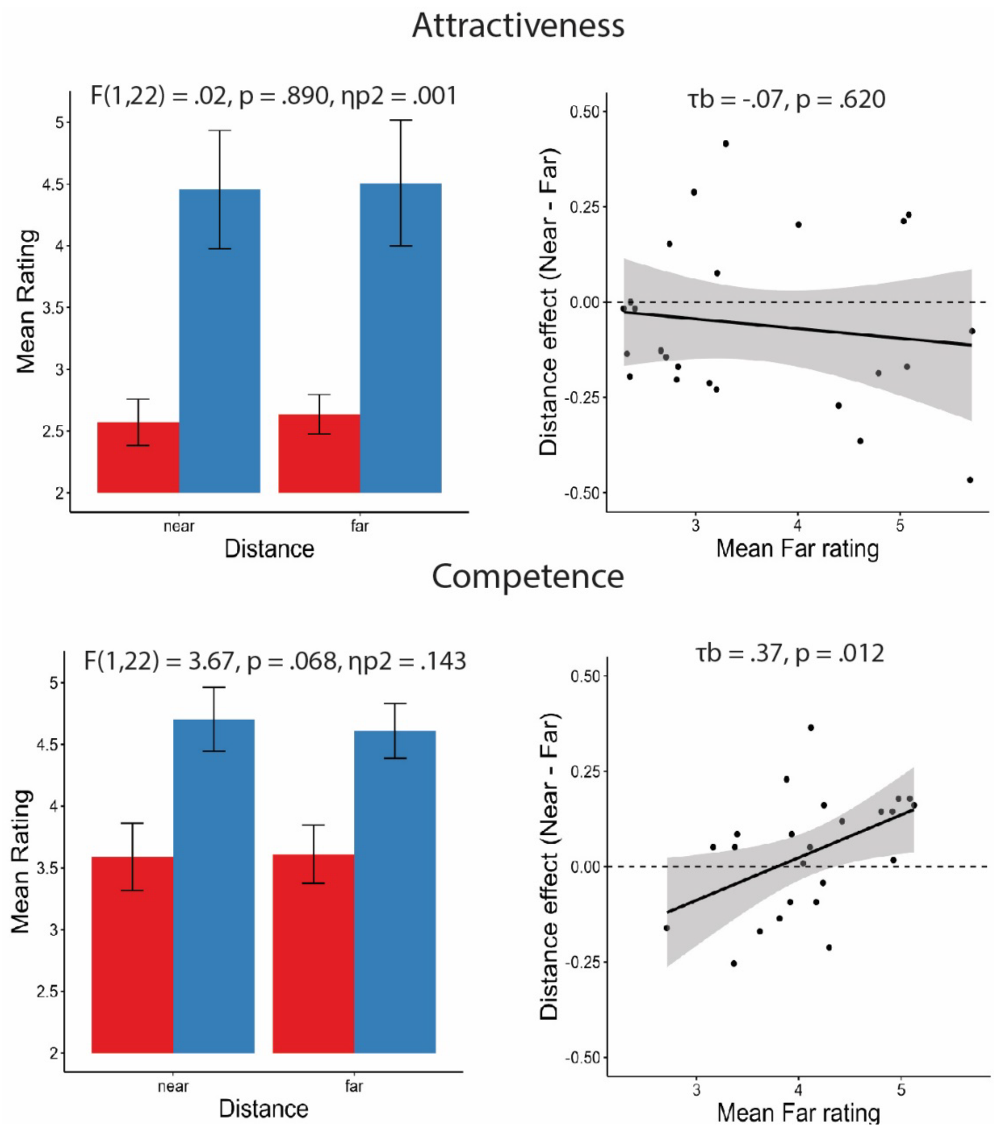
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place.

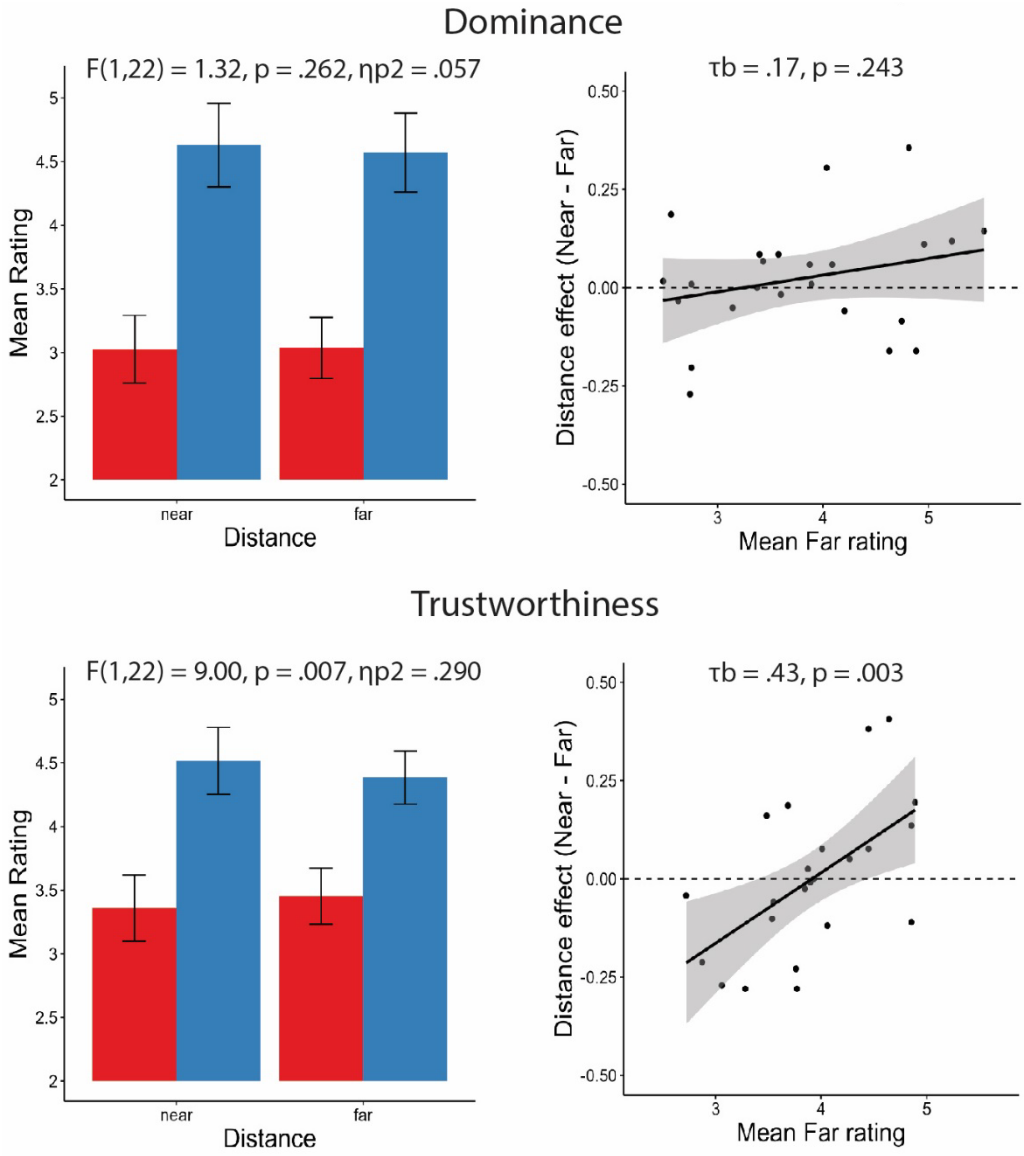
Appendix D: Supporting analyses for Chapter 2

In Figure A.1 we present 2 comparable analyses, both on the item level (participants' ratings averaged for all stimuli identities). The correlation is used to approximate the approach used with mixed effects models (used in Chapter 2), correlating baseline ratings (far) and effect of distance (near minus far). To provide additional support for the validity of our approach, used in Experiments 2, 3 and 4, we also present the results of repeated measures ANOVAs with factors: Distance (near, far) and Stimuli rating (low, high) on an item level. Median-split by stimuli rating was used to determine the stimuli identities rated lower or higher at far distances.

Figure A.1. Supporting analyses for Chapter 2

Repeated measures ANOVAs Correlations





We present these two analyses side by side to demonstrate that correlations between far and near-far show similar results as the ANOVAs. The results revealed that people rated as more trustworthy far were rated even more trustworthy near, and that people rated as less trustworthy far were rated even less trustworthy near. This was also observed for competence, although less strongly, with positive correlation and interaction approaching significance. This effect was non-significant for dominance and was not observed for attractiveness. These results broadly reflect those found by the mixed effects models, the differences between correlations and the models can be contributed to the inclusion of the participants as random factors.

Showing these effects are consistent across two alternative analyses will hopefully offset any doubts about the validity of the analyses used in Chapter 2.

Appendix E: Pre-registration deviations for Chapter 5

Figure A.2. Pre-registration deviations of Experiment 9

#	Details		Original wording	Deviation description	Extent of deviation	Judgment of impact
1	Type	Methods	The plan was to record heart rate variability.	We did not record these data to reduce technical complexity of set-up.	Minor	Improved technical implementation of study.
	Reason	Plan not possible				
	Timing	Before data collection				
2	Type	Methods	The plan was to analyse ERPs as well as oscillations.	Piloting established that data quality was appropriate for oscillations and not always for ERPs.	Minor	Bias not applicable.
	Reason	Plan not possible				
	Timing	Before data collection				
3	Type	Analyses	2 factorial ANCOVAs (2 (near, far) x 2 (approach, recede), with comfort distances and measures of social anxiety and empathy as covariates) for alpha oscillations	After preregistration it became clear that comparison of static and dynamic conditions in an omnibus test was not the most appropriate approach.	Minor	Improved central data analysis approach.
	Reason	Error				
	Timing	During data collection				

<table>
<tr><td rowspan="3">4</td><td>Type</td><td>Analyses</td><td rowspan="3">Alpha oscillations (8-13Hz) and ERPs will be calculated across 2 regions of interest: left-posterior (P7, P3, O1) and right posterior (P8, P4, O2). Alpha oscillations will be compared with the central (C3/C4) locations.</td><td rowspan="3">After pre-registration we noted that most reports of alpha oscillations do not compare electrode sites in this way.</td><td rowspan="3">Major</td><td rowspan="3">Bias not applicable. Reverting to an approach more typical in the literature enhances comparability to previous work.</td></tr>
<tr><td>Reason</td><td>Error</td></tr>
<tr><td>Timing</td><td>During data collection</td></tr>
<tr><td rowspan="3">5</td><td>Type</td><td>Analyses</td><td rowspan="3">We did not pre-register contrasts and how we would reduce the influence of outliers.</td><td rowspan="3">We used polynomial contrasts, as they were most useful in answering our hypotheses. To mitigate 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.</td><td rowspan="3">Minor</td><td rowspan="3">This approach allowed us to investigate the data pattern more fully, and the outlier hardline approach allowed for a justifiable balance of exclusion of outliers while maintaining robust sample sizes at the participant and condition levels.</td></tr>
<tr><td>Reason</td><td>Oversight</td></tr>
<tr><td>Timing</td><td>After results were known</td></tr>
</table>

Appendix F: Additional time frequency plots and topographies for Chapter 5

Figure A.3. Additional plots of Static trials

Time frequency plots — Topographies

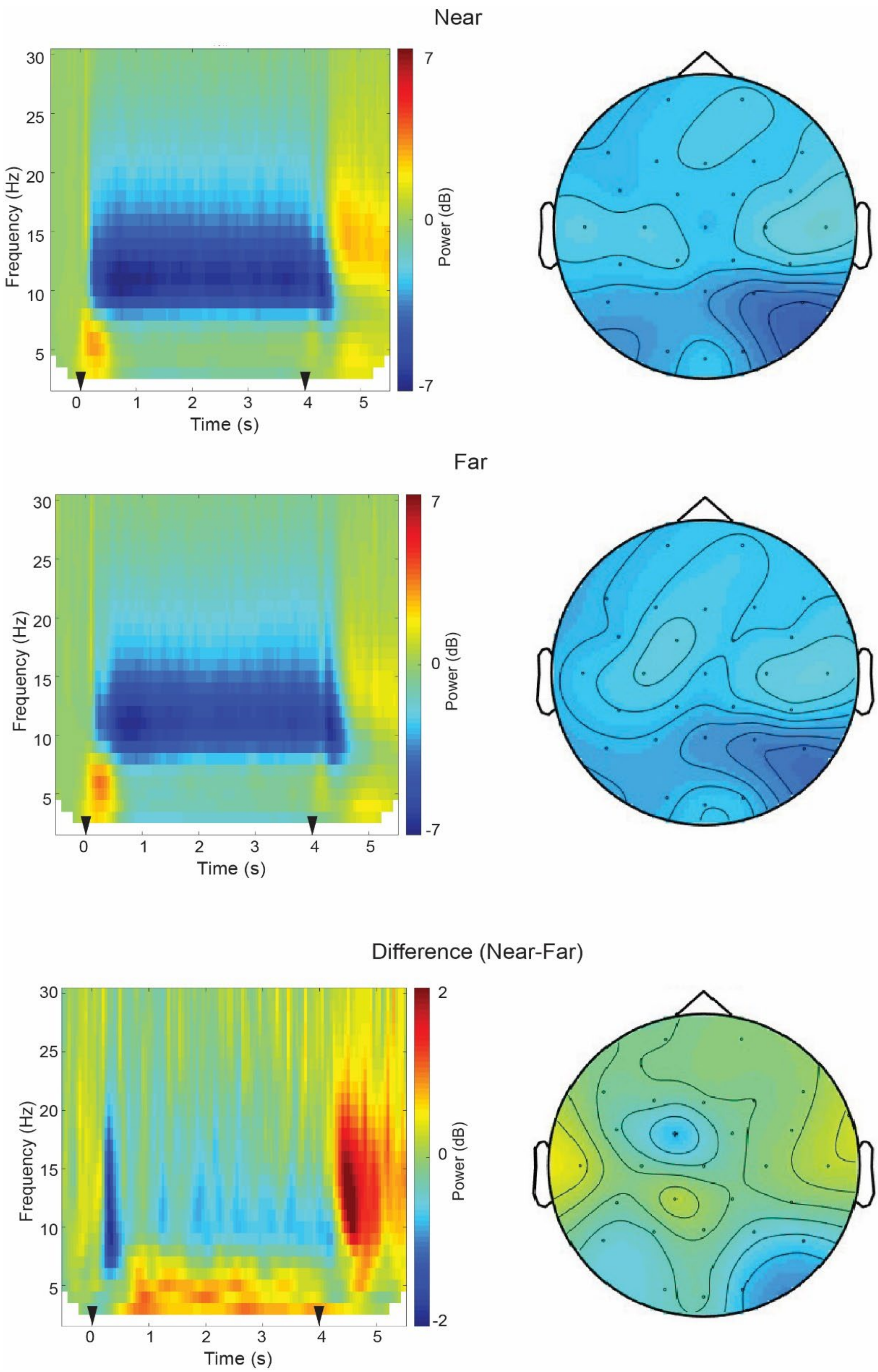
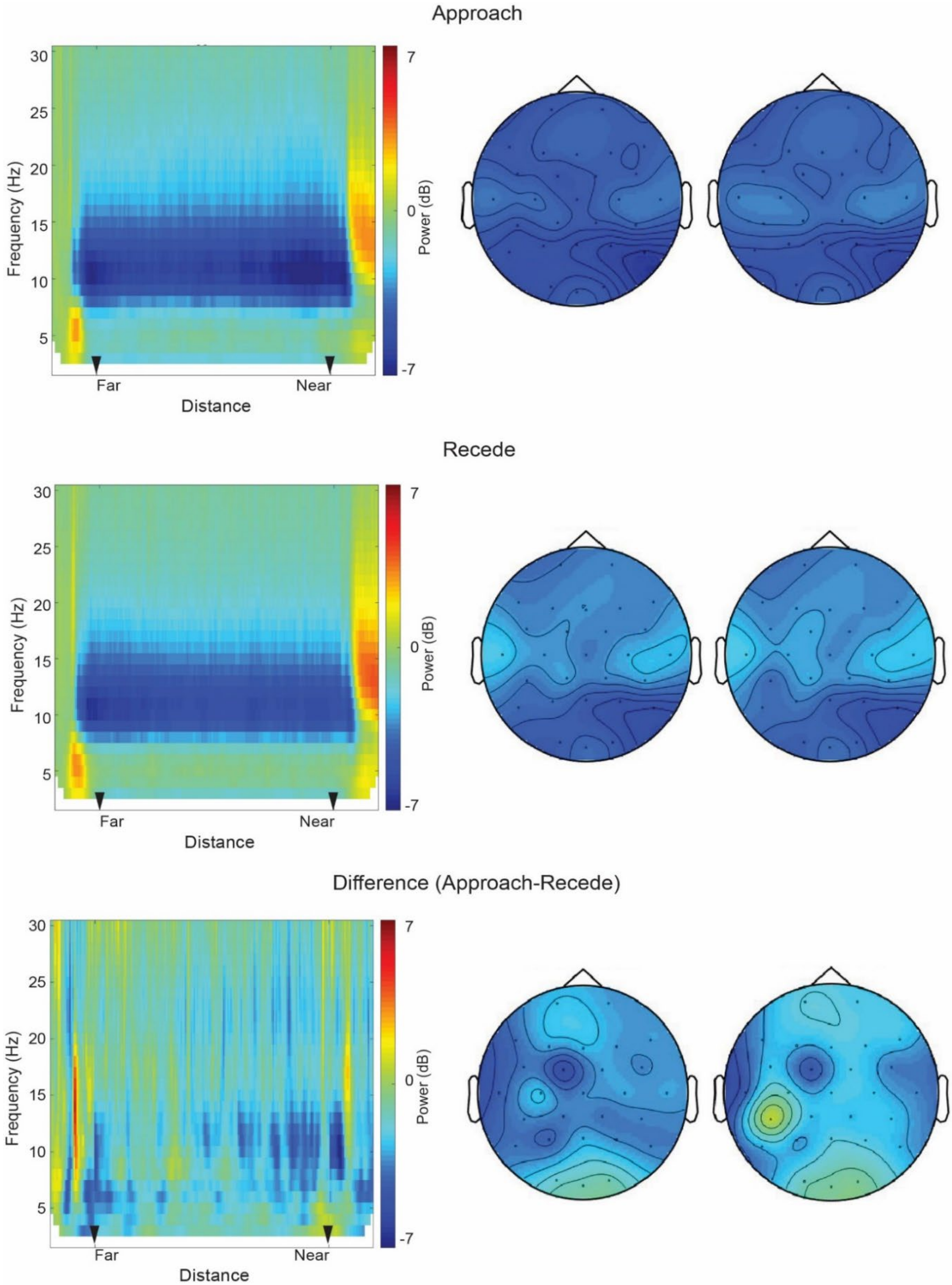


Figure A.4. Additional plots of Dynamic trials

Time frequency plots — Topographies

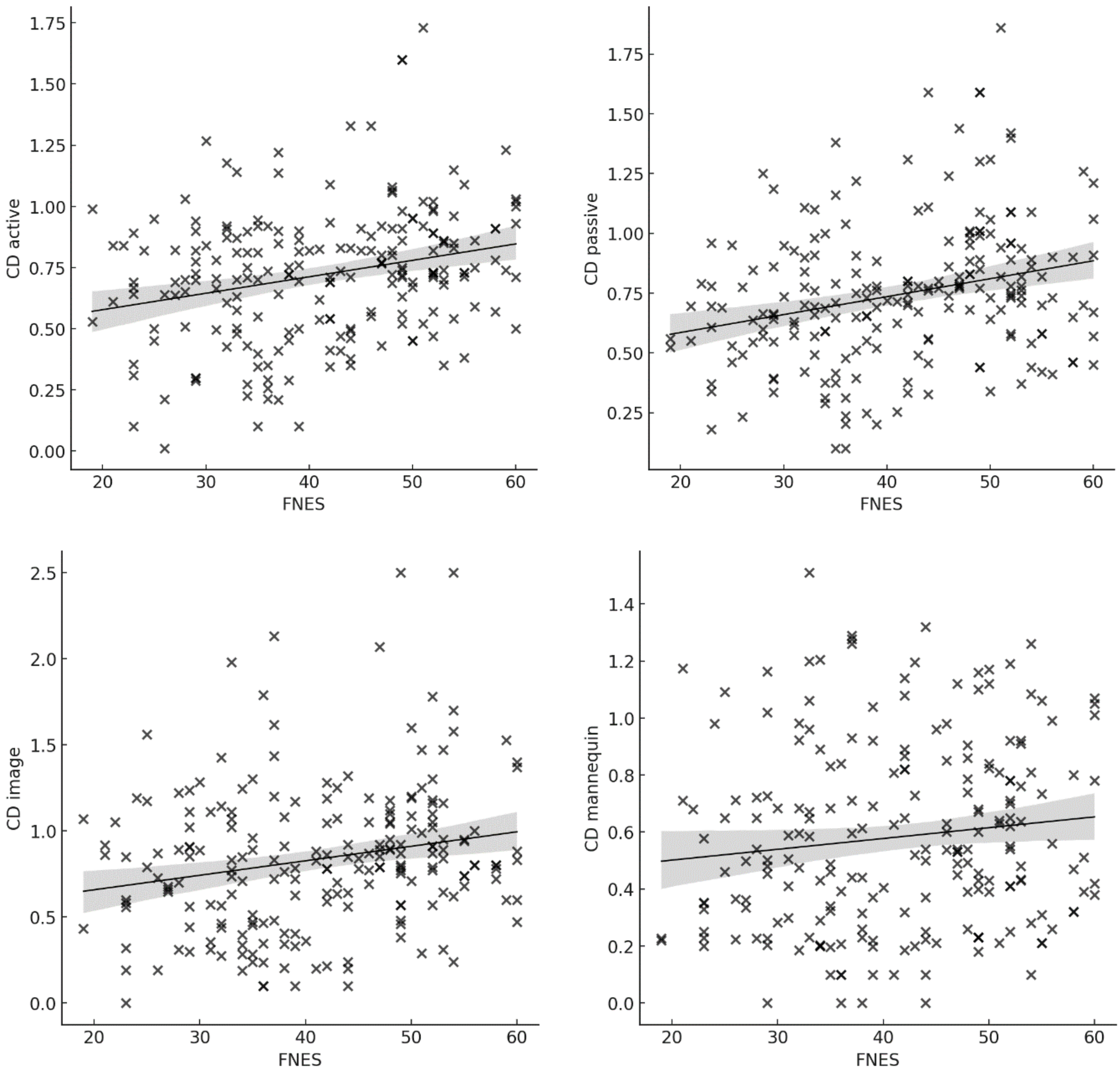
Near — Far



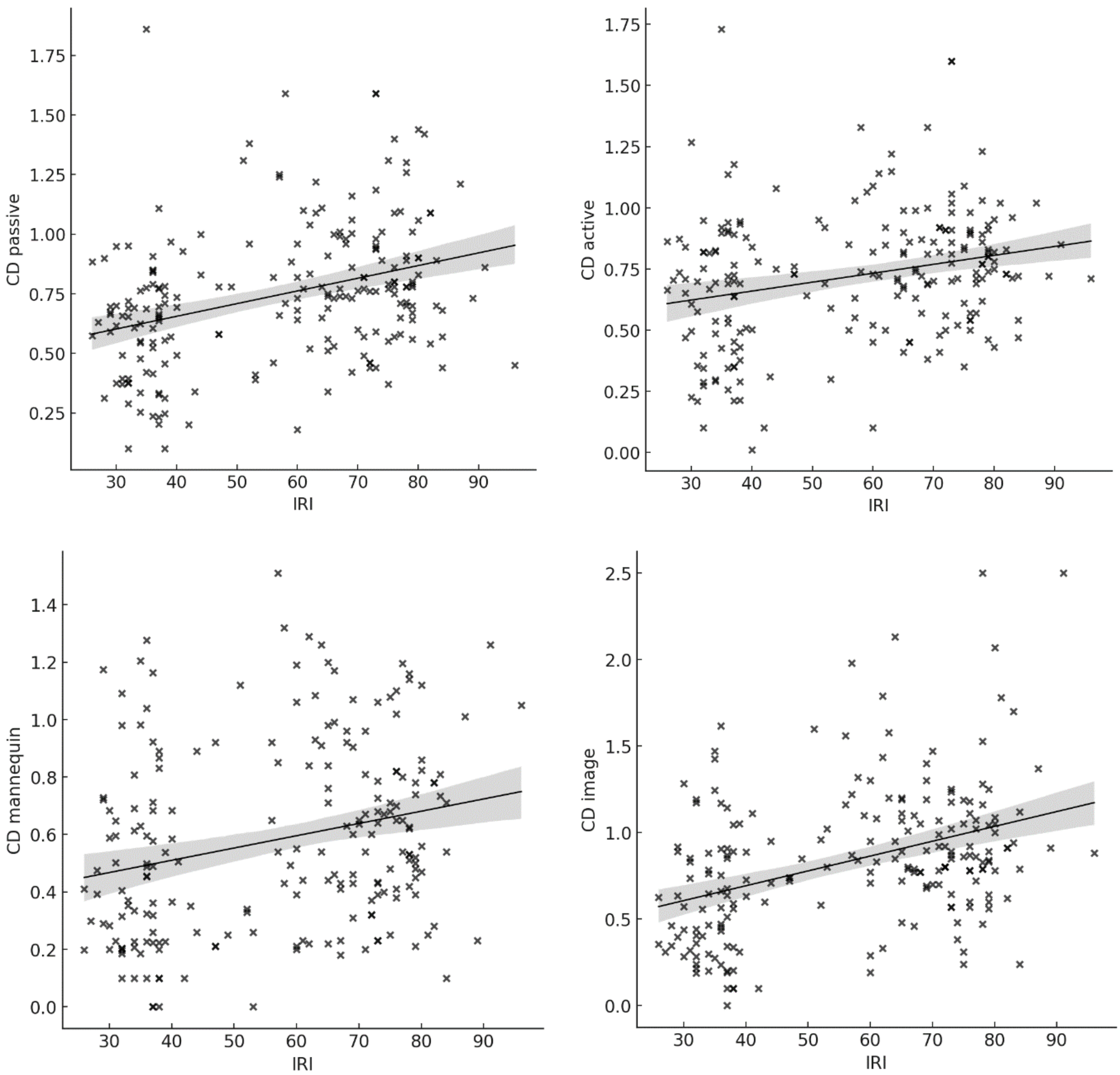
Appendix G: Scatterplots from Chapter 4

Figure A.5. Scatterplots of correlations between Comfort Distance measures, Fear of Negative Evaluation Scale scores and Interpersonal Reactivity Index scores

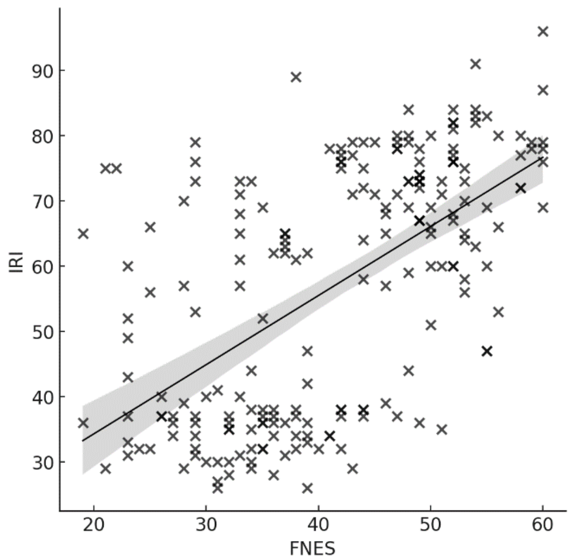
A) Fear of Negative Evaluation Scale (FNES) vs Comfort Distance (CD) measures



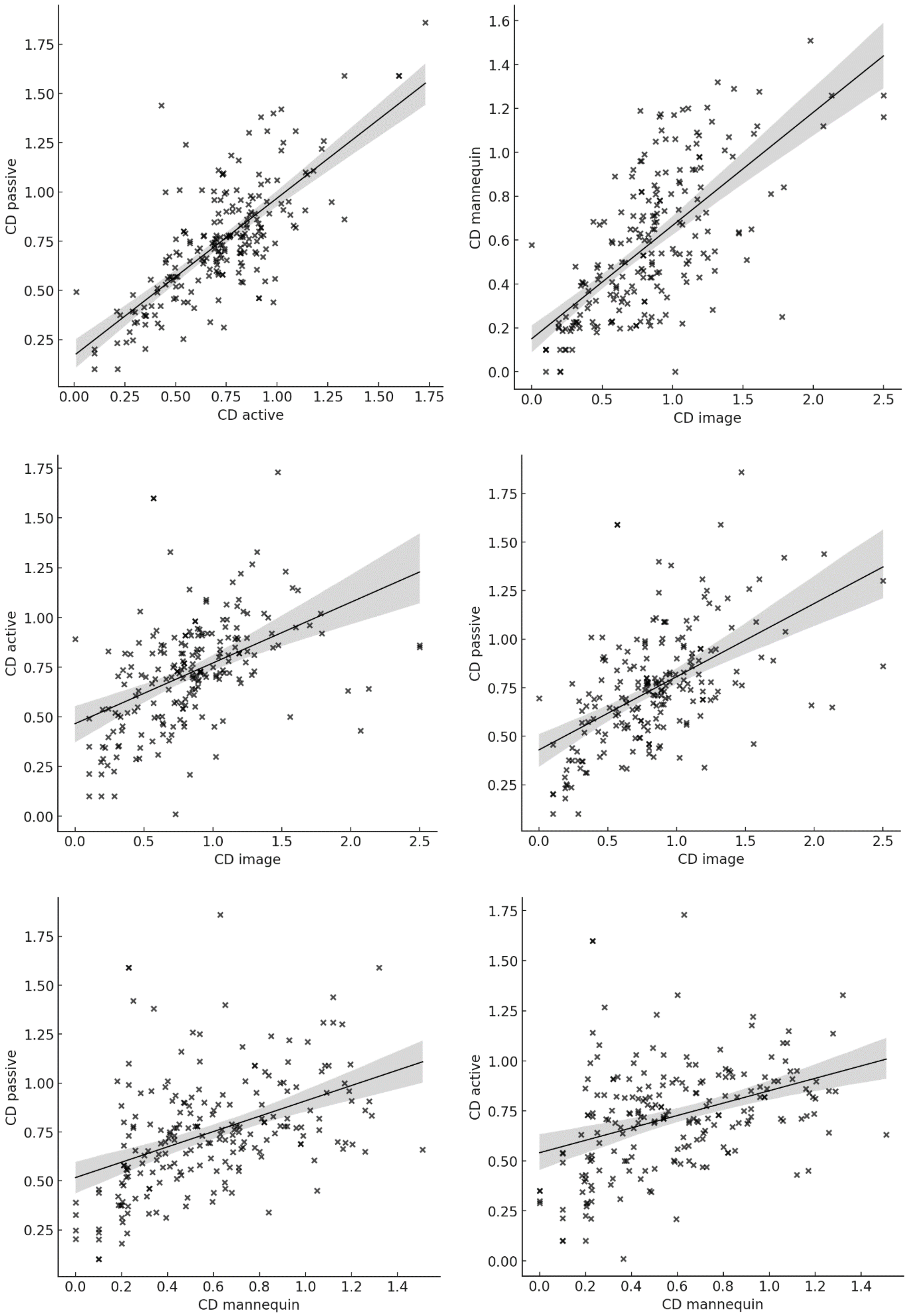
B) Interpersonal Reactivity Index (IRI) vs Comfort Distance (CD) measures



C) Interpersonal Reactivity Index (IRI) vs Fear of Negative Evaluation Scale (FNES)



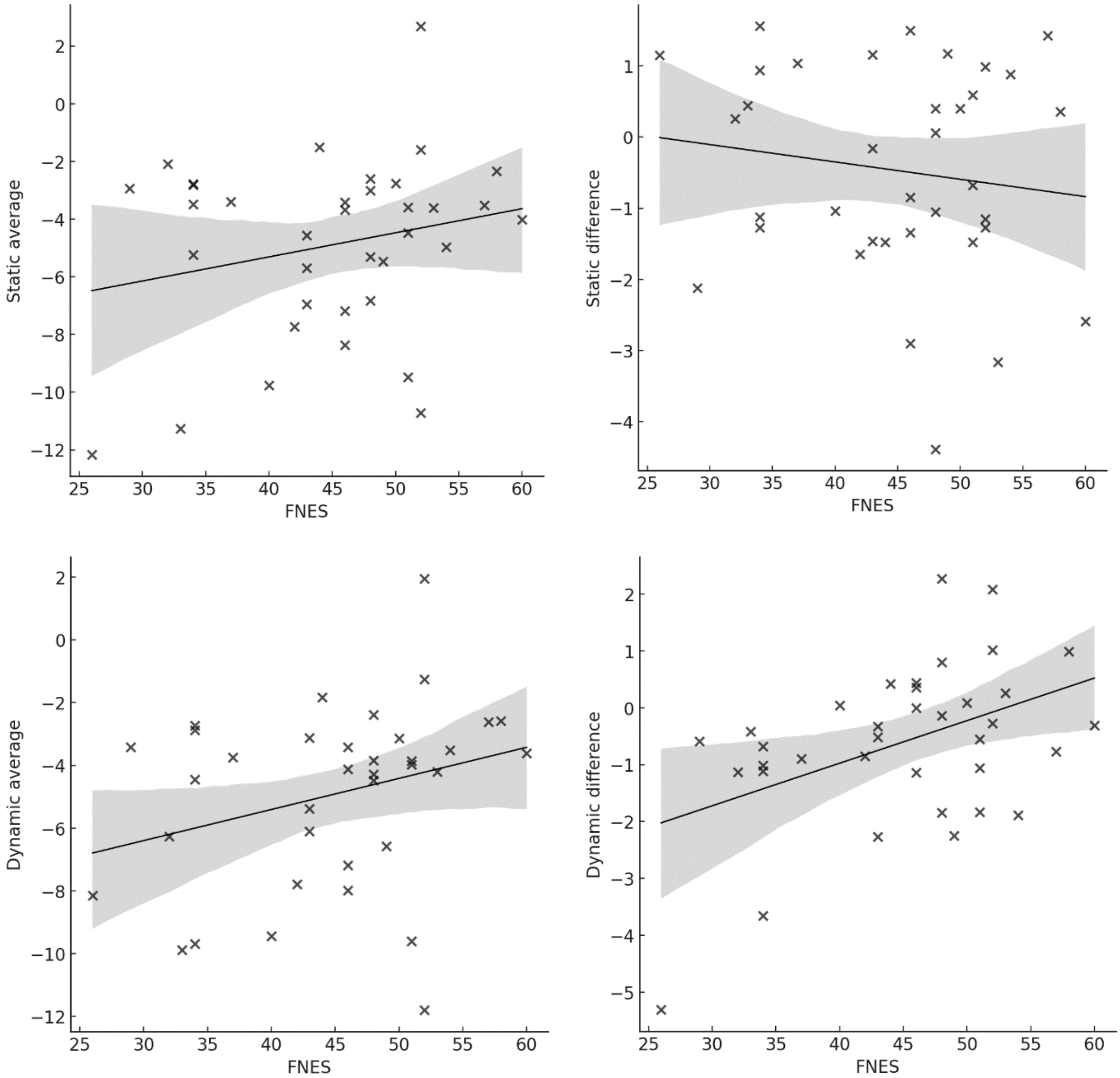
D) Comfort Distance (CD) measures



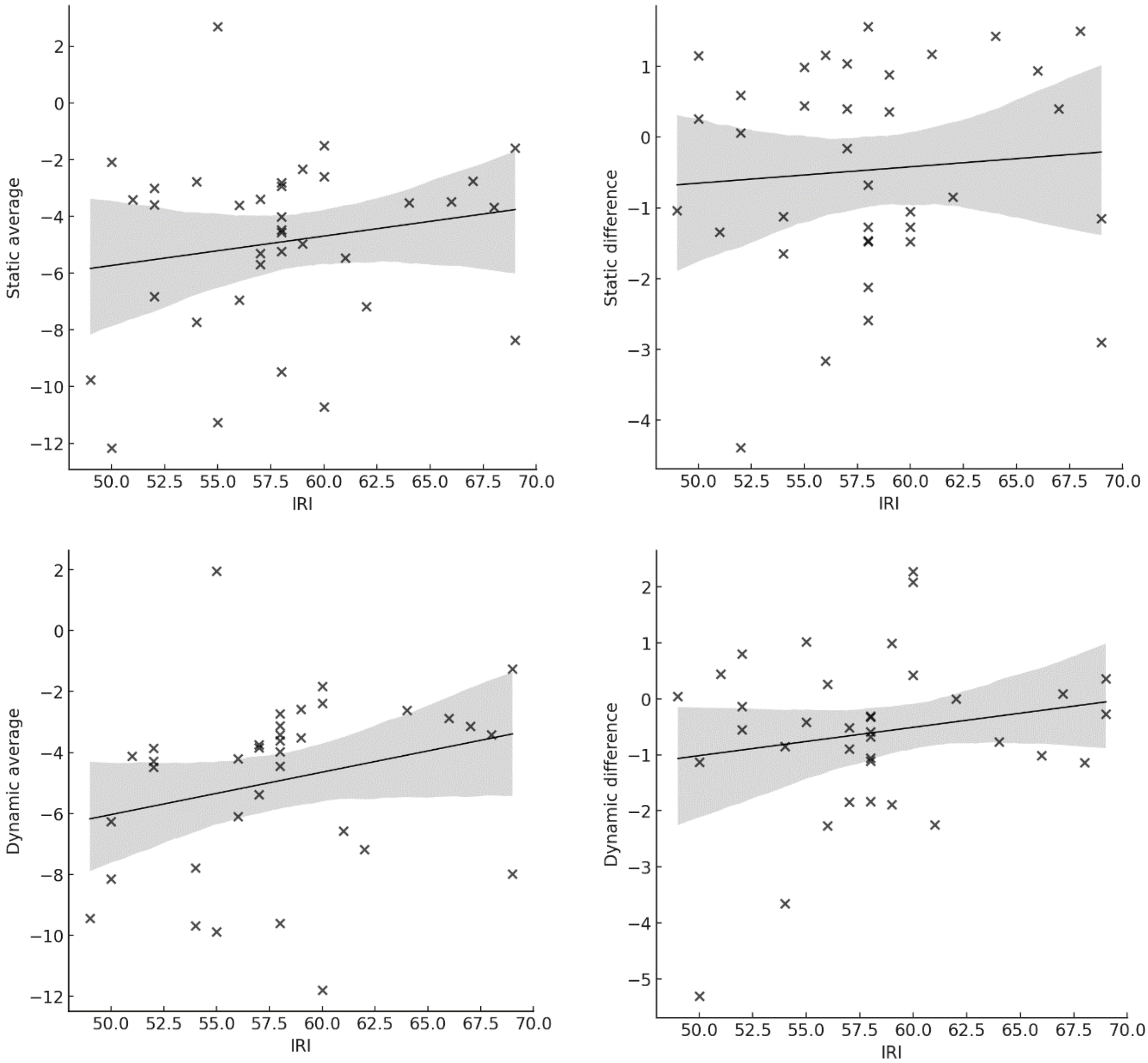
Appendix H: Scatterplots from Chapter 5

Figure A.6. Scatterplots of correlations between EEG Alpha Band Power measures, Interpersonal Reactivity Index, Fear of Negative Evaluation Scale, and Comfort Distance measures

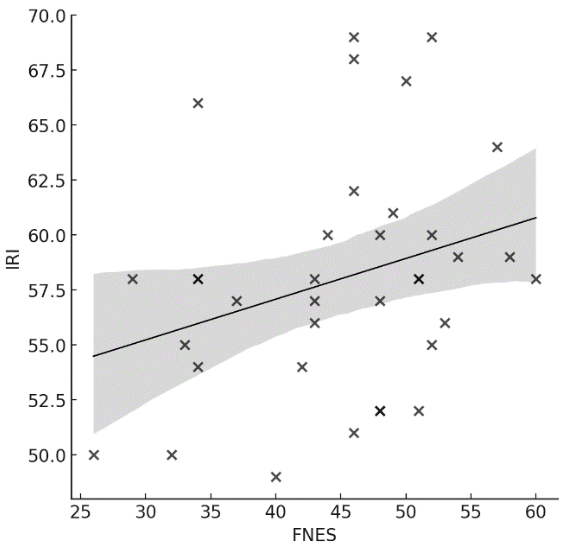
A) Fear of Negative Evaluation Scale (FNES) vs EEG Alpha Band Power Measures



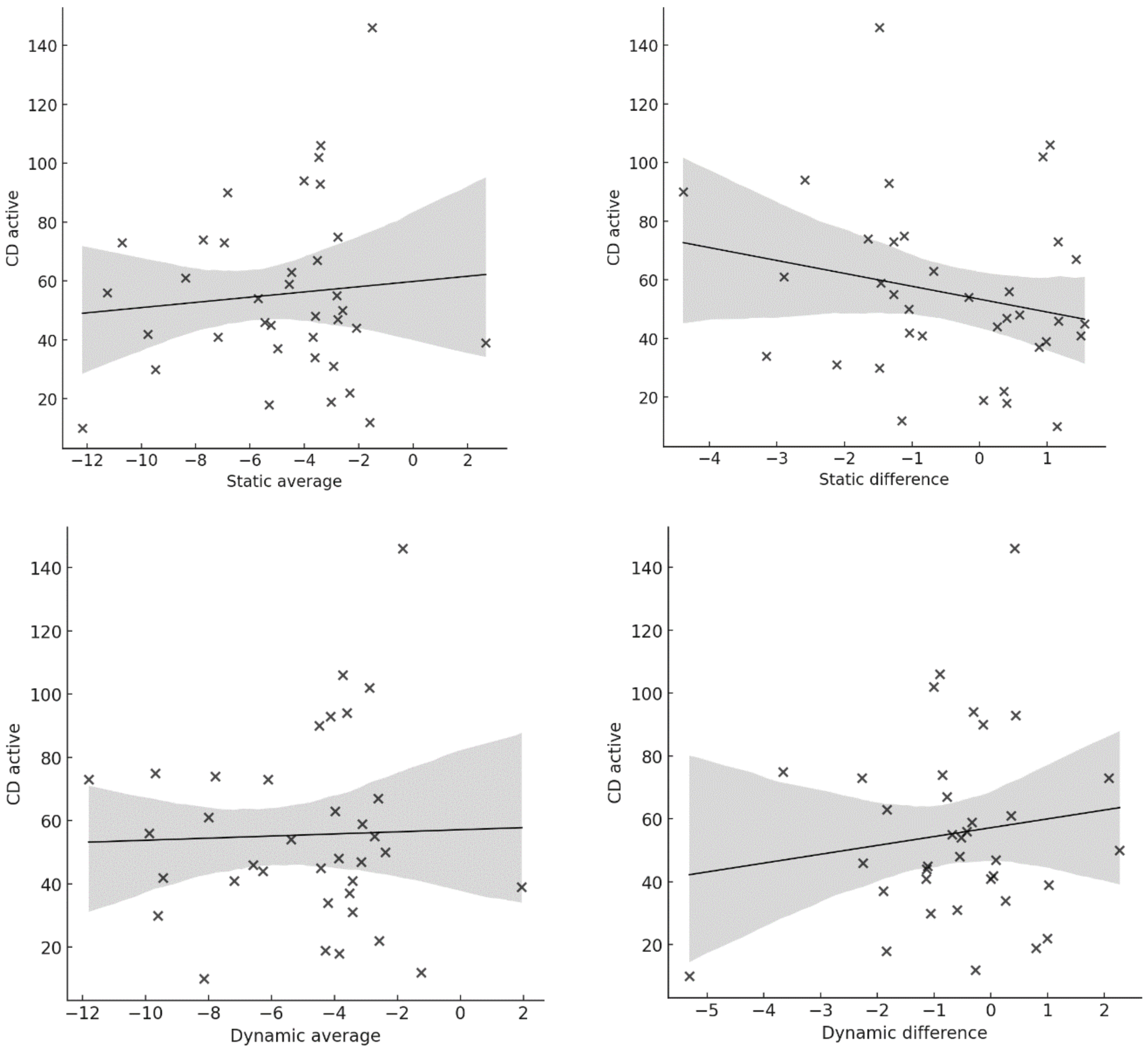
B) Interpersonal Reactivity Index (IRI) vs EEG Alpha Band Power measures



C) Interpersonal Reactivity Index (IRI) vs Fear of Negative Evaluation Scale (FNES)



D) Active Comfort Distance (CD) measures vs EEG Alpha Band Power measures



E) Passive Comfort Distance (CD) measures vs EEG Alpha Band Power measures