The visual perception of interpersonal distance

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The visual perception of interpersonal distance

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Declaration

I, Carl Bunce, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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I need to begin by expressing my deepest appreciation for my incredible supervisors, Richard Cook and Clare Press. Without their unwavering support and guidance, this thesis would not have been possible. Rich's generosity in allowing me the freedom to explore my intellectual curiosities, combined with his impeccable wisdom and patience, has immensely enriched my growth as a scientist. Clare took a gamble hiring me as a Research Assistant many years ago and has been a tremendous source of intellectual and moral support ever since.

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Peer-reviewed work

Some of the work reported in this thesis has been published in the following papers:

Chapter 2 – Bunce, C., Gray, K. L. H. & Cook, R. (2021). The perception of interpersonal distance is distorted by the Müller-Lyer illusion. *Scientific Reports, 11(*1*),* 494.

Chapter 3 – Bunce, C., Press, C., Gray, K. L. H. & Cook, R. (2024). Perceptual sensitivity to changes in interpersonal distance when observing social interactions: The effects of dyad arrangement and orientation. *Quarterly Journal of Experimental Psychology*, 17470218241275595.

Chapter 5 – Bunce, C., Gehdu, B. K., Press, C., Gray, K. L. H. & Cook, R. (2024). Autistic adults exhibit typical sensitivity to changes in interpersonal distance. *Autism Research*, *17*(7), 1464-1474.

Some of the work has also been presented at academic conferences and meetings:

Chapter 3 – Bunce, C., Gray, K. L. H. & Cook, R. *Sensitivity to changes in interpersonal distance: the effects of dyad arrangement and orientation*. Poster presented at the 43rd European Conference on Visual Perception, Virtual, August, 2021.

Chapter 4 – Bunce, C., Tsantani, M., Gray, K. L. H. & Cook, R. *Typical sensitivity to changes in interpersonal distance in developmental prosopagnosia*. Poster presented at the Vision Science Society, Florida, USA, May, 2022.

Chapter 4 – Bunce, C., Tsantani, M., Gray, K. L. H. & Cook, R. *Typical sensitivity to changes in interpersonal distance in developmental prosopagnosia*. Poster presented at the Virtual Vision Science Society, Virtual, June, 2022.

Abstract

Recent years have witnessed a surge of interest in unravelling the visual mechanisms facilitating our perception of social scenes involving multiple individuals and their interactions. This thesis aims to contribute to this growing field by investigating a frequently overlooked yet essential visual feature of observed social interactions: interpersonal distance, referring to the physical space that separates interactants.

Chapter 1 provides an overview of theoretical and empirical contributions to our understanding of person perception. Emphasis is placed on reviewing literature exploring the existence of specialized mechanisms supporting dyadic interaction perception and the pivotal role of interpersonal distance in shaping our evaluations of observed interactions.

The first empirical chapter explores biases in our perception of interpersonal distance. Chapter 2 demonstrates susceptibility to the Müller-Lyer illusion, a classic length illusion that has traditionally been studied in domains outside of social perception. These findings highlight the malleability and domain-generality of our representations of interpersonal distance.

The remaining empirical chapters test influential claims that dyadic interaction perception engages configural mechanisms akin to face perception. Where observed, configural processing involves heightened sensitivity to changes in spatial arrangements when stimuli are presented in canonical configurations. Chapter 3, using a paradigm where participants detect changes in spatial relations (i.e., interpersonal distance) between pairs of individuals, finds no differences in perceptual sensitivity between conditions manipulating dyad arrangement and orientation, challenging the configural hypothesis.

Subsequent chapters investigate individuals with neurodevelopmental conditions known for deficits in face processing. Chapter 4 examines developmental prosopagnosia, while Chapter 5 focuses on autism spectrum disorder. Remarkably, both groups exhibit comparable perceptual sensitivity to their neurotypical counterparts, questioning the extension of face processing deficits to interpersonal distance perception.

Chapter 6 summarizes the findings and discusses their implications for understanding the perceptual processes underlying interpersonal distance and the plausibility of the configural account of dyadic interaction perception.

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Chapter 1: Introduction

As social beings, humans possess a fundamental need to accurately detect and evaluate conspecifics in order to grasp the dynamics of their social surroundings and engage effectively in interpersonal behaviours. To facilitate these crucial perceptual feats, sophisticated neurobiological systems have evolved over centuries, allowing us to decode a wealth of social information from the sensory inputs of modalities such as vision[1] (Barton, 1997, 1998; Dunbar, 2009; Parr, 2011). The existence and proficiency of these perceptual mechanisms is evident in our daily lives; from a moments glance a typical observer is able to efficiently and (in most cases) veridically glean information pertaining to one's identity, emotional state, and intentions.

The faces and bodies of other people serve as primary visual sources from which these social signals are extracted, and have therefore been a central focus of study for researchers in the field of 'social perception'. Extensive research in this area has produced seminal insights into how the human visual system supports the perception of faces, facial expressions, body shapes, body postures, actions, and kinematics (Blake & Shiffrar, 2007; Duchaine & Yovel, 2015; Peelen & Downing, 2007). One of the most significant contributions of this body of work in the last several decades has been cementing the notion that the visual processing of the human form is functionally and structurally dissociated from the visual processing of

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[1] Note that social information can also be perceived through sensory modalities other than vision, such as audition (e.g., hearing another person speak). However, this falls outside the scope of this thesis which specifically focuses on visual perception.

other types of non-social stimuli. Today it is widely agreed that face and body perception engage specialised visual perceptual mechanisms (Maurer et al., 2002; Richler et al., 2011) and rely on a distributed network of dedicated neural substrates in the occipitotemporal cortex (Downing & Peelen, 2016; Duchaine & Yovel, 2015; Freiwald et al., 2016; Yovel, 2016).

However, while social perception research has made great strides elucidating how we perceive solitary individuals, a remarkable gap remains in our understanding of how we visually perceive social scenes involving interactions between two or more people from a third-person perspective. This gap is surprising considering that social interactions in which we are not active participants are a ubiquitous part of our visual experience, and their efficient and veridical interpretation holds immense adaptive value. The perception of social interactions plays a pivotal role in guiding our social behaviours, assisting the learning of social norms and expectations, and promoting the development of socio-cognitive skills (Bandura, 1977, 1986; Christ et al., 2014; Matheson et al., 2013; Quadflieg & Koldewyn, 2017).

Early findings in this area have provided empirical support for claims that the perception of social interactions is ‘special’, akin to individual face and body perception. That is, social interaction perception appears to rely on domain-sensitive visual mechanisms (Papeo, 2020; Vestner et al., 2019) and neural substrates (Isik et al., 2017; Papeo et al., 2017; Quadflieg et al., 2015; Walbrin et al., 2018). Despite this promising progress, however, substantial investigation is still required to test these claims and uncover how different visual features of social interactions are detected, processed, and represented by the visual system.

In this thesis I target a feature that is inherent to all visually observed social interactions: interpersonal distance. Interpersonal distance can be defined as the physical space which separates individuals from one another. As will be discussed in detail, one’s spatial proximity to others is imbued with social and psychological meaning (Bessenoff & Sherman, 2000; Dotsch & Wigboldus, 2008; Hall, 1963, 1966; McCall, 2017a; McCall & Singer, 2015; Word et al., 1974; Worthington, 1974). Moreover, evidence suggests that observers are able to harness proxemic cues to facilitate recognition and categorisation of social interactions that are observed from a third-person perspective. The perception of interpersonal distance allows us to infer whether individuals are interacting, the nature of their relationship, and the valence of their current interaction (Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; McCall & Singer, 2015).

The objective of this thesis is to advance our understanding of the visual mechanisms underlying the perception of interpersonal distance. To this end, a series of empirical investigations were undertaken to address crucial and pertinent questions about this perceptual ability. Specifically, I sought to explore how the visual system encodes interpersonal distance, whether this representation differs from other types of distance processing (such as inter-object distance), how susceptible interpersonal distance representations are to illusory perceptual distortions, whether sensitivity to changes in this cue provides insights into the underlying processing of social interactions in general, and whether groups with neurodevelopmental conditions characterised by socio-perceptual and socio-cognitive difficulties, such as developmental prosopagnosia and autism spectrum disorder, exhibit deficits in perceiving this cue.

This introductory chapter is organised to first provide an overview of what is currently known about the visual perception of individual faces and bodies. The focus is then narrowed to summarizing the literature on the perception of social scenes involving multiple individuals within and outside of social interaction contexts. Next, interpersonal distance is introduced, offering a thorough overview of how researchers from different disciplines have attempted to conceptualise and study it. The chapter concludes with an overview of the open research questions related to the perception of interpersonal distance and social interactions more broadly, followed by an outline of the empirical chapters that follow, detailing how they aim to address these questions.

1.1. What is known about the visual perception of individual people?

Before delving into the realm of visual processing of social interactions and interpersonal distance, it is important to explore our current understanding of how individual people are visually perceived. Specifically, I will provide an overview of how faces and bodies belong to a unique category of visual stimuli that are detected, processed, and represented differently than non-face and non-body stimuli. This mini-review serves three key purposes.

Firstly, the bulk of research in the field of social perception that has been conducted up until now has employed tasks that involve presenting participants isolated faces, face parts, bodies, or body parts and measuring the behavioural and/or neural consequences. This research tradition has yielded remarkable advancements in methodological approaches and provided valuable theoretical insights into social perceptual mechanisms. Therefore, it is useful to contextualise current understanding of social interaction perception within this historical background.

Secondly, what sets the perception of interpersonal distance apart from other forms of distance perception, such as inter-object distance, is that the defining boundaries that delineate spatial extent are marked by *people*. Consequently, the ability to detect and recognise individual people as distinct human entities is a prerequisite for perceiving and assessing interpersonal distance.

Thirdly, as will be discussed in more detail later, it has been suggested that the detection, representation, and processing of dyadic social interactions share mechanistic overlap with the processes involved in detecting, representing, and processing individual faces / bodies. Therefore, it becomes necessary to elaborate on the unique challenges posed by individual faces and bodies, highlighting how the visual system overcomes them, in order to substantiate and evaluate claims of such overlap.

1.1.1. Face processing

Detection and recognition

The visual detection of a face is an obligatory initial step in extracting information about identity, emotional expression, and other facial attributes. Compared to the detection of objects and other non-face stimuli, face detection has been shown to differ in several ways. Infants, even shortly after birth, reliably orient towards and fixate on face-like stimuli more than other equally complex visual patterns (Buiatti et al., 2019; Goren et al., 1975; Shah, Happé, et al., 2015; Valenza et al., 1996). This suggests that a face detection mechanism, in at least a rudimentary form, is established prior to exposure to significant postnatal visual experience (Farah et al., 2000; Johnson et al., 2015; Morton & Johnson, 1991; Simion &

Giorgio, 2015). Throughout one's lifespan, faces continue to automatically and rapidly capture our attention, even when they are task-irrelevant or known to pose a hinderance to task performance (Bindemann et al., 2005, 2007; Crouzet et al., 2010; Devue et al., 2009; Eimer, 2011; Langton et al., 2008; Ro et al., 2001; Theeuwes & Van der Stigchel, 2006). The speed and automaticity of face detection is further supported by research utilizing continuous flash suppression, which has shown that faces tend to breach conscious awareness more rapidly than other stimuli, indicating privileged unconscious processing (Jiang et al., 2007).

Most models of face detection propose a template-based matching process that exploits commonalities in visual appearance shared by almost all faces (Tsao & Livingstone, 2008). In infants, these templates are believed to be relatively crude, as facial-orienting behaviours are reliably elicited by so-called “protofaces”, which consist of three high-contrast patches in a face-like spatial configuration (Farroni et al., 2005; Morton & Johnson, 1991; Shah et al., 2015). The subcortical mechanisms responsible for the orienting response to this minimalist, low spatial frequency depiction of a face persist into adulthood (Gabay et al., 2014; Stein et al., 2011; Tomalski, Csibra, et al., 2009; Tomalski, Johnson, et al., 2009), although the maturation of visual acuity, attentional control, and accumulation of visual experience between these timepoints is thought to promote functional sophistication of these mechanisms (Grill-Spector et al., 2004; Johnson, 2005; Tsao & Livingstone, 2008). The simplicity of this face detection solution has its advantage in that almost any face-like pattern appearing in the visual field can be swiftly detected, even when presented under impoverished viewing conditions (Burton & Bindemann, 2009; Hershler et al., 2010). However, this liberal criterion of what constitutes a face also has a major drawback, as it inevitably leads to false alarms. The prevalence of this error is corroborated by the commonly experienced phenomena of face pareidolia, which refers to the tendency to misperceive the presence of a face when viewing objects or ambiguous visual patterns possessing similar spatial configural characteristics as faces (Keys et al., 2021; Liu et al., 2014; Summerfield et al., 2006).

While face detection relies on identifying visual features shared by all faces, face recognition depends on identifying visual features that allow for their individuation. In typical infants, the ability to discriminate the face of a primary caregiver from that of a stranger is thought to emerge shortly after birth (Bushneil et al., 1989; Bushnell, 2001; Field et al., 1984), and within a few days most infants are believed to possess the ability to discern whether a face is familiar or unfamiliar (Pascalis et al., 1995; Pascalis & de Schonen, 1994). The trajectory of face recognition development is thought to hit a peak sometime between late childhood and early adulthood (Feinman & Entwisle, 1976; Germine et al., 2011), at which point most people with typical vision are able to effortlessly learn, recall, and recognise many thousands of facial identities (Diamond & Carey, 1986; Ellis, 1986). However, a small portion of the population with neurodevelopmental conditions, such as developmental prosopagnosia, struggle to acquire this skill and experience persistent difficulties with face identity recognition (Chapter 4; Behrmann & Avidan, 2005; Duchaine & Nakayama, 2006; Susilo & Duchaine, 2013; Cook & Biotti, 2016).

Neural substrates

Further evidence supporting the specialization of face processing comes from studies exploring the neural correlates of face and object perception. Neuroimaging research has identified a distributed network of face-selective neural substrates in the occipitotemporal cortex. Regions involved in the recognition and representation of invariant aspects (e.g., race, sex, age) include the fusiform face area (FFA) and occipital face area (OFA), while the superior temporal sulcus (STS) has been implicated in processing variant aspects (e.g., emotional expressions; Bernstein et al., 2018; Haxby & Gobbini, 2011; Kanwisher et al., 1997; Quadflieg & Koldewyn, 2017; Rhodes et al., 2004). The lateral occipital complex has been identified as a region broadly tuned to perception and recognition of various object categories, however the viewing of objects can evoke activation in ostensibly face-selective regions, suggesting the structural delineation between face and object processing may not always be clear-cut (Grill-Spector, 2003; Grill-Spector et al., 2001; Haxby et al., 2001; Pitcher et al., 2009).

Some of the strongest evidence for the bifurcation of face and object processing comes from neuropsychological case studies. Cortical lesions to face-selective regions resulting from traumatic head injury or neurological illness can lead to an acquired form of prosopagnosia (Barton, 2008; Corrow et al., 2016; Farah et al., 2000). Although these patients suffer severe difficulties in their ability to recognise other people, including close friends and family members, in most cases they are reported as having intact object recognition ability. This condition can be contrasted with a disorder known as object agnosia, in which many patients experience severe impairments in object recognition despite preserved face recognition ability (Moscovitch et al., 1997). Thus, the double dissociation observed in these cases, along with the neuroimaging evidence, supports the notion of structurally and functionally distinct pathways for face and object processing.

Specialised cognitive mechanisms

A significant advancement in the field of face perception has been the discovery of domain-specialised processing mechanisms that the visual system employs when perceiving faces compared to non-face stimuli. This thesis focuses on two prominent modes of face processing known as holistic processing and configural processing. These mechanisms are believed to operate in parallel and share the common goal of facilitating face individuation through the efficient encoding of facial information (Maurer et al., 2002; McKone & Yovel, 2009). The precise conceptual and mechanistic distinctions between these processing styles have been somewhat ambiguous in the literature (for review, see Piepers & Robbins, 2012). In fact, some researchers, such as Maurer et al. (2002), propose an umbrella definition of configural processing that incorporates holistic processing as a subtype. What unites these processing styles and distinguishes them from the mechanisms engaged in perceiving non-social objects (e.g., feature-based or piecemeal processing) is their emphasis on encoding emergent properties of a stimulus. These emergent properties arise from the relational information between features of the stimulus, rather than from the isolated features themselves. The following subsection provides more concrete definitions of holistic and configural processing and describes the experimental paradigms devised to investigate their presence.

Holistic processing is a mode of visual processing that involves the integration and analysis of facial features as a cohesive unit (Richler et al., 2012; Rossion, 2013; Tanaka & Farah, 1993). The term “holism” stems from the notion that the entire configuration of a face holds a significance beyond the mere combination of its individual components. Holistic representations emerge through mechanisms that simultaneously process disparate features and integrate them into unified perceptual wholes. These higher-level descriptions are believed to permit efficient and rapid recognition (Richler et al., 2011). In contrast, piecemeal feature-based modes of processing, commonly employed for non-face stimuli, are thought to rely on slower and less accurate serial analysis of individual features (Biederman, 1987).

Configural processing, similar to holistic processing, is thought to be highly attuned to the spatial arrangement of facial features. However, unlike the holistic approach, most conceptualisations of configural processing place less emphasis on binding the entire face into a unified whole. Instead, configural processing focuses on analysing the spatial relationships between facial features to facilitate the encoding of facial identity (Freire et al., 2000; Maurer et al., 2002; Piepers & Robbins, 2012). This process involves extracting so-called 'second-order' relational information, such as the distances between facial features, the angles formed by these features, and the overall facial arrangement. Researchers argue that the spatial data obtained through this process offers a more precise and efficient method for distinguishing individual faces compared to a feature-based approach, given that the visual appearance of facial features across different individuals likely exhibits less variability compared to the spatial interrelations between those facial features.

One of the most widely employed paradigms used to investigate and quantify the phenomenon of holistic processing is the composite face task. In one specific variant of this task, participants are presented with pairs of faces side-by-side, and their objective is to determine whether the two faces within each pair depict the same upper or lower face halves (Young et al., 1987; Rossion, 2013; Murphy et al., 2017). Crucially, the alignment of the face halves varies across trials. Some trials show aligned face halves that form a coherent whole face (as depicted on the top row of Figure 1.1a), while others show misaligned halves by shifting the upper or lower half laterally (as depicted on the bottom row of Figure 1.1a). Participants typically experience minimal difficulty in judging whether the target face halves depict the same or different identities on misaligned trials. However, on aligned trials, participants often exhibit reduced accuracy and longer reaction times. This discrepancy is believed to arise from a novel holistic representation being formed from the fusing of the aligned face halves, which in turn induces illusory alterations in how each face half is perceived. In contrast, the absence of a whole face on misaligned trials prevents the formation of a holistic representation and, therefore, does not induce such illusory alterations in the target face half.

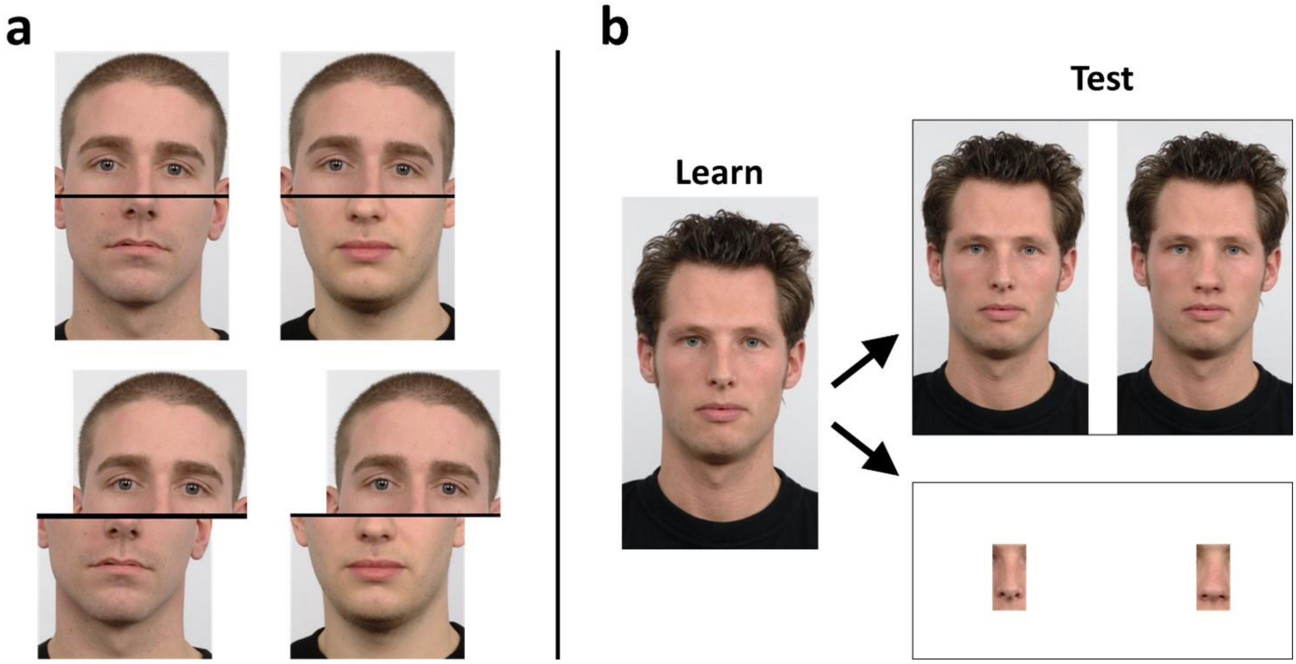

Figure 1.1: Composite and part/whole tasks. **(a)** Example stimuli from a variant of the composite face task. Participants commonly show enhanced recognition matching upper or lower face halves among face pairs when faces are presented with misaligned face halves (bottom pair) compared to aligned face halves (top pair). **(b)** Schematic illustration of trial sequences from a part/whole task. Participants typically demonstrate improved discrimination of face parts from learned faces (left) when they are presented in the context of a whole-face stimulus (top right) compared to when presented in isolation (bottom right). Face images from the Radboud Faces Database (Langner et al., 2010).

The part/whole task serves as an alternative paradigm to assess holistic processing (Tanaka & Farah, 1993, 1993). Figure 1.1b presents a schematic diagram illustrating a classic variant of this task. In each trial, participants are first presented with a whole-face stimulus to study. After a brief interval, the studied face disappears, and participants are shown two face parts of the same category (in this case, a nose), with one belonging to the studied face and the other to a novel face. Some trials present the face parts in isolation without any face context, while on other trials the face parts are shown within the context of the studied face (either the original studied face image or a version with the different face part superimposed on it). Typically, the results of this task reveal that participants exhibit superior recognition of the face parts when they are presented in the context of the studied face compared to when they are shown in isolation. This pattern of findings further supports the notion that the holistic approach is a superior mechanism for recognition compared to piecemeal approaches.

One of the most frequently used methods of researchers seeking to assess holistic / configural processing is to measure the effect of stimulus inversion. In the classic demonstration of the face inversion effect by Yin (1969), participants were presented with images of faces, houses, and airplanes to study. After a short interval, participants were shown pairs of test stimuli, one from the study set and the other from a set of novel stimuli. Their memory for the study stimuli was assessed by selecting the familiar test stimulus. Importantly, the study and test stimuli were either presented in their canonical orientation (‘upright’) or upside down (‘inverted’; see Figure 1.2a). The results revealed that inversion impaired recognition performance for all stimulus categories (faces, houses, and airplanes), but the magnitude of impairment was stronger for face stimuli. This disproportionate effect of inversion on face recognition (and face processing more generally) has been replicated in numerous subsequent studies, examining behavioural measures (Diamond & Carey, 1986; Bartlett & Searcy, 1993;

Freire et al., 2000; Bruyer, 2011) as well as neural responses (Yovel & Kanwisher, 2005). Furthermore, the act of inversion has been applied to holistic processing tasks where it has been found that the act of inverting a face stimulus in many cases diminishes or eliminates composite and part/whole effects (Farah et al., 1995; Murphy et al., 2017). The greater disruption caused by inversion for face stimuli in these tasks is believed to stem from the sensitivity of holistic / configural mechanisms to the canonical orientation of faces (Freire et al., 2000). Inverted faces may disrupt the extraction of spatial relationships and configural information that are crucial for both holistic and configural processing.

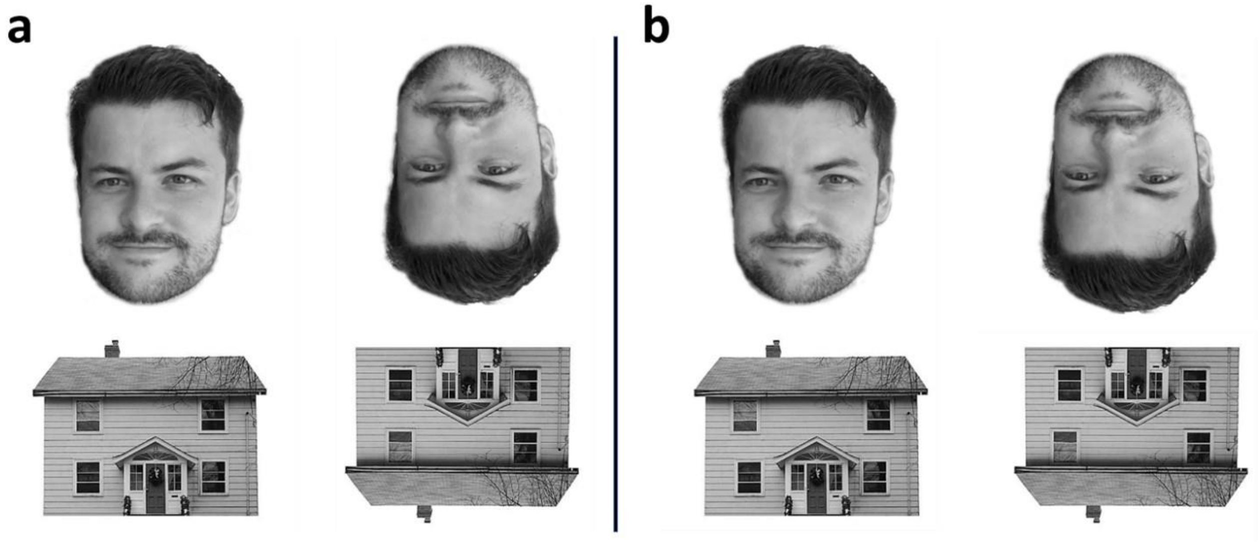

Figure 1.2: Face inversion and feature-spacing tasks. **(a)** Examples of upright and inverted faces and houses often used to demonstrate the face inversion effect. Inversion typically leads to a more significant decline in recognition accuracy and response speed for faces compared to houses. **(b)** Examples of stimuli from a feature-spacing task. Participants usually exhibit heightened sensitivity to changes in the spatial relationships between internal features (e.g., spacing between eyes or windows) when the stimulus is a face compared to a house. The changes are usually less noticeable when a face is inverted. Face images used with permission. House images from the DalHouses stimulus set (Filliter et al., 2016).

The final task that will be covered that sheds light on configural processing for faces is what will be referred to as the feature-spacing effect. One of the key distinctions between configural and featural processing lies in whether faces are perceived based on the spatial relationships between facial features or by analysing the features themselves (Maurer et al., 2002). If a stimulus is processed primarily on the basis of spatial interrelations, rather than appearance of individual features, it would be expected that observers would exhibit acute sensitivity to subtle changes in the spatial positioning of its features. This aspect was investigated in a task devised by Haig (1984), where participants were presented with original images of learned faces and manipulated versions of the same faces where different facial features were spatially displaced (see Figure 1.2b). The study's findings suggested that typical observers demonstrate remarkable sensitivity to changes in the spatial positioning of most face parts. However, this particular experiment did not include a control condition to assess whether this sensitivity enhancement was gated to whole faces shown in their canonical orientation. Subsequent studies that have used an inverted face condition as a control found evidence supporting heightened sensitivity to spatial changes in upright faces compared to inverted faces (Leder & Bruce, 1998, 2000; Freire et al., 2000; Leder et al., 2001; Barton et al., 2001). These findings support the notion that the sensitivity of configural mechanisms to second-order spatial relations facilitates expertise in face processing ability (Le Grand et al., 2001a; Mondloch et al., 2002; Chard et al., 2022). A similar paradigm to the one described here will feature in Chapters 3, 4, and 5.

Further support for the role of holistic and configural processing as key factors driving individual differences in face processing ability comes from studies comparing the performance markers of these visual processing mechanisms in participants with typical and atypical face processing ability. For example, individuals with developmental prosopagnosia have demonstrated atypical performance patterns on both holistic and configural tasks (Avidan et al., 2011; Le Grand et al., 2006; Levine & Calvanio, 1989; Palermo et al., 2011; Yovel & Duchaine, 2006; Zhang et al., 2015; however, see Duchaine, 2000; Le Grand et al., 2006; Susilo et al., 2010). Similarly, individuals with autism spectrum disorder are known to exhibit deficits across various face processing domains (Behrmann, Thomas, et al., 2006; Dawson et al., 2005). They have also shown atypical performance on both holistic and configural tasks (Dawson et al., 2005; Gauthier et al., 2009; Hobson et al., 1988; Langdell, 1978; López et al., 2004; Teunisse & de Gelder, 2003; Wallace et al., 2008; however, see Brewer et al., 2019; Joseph & Tanaka, 2003; Lahaie et al., 2006; Nishimura et al., 2008; Teunisse & de Gelder, 2003; Weigelt et al., 2012). Further discussion regarding the nature and extent of these differences in developmental prosopagnosia and autism can be found in Chapters 4 and 5, respectively.

1.1.2. Body processing

Compared with the visual mechanisms engaged by faces, much less is known about the visual analysis of bodies. However, several parallels have been identified between the visual processing of faces and bodies.

Detection and recognition

Evidence demonstrating that individual bodies, like individual faces, are highly salient visual stimuli that capture our attention more effectively than other classes of stimuli comes from a study using an inattentional blindness paradigm (Downing et al., 2004). In this paradigm, participants were shown fixation crosses followed by visual masks, and their task was to respond whether the horizontal or vertical bars of the crosses were longer. Importantly, during certain trials, a “critical stimulus” briefly appears in one quadrant of the cross (200 ms). The critical stimulus could consist of silhouettes of bodies, hands, or objects, presented either in a normal form or as a scrambled image with rearranged features. After each critical trial, participants were asked if they had noticed the critical stimulus, and if they responded affirmatively, they were required to identify it from an array of options. Participants who were initially exposed to an unscrambled body silhouette as their first critical stimulus demonstrated superior detection and recognition performance relative to those who encountered any of the comparison stimuli (objects or scrambled bodies). Notably, participants had not been informed in advance about the critical stimulus, supporting the view bodies elicit heightened attentional capture even when unexpected and task-irrelevant.

A related study by Ro et al. (2007) produced similar results. Participants were presented search arrays and tasked with locating and making categorical judgements about a visual stimulus appearing within a frame of a specific colour. The results showed that participants were significantly faster at responding to the target stimulus when it was a face or body. Moreover, the presence of a face or body within a non-target frame resulted in greater reaction time delays compared to the presence of other types of stimuli.

Together, these studies support the notion our visual and attentional systems are highly attuned to bodies, enabling rapid detection and preferential processing.

Neural substrates

Two prominent brain regions that have been heavily implicated in the visual processing of bodies are the extrastriate body area (EBA) and fusiform body area (FBA). These areas exhibit a marked preference for processing both static and dynamic representations of the human form, including photographs, videos, line drawings, and silhouettes (Downing et al., 2006; Downing & Peelen, 2011, 2016; Peelen & Downing, 2007). Furthermore, researchers who have studied the application of transcranial magnetic stimulation to EBA have been able to compellingly demonstrate selective disruption to body perception (Pitcher et al., 2009). Therefore, the distinct patterns of activation and function observed in EBA and FBA strongly support their specialisation in processing and representing visual characteristics related to the human body, such as body shape and movement.

Specialised cognitive mechanisms

Evidence supporting the existence of holistic processing for bodies comes from a study that adapted the face composite task to body stimuli (Robbins & Coltheart, 2012). Participants were tasked with matching body halves of sequentially presented bodies, which could be either aligned (body halves coinciding) or misaligned (body halves spatially offset). The findings revealed a composite effect (i.e., superior misaligned performance). This effect was observed in separate experiments that employed vertical (left-right halves) and horizontal (top-bottom halves) splits, although the composite effect was larger for the vertical split, indicating stronger integration of left-right body halves. However, it is worth noting that another study with a similar design, but limited to a horizontal split, did not find an effect for bodies (Bauser et al., 2011). Additionally, a different study demonstrated a composite effect in a version of the task that required matching body postures of body halves rather than identities (Willems et al., 2014).

Further support for holistic processing in bodies comes from a study conducted by Harris et al. (2016) that adapted the part/whole task using body stimuli. In this study, participants were required to identify individual body parts (e.g., arm, leg, torso) they had seen in a prior study phase. During the recognition phase, the researchers manipulated stereoscopic depth to create the percept of a body projecting in front of or behind a set of occluding bars. A consequence of this manipulation was that only the strips of bodies that appeared behind the bars were perceived as whole bodies due to amodal completion. Despite both viewing conditions having identical low-level properties, participants exhibited higher accuracy when identifying body parts that appeared in “whole” bodies, mirroring the face part/whole effect (Tanaka & Farah, 1993, 1993).

Another hallmark of holistic and configural processing for faces that has been replicated with bodies is the inversion effect (Reed et al., 2003). In a study resembling Yin's (1969) original demonstration, participants completed a same/different recognition task with upright and inverted face, body, and house stimuli. It was found that bodies were disproportionately affected by inversion, at a level comparable with faces. Houses, expectedly, did not show an equivalently strong effect. Interestingly, in a follow-up experiment it was revealed that the inversion effect for bodies vanished when the body configurations presented were biomechanically impossible, strengthening evidence that body-sensitive configural mechanisms are tuned to canonical body configurations.

An important question arising from these findings is whether the putative specialised mechanisms involved in body processing are truly identical to those used for faces, or merely analogous; i.e., sharing functional similarities but implemented via distinct neurocognitive systems. To date, much of the research in this area has been focused on simply demonstrating similar behavioural effects across stimulus types; however, a noteworthy fMRI adaptation study by Brandman and Yovel (2010) provides valuable insight into this question. The authors investigated sensitivity to body orientation (upright vs. inverted) in face-selective brain regions (OFA and FFA) and body-selective brain regions (EBA and FBA). The study found that face-selective regions exhibited significantly stronger neural responses and discrimination for upright compared to inverted bodies, mirroring the behavioural body inversion effect. In contrast, body-selective regions showed similar responses regardless of orientation, suggesting that they were not specially tuned to configural information. These findings support the view that face and body configural processing share a neural basis within the face perception network, consistent with the hypothesis of mechanistic overlap between these stimulus types.

Overall, there is reasonable support for the notion that individual bodies are processed in a mechanistically similar manner to individual faces, which is qualitatively distinct from how non-face and non-body stimuli are processed.

1.2. What is known about the visual perception of social interactions?

A social interaction can be broadly defined as a reciprocal engagement between two or more individuals (Sorokin, 1928). Historically, the study of social interactions has been conducted primarily by academics outside of vision science, such as anthropologists, sociologists, and social psychologists. This body of research has contributed significantly to the classification of social interactions based on factors such as implicit or explicit communitive behaviours (Goffman, 1963) and the purposes or goals of the engagement (e.g., cooperation, competition, exchange; Nisbet & Perrin, 1977).

However, in recent years, there has been a burgeoning interest in understanding how the visual system enables us to efficiently and veridically perceive and interpret social interactions that we observe from a third-person perspective. This poses a substantial computational challenge for the visual system, as it must not only detect, process, and represent multiple faces and bodies simultaneously, but also take into account the unique dynamics and relationships between those individuals. In this section, I will review the literature that has emerged to shed light on the visual mechanisms involved in the perception of social interactions.

It is important to note that unless otherwise stated, the research featured in this literature review, as well as the studies presented in the empirical chapters that follow, will adopt a narrower definition of social interaction than the broader definition described above. The social interactions featured in these investigations will predominantly consist of engagements between two individuals (‘dyadic social interactions’; see Figure 1.3a). In some cases the presented interactions will involve only the interactants’ faces, while in other cases full bodies will be presented. Furthermore, in almost all cases, the participants in these studies will serve the role of a passive observer of the social interactions rather than an active agent. Therefore, these interactions will have been viewed from an allocentric or third-person perspective rather than an egocentric or first-person perspective.

Another crucial clarification relates to the terminology used to operationalise social interaction in many of these studies. Researchers seeking to isolate and test putative visual perceptual mechanisms involved in social interaction processing have primarily employed three different methods, two of which involve manipulating the spatial configuration of the dyad. The first method is picture-plane inversion, which involves presenting the dyads upside-down (see Figure 1.3b), a control borrowed from the literature on individual face and body processing (Yin, 1969; Reed et al., 2003). The second method involves manipulations of dyadic arrangement by altering the facing direction of each dyad member so that they look away from each other (see Figure 1.3c), a control based on the observation that real-world interactions generally involve interactants looking towards each other (Hall, 1963, 1966). The third method involves using dyads comprised of inanimate objects that have canonical fronts and backs (e.g., grandfather clocks, cars), a control based on the fact that objects do not have the capacity to interact socially.

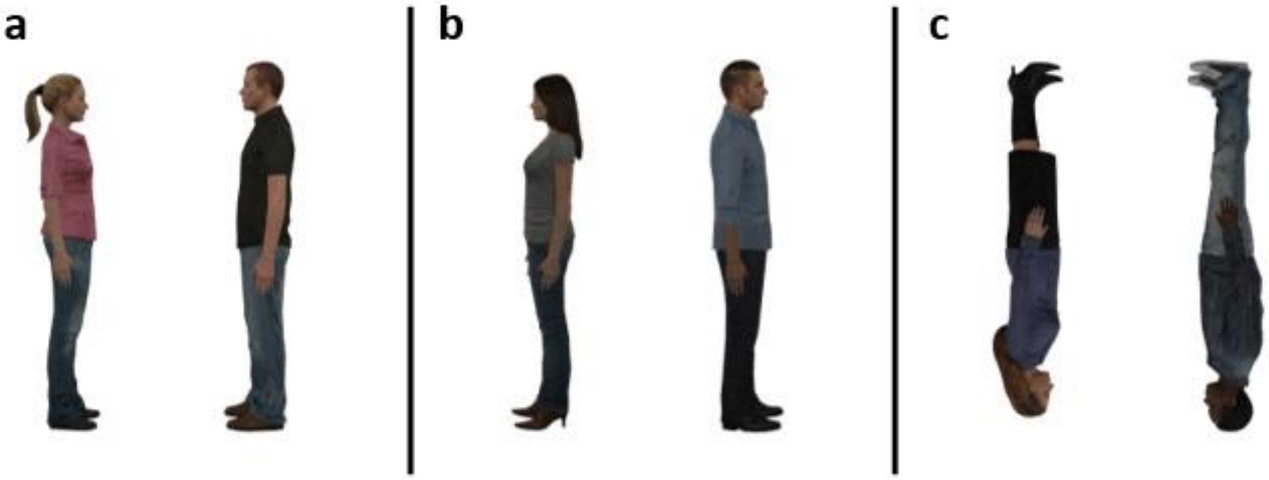

Figure 1.3: Human dyads in different spatial configurations. **(a)** An example of an upright, face-to-face dyad, **(b)** an upright, back-to-back dyad, and **(c)** an inverted, face-to-face dyad.

1.2.1. What can be inferred from observed social interactions?

Typical observers are known to possess a remarkable capacity to extract valuable social information from brief observations of social interactions, providing insights into the individuals involved, the ongoing interaction, and the underlying relationship dynamics. However, the precise mechanisms by which observers accomplish this perceptual feat are still not fully understood (for reviews, see Quadflieg & Penton-Voak, 2017; Quadflieg & Westmoreland, 2019).

Observers' sensitivity to non-verbal cues is demonstrated in a study by Costanzo and Archer (1989) that aimed to validate a standardised measure for assessing the ability to decode status, intimacy, kinship, competition, and deception from brief, unscripted, real-life social interactions. Each trial of the test began with a question (e.g., "who is the child of the two adults?", "what is the relationship between the man and woman?") followed by a video showing interactions among up to four individuals, with multiple-choice options for response. The authors found that the majority of participants achieved above-chance accuracy in inferring objective answers from the non-verbal cues. Female participants generally scored higher, consistent with previous research highlighting sex differences in proficiency in communicating and deciphering non-verbal cues (Hall, 1984). Additionally, participants who performed well on the test were more likely to be perceived as socially skilled by their peers, providing further validation for the measure.

Researchers have identified a wide array of non-verbal visual cues that are believed to be harnessed in deriving inferences about interactants' rapport, affiliation, and other social judgements. These cues encompass various dimensions, including interpersonal proximity (see Section 1.3.3.), touch, gaze, gestures, postures, imitation, motion synchrony, and action context (Schirmer et al., 2015; Thayer & Schiff, 1974; Kleinke et al., 1974; Gallotti et al., 2017; Bernieri et al., 1996; Tiedens & Fragale, 2003; Trout & Rosenfeld, 1980; Over &

Carpenter, 2015; Bernieri et al., 1994; Kimura & Daibo, 2006; Latif et al., 2014; Tsantani, Yon, et al., 2022; Bunce et al., unpublished; Plötner et al., 2016). However, the precise contribution of each visual cue and the extent to which they interact with one another to convey different meanings remain unclear (for review, see Quadflieg & Westmoreland, 2019; Morris, 2002; Burgoon, 1991).

It should also be acknowledged that systematic biases can influence our social evaluations and lead to inaccurate interpretations. Observers are known to rate and categorize observed interactions based on (often inaccurate) stereotypes and prejudices. For instance, there is a tendency to perceive romantic partners who are similar in physical attractiveness as having healthier relationships (Forgas, 1993, 1995), while interaction partners with different racial appearance may trigger increased negative appraisals (Skinner & Hudac, 2017), potentially leading to the perception of ambiguous interactions as more violent (Duncan, 1976). In some cases observers may also misinterpret emotional expressions of an interactant based on the emotional expression of their interaction partner (Gray, Barber, et al., 2017). For example, target faces are often judged as happier when presented alongside a happy partner, but this bias disappears when the interactants face opposite directions.

1.2.2. Do social interactions benefit from detection and attentional enhancements?

As discussed in Sections 1.1.1 and 1.1.2, extensive research has provided compelling evidence for the existence of specialised mechanisms that facilitate rapid and automatic detection of faces and bodies. Building on this knowledge, researchers have begun to investigate the potential existence of similar mechanisms that support the fast and efficient detection of social interactions.

A series of studies employing backwards masking techniques have provided support for the perceptual prioritization of dyadic interactions (Papeo et al., 2017; Papeo & Abassi, 2019; Abassi & Papeo, 2022). In these tasks, dyadic stimuli were shown for 30 ms before being masked. After this incredibly brief presentation, participants were required to categorise the dyads as pairs of people or pairs of chairs. Participants were found to show greater accuracy for trials involving human dyads compared to the chair dyads. Spatial configuration manipulations were also included in these studies, revealing that, for human trials, facing dyads were recognised better than non-facing dyads, and stimulus inversion had a disproportionately detrimental effect on facing dyads. These findings support the notion that dyadic interactions benefit from lower perceptual thresholds, akin to the privileged unconscious processing observed for faces (Jiang et al., 2007).

Further evidence for the attentional advantage of dyadic interactions comes from studies employing visual search paradigms (Papeo et al., 2019; Vestner et al., 2019). Participants were found to be much faster at locating a target facing dyad within a search array of non-facing dyads compared to the reverse. The study be Vestner et al. could not replicate this search asymmetry for pairs of wardrobes arranged front-to-front and back-to-back suggesting the effect is gated to human dyads. These findings appear supportive of the existence of attentional mechanisms highly tuned to social interactions that match the minimalist dyadic interaction template. It is important to note, though, that recent research has found a similar search advantage for dyads consisting of arrow-arrow and arrow-face pairs when arranged point-to-point and point-to-face, respectively (Vestner et al., 2020, 2022). Therefore, a more parsimonious explanation may be that the asymmetry is attributable to domain-general attentional mechanisms sensitive to salient directional cues within the faces/arrow dyads.

1.2.3. Are there dedicated brain regions for processing social interactions?

Unsurprisingly, the visual perception of multiple faces / bodies engages many of the same regions of the occipitotemporal cortex involved in processing singular faces and bodies, such as the FFA, OFA, EBA, and STS. However, two regions in particular consistently show sensitivity to the social context the dyads are presented in, suggesting that their activation cannot be solely attributed to the additive nature of observing multiple faces / bodies simultaneously.

When viewing static images of pairs of people, the EBA and posterior STS (pSTS) exhibit greater activation when the dyads are arranged facing relative to non-facing (Abassi & Papeo, 2020, 2022; Kujala et al., 2012). Both regions also demonstrate preferential activation for dynamic stimuli that depict interaction behaviours as opposed to independent actions (Centelles et al., 2011; Isik et al., 2017; Walbrin et al., 2018; Bellot et al., 2021; Tsantani, Yon, et al., 2022; Bunce et al., unpublished). Additionally, a study by Walbrin and Koldewyn (2019) employing multi-voxel pattern analysis found classifiers trained on functional data from these regions can achieve above-chance accuracy categorising the type of interaction observed (arguing, celebrating, and laughing), indicating EBA and pSTS are sensitive to the specific content of the interaction rather than merely the presence of an interaction.

1.2.4. Do social interactions engage specialised ‘face-like’ visual processing?

In Section 1.1 it was established that the observation of individual faces and bodies engages specialised modes of visual processing that permit their efficient and accurate perception. These mechanisms are considered domain-specific as they exhibit selective visual tuning to the typical spatial configuration shared by faces / bodies (Maurer et al., 2002; Yin, 1969). Stimulus types that do not possess these spatial configural characteristics, such as inverted or scrambled faces / bodies or objects, are believed to rely on less efficient parts-based mechanisms. However, there is evidence to suggest that, under certain circumstances, individuals can acquire similar advanced forms of processing for stimulus categories beyond human faces and bodies (Tanaka & Gauthier, 1997; Gauthier et al., 1998; Bukach et al., 2006; Gauthier & Bukach, 2007; Wong et al., 2009). For example, individuals with expertise in distinguishing identities of same breed dogs have been shown to exhibit inversion effects for dog faces (Diamond & Carey, 1986). Similarly, experienced radiographers demonstrate inversion effects in mammogram classification, while less experienced radiographers do not (Chin et al., 2018). These findings suggest that identifying markers of holistic and configural processing may reflect perceptual expertise in that particular stimulus class.

Dyadic social interactions are ubiquitous in everyday life, and their efficient and veridical evaluation holds significant adaptive value and social importance for observers. Moreover, the dyadic interactions we typically observe often feature predictable spatial configural structures (e.g., two people standing face-to-face), which could in principle be leveraged by specialised visual perceptual mechanisms to enhance their processing (Papeo et al., 2017; Papeo, 2020; Vestner et al., 2019; Abassi & Papeo, 2022). To investigate the existence of such mechanisms, researchers have aimed to identify markers of holistic and configural processing for interactions. Here, the literature that has emerged from these endeavours will be reviewed.

In the context of faces, holistic mechanisms are believed to bind together disparate visual features to form unified perceptual wholes (Richler et al., 2012; Rossion, 2013; Tanaka & Farah, 1993). Evidence supporting the occurrence of analogous perceptual grouping processes operating on dyadic interactions can be found in studies investigating participants' memory of interpersonal distances (Weller et al., 2018; Vestner et al., 2019; Sun et al., 2022). These studies presented participants with dyads comprised of either two humans or two objects in facing or non-facing arrangements. After a short retention interval, participants were instructed to recall the distance between dyad members. The findings consistently revealed a bias in participants' judgements for facing human dyads, remembering them as being closer together compared to non-facing dyads. Crucially, an equivalent compression effect for object dyads was not observed. Because the objects used within these experiments possessed canonical fronts and backs (e.g., wardrobes, fans, and cars), an explanation that the compression effect was solely driven by directional cues due to the arrangement was ruled out. The study by Sun et al. (2022) included inversion as a factor in their design, and were unable to find evidence of a compression effect for human dyads that were both inverted and facing. These findings lend support for a perceptual grouping process gated to facing human dyads presented in their canonical upright orientation (this series of studies are discussed further in Section 1.3.4)

Another marker of holistic processing in faces, known as the part/whole effect, describes enhanced recognition of face parts (e.g., eyes, noses, mouths) when presented within the context of a whole-face stimulus relative to when presented in isolation. In the context of dyadic interactions, an analogous effect would be an enhanced ability to recall details of dyad members when they are perceived as belonging to an interaction. Findings from Experiment 3 of Vestner et al. (2019) support this hypothesis. After completing a spatial task identical to that described earlier, participants were given a surprise memory test to recall the individuals seen within the presented dyads. Throughout the experiment, certain individuals appeared more frequently in facing arrangements than non-facing arrangements, and it was expected that details concerning those individuals would be better recalled. One finding was that participants exhibited superior recognition of which identities had been paired together when those dyads had more frequently been seen face-to-face, suggesting the perceived interaction context strengthened the encoding of group representation. More crucially, participants also demonstrated enhanced recognition of task-irrelevant details of those same individuals, such as the colour of the clothes they wore. This finding indicates that perceiving individuals as belonging to an interaction confers a mnemonic advantage similar to the part/whole effect observed in face processing.

Further support for interaction context enhancing processing of individual faces/bodies comes from a functional magnetic resonance imaging study conducted by Papeo and Abassi (2019). Using multi-voxel pattern analysis, the study examined the neural representations of body postures when presented within the context of dyads. In one analysis, classifiers were trained on functional data collected from regions of the occipitotemporal cortex while participants had observed single bodies displaying different postures. These classifiers were then tested on separate functional data acquired while participants observed similar bodies presented in either facing or non-facing dyads. Body-selective EBA was the only region found to achieve above-chance accuracy in decoding body posture, but, importantly, this effect was restricted to the face-to-face condition. This suggests that neural representations of single bodies are sharpened when presented in interaction contexts.

A collection of studies that included inversion conditions in their experiments also support the existence of face-like processing for interactions. Inversion effects are often considered compelling evidence for configural and holistic mechanisms specifically tuned to faces / bodies in their canonical orientations (Yin, 1969; Reed et al., 2003, 2006; Maurer et al., 2002). The first demonstration of an inversion effect for dyadic interactions was reported by Papeo et al. (2017). Across three studies employing a backwards masking paradigm, participants were shown incredibly brief displays of target dyads (30 ms) which were immediately followed by a visual mask (250 ms). Participants were tasked with categorising the dyads according to type (humans or chairs). There was a main effect of facing arrangement, which suggested a perceptual advantage for dyads presented face-to-face compared to back-to-back. More relevantly, it was shown that inversion disproportionately hampered participants' accuracy for facing dyads compared to non-facing ones. The authors were also able to reproduce this effect when the heads of the dyad members were obscured.

A follow-up study of this 'two-body inversion effect' was able to replicate the previous studies findings among participants who were tested at two different timepoints, ranging from two weeks to a month apart (Abassi & Papeo, 2020). The magnitudes of participants' facing dyad inversion effects were found to correlate between the two sessions. This finding demonstrates the strong test-retest reliability of the paradigm and suggests individuals' visual processing of dyadic interactions remains stable across time. Another significant finding was a weak, but significant, correlation indicating participants with smaller inversion effects were more likely to possess autistic-like traits. This finding is potentially important considering that autism spectrum disorder has been associated with deficits in face processing ability (Behrmann, Thomas, et al., 2006; Dawson et al., 2005) and atypical markers of configural processing for faces (Chapter 5; Dawson et al., 2005; Wallace et al., 2008).

Overall, this collection of research provides persuasive initial evidence for the existence of specialised visual processing mechanisms that facilitate the efficient and accurate perception of social interaction. These mechanisms appear to be selectively tuned to dyads with spatial configurations that conform the visual appearance of social interactions in their most minimal form: upright and face-to-face. Furthermore, there are compelling parallels between the effects observed in dyadic interactions and the robust markers of holistic and configural processing found in the face and body literature, implying a possible overlap between the visual mechanisms underlying individual face / body perception and social interaction perception.

1.3. Interpersonal distance

Thus far, this review has primarily examined the impact of two spatial configural dimensions that play key roles in the visual processing of social interactions: facing arrangement and orientation. This section introduces a third dimension that, like the previous two, is inherent to all visually observed social interactions[2]: interpersonal distance. Interpersonal distance can be defined simply as the physical space that separates individuals from one another.

Interpersonal distance holds a fundamental role in our social lives. How we choose to occupy space in relation to others, and conversely, how others choose to distance themselves from us, reveals deep insight into our current attitudes towards one another and the underlying nature

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[2] The qualifier "visually observed" is used here to exclude instances of social interaction where interpersonal distance is not directly observable, as one or more interactants are not situated in a shared physical environment. For instance, modern technological advances, such as videocalls and online multiplayer videogames, allow for rich social exchanges across vast distances.

of our relationships. Moreover, the automatic and effortless fluctuations in interpersonal distance that occur during social interactions can serve as a subtle form of non-verbal communication. Our intuitive grasp of the tight coupling between physical proximity and social connection is reflected in the language we use to describe those we interact with. For instance, it is commonplace to refer to an acquaintance whom we have a deep fondness as a “close friend”, while we might label another acquaintance with whom we have a strained relationship as “distant”.

While extensive theoretical and empirical research has predominantly examined interpersonal distance from the egocentric/first-person perspectives of active participants in social interactions, the perception of interpersonal distance from the allocentric/third-person perspective of passive observers remains relatively unexplored. The primary aim of this thesis is to address this knowledge gap by uncovering the visual perceptual mechanisms that enable us to accurately and effortlessly perceive interpersonal distance.

This section will provide an overview of the knowledge that has been gained from the study of interpersonal distance. It will begin by outlining early observations by the anthropologist Edward T. Hall regarding the significance of interpersonal distance. It will cover his seminal contributions in devising conceptual frameworks like ‘proxemics’ and his introducing new terminology that has become ubiquitous within and beyond academia.

Next, attention will be turned towards how these theories hold up to reality, by considering experimental work that has examined the validity of proxemic zones and explored the factors that mediate how people choose to position themselves from others.

I will then provide an overview of the limited knowledge that exists regarding the perception of interpersonal distance from third-person perspectives. This will cover how individuals are able to utilize proxemic cues to appraise social interactions in which they are not actively involved (‘people watching’).

Finally, the focus will be narrowed to examine the limited empirical research that has investigated the visual perceptual mechanisms underlying the perception of interpersonal distance.

1.3.1. Proxemic theory

The work of Hall on what he referred to as “proxemics” represents the most influential formulisations of social space (Hall, 1963, 1966). A central component of proxemic theory is the concept of “proxemic zones”. Through his observations of human interpersonal behaviour, Hall proposed that interpersonal space can be carved up into four distinct zones. These zones can be thought of as “invisible bubbles” emanating from individuals, each with a specific radius and serving unique social and cultural purposes (see Figure 1.4).
The largest of these bubbles is the public distance zone, which extends beyond 3.7 metres. This zone is typically reserved for situations such as public speaking to a large group. The social zone ranges from 1.2 to 3.7 metres and is commonly maintained when interacting with unfamiliar people, particularly in formal or professional settings. The personal zone spans from approximately 45 centimetres to 1.2 metres and is frequently used in everyday casual social interactions with friends, acquaintances, and colleagues. Lastly, the closest bubble is known as the intimate zone, which extends from personal contact up to 45 centimetres. This distance is typically reserved for individuals with whom we share very close relationships, such as romantic partners or family members.

It is important to note that Hall did not prescribe the above measurements, meanings, and purposes of the proxemic zones as rigid and universal. Hall recognised that each individuals' perception and use of each zone are influenced by personal preferences, as well as cultural and social norms.

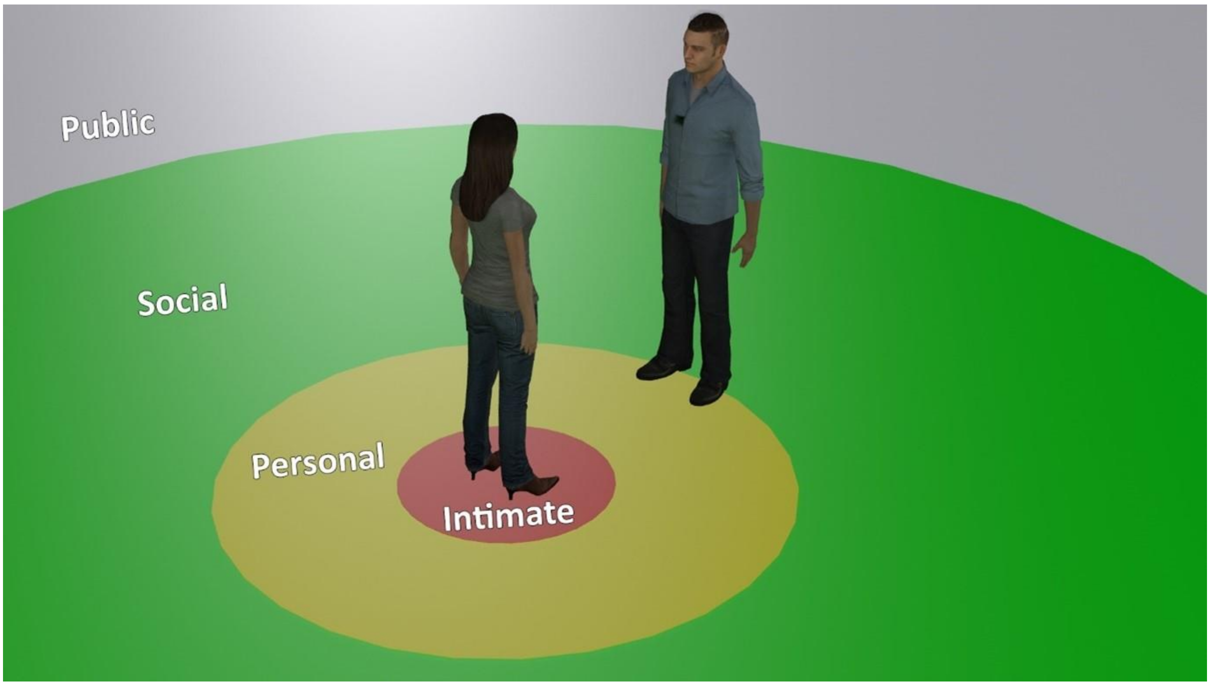

Figure 1.4: Proxemic zones. Illustration of Hall's conceptualisation of proxemic zones.

1.3.2. Proxemic behaviours and the factors that influence them

Since the inception of proxemic theory, a wealth of literature has emerged that enables us to examine the validity of the conceptualisations of proxemic zones and unravel the underlying determinants that shape our decisions and behaviours regarding interpersonal distance.

The personal space zone has received particular attention from researchers who have devised operational definitions in order to formalise methods for measuring it. According to Hayduk (1978), personal space refers to “the area individual humans actively maintain around themselves into which others cannot intrude without arousing discomfort”. A definition based on one’s feeling of comfort led to the development of the stop-distance task (Hayduk, 1983). In this task, participants are placed in a room with a confederate and given instructions to either actively approach the confederate or signal for the confederate to stop as they approach the participant (Eberts, 1972; Williams, 1971). Different variations of the task exist, with some studies explicitly informing participants that their comfort levels are being measured, while others employ deception to disguise the true purpose of the measurement and minimize potential confounding effects on behaviour (Bailenson et al., 2003). A more recent trend in personal space measurement has been to conduct the stop-distance task in virtual environments, which benefit from tighter experimental control in some respects, such as the increased consistency in performance of virtual confederates across experimental trials and between participants. Although concerns have been raised about peoples’ ability to accurately gauge distance in immersive virtual reality (Kunz et al., 2009), researchers have found comparable results between real-life and virtual approaches (Hecht et al., 2019; Iachini et al., 2016).

Studies utilizing these techniques have consistently found support for Hall’s dimensions of personal space, with most individuals’ preferences being around one metre (Hecht et al., 2019). Studies that have collected measurements from multiple angles relative to the participant have found the shape of personal space to be largely concentric, consistent with Hall’s conceptualisation. However, most report slight elongation, where personal space boundaries project further in front and to the sides of individuals compared to their rear

(Hayduk, 1981; Bailenson et al., 2003; Hecht et al., 2019). Longitudinal studies assessing the same participants over years have demonstrated the stability of these preferences and further validate the reliability of these measurement methods (Hayduk, 1983; Wormith, 1984).

Personal space preferences have been found to vary across the population based on various individual factors, such as sex, age, and location (Aiello & De Carlo Aiello, 1974; Hayduk, 1983; Hecht et al., 2019; Tennis & Dabbs, 1975; Webb & Weber, 2003; Sorokowska et al., 2017). Researchers have also found varying levels of influence from individual differences in personality traits, including introversion/extraversion (Williams, 1971), self-esteem (Roger, 1982), and psychopathy (Welsch et al., 2018). Certain populations have also been found to possess atypical preferences compared to the general population. This includes patients with amygdala lesions (Kennedy et al., 2009), those with disorders such as anorexia (Nandrino et al., 2017), schizophrenia (Deus & Jokić-Begić, 2006), and social anxiety disorder (Givon-Benjio et al., 2020), as well as conditions like autism (Chapter 5, Freitag, 1970; Gessaroli et al., 2013; Farkas et al., 2022; Asada et al., 2016; Pedersen et al., 1989; Perry et al., 2015).

Our personal space preferences are also dependent on situational factors, such as the identity and behavioural characteristics of our interaction partners. The boundaries that define our personal space are shown to be flexible for individuals we like (Little, 1965; Hall, 1966; Hayduk, 1978; Gifford, 1983; Sundstrom & Altman, 1976) and perceive as sexually attractive (Welsch et al., 2020). In contrast, we tend to distance ourselves from those that have treated us unfairly in the past (McCall & Singer, 2015) or belong to stigmatised outgroups, such as individuals with different ethnicities (Dotsch & Wigboldus, 2008; McCall et al., 2009; Word et al., 1974), obese individuals (Bessenoff & Sherman, 2000), and those with a disability (Worthington, 1974).

While most studies have considered interpersonal distance during social interactions as a static variable, more recent research has examined it as a dynamic one. Fluctuations in the distances we maintain with our interaction partners over the course of a social encounter elicit reliable behavioural and physiological outcomes (Candini et al., 2021; Kroczek et al., 2020; Perry et al., 2013). For instance, we may, consciously or unconsciously, engage subtle approach or avoidance behaviours based on our partners treatment of us, their eye gaze, and their body movements (Argyle & Dean, 1965; Bailenson et al., 2003; Kroczek et al., 2020; McCall & Singer, 2015).

1.3.3. Proxemic influences on social interaction appraisals

When it comes to passively observing a social interaction, it may seem self-evident that the magnitude of distance between the interactants would have a bearing on our evaluation of the interaction in terms of its valence (positive or negative) and nature (e.g., cooperation or conflict). For instance, it is conceivable that we might be more inclined to interpret a smiling couple standing at a moderate distance as work colleagues, whereas the same couple standing very close together may be perceived as engaging in an intimate or flirtatious encounter. This intuitive understanding of the social implications of observed proxemic behaviours is supported by a handful of studies.

Early evidence that observers are sensitive to proxemic cues when decoding meanings from dyads came from a study by Goldring (1967). In this study, participants were presented with simple line drawings of human figures positioned at different distances and displaying different postures. They were then asked to rate the figures based on certain dimensions. It was found that participants were more inclined to perceive the figures as warm, accepting, and natural when they were depicted in close proximity and reclined postures, compared to when they were depicted further apart and standing.

A later study conducted by Burgoon (1991) was able to attain similar results using a more sophisticated stimulus set and comprehensive rating system. This field experiment involved approaching participants with a series of images depicting naturalistic dyadic interactions, varying in terms of expressed proximity, posture, gender composition, and other variables. Participants were asked to rate each photograph along multiple dimensions using a Likert scale. The findings revealed that increased dyadic closeness resulted in higher judgements of immediacy (indicating mutual interest), similarity (establishing common ground), composure (perceived relaxation), and dominance (unequal power dynamic). Moreover, there were interactions between dyadic closeness and postural openness, leading to different interpretations along the dimensions of composure, similarity, and affection (mutual liking).

A final noteworthy study exploring the influence of proxemic cues on social interaction evaluations that will be mentioned is from Haase and Tepper (1972). The participants in this study were trained and experienced counsellors who were asked to watch short videos depicting staged client-counsellor interactions. These interactions varied according to proximity, eye contact, body posture, body orientation, and verbal empathy. Each video was judged according to the perceived level of empathy in the interaction. The findings revealed a main effect of distance, indicating closer distances facilitated higher ratings of empathy. However, there were also complex interactions with the other factors. The most optimal combinations of factors were found to be: 1) eye contact, forward trunk lean, medium empathic verbal message, and a far distance; and 2) eye contact, forward trunk lean, high empathic verbal message, and a close distance. Interestingly, the non-verbal components of the interaction were found to contribute more to the variance in perceived empathy than the verbal components.

Taken together, these three studies collectively demonstrate that proxemic cues significantly contribute to the shaping of social appraisals of dyadic interactions, even when the depicted interaction is simplistic. They also highlight the intricate interplay between interpersonal distance and other dimensions. The Haase and Tepper study, in particular, sheds light on the nuanced contexts under which observed distances can evoke varied interpretations and meanings.

1.3.4. The visual perception of interpersonal distance

Having established the proficiency of typical observers in utilizing proxemic cues, more fundamental questions arise regarding the underlying visual perceptual mechanisms that support this ability. Specifically, how does the visual system detect and represent interpersonal distance, and are these mechanisms specialised from other forms of distance perception? Unfortunately, there exists very little research that has addressed these questions.

A selection of studies previously referred to in Section 1.2.4. have provided some insight into the question of domain-generality (Vestner et al., 2019; Sun et al., 2022). These studies employed trials where participants were briefly shown dyads (1-2 s) presented under different viewing conditions, such as facing arrangement (facing or non-facing), orientation (upright or inverted), or type (human-human or object-object). After a blank retention interval (1-1.5 s), the dyadic stimulus reappeared with a member missing, and participants had to reconstruct the distance by indicating the rightful position of the missing dyad member.

The collective results of these two studies indicate that distances between dyad members that are human, upright, and facing are remembered as compressed compared to distances between dyads members that are non-human, inverted, or non-facing. Another closely related study by Weller et al. (2018) demonstrated a similar effect in a virtual reality environment, where participants watched pairs of animated avatars and had to subsequently match their last presented distance using an adjustable virtual bar. The effect was found to persist even when the physical landscape the dyads inhabited was distorted to give the impression that dyad members could not physically move closer or further away from one another.

Despite the abundance of evidence for the compression effect using these broadly similar paradigms, there is not yet a clear consensus on why the phenomenon occurs. Some possible explanations have been ruled out by the studies mentioned. One account suggests that the bias reflects an extrapolation of probable future spatial states of dyad members based on the statistical likelihood of individuals moving in a direction congruent with their facing direction. However, this explanation seems unlikely as the bias is not observed for objects that have similar movement capabilities as people, such as cars (Sun et al., 2022), and it persists even in environmental contexts where physically moving closer together is not possible (Weller et al., 2018). Another proposed explanation is that the bias is a by-product of the phenomenon in which facing human dyads command privileged attention relative to non-facing ones (Papeo et al., 2019; Vestner et al., 2019). However, recent experimental work suggests that this attentional asymmetry is domain-general and extends to other objects with salient direction cues, such as arrows (Vestner et al., 2020).

An explanation proposed by Vestner et al. (2019) for the compression effect is that the perceived context of an interaction activates mid-level perceptual grouping processes that bind interactants into a structured unit, analogous to Gestalt principles of perception that explain various illusions (Coren & Girgus, 1980; Pomerantz & Portillo, 2011; Wagemans et al., 2012). Some studies have found support for Gestalt principles sharing mechanistic overlap with holistic processing in faces (Curby & Moerel, 2019; Zhao M et al., 2016), supporting the notion of face-like holistic processing in dyadic interactions; however, other research has indicated a dissociation between Gestalt and holistic processing (Curby et al., 2019).

It remains unclear whether the observed compression effects reflect an illusory, cognitively impenetrable perceptual distortion, akin to the Müller-Lyer Illusion (Müller-Lyer, 1889), or if it is a by-product of other factors such as memory or cognitive decision-making. Numerous studies have proposed that high-level top-down influences, including beliefs, moods, desires, and action capabilities, can distort our perception of space (e.g., Proffitt, 2006). For example, studies have reported that wearing a heavy backpack can make hills appear steeper (Bhalla & Proffitt, 1999), and that coins may appear larger to children from lower-income socioeconomic backgrounds (Bruner & Goodman, 1947). Thus, the spatial compression of dyadic interactions may result from higher-level social cognition penetrating our perceptual experience. However, it should be noted that many of these purported top-down effects have been subject to scrutiny on methodological and theoretical grounds (Firestone, 2013). Some effects fail to replicate when confounding influences, such as experimental demand characteristics, are controlled (Durgin et al., 2009; Firestone & Scholl, 2014). Additionally, in some cases, effects like the coin study by Bruner and Goodman have shown to be attributed to memory rather than perception (Carter & Schooler, 1949; Landis et al., 1966; see also: McCurdy, 1956; Firestone & Scholl, 2016).

In summary, there is some evidence suggesting that the context of perceived social interaction biases our judgements of interpersonal distance. However, it remains unclear whether this “social binding” effect arises from perception, memory, or other cognitive processes. Further research is required to adjudicate between these accounts.

1.4. Open questions and thesis outline

There is currently a paucity of literature devoted to understanding the perception of interpersonal distance. The research that does exist on this topic has revealed that physical space between interactants is a fundamental factor in driving our social evaluations of the people involved and the nature of their relationships (Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; McCall & Singer, 2015). Despite this apparent high importance, however, very few investigations have been conducted to elucidate the visual mechanisms that underpin our perception of interpersonal distance. This thesis was motivated address several important questions regarding this that have so far been overlooked.

Recent experimental work has suggested that the perception of interpersonal distance is susceptible to illusory spatial distortions driven by dyad arrangement (Sun et al., 2022; Vestner et al., 2019; Weller et al., 2018). However, these investigations have employed broadly similar experimental paradigms that have relatively lengthy time intervals between stimulus presentations and judgements, rendering it unclear whether these ‘social binding’ biases are the product of perceptual or memory processes. It is also unclear whether interpersonal distance is affected by classic perceptual illusions of length that are observed in domains outside of social perception. Resolving this question has importance for understanding whether the encoding of interpersonal distance is ‘domain-specific’, in the sense that it is dissociated from other forms of distance processing (e.g., low-level or inter-object distance).

Another aim of this thesis was to elucidate the visual processing mechanisms underlying social interaction perception more broadly. Researchers have recently suggested that perceiving dyadic interactions may recruit visual mechanisms analogous to those used in face processing (Papeo, 2020; Vestner et al., 2019). Thus far, there has been some evidence to support this claim. Some studies have been able to successfully replicate ostensibly face / body-specific markers of holistic and configural processing in tasks that have employed dyadic stimuli (Abassi & Papeo, 2022; Papeo et al., 2017; Papeo & Abassi, 2019; Vestner et al., 2019). While this early work is promising, further research is required to evaluate these claims. Configural mechanisms in face processing are thought to provide observers with exquisite sensitivity to changes in spatial relations between internal facial features (e.g., interocular distance), but this process can be disrupted through manipulations of spatial configuration such as inversion (Yin, 1969; Yovel & Kanwisher, 2005). Assuming similar mechanisms operate for dyadic interactions, would it be expected that observers should exhibit heightened sensitivity to changes in spatial relations between dyad members (e.g., interpersonal distance) when viewed in their canonical facing arrangement and upright orientation versus other configurations?

Another important unresolved question is whether populations with neurodevelopmental conditions characterised by socio-perceptual and/or socio-cognitive differences relative to the general population exhibit differences in their perception of interpersonal distance. Individuals with developmental prosopagnosia and autism spectrum disorder are known to exhibit impairments in face processing ability (Behrmann, Thomas, et al., 2006; Cook & Biotti, 2016; Dawson et al., 2005; Hobson et al., 1988). It is currently unclear to what extent these deficits may impair perceptual sensitivity to socially-relevant visual features that are exclusive to multiple-person scenarios, such as interpersonal distance. Furthermore, breakdowns in configural mechanisms have been a suggested reason why these two groups exhibit face processing impairments (e.g., Le Grand et al., 2006; Levine & Calvanio, 1989; Behrmann, Avidan, et al., 2006). Therefore, whether developmental prosopagnosic and autistic individuals are impaired in their sensitivity to changes in dyadic spatial relations has important implications for the configural hypothesis.

The thesis contains four empirical chapters that sought to address these questions:

The aim of Chapter 2 was to assess whether perception of interpersonal distances can be distorted by a classic visual illusion of length, the Müller-Lyer illusion. Over a series of nine experiments designed to systematically test the conditions under which the illusion manifests, it is found that interpersonal distance is susceptible. Positioning face or body pairs within or outside of a target interval induces a bias to judge the interval as compressed or expanded, respectively.

Chapter 3 introduces a paradigm designed to assess participants' sensitivity to changes in interpersonal distance. Across four well-powered experiments, the ability to detect changes in spatial relations between dyad members is shown to not be affected by manipulations of spatial configuration such as facing arrangement and orientation. In contrast, two follow-up experiments that used an identical experimental paradigm were able to replicate the feature-spacing effect using upright and inverted faces. These results cast doubt on the configural hypothesis of dyadic interactions.

In Chapter, 4 the aim was to examine whether participants with developmental prosopagnosia exhibit deficits in their sensitivity to changes in interpersonal distance relative to a neurotypical control group. Despite experiencing severe face recognition difficulties, the developmental prosopagnosic group are shown to demonstrate comparable performance to the control group.

The final empirical investigation presented in Chapter 5 compares performance of participants diagnosed with autism spectrum disorder against a non-autistic control group on the distance change task. Despite discovering robust differences in self-reported and objectively measured face recognition ability between the groups, no evidence is found for differences in their perception of interpersonal distance.

The thesis culminates with a general discussion in Chapter 6. I discuss the implications of the empirical investigations' findings and their contribution to understanding the visual processing of interpersonal distance and social interactions. Limitations of the work are acknowledged, and suggestions for future research directions in this area are provided.

Chapter 2: The perception of interpersonal distance is distorted by the Müller-Lyer illusion

Interpersonal distance is a critical visual feature when appraising social scenes; proxemic cues allow observers to infer whether two people are interacting, the nature of their relationship, and the valence of their current interaction. Presently, however, remarkably little is known about how this attribute is encoded within the human visual system. This chapter demonstrates that judgements of interpersonal distance are affected by a classic illusory perceptual bias – the Müller-Lyer illusion. Over a series of nine experiments, evidence is presented that participants perceive the distance between two target points as compressed or expanded depending on whether face pairs are positioned within or outside the to-be-judged interval, respectively. This illusory bias was found to be unaffected by manipulations of face direction. These findings aid our understanding of how human observers perceive interpersonal distance and may inform theoretical accounts of the Müller-Lyer illusion.

2.1. Introduction

In recent years there has been a growing interest in how human observers visually perceive social scenes containing multiple people. Early findings suggest that viewing interacting individuals may recruit regions of visual cortex that are not engaged by non-interacting individuals (Abassi & Papeo, 2020, 2022). Similarly, social interaction displays may also recruit perceptual integration mechanisms that are not engaged by non-interacting individuals (Papeo, 2020). For example, where two people appear to be interacting, the facial emotion of one individual alters the perceived expression of the other (Gray, Barber, et al., 2017), and the individuals are remembered at standing closer together than they actually were (Vestner et al., 2019; Weller et al., 2018; Sun et al., 2022). These perceptual and mnemonic biases are not seen for non-interacting individuals.

Interpersonal distance is known to be a critical visual cue for appraising scenes of dyadic social interaction (Section 1.3.3; Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; Hall, 1963, 1966; McCall, 2017a; McCall & Singer, 2015). Despite its importance, however, surprisingly little is known about how this attribute is represented within the human visual system. The aim of the experiments described in this chapter was to explore whether the mechanisms that govern the encoding of interpersonal distance are susceptible to an illusion of length that has traditionally been studied with spatial intervals defined by non-social elements.

The Müller-Lyer illusion is a classic optical illusion in which the distance between two points is perceived as expanded or compressed depending on the contextual information surrounding the to-be-judged interval. In conventional demonstrations, the distance between two arrow points appears to differ when the arrows point inwards and outwards (see Figure

2.1a; Müller-Lyer, 1889). Although a connecting line is a common feature in demonstrations, the illusion remains strong in its absence. Compelling demonstrations of the illusion can also be seen with other geometric forms, including diamonds (Figure 2.1b). In these cases, the distance between the interior edges of two elements appears to be expanded, while the distance between the exterior edges appears compressed (for review, see Howe & Purves, 2005).

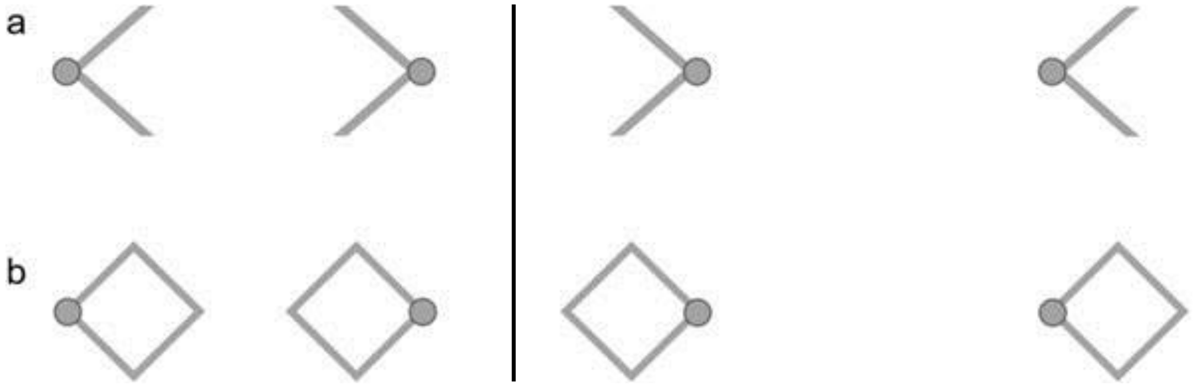

Figure 2.1: Traditional demonstrations of the Müller-Lyer illusion. The illusion is conventionally demonstrated using simple geometric forms including **(a)** arrows (Experiment 1) and **(b)** diamonds (Experiment 2). In both cases, the target circles are the same distance apart in the left and right arrangements, but they appear closer together in the arrangements on the left.

To date, research on the Müller-Lyer illusion has primarily focused on simple geometric forms such as arrows and diamonds (Howe & Purves, 2005; Weidner & Fink, 2007; Restle & Decker, 1977; Nijhawan, 1991; Greist-Bousquet & Schiffman, 1981; Gregory, 1966; Day, 1989; Woloszyn, 2010). It is currently unclear the extent to which these illusory biases manifest in everyday life; for example, when we view social scenes. This knowledge gap is particularly notable considering the pivotal role of proxemic cues in shaping our evaluations of the social interactions we observe. Moreover, gaining insights into the conditions under which the illusion operates is essential for adjudicating competing explanations of the Müller-Lyer illusion itself.

A series of psychophysical experiments were designed to systematically investigate the conditions under which Müller-Lyer-like illusory distortions of length occur when viewing dyadic social interactions. Experiments 1 and 2 aimed to validate the experimental paradigm by replicating conventional demonstrations of the illusion with arrows and diamonds as contextual elements. Experiments 3 to 8 examined whether equivalent effects could be elicited with pairs of faces viewed in profile, focusing on how their relative arrangement (face-to-face vs. back-to-back) and placement (interior vs. exterior of the to-be-judged interval) modulates the illusion. A final experiment aimed to explore whether the illusion manifests when the faces pairs are embedded within the context of whole bodies.

2.2. Online testing and participant recruitment

All the experiments described were conducted online using Gorilla (Anwyl-Irvine et al., 2020). The use of online testing is increasingly common. Carefully-designed online tests of cognitive and perceptual processing can yield high-quality data, indistinguishable from that collected in the lab (Crump et al., 2013; Germine et al., 2012; Woods et al., 2015). Participants were recruited through the Prolific subject pool (https://www.prolific.co).

A sample size of 30 was chosen for each experiment. A sensitivity analysis conducted using GPower 3.1 (Faul et al., 2009) revealed that a sample of this size is sufficient to reliably detect a moderate effect size of $d_z = 0.612$ when conducting a paired samples *t*-test with a target power of 90% ($\alpha = 0.05$, two-tailed). Previous studies on standard demonstrations of the Müller-Lyer illusion have reported effect sizes within a similar range ($d_z = 0.464$-1.096; Woloszyn, 2010). Participants were required to be aged 18 to 50 years-old, to have normal or corrected-to-normal visual acuity, to have no history of psychiatric or neurological illness, to reside in the United Kingdom, and to have a Prolific approval rating above 80%.

Ethical clearance was granted by the Psychological Sciences Departmental Ethics Committee at Birkbeck, University of London. The experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent.

2.3. Experiment 1

The first and second experiments sought to replicate the Müller-Lyer illusion with arrows and diamonds, respectively, in order to validate the experimental paradigm.

2.3.1. Method

Thirty participants recruited via prolific ($M_{\text{age}} = 27.23$ years; $SD_{\text{age}} = 8.30$ years; 19 female) participated in Experiment 1. On each trial, participants were presented with two spatial intervals, both of which were defined as the distance between two circles. One of the intervals—the to-be-judged or 'standard' interval—was fixed throughout the procedure. The second interval was a comparison stimulus that varied from trial to trial. The seven comparison intervals ranged from 70% the width of the standard to 130% the width of the standard, in equidistant intervals of 10%. The two spatial intervals were presented side-by-side for 800 ms with the standard on the right and the comparison on the left (Figure 2.2a). Following stimulus offset, participants had to indicate which spatial interval was greater with a keypress.

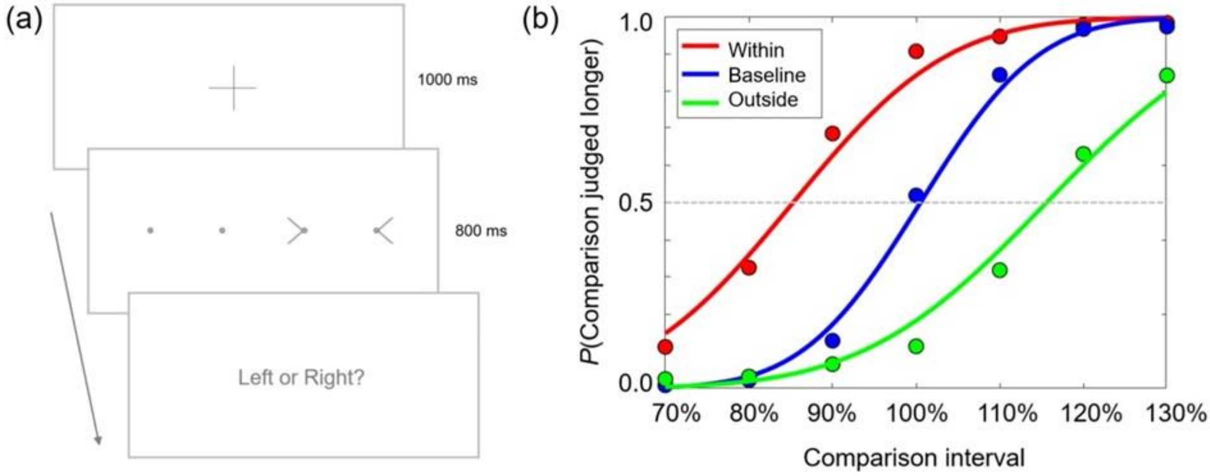

Figure 2.2: Overview of methodology. **(a)** Schematic illustration of the sequence of an experimental trial. **(b)** Participants' binary responses were used to construct psychometric functions. The examples shown are the average functions from Experiment 4.

The context element manipulation – the addition of the arrows – was applied to the standard interval only. The arrows were positioned such that their points were coincident with the target circles (Figure 2.1a). In one condition the arrows were positioned outside the target circles, facing inwards. In a second condition the arrows were positioned within the target circles, facing outwards. A third condition in which no contextual information was provided served as a baseline. The width of each arrow was approximately 25% the width of the to-be-judged interval. Because the study was conducted online, it was not possible to control the monitor size or the viewing distance employed by participants. Assuming a viewing distance of ~ 50 cm, it can be estimated that the to-be-judged interval typically subtended between 9.0° and 11.5° of visual angle. In each condition, the to-be-judged interval was presented alongside each level of comparison stimulus 20 times, yielding a total of 420 trials (7 levels of comparison × 20 presentations × 3 conditions). Trials were presented in a randomized order with breaks interspersed every 70 trials.

Participants' binary-choice responses were used to construct psychometric functions that modelled the probability that the comparison interval was judged greater, as a function of the increasing width of the comparison interval. The perceived width of the standard interval was inferred from the point of subjective equivalence (PSE) on the resulting psychometric function (Figure 2.2b). This is the hypothetical value of comparison stimulus likely to be judged identical to the standard stimulus. Psychometric functions were estimated by fitting cumulative Gaussians in Matlab (The MathWorks Inc., Natick, USA) using the Palamedes toolbox (Prins & Kingdom, 2009). The distributions of PSE estimates in the different viewing conditions were compared using paired-samples *t*-tests ($\alpha = 0.05$, two-tailed). Effect sizes for each comparison were estimated by calculating Cohen's d_z (the mean difference divided by the standard deviation of the differences). Data for this and all subsequent experiments can be accessed via the Open Science Framework (https://osf.io/bswx4/).

2.3.2. Results

In the absence of arrows, participants judged the distance between the circles to be 97.65% (*SD* = 4.34%) of the physical distance. When inwards-pointing arrows were positioned outside the target circles, the mean distance estimate increased significantly to 116.48%

($SD = 7.42\%$) [$t(29) = 14.873$, $p < .001$, $d_z = 2.72$, $CI_{95\%} = 1.93, 3.49$]. When outwards-pointing arrows were positioned within the target circles, the mean distance estimate decreased significantly to 85.79% ($SD = 9.82\%$) [$t(29) = 9.354$, $p < .001$, $d_z = 1.71$, $CI_{95\%} = 1.14, 2.27$]. As expected, the positioning of the context elements outside the to-be-judged interval induced illusory expansion, while the positioning of the context elements within the to-be-judged interval induced illusory compression. The results of this experiment and every subsequent experiment are shown in Figure 2.4.

2.4. Experiment 2

The second experiment sought to replicate the Müller-Lyer illusion with diamonds (Figure 2.1b). Thirty participants were recruited via prolific ($M_{age} = 28.47$ years; $SD_{age} = 7.16$ years; 12 female). In one condition, diamonds were positioned outside the target circles, such that the circles were coincident with the interior points of the diamonds. In a second condition, they were positioned within the target circles, such that the circles were coincident with the exterior points of the diamonds. A third condition in which the contextual information was absent served as a baseline. The width of each diamond was approximately 35% the width of the to-be-judged interval.

In the absence of diamonds, participants judged the distance between the two circles to be 99.77% ($SD = 3.48\%$) of the physical distance. When the diamonds were positioned outside the target circles, the mean distance estimate increased significantly to 115.66% ($SD = 5.96\%$) [$t(29) = 13.793$, $p < .001$, $d_z = 2.52$, $CI_{95\%} = 1.78, 3.25$]. When the diamonds were positioned within the target circles, the mean distance estimate decreased significantly to 83.96% (*SD* = 8.20%) [$t(29) = 9.926$, $p < .001$, $d_z = 1.81$, $CI_{95\%} = 1.22, 2.39$].

2.5. Experiment 3

In the third experiment, identical effects were obtained when the geometric forms were replaced by faces viewed in profile (Figure 2.3a). The sample ($N = 30$; $M_{age} = 30.23$ years; $SD_{age} = 9.44$ years; 16 female) included one replacement for a participant for whom psychometric functions could not be modelled in all conditions. Face images were taken from the Radboud Faces Database (Langner et al., 2010), a collection of facial images that are freely available for use in academic research (http://www.socsci.ru.nl:8180/RaFD2/RaFD). The faces were positioned such that the tips of their noses were coincident with the centre of the target circles. In one condition the faces were positioned outside the target circles, facing inwards. In a second condition the faces were positioned within the target circles, facing outwards. A third condition in which no contextual information was provided served as a baseline. The width of each face was approximately 35% the width of the to-be-judged interval.

In the absence of the faces, participants judged the distance between the two circles to be 100.15% (*SD* = 4.26%) of the physical distance. When two faces (arranged face-to-face) were positioned outside the target circles, the mean distance estimate increased significantly to 119.62% (*SD* = 8.00%) [$t(29) = 14.264$, $p < .001$, $d_z = 2.60$, $CI_{95\%} = 1.84, 3.36$]. When two faces (arranged back-to-back) were positioned within the target circles, the mean distance estimate decreased significantly to 77.47% (*SD* = 11.22%) [$t(29) = 10.894$, $p < .001$, $d_z = 1.99$, $CI_{95\%} = 1.36, 2.61$].

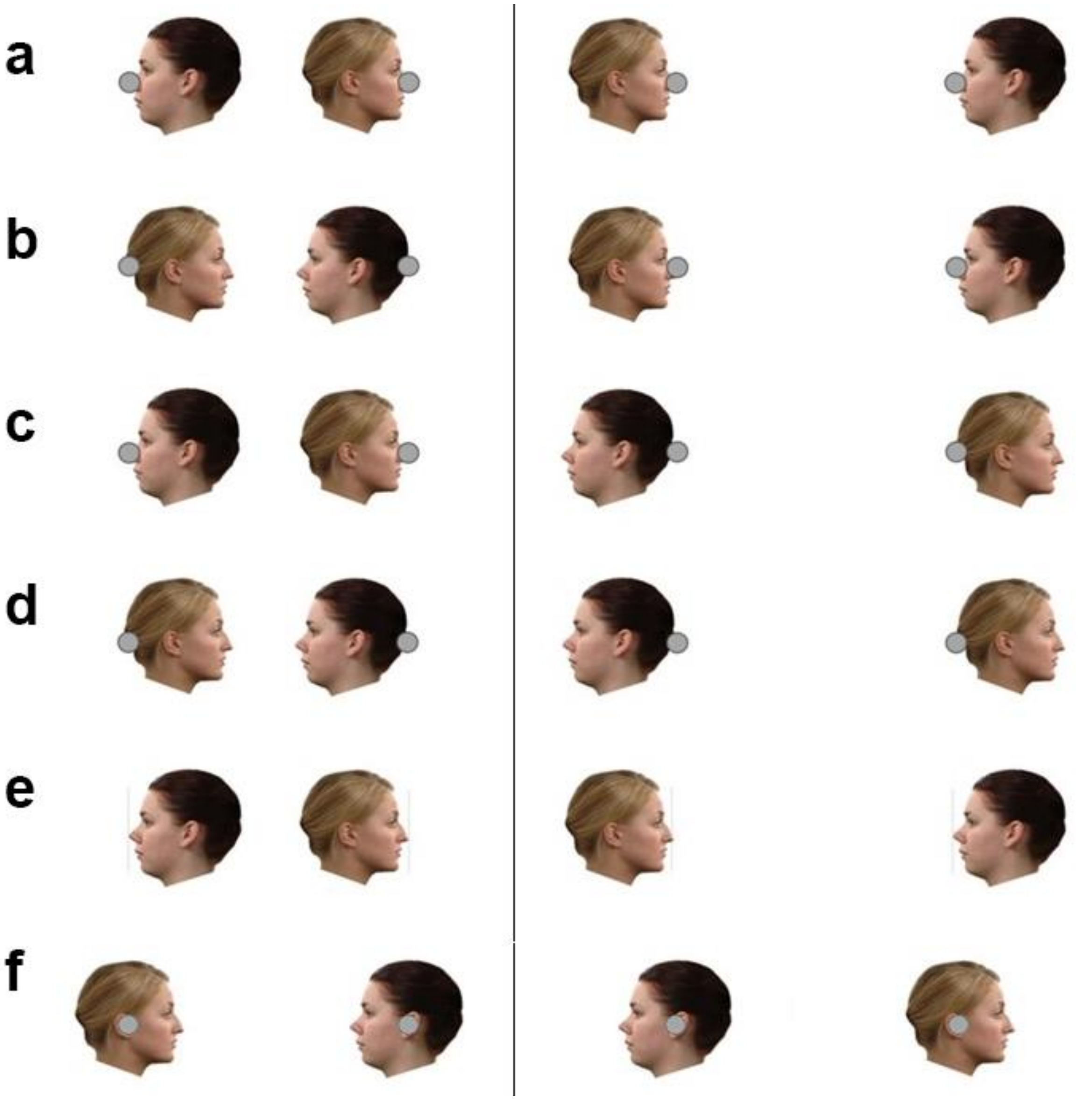

Figure 2.3: The Müller-Lyer illusion induced by faces. **(a–d)** Faces produce the illusion irrespective of their arrangement. In each case, the target circles are the same distance apart in the left and right arrangements, but they appear closer together in the arrangements on the left. **(e)** The effect manifests strongly in the absence of the target circles. The tips of the noses are equidistant in both arrangements, but appear closer in the back-to-back arrangement. **(f)** No such effect manifests when the arrangement of the faces differ (face-to-face vs. back-to-

back) but face placement around the target circles is held constant between arrangements. Stimuli a-f correspond to the face pairs shown in Experiments 3-8, respectively.

2.6. Experiment 4

Next, it was found that the direction of the faces made little difference; rather, the key factor was the positioning of the faces relative to the target circles. In the fourth experiment ($N = 30$; $M_{\text{age}} = 28.97$ years; $SD_{\text{age}} = 7.28$ years; 21 female), the expansion and compression effects were replicated using faces that were always arranged face-to-face (Figure 2.3b). In one condition, the faces were positioned outside the target circles, such that the circles were coincident with the tips of the noses. In a second condition, they were positioned within the target circles, such that the points were coincident with the backs of the heads. A third condition in which the contextual information was absent served as a baseline.

In the absence of faces, participants judged the distance between the two circles to be 100.61% ($SD = 5.01\%$) of the physical distance. When the faces were positioned outside the target circles, the mean distance estimate increased significantly to 115.47% ($SD = 10.69\%$) [$t(29) = 8.773$, $p < .001$, $d_z = 1.60$, $\text{CI}_{95\%} = 1.05, 2.14$]. When two faces were positioned within the target circles, the mean distance estimate decreased significantly to 84.13% ($SD = 9.39\%$) [$t(29) = 11.340$, $p < .001$, $d_z = 2.07$, $\text{CI}_{95\%} = 1.43, 2.70$].

2.7. Experiment 5

In the fifth experiment ($N = 30$; $M_{\text{age}} = 30.43$ years; $SD_{\text{age}} = 8.07$ years; 16 female), the expansion and compression effects were replicated using faces that were always arranged back-to-back (Figure 2.3c). In one condition, the faces were positioned outside the target circles, such that the circles were coincident with the backs of the heads. In a second condition, they were positioned within the target circles, such that the points were coincident with the tips of the noses. A third condition in which the contextual information was absent served as a baseline.

In the absence of faces, participants judged the distance between the two circles to be 100.95% ($SD = 4.85\%$) of the physical distance. When the faces were positioned outside the target circles, the mean distance estimate increased significantly to 114.72% ($SD = 8.26\%$) [$t(29) = 9.147$, $p < .001$, $d_z = 1.67$, $CI_{95\%} = 1.11, 2.22$]. When two faces were positioned within the target circles, the mean distance estimate decreased significantly to 83.62% ($SD = 7.08\%$) [$t(29) = 12.893$, $p < .001$, $d_z = 2.35$, $CI_{95\%} = 1.65, 3.05$].

2.8. Experiment 6

For completeness, the sixth experiment sought to confirm that the results of Experiment 3 replicate when the direction in which the faces were pointed was reversed (Figure 2.3d). In one condition the faces were positioned outside the target circles, facing outwards. In a second condition the faces were positioned within the target circles, facing inwards. A third condition in which the contextual information was absent served as a baseline. The sample ($N = 30$; $M_{age} = 29.27$ years; $SD_{age} = 9.15$ years; 16 female) included two replacements for participants for whom psychometric functions could not be modelled in all conditions.

In the absence of faces, participants judged the distance between the two circles to be 101.56% ($SD = 4.23\%$) of the physical distance. When the faces were positioned outside the target circles, the mean distance estimate increased significantly to 117.36% (*SD* = 12.49%) [$t(29) = 6.353$, $p < .001$, $d_z = 1.16$, $CI_{95\%} = 0.69, 1.62$]. When two faces were positioned within the target circles, the mean distance estimate decreased significantly to 81.51% (*SD* = 6.78%) [$t(29) = 14.465$, $p < .001$, $d_z = 2.64$ $CI_{95\%} = 1.87, 3.40$].

2.9. Experiment 7

In Experiments 1–6, participants were asked to judge the distance between two target circles, and how these judgements were affected by the positioning of arrows, diamonds, and faces was examined. The use of target circles was intended to help participants understand what was required of them. In the seventh experiment, however, it was confirmed that the previously observed expansion and compression effects alter the perception of interpersonal distance in the absence of the target circles. The sample ($N = 30$; $M_{age} = 30.10$ years; $SD_{age} = 9.22$ years; 19 female) included three replacements for participants for whom psychometric functions could not be modelled in all conditions.

In the experimental conditions, participants were asked to judge the distance between the tips of the two actors' noses (Figure 2.3e). In one condition, the faces were arranged face-to-face (akin to the 'outside' conditions described above); in the other they were arranged back-to-back (akin to the 'within' conditions described above). In a baseline condition, participants judged the length of a horizontal line in the absence of any other elements. The to-be-judged distance was the same in all three conditions. The seven levels of comparison distance were defined by the length of a horizontal line.

In the baseline condition, participants judged the length of the line to be 100.84% (*SD* = 2.71%) of the physical distance. When judging the nose-to-nose distance of two faces positioned face-to-face, distance estimates (*M* = 121.32%; *SD* = 11.05%) increased significantly [$t(29) = 10.038$, $p < .001$, $d_z = 1.83$, $CI_{95\%} = 1.24, 2.42$]. When judging the nose-to-nose distance of two faces positioned back-to-back, distance estimates (*M* = 77.64%; *SD* = 10.67%) decreased significantly [$t(29) = 11.518$, $p < .001$, $d_z = 2.10$, $CI_{95\%} = 1.45, 2.74$].

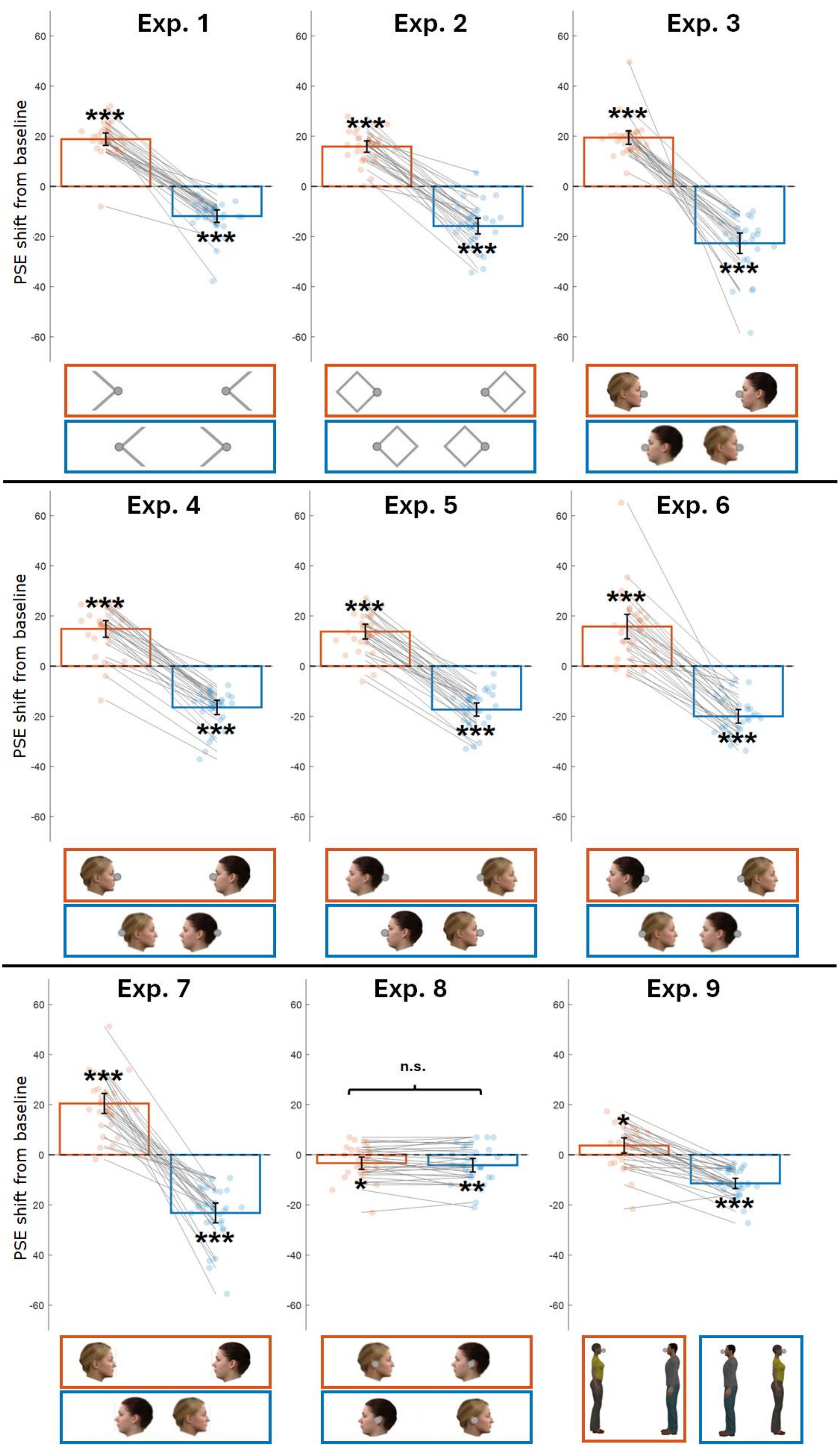
Exp. 1
Exp. 2
Exp. 3
Exp. 4
Exp. 5
Exp. 6
Exp. 7
Exp. 8
Exp. 9
PSE shift from baseline
60
40
20
0
-20
-40
-60
***
*
**
n.s.

Figure 2.4. Results of Experiments 1-9. The magnitude of illusory distortion in participants' distance judgements are shown as PSE shifts, calculated by subtracting baseline PSE values from experimental condition PSE values. Values above and below the dashed lines (representing baseline) reflect expansion and compression effects, respectively. Bars represent means, individual participant datapoints are plotted as dots, and error bars represent 95% confidence intervals. Asterisks denote level of significance when contrasted with baseline ($*p < 0.05$, $**p < 0.01$, $***p < .001$).

2.10. Cross-experiment analysis: effect of face arrangement

In Experiments 3-7 it was found that face pairs positioned outside and within the target points marking the to-be-judged intervals induced illusory compression and expansion effects, respectively. The direction the faces were pointed (face-to-face or back-to-back) appeared to have no impact on the presence of these effects. To formally test this hypothesis, the PSE estimates from Experiment 4 (faces always arranged face-to-face) and Experiment 5 (faces always arranged back-to-back) were entered into a 2 × 2 mixed ANOVA with Stimulus Placement (outside, within) as a within-subjects factor and Face Arrangement (face-to-face, back-to-back) as a between-subjects factor.

The ANOVA revealed a significant main effect of Stimulus Placement [$F(1, 58) = 1105.716$, $p < .001$, $\eta_p^2 = .950$], whereby participants judged the distance between the target circles to be expanded on trials where face pairs were positioned outside the interval ($M = 115.10\%$, $SD = 9.48\%$) compared to within the interval ($M = 83.88\%$, $SD = 8.25\%$). In contrast, there was no significant main effect of Face Arrangement, [$F(1, 58) = 0.017$, $p = .896$, $\eta_p^2 < .001$], indicating that participants in the face-to-face ($M = 99.80\%$, $SD = 9.41\%$) and back-to-back ($M = 99.17\%$, $SD = 6.74\%$) experiments exhibited comparable biases. The interaction between both factors was also non-significant [$F(1, 58) = 0.017$, $p = .896$, $\eta_p^2 < .001$], suggesting that the direction of the faces did not modulate the effect of stimulus placement.

Follow-up independent samples *t*-tests confirmed that no significant differences emerged between the face-to-face and back-to-back groups on baseline trials [$M_{F2F} = 100.61\%$, $SD_{F2F} = 5.01\%$, $M_{B2B} = 100.95\%$, $SD_{B2B} = 4.85\%$, $t(58) = -.265$, $p = .792$, $d_z = -0.07$ $CI_{95\%} = -0.43$, 0.59], outside trials [$M_{F2F} = 115.47\%$, $SD_{F2F} = 10.69\%$, $M_{B2B} = 114.72\%$, $SD_{B2B} = 8.26$, $t(58) = 0.306$, $p = .761$, $d_z = 0.08$ $CI_{95\%} = -0.43$, 0.56], or within trials [$M_{F2F} = 84.13\%$, $SD_{F2F} = 9.39\%$, $M_{B2B} = 83.62\%$, $SD_{B2B} = 7.08\%$, $t(58) = 0.237$, $p = .814$, $d_z = 0.06$ $CI_{95\%} = -0.45$, 0.57].

2.11. Experiment 8

The foregoing analysis found no evidence that the arrangement of faces (face-to-face vs. back-to-back) modulated the illusion. In the eighth experiment ($N = 30$; $M_{age} = 30.37$ years; $SD_{age} = 8.64$ years; 16 female), this result was replicated under conditions where face-to-face and back-to-back face pairs were presented with their placement around the target circles held constant between conditions.

As in Experiments 1-6, participants were asked to judge the distance between target circles. In both experimental conditions that included faces as contextual elements, the target circles appeared at the midpoints of each head, approximately overlapping the ear regions (Figure 2.3f). In one condition the faces were arranged face-to-face. In a second condition the faces were arranged back-to-back. A third condition in which the contextual information was absent served as the baseline.

Due to the expectation of a null effect and the inherent limitations of traditional null-hypothesis significance testing, the frequentist approach was complemented with Bayesian equivalent paired *t*-tests using JASP (default Cauchy priors: centre = 0, width = 0.707; JASP-Team, 2022). A Bayes Factor (BF_{01}) larger than 1, 3, and 10 reflects anecdotal, substantial, and strong evidence, respectively, in favour of the null hypothesis (i.e., no effect of arrangement; Jeffreys, 1998). BF_{01} values smaller than 1, 1/3, and 1/10, on the other hand, indicate anecdotal, substantial, and strong evidence, respectively, in favour of the alternative hypothesis (i.e., an effect of arrangement).

In the absence of faces, participants judged the distance between the two circles to be 100.43% (*SD* = 5.19%) of the physical distance. When the faces were arranged face-to-face and centred on the target circles, the mean distance estimate decreased significantly from baseline to 97.15% (*SD* = 6.72%) [*t*(29) = 2.615, *p* = .014, $d_z = 0.48$, $CI_{95\%} = 0.10, 0.85$, $BF_{01} = 0.295$]. When the faces were arranged back-to-back and centred on the target circles, the mean distance estimate also decreased significantly from baseline to 96.32% (*SD* = 6.90%) [*t*(29) = 2.938, *p* = .006, $d_z = 0.54$ $CI_{95\%} = 0.15, 0.92$, $BF_{01} = 0.152$]. There was no significant difference between participants' mean distance estimates in the face-to-face and back-to-back conditions [*t*(29) = 1.249, *p* = .222, $d_z = 0.23$ $CI_{95\%} = -0.14, 0.59$, $BF_{01} = 2.540$].

2.12. Experiment 9

The final experiment sought to confirm that similar effects are induced when the faces are presented in the context of whole bodies. Three-dimensional models arranged in Poser Pro 11.2 (Bondware, Inc., Murfreesboro, USA) were used as stimuli. Target dots were positioned at face level, coincident with the tips of the models' noses (Figure 2.5). The width of each model was approximately 20% of the width of the to-be-judged interval. In one condition the models were positioned outside the target circles, facing inwards. In a second condition they were positioned within the target circles, facing outwards. A third condition in which no contextual information was provided served as a baseline. The sample ($N = 30$; $M_{\text{age}} = 29.53$; $SD_{\text{age}} = 8.84$; 10 female) included two replacements for participants for whom psychometric functions could not be modelled in all conditions.

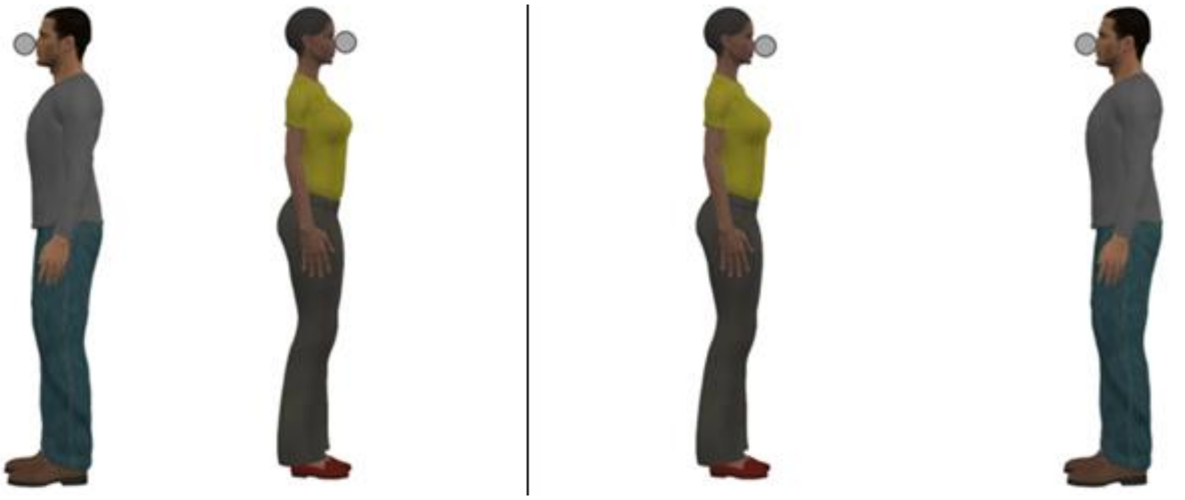

Figure 2.5: The Müller-Lyer illusion induced by whole-body stimuli. The target circles are the same distance apart in the left and right arrangement, but they appear closer together in the arrangement on the left.

In the absence of the faces/bodies, participants judged the distance between the two circles to be 101.91% ($SD = 4.94\%$) of the physical distance. When the faces/bodies were positioned outside the target circles, the mean distance estimate increased significantly to 105.62% ($SD = 7.86\%$) [$t(29) = 2.384$, $p = .024$, $d_z = 0.44$, $\text{CI}_{95\%} = 0.06, 0.81$]. When faces/bodies were positioned within the target circles, the mean distance estimate decreased significantly to 90.49% (*SD* = 5.18%) [$t(29) = 10.938$, $p < .001$, $d_z = 2.00$ $\mathrm{CI}_{95\%} = 1.37, 2.62$].

2.13. Discussion

Interpersonal distance serves as a critical visual cue for facilitating accurate and efficient appraisals of social scenes (Hall, 1963, 1966; McCall, 2017a). However, relatively little is currently known about how this attribute is encoded by the visual system. The experiments described in this chapter aimed to determine whether perceptual judgements regarding interpersonal distance are influenced by the Müller-Lyer illusion.

Across nine experiments, participants were presented pairs of spatial intervals and asked to indicate which appeared longer. In some experimental conditions one of the intervals was accompanied by contextual elements positioned around its endpoints. Experiments 1 and 2 validated the psychophysical paradigm by successfully replicating results of conventional demonstrations of the illusion using pairs of arrows and diamonds. In subsequent experiments it was shown that comparable illusory effects can be induced when these contextual elements are replaced with social stimuli: pairs of faces (Experiments 3-7) and whole bodies (Experiment 9). When the social elements were positioned outside the to-be-judged interval, participants perceived distances as expanded, whereas when the elements were positioned within the interval, participants perceived distances as compressed.

These findings reveal that judging interpersonal distance is more complex than it may first appear. Observers' judgements may be subject to opposing biases depending on the particular distance being judged. For example, when viewing two people standing face-to-face, the present findings indicate that the nose-to-nose distance between them would appear expanded; for example, a physical distance of 100 cm may appear to be closer to 105–115 cm. Conversely, when shown back-to-back, the nose-to-nose distance would appear compressed; for example, a physical distance of 100 cm may appear to be closer to 85–95 cm. Consequently, these biases may exert considerable influence on how observers appraise such scenes, given the pivotal role of proxemic cues in interpreting social interactions (Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; McCall, 2017).

The effects of the illusory distortion described appear maladaptive and counter-intuitive. For example, when learning to dance or socially distance, a perceptual bias that distorts judgements of interpersonal distance may hinder our ability to replicate interpersonal distances modelled by others. There is currently a lack of consensus about the cause and functional significance of the Müller-Lyer illusion (Howe & Purves, 2005; Weidner & Fink, 2007; Restle & Decker, 1977; Nijhawan, 1991; Greist-Bousquet & Schiffman, 1981; Gregory, 1966; Day, 1989; Woloszyn, 2010). Prominent explanations have argued the illusion is a product of misapplied size constancy scaling due to misperception of embedded three-dimensional cues (Gregory, 1966), perceptual compromise due to conflicting local and global features (Day, 1989), or reliance on probabilistic visual processing strategies that depend on statistical regularities in the environment (Howe & Purves, 2005). It is unclear whether any of these accounts can fully explain the version of the illusion described here.

An intuitive and logical explanation for the pattern of findings could be provided by the Centroid hypothesis (Morgan et al., 1990; Woloszyn, 2010). According to this account, the Müller-Lyer illusion arises because the visual system computes length based on the “centroid” (or centre of mass) of the interval and its surrounding contextual elements (e.g., the arrows or faces). The resulting perceptual distortion reflects a weighted average of all visual elements in the configuration. This explanation would account for why the illusion occurs across a diverse range of stimuli, including those with salient directional cues (arrows, Experiment 1) and those without (diamonds, Experiment 2). It also aligns with findings from the social variants of the illusion with faces (Experiments 3-7) and whole bodies (Experiment 9). In cases where the spatial extent of the contextual elements is distributed symmetrically around the target circles marking the interval endpoints (Experiment 8), it would appear that the visual system prioritises information located within the interval, inducing a (relatively attenuated) compression effect.

However, while this may initially appear a tidy explanation for the variants of the illusion described here and in much of the broader literature, the spatial averaging account cannot fully explain examples of similar configurations that fail to robustly trigger the illusion. For instance, the “dumbbell” variant – a horizontal line flanked by circles – typically induces classic expansion effects when the circles are positioned outside the interval (Parker & Newbigging, 1963; Woloszyn, 2010). However, when the circles are positioned within the interval, the expected compression effect from this configuration is nullified or greatly diminished. A plausible explanation for this anomaly is that the circular “bells” are perceived as three-dimensional spheres and the presence of the overlapping interval line is (mis)interpreted by the visual system as lying in a separate depth plane, projected closer towards the observer (Woloszyn, 2010). Given exception cases such as this where depth-based modulation is observed, it remains likely that there are multiple routes to inducing – or affecting the magnitude of – the illusion.

There has been much interest in apparent cross-cultural variation in susceptibility to the Müller-Lyer illusion (for review, see Henrich et al., 2010). For example, while adult observers from the US are highly sensitive to the traditional version of the Müller-Lyer illusion created with inwards and outwards facing arrows, adults from a forager community in the Kalahari showed little or no susceptibility (Segall et al., 1966). Evidence of cross-cultural variability has led some authors to suggest that the illusion induced by simple geometric forms is a product of exposure to particular kinds of sensory input that are more common in WEIRD (Western Educated Industrialized Rich Democratic) cultures, including the corners of rooms (Henrich et al., 2010; Segall et al., 1966). Given that human faces are a ubiquitous feature of the visual environment in all human societies, it may be interesting to examine whether observers who show little susceptibility to traditional variants of the Müller-Lyer illusion, show greater susceptibility to the face variant.

A key finding of the present study is that the arrangement of the face pairs – whether viewed face-to-face or back-to-back – did not appear to modulate the illusion. This result was seen both in a cross-experiment analysis of the face-to-face and back-to-back experiments (Experiments 4 and 5) and in a standalone experiment where the spatial placement of the face pairs was held constant across arrangement conditions (Experiment 8). In the latter analysis, the associated Bayes factor ($BF_{01} = 2.540$) indicated modest evidence in favour of the null hypothesis. At first glance, these findings seem to conflict with prior reports of the "social binding effect", a phenomenon in which participants tend to recall observed interpersonal distances as being compressed when dyads are arranged facing compared to non-facing (Section 1.2.4; Vestner et al., 2019; Sun et al., 2022; Weller et al., 2018).

Upon closer examination of the experimental paradigms underlying these results, however, it becomes clearer how these seemingly contradictory outcomes can be reconciled. In the social binding experiments, participants were tasked with reconstructing interpersonal distances that had been shown for longer durations (1000-1500 vs. 800 ms in the present study) and with longer delays between stimulus offset and response prompt (1000-2000 vs. 0 ms).

Additionally, the nature of the distance adjustment procedure employed in these studies likely further extended the overall duration between participants' initial observation of the stimulus and point at which they submitted their response. By contrast, the present paradigm encouraged participants to make immediate binary choice judgements via a simple key press.

Overall, these methodological differences suggest that the social binding experiments imposed greater working memory and cognitive decision-making demands. It is therefore plausible that the compression effects observed in these earlier studies are the product of post-perceptual processes, rather than reflecting cognitively impenetrable visual biases like those observed in the present experiments or in other examples of the Müller-Lyer illusion. One possibility is that the social binding effect arises due to aberrant encoding and/or retrieval of the memory representations of the observed interpersonal distances. Another possibility is that the effect stems from theoretically uninteresting decision-making biases, such as demand characteristics or social desirability effects. Such alternative accounts align with critiques of similar (non-social) spatial illusions (Durgin et al., 2009; Firestone, 2013; Firestone & Scholl, 2014, 2016; Landis et al., 1966; McCurdy, 1956). Future research will need to conduct similar control experiments to rule out these alternative accounts to elucidate the true nature of the social binding effect.

A prominent claim in the social interaction perception literature is that pairs of individuals arranged face-to-face engage domain-specific visual processing in observers, aiding the detection and representation of social interactions (Vestner et al., 2020; Papeo, 2020). Conversely, back-to-back arrangements are not thought to be processed as social interactions, and thus do not benefit from domain-specific social interaction processing. Consistent with this suggestion, face-to-face arrangements engage distinct regions of visual cortex, not recruited by back-to-back arrangements (Abassi & Papeo, 2020). Similarly, the affective state of one individual alters the perceived emotion of another, when two people are shown face-to-face, but not back-to-back (Gray, Barber, et al., 2017).

Unsurprisingly, however, the perception of social scenes is also affected by domain-general attentional and perceptual processes. In visual search tasks, for example, pairs of individuals arranged face-to-face are found faster than pairs arranged back-to-back (Papeo et al., 2019; Vestner et al., 2019). Early interpretations argued that this effect was the product of a domain-specific mechanism (Papeo et al., 2019; Vestner et al., 2019; Papeo, 2020). However, it was subsequently shown that pairs of arrows arranged point-to-point are also found faster than pairs of arrows arranged base-to-base (Vestner et al., 2020). The fact that the search advantage was replicated with arrows argues against the domain-specific view, and instead suggests that the search advantage is a product of domain-general direction cueing.

The illusory effects described here appear to be another kind of domain-general influence on the perception of social scenes. It is well established that a range of simple (non-social) geometric forms induce the Müller-Lyer illusion (Howe & Purves, 2005; Weidner & Fink, 2007; Restle & Decker, 1977; Nijhawan, 1991; Greist-Bousquet & Schiffman, 1981; Gregory, 1966; Day, 1989). Similarly, the fact that the illusion manifests strongly irrespective of the arrangement of the faces (i.e. face-to-face, back-to-back) further argues against any explanation based on the perception of social interaction (Papeo, 2020). Nevertheless, authors seeking to use the back-to-back vs. face-to-face manipulation to isolate the neurocognitive mechanisms recruited by interacting (but not non-interacting) individuals, should consider how the illusory effects described here may affect their results. For example, it is possible that a spontaneous tendency to focus on the eyes and nose of the people shown, might induce an expansion effect when viewing face-to-face dyads, but a compression effect when viewing back-to-back dyads.

In conclusion, the experiments described in this chapter provide the first evidence that high-level social stimuli, such as pairs of faces or bodies, can induce the Müller-Lyer illusion. When positioned around a to-be-judged spatial interval, these elements are capable of eliciting robust compression and expansion effects. The fact these biases manifest irrespective of their face-to-face or back-to-back arrangement lends support to the domain-general account of dyadic social interaction processing.

Chapter 3: Sensitivity to changes in interpersonal distance: the effects of dyad arrangement and orientation

It has been proposed that pairs of individuals shown upright and face-to-face recruit a form of configural processing, analogous to that engaged by faces, whereby information from local regions is integrated into a unified, coherent percept, aiding the detection and interpretation of social interactions. Dyads shown back-to-back or upside-down are not thought to engage this configural processing. However, behavioural effects attributed to configural dyad processing may reflect the differential arrangement of attention cues in face-to-face and back-to-back dyadic arrangements, rather than true configural processing. One of the key advantages conveyed by configural processing is greater sensitivity to the spatial relationships between component features. If upright dyads arranged face-to-face engage configural processing not engaged by non-facing or inverted dyads, participants should exhibit disproportionate sensitivity to the spatial relations between the actors under these conditions. In four well-powered experiments, no evidence is found for this prediction. Instead, participants exhibited similar levels of sensitivity to changes in interpersonal distance regardless of whether dyads were shown upright or inverted, face-to-face or back-to-back. In two follow-up experiments, the feature-spacing effect was replicated with face stimuli using the same experimental paradigm employed in the previous experiments; participants demonstrated heightened sensitivity to changes in interocular distance when viewing upright faces compared to inverted faces. Taken together, these findings challenge the view that upright dyads arranged face-to-face selectively engage configural processing analogous to that engaged by upright faces.

3.1. Introduction

Traditionally, social perception research has sought to elucidate the visual processing engaged by individual faces (Duchaine & Yovel, 2015; Tsao & Livingstone, 2008) and bodies (Peelen & Downing, 2007; Slaughter et al., 2004). An important finding from this literature is that upright faces engage configural or holistic processing that helps observers integrate information from local regions into a unified, coherent percept (Bukach et al., 2006; Farah et al., 1998; Maurer et al., 2002; McKone et al., 2007). According to configural accounts, this processing improves the perception of upright faces by augmenting the representation of inter-feature spatial relationships (Maurer et al., 2002; Piepers & Robbins, 2013). Holistic accounts are similar, but posit that processing augments the description of local features as well as their spatial relationships (Farah et al., 1998; Piepers & Robbins, 2012; Yovel & Kanwisher, 2008). Many regard configural / holistic processing as ‘gated’ such that it is engaged only in the presence of whole upright faces (Murphy et al., 2017; Tsao & Livingstone, 2008).

Recently, there has also been growing interest in how we perceive dyadic interactions between people (Papeo, 2020; Quadflieg & Koldewyn, 2017). This new field of study has yielded several new behavioural effects identified as putative markers of social interaction processing. For example, when two individuals are presented face-to-face (though not back-to-back), the facial and bodily expressions of one actor biases how observers interpret the expressions of the other (Abramson et al., 2021; Gray, Barber, et al., 2017). Similarly, dyadic targets shown face-to-face are found faster in visual search tasks, than dyadic targets shown back-to-back (Papeo et al., 2019; Vestner et al., 2019). This search advantage for facing dyads is not seen when target and distractor dyads are shown upside-down (Vestner et al., 2019). When dyads are presented briefly (30ms) and subject to backwards masking, participants are also better able to detect upright face-to-face arrangements, than inverted face-to-face arrangements. Conversely, little or no modulation-by-orientation is observed for back-to-back dyads (Papeo et al., 2017).

These findings have led some authors to speculate that pairs of individuals shown upright and face-to-face recruit a form of configural processing, analogous to that engaged by faces (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). It is hypothesised that relations among body pairs are captured automatically, aiding the detection, discrimination, and interpretation of social interactions (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). Drawing on domain-specific accounts of face processing, it is proposed that the configural processing engaged by dyads is gated such that it is selectively recruited when viewing upright facing dyads only: Dyads shown back-to-back or upside-down are not thought to engage configural processing (Abassi & Papeo, 2020, 2022; Papeo et al., 2017).

This account is not universally accepted, however. A different perspective is that many of the putative markers of domain-specific dyadic processing are products of domain-general attentional phenomena (Vestner et al., 2020, 2021). When viewed in profile, faces and bodies cue observers' visuospatial attention leftwards or rightwards, in accordance with their directionality (Langton & Bruce, 1999; Vestner et al., 2021). The arrangement of these attention cues is very different when viewing face-to-face and back-to-back dyadic arrangements (Vestner et al., 2020). In face-to-face arrangements, these attention cues form an 'attention trap': the face / body on the left of the dyad directs observers' attention to the face / body on the right, which in turn re-directs observers' attention back to the face / body on the left. When dyads are arranged back-to-back, however, the same face / body cues direct observers' attention toward the display periphery.

There is now compelling evidence that the differential arrangement of attention cues present in face-to-face and back-to-back dyads is responsible for the search advantage for facing dyads (Vestner et al., 2020, 2021). Consistent with this explanation, the same search advantage is seen for non-social stimuli that also cue attention – including arrows (Vestner et al., 2020), desk fans, desk lamps, power drills, cameras, and cars – when exemplar pairs are arranged front-to-front (Vestner et al., 2021). Moreover, the ability of a stimulus category to cue attention correlates closely with the strength of the search advantage for facing dyads produced by that category (Vestner et al., 2021). Importantly, faces and bodies viewed in profile fail to cue attention, or produce much weaker cueing effects, when they are inverted (Langton & Bruce, 1999; Vestner et al., 2021, 2022). As such, the attention cueing account can also explain why the search advantage is eliminated / attenuated when target and distractor dyads are shown upside-down.

Related evidence from eye-tracking confirms that observers inspect face-to-face and back-to-back stimuli in different ways. In particular, observers spend more time fixating actors’ faces when viewing dyads arranged face-to-face (Kujala et al., 2012). This potentially explains why the expression cues of one actor alter the perceived emotion of another when the two are arranged face-to-face, but not back-to-back (Abramson et al., 2021; Gray, Barber, et al., 2017). These different patterns of fixation, together with the differential arrangement of attention cues present in face-to-face and back-to-back dyads, may also account for the higher rates of detection for upright facing dyads in backwards masking procedures (Papeo et al., 2017). In sum, it is possible to explain putative behavioural markers of social interaction processing without invoking gated configural processing selectively recruited by upright face-to-face dyads.

One of the key advantages conveyed by configural face processing is greater sensitivity to the spatial relationships between component features (Farah et al., 1998; Maurer et al., 2002; Piepers & Robbins, 2012). For example, participants exhibit greater perceptual sensitivity to the distances between features when faces are shown upright, than when faces are shown upside-down (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001a). If upright dyads arranged face-to-face selectively engage a comparable form of configural processing that is not engaged by non-facing or inverted dyads, participants should exhibit disproportionate sensitivity to the spatial relations between the constituent actors (i.e., interpersonal distance) when viewing upright face-to-face dyads. In contrast, the domain-general attentional account predicts no such perceptual advantage for upright face-to-face dyadic arrangements; observers should exhibit similar sensitivity to interpersonal distance regardless of dyadic arrangement (face-to-face vs. back-to-back) and orientation (upright face-to-face vs. inverted face-to-face) viewing conditions.

The experiments described in this chapter sought to test these rival accounts. In the first set of experiments, observers' ability to detect changes in interpersonal distance when pairs of boxers (Experiment 1a) or dancers (Experiment 1b) were presented face-to-face or back-to-back was compared. In the second set of experiments, observers' ability to detect changes in interpersonal distance when pairs of facing boxers (Experiment 2a) or facing dancers (Experiment 2b) were presented upright or inverted was compared. In the third set of experiments, observers' ability to detect changes in interocular distance when individual male (Experiment 3a) and female (Experiment 3b) faces were presented upright and inverted was compared. The purpose of this final experiment was to confirm whether the task format used in the previous two experiments was capable of reproducing findings of prior studies demonstrating enhanced configural sensitivity for faces viewed in their canonical upright orientation (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001a).

3.2. Experiments 1a & 1b

In the first set of experiments, observers' ability to detect changes in interpersonal distance when pairs of boxers (Experiment 1a) or dancers (Experiment 1b) were presented face-to-face or back-to-back was compared. All to-be-judged dyads were presented upright. If face-to-face dyads recruit configural processing that is not engaged by upright back-to-back dyads, then we should see greater sensitivity to changes in interpersonal distance in the face-to-face condition.

3.2.1. Method

Sample size and inclusion criteria

Each of the experiments described was conducted online using a sample of 100 participants recruited through www.prolific.co. A sample size of N = 100 was agreed *a priori*. Previous reports of the feature-spacing effect obtained with faces suggest a large effect size (e.g., Freire et al., 2000; Leder et al., 2001). However, a more conservative approach was adopted, given that i) these previous effects were obtained with small samples (e.g., N's < 20), and ii) the fact that effect size estimates obtained with small samples are notoriously unreliable. A power analysis conducted in GPower 3.1 (Faul et al., 2009) revealed that a paired samples *t*-

test ($\alpha = 0.05$, two-tailed) has a 97.7% chance of detecting an effect size of $d_z = .40$ with a sample size of $N = 100$.

Participants were required to be aged 18 to 50 years-old, to have normal or corrected-to-normal visual acuity, to have no history of psychiatric (e.g., autism, schizophrenia) or neurological illness, to reside in the United Kingdom, and to have a Prolific approval rating above 90%. Any participant who failed to achieve an overall *d*' of at least 0.5 (having collapsed across move closer and move apart trials) were excluded and replaced.

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London. The experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent.

Participants

The 100 participants to complete Experiment 1a (29 males, 69 females, 2 non-binary, M_{age} = 28.21 years, SD_{age} = 8.72) included 6 replacements for participants who did not satisfy the performance requirements. The 100 participants to complete Experiment 1b (38 males, 61 females, 1 non-binary, M_{age} = 28.23 years, SD_{age} = 8.40) included 10 replacements for participants who did not satisfy the performance requirements.

Stimuli

The stimuli used in Experiment 1 were derived from two stock images, one depicting a pair of dancers and one depicting a pair of boxers, obtained from www.shutterstock.com. The dancing couple comprised a male and a female actor. The boxers were both male. All individuals were depicted in profile against a white background. From each stock image, 12 stimulus images were derived: 3 levels of interpersonal distance (~150 cm, ~180 cm, ~210 cm) × 2 levels of dyadic configuration (face-to-face, back-to-back) × 2 levels of actor configuration (actor-1 on the left, actor-2 on the left). The smallest and largest level of interpersonal distance represent ~16.68% decrease and increase, respectively, relative to the middle interpersonal distance. The estimates of interpersonal distance provided assume an actor height of 180 cm. The distances between the actors in the face-to-face and back-to-back stimulus sets were matched by fitting a minimum bounding box to each model and horizontally flipping them about the central axis. When viewed at a distance of 57.1 cm, the dancer stimuli subtended between ~17° and ~22° of horizontal visual angle and ~13° of vertical visual angle. When viewed at the same distance, the boxer stimuli subtended between ~17° and ~22° horizontally and ~13° vertically.

Design and procedure

The experiments were conducted online via Gorilla (Anwyl-Irvine et al., 2020). Each experiment comprised 180 trials in total, split evenly into two blocks. Participants completed 90 face-to-face trials (30 no change, 30 move closer, 30 move apart) and 90 back-to-back trials (30 no change, 30 move closer, 30 move apart). The different trial types were interleaved and stimulus order was randomized. Participants could take a break midway through each of the blocks, and between blocks.

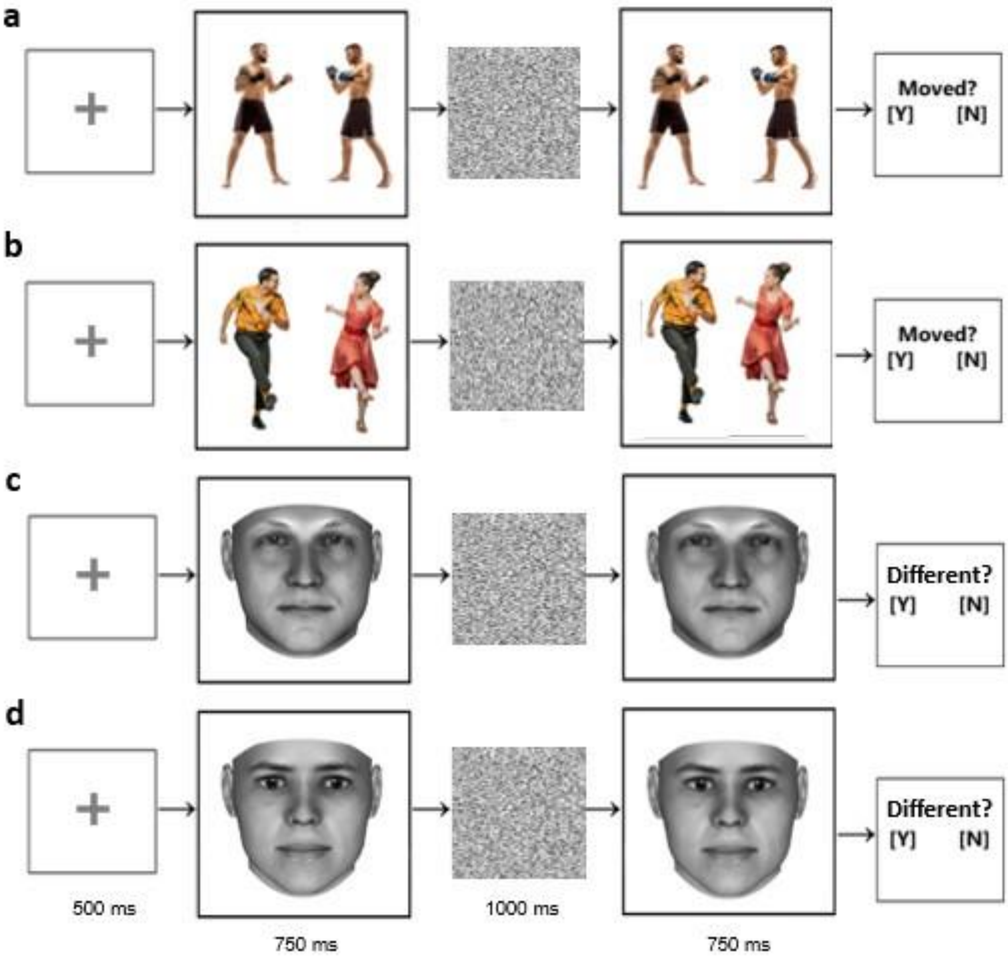

Figure 3.1: Overview of task sequences. Schematic illustration of four experimental trials in which **(a)** facing boxer dyads, **(b)** facing dancer dyads, **(c)** male faces, and **(d)** female faces are presented. The sequences depict signal present move apart, move closer, move apart, and move closer trials, respectively. Distances depicted in the dyadic stimuli have been reduced for illustrative purposes.

The trial sequences are illustrated in Figure 3.1. Trials began with a grey fixation cross (500 ms) which was followed by the sequential presentation of two dyadic stimuli (750 ms each). A visual mask was presented in the inter-stimulus interval (1000 ms) to prevent an afterimage. The first image always depicted an interpersonal distance of ~180 cm. On signal absent trials, the same image was presented in the second stimulus interval. On signal present trials, a different image was presented: the actors appeared closer together (~150 cm) or further apart (~210 cm). Participants were asked to judge whether the distance between the actors was different in the two intervals. Participants recorded their binary decision via keypress.

The placement of each actor on the left- and right-side of the dyadic stimuli was counterbalanced across trials, but held consistent within a trial (e.g., if the female dancer appeared on the left in the first interval, she would also appear on the left in the second interval). The stimuli presented in the first and second interval would always be shown on opposite sides of the screen (left or right) in a counter-balanced fashion. On 50% of trials the stimulus presented in the first interval would appear to the right of the fixation, while the stimulus presented in the second interval would appear on the left. The precise positioning on the left and right was jittered to discourage participants from using distance to the display edge as a cue. The experimental tasks are available as Open Materials at gorilla.sc (https://app.gorilla.sc/openmaterials/644528).

Analysis

Performance was analysed using signal detection theory (Green & Swets, 1966). For each participant, separate measures of perceptual sensitivity (*d*') and bias (C) were calculated for move closer and move apart trials from hit rates (the proportion of signal present trials for which a change was correctly reported) and false alarm rates (the proportion of signal absent trials for which a change was incorrectly reported). Higher *d*' scores, *z*[hit rate] – *z*[false alarm rate], reflect superior discrimination of signal presence and absence. C scores, (*z*[hit rate] + *z*[false alarm rate]) / 2, gauge participants' tendency to favour one response option over another regardless of signal presence and absence; positive scores indicate more 'yes' responses, negative scores indicate more ‘no’ responses, and a score of 0 indicates the absence of systematic bias. Signal detection analyses were conducted in Matlab (The MathWorks Inc., Natick, USA) using routines from the Palamedes toolbox (Prins & Kingdom, 2009). Log-linear corrections (e.g., Hautus, 1995) were applied to guard against extreme values in hit and false alarm rates.

The distributions of sensitivity (*d*’) and bias (C) estimates were evaluated using both traditional null-hypothesis significance testing ($\alpha = 0.05$, two-tailed) and Bayesian analysis (JASP-Team, 2022). A Bayes Factor (BF_{01}) larger than 1, 3, and 10 reflects anecdotal, substantial, and strong evidence, respectively, in favour of the null hypothesis (Jeffreys, 1998). A Bayes Factor (BF_{01}) less than 1, 1/3, and 1/10 reflects anecdotal, substantial, and strong evidence, respectively, in favour of the alternative hypothesis. Unless the associated BF_{01} exceeds 3.0, non-significant *p*-values (> .05) should be treated as ambiguous (i.e., as providing no clear support for either the null or alternative hypotheses). The Bayesian paired *t*-tests and Bayesian ANOVAs were conducted using the default Cauchy priors (*t*-tests: centre = 0, width = 0.707; ANOVAs: fixed effects width = 0.5, random effects width = 1). Robustness checks revealed that different prior specifications had little impact on the obtained results. Data for all experiments can be accessed via the Open Science Framework (https://osf.io/4pqm6/).

3.2.2. Results

Experiment 1a

The results from Experiment 1a are shown in Figure 3.2a. Sensitivity estimates (*d´*) were subjected to ANOVA with Dyad Arrangement (face-to-face, back-to-back) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 18.404$, $p < .001$, $\eta^2_G = .031$, $BF_{01} = .002$], whereby participants exhibited superior sensitivity on move closer trials. No main effect of Dyad Arrangement was observed [$F(1, 99) = 0.951$, $p = .332$, $\eta^2_G = .002$, $BF_{01} = 3.402$], and there was a non-significant Dyad Arrangement × Movement Direction interaction [$F(1, 99) = 3.324$, $p = .071$, $\eta^2_G = .002$, $BF_{01} = 1.125$]. Simple contrasts revealed no effect of Dyad Arrangement on sensitivity scores in either the move closer [$M_{F2F} = 1.63$, $SD_{F2F} = 0.72$, $M_{B2B} = 1.74$, $SD_{B2B} = 0.68$, $t(99) = 1.727$, $p = .087$, $d_z = 0.17$, $BF_{01} = 2.16$] or move apart conditions [$M_{F2F} = 1.44$, $SD_{F2F} = 0.69$, $M_{B2B} = 1.44$, $SD_{B2B} = 0.67$, $t(99) = 0.077$, $p = .939$, $d_z = 0.01$, $BF_{01} = 9.01$]. Participants' sensitivity scores in the face-to-face and back-to-back conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .569$, $p < .001$; move apart: $r_p = .579$, $p < .001$] and non-parametric analyses [move closer: $r_s = .562$, p < .001; move apart: $r_s = .597$, p < .001]. Scatterplots of these relationships are shown in Figure 3.3a.

Bias estimates (C) were subjected to ANOVA with Dyad Arrangement (face-to-face, back-to-back) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 18.238$, $p < .001$, $\eta^2_G = .028$, $BF_{01} = .002$], whereby participants were more likely to report a distance change on move closer trials. No main effect of Dyad Arrangement was observed [$F(1, 99) = 0.83$, $p = .489$, $\eta^2_G = .002$, $BF_{01} = 4.478$], and there was a non-significant Dyad Arrangement × Movement Direction interaction [$F(1, 99) = 3.235$, $p = .075$, $\eta^2_G = .002$, $BF_{01} = 1.556$]. Simple contrasts revealed no effect of Dyad Arrangement on bias scores in either the move closer [$M_{\mathrm{F2F}} = -0.17$, $SD_{\mathrm{F2F}} = 0.32$, $M_{\mathrm{B2B}} = -0.12$, $SD_{\mathrm{B2B}} = 0.39$, $t(99) = -1.369$, $p = .174$, $d_z = -0.14$, $\mathrm{BF}_{01} = 3.66$] or move apart conditions [$M_{\mathrm{F2F}} = 0.270$, $SD_{\mathrm{F2F}} = 0.34$, $M_{\mathrm{B2B}} = 0.27$, $SD_{\mathrm{B2B}} = 0.39$, $t(99) = 0.270$, $p = .788$, $d_z = 0.03$, $\mathrm{BF}_{01} = 8.72$]. Participants' bias scores in the face-to-face and back-to-back conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .498$, $p < .001$; move apart: $r_p = .651$, $p < .001$] and non-parametric analyses [move closer: $r_s = .416$, $p < .001$; move apart: $r_s = .637$, $p < .001$].

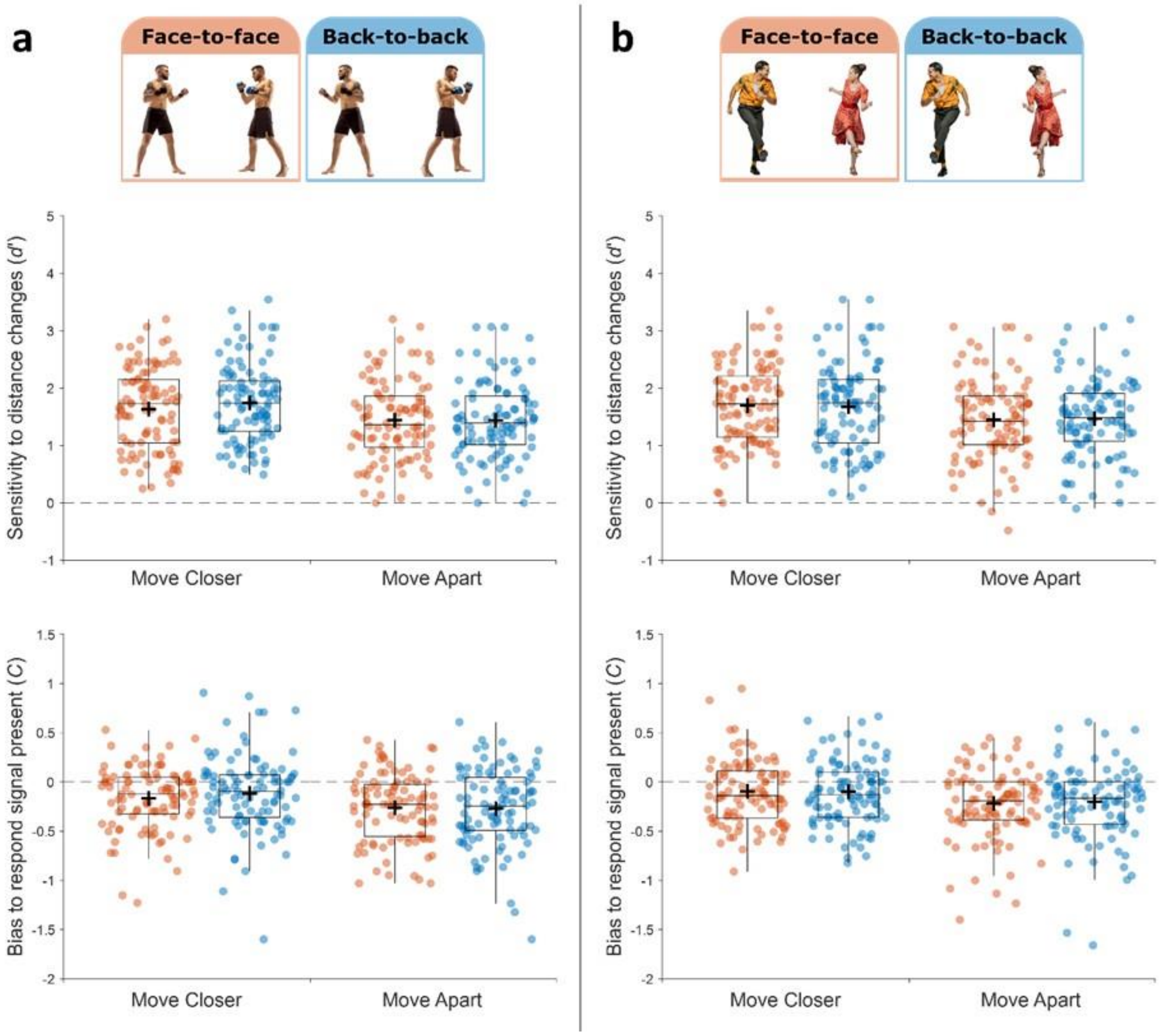

Figure 3.2: Results of Experiment 1. **(a)** Results for Experiment 1a obtained with boxing dyads. **(b)** Results for Experiment 1b obtained with dancing dyads. No significant effects of

Arrangement (face-to-face vs. back-to-back) were observed in either experiment. Boxplots denote median and interquartile range. Plus signs denote means.

Experiment 1b

The results from Experiment 1b are shown in Figure 3.2b. Sensitivity estimates (*d*′) were subjected to ANOVA with Dyad Arrangement (face-to-face, back-to-back) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 9.819$, $p = .002$, $\eta^2_G = .025$, $BF_{01} = 0.070$], whereby participants exhibited superior sensitivity on move closer trials. No main effect of Dyad Arrangement was observed [$F(1, 99) < .001$, $p = .991$, $\eta^2_G < .001$, $BF_{01} = 5.729$], and there was a non-significant Dyad Arrangement × Movement Direction interaction [$F(1, 99) = 0.597$, $p = .441$, $\eta^2_G < .001$, $BF_{01} = 5.237$]. Simple contrasts revealed no effect of Dyad Arrangement on sensitivity scores in either the move closer [$M_{F2F} = 1.69$, $SD_{F2F} = 0.69$, $M_{B2B} = 1.67$, $SD_{B2B} = 0.77$, $t(99) = 0.368$, $p = .713$, $d_z = 0.37$, $BF_{01} = 8.46$] or move apart conditions [$M_{F2F} = 1.45$, $SD_{F2F} = 0.71$, $M_{B2B} = 1.47$, $SD_{B2B} = 0.68$, $t(99) = 0.447$, $p = .656$, $d_z = 0.05$, $BF_{01} = 8.20$]. Participants' sensitivity scores in the face-to-face and back-to-back conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .721$, $p < .001$; move apart: $r_p = .766$, $p < .001$] and non-parametric analyses [move closer: $r_s = .741$, $p < .001$; move apart: $r_s = .782$, $p < .001$]. Scatterplots of these relationships are shown in Figure 3.3b.

Bias estimates (C) were subjected to ANOVA with Dyad Arrangement (face-to-face, back-to-back) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 9.819$, $p = .002$, $\eta^2_G = .020$, $BF_{01} = 0.065$], whereby participants were more likely to report a distance change on move closer trials. No main effect of Dyad Arrangement was observed [$F(1, 99) = 0.046$, $p = .830$, $\eta^2_G < .001$, $BF_{01} = 5.676$], and there was a non-significant Dyad Arrangement × Movement Direction interaction [$F(1, 99) = 0.597$, $p = .441$, $\eta^2_G < .001$, $BF_{01} = 6.780$]. Simple contrasts revealed no effect of Dyad Arrangement on bias scores in either the move closer [$M_{F2F} = -0.09$, $SD_{F2F} = 0.40$, $M_{B2B} = -0.10$, $SD_{B2B} = 0.37$, $t(99) = 0.209$, $p = .835$, $d_z = 0.02$, $BF_{01} = 8.841$] or move apart conditions [$M_{F2F} = -0.22$, $SD_{F2F} = 0.41$, $M_{B2B} = -0.20$, $SD_{B2B} = -0.42$, $t(99) = -0.572$, $p = .569$, $d_z = 0.06$, $BF_{01} = 7.71$]. Participants' bias scores in the face-to-face and back-to-back conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .770$, $p < .001$; move apart: $r_p = .794$, $p < .001$] and non-parametric analyses [move closer: $r_s = .651$, $p < .001$; move apart: $r_s = .707$, $p < .001$].

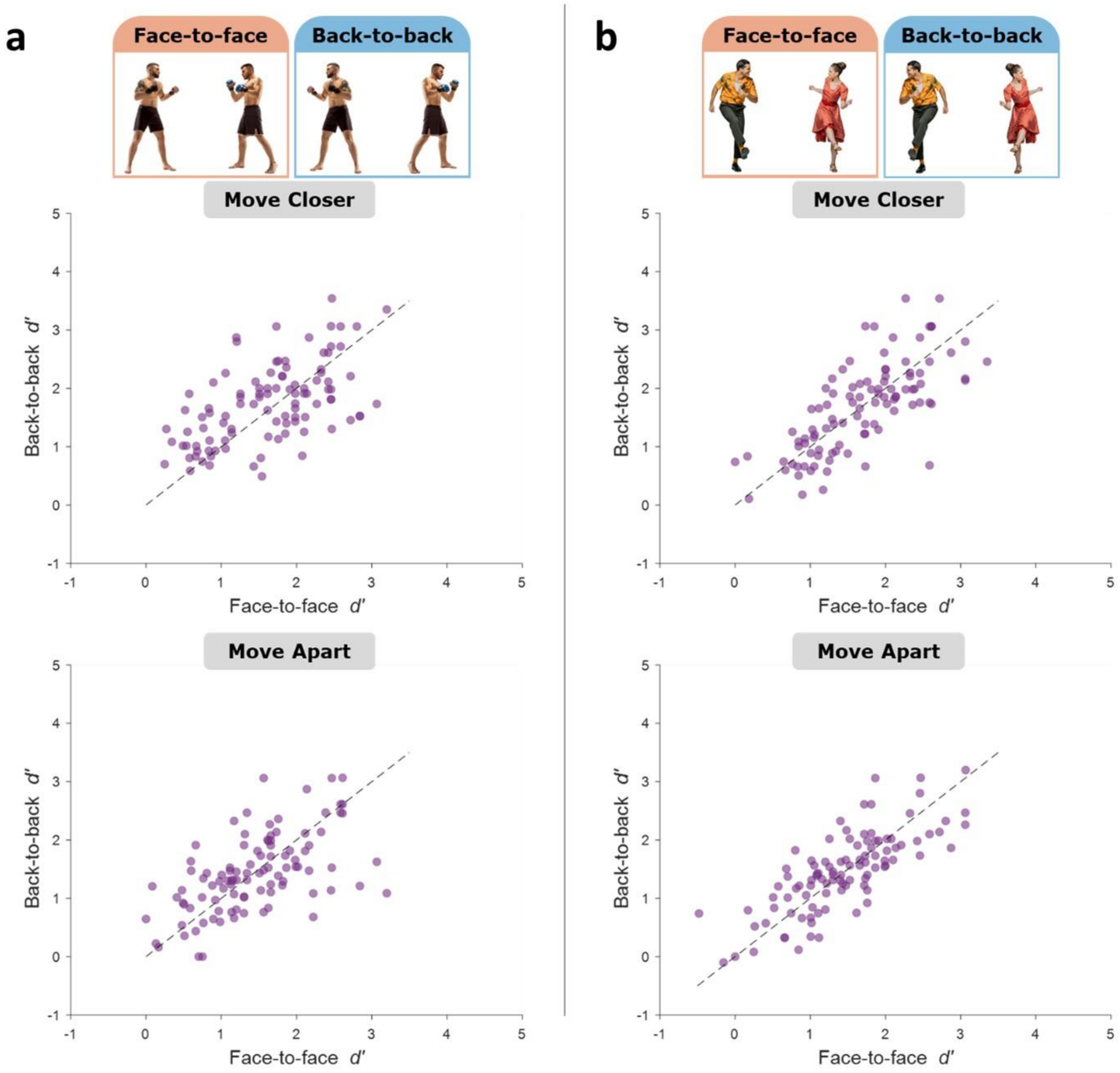

Figure 3.3: Scatterplots of sensitivity scores observed in Experiment 1. **(a)** Results for Experiment 1a obtained with facing and non-facing boxing dyads. **(b)** Results for Experiment 1b obtained with facing and non-facing dancing dyads. Dashed line represents unity.

3.3. Experiments 2a & 2b

In Experiment 1 it was found that Dyad Arrangement (face-to-face vs. back-to-back) had little impact on observers' sensitivity to interpersonal distance. In the second set of experiments, observers' ability to detect changes in interpersonal distance when pairs of boxers (Experiment 2a) or dancers (Experiment 2b) were presented upright or inverted was compared. All to-be-judged dyads were arranged face-to-face. If upright face-to-face dyads recruit configural processing that is not engaged by inverted face-to-face dyads, we should see greater sensitivity to changes in interpersonal distance in the upright condition.

3.3.1. Method

Participants

One hundred participants completed Experiment 2a (40 males, 60 females, M_{age} = 28.47 years, SD_{age} = 9.42), including 2 replacements for participants who did not satisfy the performance requirements. Similarly, 100 participants completed Experiment 2b (25 males, 75 females, M_{age} = 29.88 years, SD_{age} = 8.64), including 8 replacements for participants who did not satisfy the performance requirements. The same inclusion and exclusion criteria employed in the first two experiments (1a and 1b) were employed in the second two experiments (2a and 2b).

Design and procedure

The design and procedure of the second two experiments (2a and 2b) were identical to those employed in the first two experiments (1a and 1b), with the following exception. In Experiments 1a and 1b, participants completed 90 face-to-face trials (30 no change, 30 move closer, 30 move apart) and 90 back-to-back trials (30 no change, 30 move closer, 30 move apart). In Experiments 2a and 2b, however, participants completed 90 upright trials (30 no change, 30 move closer, 30 move apart) and 90 inverted trials (30 no change, 30 move closer, 30 move apart). The inverted stimulus images were created by subjecting the facing boxer and facing dancer dyad images used in Experiments 1a and 1b to picture-plane inversion. Once again, the experiments were conducted online via Gorilla (Anwyl-Irvine et al., 2020).

3.3.2. Results

Experiment 2a

The results from Experiment 2a are shown in Figure 3.4a. Sensitivity estimates (*d´*) were subjected to ANOVA with Dyad Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 21.162$, $p < .001$, $\eta^2_G = .038$, $BF_{01} < .001$], whereby participants exhibited superior sensitivity on move closer trials. No main effect of Dyad Orientation was observed [$F(1, 99) = 0.966$, $p = .328$, $\eta^2_G < .001$, $BF_{01} = 3.714$], however, there was a significant Dyad Orientation × Movement Direction interaction [$F(1, 99) = 9.575$, $p = .003$, $\eta^2_G = .003$, $BF_{01} < .001$]. Simple contrasts revealed no effect of Dyad Orientation on sensitivity scores in the move closer condition [$M_{upr} = 1.73$, $SD_{upr} = 0.73$, $M_{inv} = 1.69$, $SD_{inv} = 0.72$, $t(99) = 0.709$, $p = .480$, $d_z = 0.07$, $BF_{01} = 7.076$]. However, participants were significantly less sensitive to distance changes in the upright condition on move apart trials [$M_{upr} = 1.36$, $SD_{upr} = 0.75$, $M_{inv} = 1.49$, $SD_{inv} = 0.71$, $t(99) = 2.564$, $p = .012$, $d_z = 0.26$, $BF_{01} = 0.407$]. Participants' sensitivity scores in the upright and inverted conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .708$, $p < .001$; move apart: $r_p = .767$, $p < .001$] and non-parametric analyses [move closer: $r_s = .680$, $p <$

.001; move apart: r_s = .765, p < .001]. Scatterplots of these relationships are shown in Figure 3.5a.

Bias estimates (C) were subjected to ANOVA with Dyad Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [F(1, 99) = 21.162, p < .001, η^2_G = .034, BF_{01} < .001], whereby participants were more likely to report a distance change on move closer trials. A significant main effect of Dyad Orientation was observed [F(1, 99) = 6.331, p = .013, η^2_G = .009 , BF_{01} = 0.305], whereby participants were more likely to report a distance change in the inverted condition. The analysis also revealed a significant Dyad Orientation × Movement Direction interaction [F(1, 99) = 9.575, p = .003, η^2_G = .003 , BF_{01} < .001]. Simple contrasts revealed no effect of Dyad Orientation on bias scores in the move closer condition [M_{upr} = -0.13, SD_{upr} = 0.41, M_{inv} = -0.10, SD_{inv} = 0.37, t(99) = -0.895, p = .373, d_z = -0.09, BF_{01} = 6.124]. However, participants were significantly less likely to report a distance change in the upright condition on move apart trials [M_{upr} = -0.31, SD_{upr} = 0.39, M_{inv} = -0.20, SD_{inv} = 0.36, t(99) = -3.818, p < .001, d_z = -0.38, BF_{01} < .001]. Participants’ bias scores in the upright and inverted conditions exhibited significant correlation. This was evident in both the parametric [move closer: r_p = .640, p < .001; move apart: r_p = .694, p < .001] and non-parametric analyses [move closer: r_s = .620, p < .001; move apart: r_s = .673, p < .001].

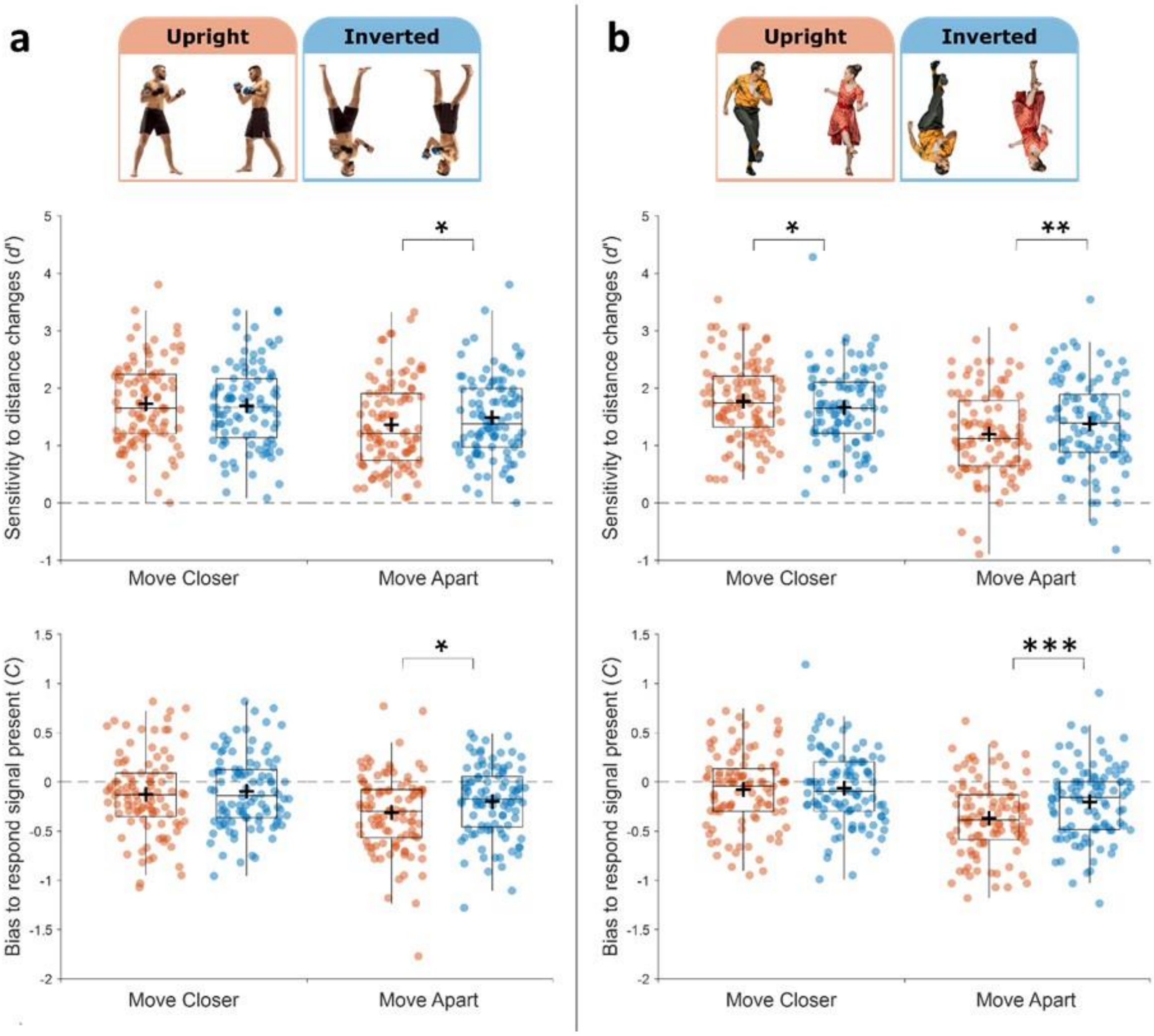

Figure 3.4: Results of Experiment 2. **(a)** Results for Experiment 2a obtained with boxing dyads. **(b)** Results for Experiment 2b obtained with dancing dyads. Boxplots denote median and interquartile range. Plus signs denote means. * denotes $p < .05$, ** denotes $p < .01$, *** denotes $p < .001$.

Experiment 2b

The results from Experiment 2b are shown in Figure 3.4b. Sensitivity estimates ($d´$) were subjected to ANOVA with Dyad Orientation (upright, inverted) and Movement Direction (move close, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction, [$F(1, 99) = 36.731$, $p < .001$, $\eta^2_G = .082$, $BF_{01} < .001$], whereby participants exhibited superior sensitivity on move closer trials. No main effect of Dyad Orientation was observed [$F(1, 99) = 0.504$, $p = .480$, $\eta^2_G < .001$, $BF_{01} = 5.343$], however, there was a significant Dyad Orientation × Movement Direction interaction [$F(1, 99) = 20.936$, $p < .001$, $\eta^2_G = .010$, $BF_{01} < .001$]. Participants were significantly more sensitive to distance changes on move closer trials in the upright condition, than in the inverted condition [$M_{upr} = 1.77$, $SD_{upr} = 0.68$, $M_{inv} = 1.66$, $SD_{inv} = 0.68$, $t(99) = 2.059$, $p = .042$, $d_z = 0.21$, $BF_{01} = 1.198$]. However, participants were significantly less sensitive to distance changes on move apart trials in the upright condition, than in the inverted condition [$M_{upr} = 1.20$, $SD_{upr} = 0.74$, $M_{inv} = 1.38$, $SD_{inv} = 0.77$, $t(99) = 3.132$, $p = .002$, $d_z = 0.31$, $BF_{01} = 0.095$]. Participants' sensitivity scores in the upright and inverted conditions exhibited significant correlation. This was evident in both the parametric [move closer: $r_p = .667$, $p < .001$; move apart: $r_p = .711$, $p < .001$] and non-parametric analyses [move closer: $r_s = .667$, $p < .001$; move apart: $r_s = .698$, $p < .001$]. Scatterplots of these relationships are shown in Figure 3.5b.

Bias estimates (C) were subjected to ANOVA with Dyad Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Distance Direction [$F(1, 99) = 36.731$, $p < .001$, $\eta^2_G = .076$, $BF_{01} < .001$], whereby participants were more likely to report a distance change on move closer trials. A significant main effect of Dyad Orientation was observed [$F(1, 99) = 13.254$, $p < .001$, $\eta^2_G = .014$, $BF_{01} < .001$], whereby participants were more likely to report a distance change in the inverted condition. The analysis also revealed a significant Dyad Orientation × Movement Direction interaction [$F(1, 99) = 20.936$, $p < .001$, $\eta^2_G = .010$, $BF_{01} = 0.001$]. Simple contrasts revealed no effect of Dyad Orientation on bias scores in the move closer condition [$M_{upr} = -0.08$, $SD_{upr} = 0.38$, $M_{inv} = -0.06$, $SD_{inv} = 0.37$, $t(99) = -0.495$, $p =$

.622, $d_z = -0.05$, $BF_{01} = 8.019$]. However, participants were significantly less likely to report a distance change in the upright condition on move apart trials [$M_{upr} = -0.37$, $SD_{upr} = 0.37$, $M_{inv} = -0.20$, $SD_{inv} = 0.36$, $t(99) = -5.656$, $p < .001$, $d_z = -0.57$, $BF_{01} < .001$]. Participants' bias scores in the upright and inverted conditions exhibited significant correlation. This was evident in both the parametric [move closer: $r_p = .690$, $p < .001$; move apart: $r_p = .705$, $p < .001$] and non-parametric analyses [move closer: $r_s = .685$, $p < .001$; move apart: $r_s = .691$, $p < .001$].

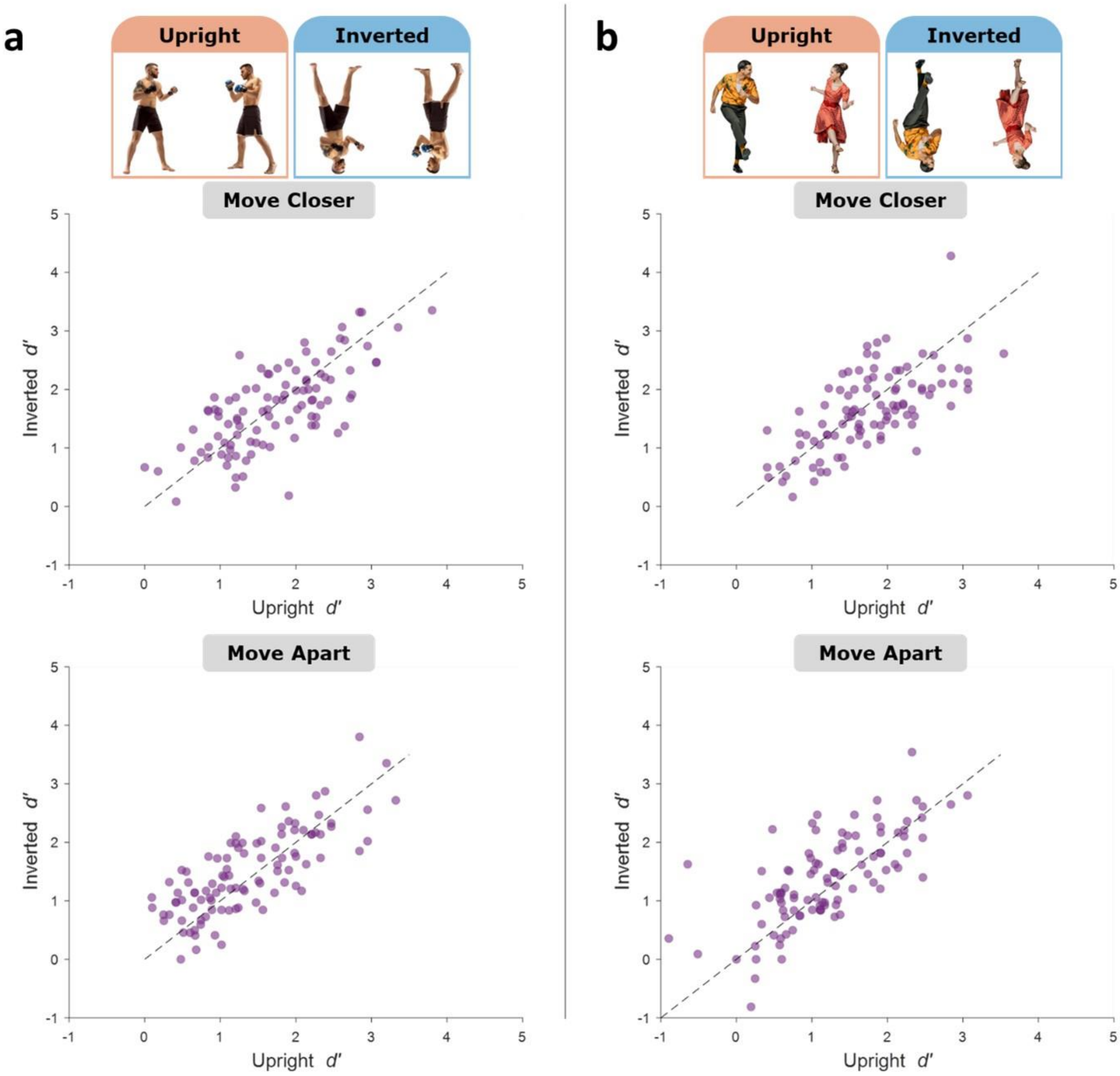

Figure 3.5: Scatterplots of sensitivity scores observed in Experiment 2. **(a)** Results for Experiment 1a obtained with upright and inverted boxing dyads. **(b)** Results for Experiment 1b obtained with upright and inverted dancing dyads. Dashed line represents unity.

3.4. Experiments 3a & 3b

In Experiment 1 it was found that Dyad Arrangement (face-to-face vs. back-to-back) had little impact on observers’ sensitivity to interpersonal distance. Similarly, in Experiment 2 it was found Dyad Orientation (upright vs. inverted) had little impact on observers’ sensitivity to interpersonal distance. The distance change paradigm used in these experiments was designed to mirror tasks employed in the face perception literature, which are thought to demonstrate configural processing through heightened sensitivity to changes in inter-feature spatial relationships when faces are viewed upright, compared to inverted (Maurer et al., 2002; Piepers & Robbins, 2012). The absence of a perceptual sensitivity advantage for upright, facing dyads in Experiments 1 and 2 therefore calls into question the extension of configural processing to dyadic interaction perception.

However, to confirm these differential sets of results were not a consequence of methodological discrepancies between studies (e.g., differences in stimulus timings or the use of online testing), Experiment 3 aimed to replicate the face version of the effect under a broadly identical paradigm to that used in Experiments 1 and 2. Instead of detecting changes in interpersonal distance for dyadic stimuli, participants viewed images of individual faces and were tasked with detecting changes in the horizontal spacing of eyes. This spatial manipulation is consistent with previous face studies (e.g., Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001a). In Experiment 3a, observers' ability to detect changes in interocular distance in a male face presented upright and inverted was compared. In Experiment 3b, observers' ability to detect changes in interocular distance when a female face was presented upright and inverted was compared.

3.4.1. Method

Participants

One hundred participants completed Experiment 3a (63 males, 36 females, 1 non-binary, M_{age} = 33.89 years, SD_{age} = 8.32), including 21 replacements for participants who did not satisfy the performance requirements. Similarly, 100 participants completed Experiment 3b (62 males, 38 females, M_{age} = 35.89 years, SD_{age} = 8.71), including 9 replacements for participants who did not satisfy the performance requirements. The same inclusion and exclusion criteria employed in the previous four experiments (1a, 1b, 2a and 2b) were employed in the present two experiments (3a and 3b).

Stimuli

The stimuli used in Experiment 3 were derived from two computer-generated faces using FaceGen Modeller (Version 3.31; Singular Inversions Inc.). Experiment 3a featured a male face, and Experiment 3b featured a female face. Both faces were depicted in portrait against a white background. From each of the two face identities, 6 stimulus images were derived: 3 levels of interocular distance (closer, standard, apart) × 2 levels of orientation (upright, inverted). Interocular distance – the amount of space between the eyes – was morphed in FaceGen. The closer and apart distances represented ~11% decreases and increases, respectively, relative to the standard distance. These estimates of eye distance represent pupil-to-pupil measurements. When viewed at a distance of 57.1 cm, the face stimuli subtended ~10° of horizontal visual angle and ~9° of vertical visual angle.

Design and procedure

The design and procedure of Experiments 3a and 3b were identical to those employed in the previous four experiments (1a, 1b, 2a and 2b), with the following exceptions. Similar to Experiments 2a and 2b, participants completed 90 upright trials (30 no change, 30 move closer, 30 move apart) and 90 inverted trials (30 no change, 30 move closer, 30 move apart). The dyadic stimulus images used in the previous experiments were replaced with face stimulus images. The first image in a trial sequence always depicted a face identity displaying the ‘standard’ interocular distance. On signal absent trials, the same image was presented in the second stimulus interval. On signal present trials, a different image of the same face was presented: the eyes of the individual appeared closer together (~-11%) or further apart (~+11%). Once again, the experiments were conducted online via Gorilla (Anwyl-Irvine et al., 2020).

3.4.2. Results

Experiment 3a

The results from Experiment 3a are shown in Figure 3.6a. Sensitivity estimates (*d´*) were subjected to ANOVA with Face Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [$F(1, 99) = 5.619$, $p = .020$, $\eta^2_G = .012$, BF01 = 0.407], whereby participants exhibited superior sensitivity on move closer trials. A significant main effect of Face Orientation was observed [$F(1, 99) = 53.829$, $p < .001$, $\eta^2_G = .040$, BF01 < .001], whereby participants were more sensitive to distance changes in the upright condition. There was no significant Face Orientation × Movement Direction interaction [$F(1, 99) =$

1.534, p = .218 η^2_G < .001, BF01 = 3.692]. Participants were significantly more sensitive to distance changes on move closer trials in the upright condition, than in the inverted condition [M_{upr} = 2.12, SD_{upr} = 0.92, M_{inv} = 1.77, SD_{inv} = 0.82, t(99) = 5.767, p < .001, d_z = 0.58, BF01 < .001]. Participants were also significantly more sensitive to distance changes on move apart trials in the upright condition, than in the inverted condition [M_{upr} = 1.95, SD_{upr} = 1.16, M_{inv} = 1.51, SD_{inv} = 0.95, t(99) = 6.021, p < .001, d_z = 0.60, BF01 < .001]. Participants' sensitivity scores in the upright and inverted conditions exhibited significant correlation. This was evident in both parametric [move closer: r_p = .769, p < .001; move apart: r_p = .772, p < .001] and non-parametric analyses [move closer: r_s = .746, p < .001; move apart: r_s = .784, p < .001]. Scatterplots of these relationships are shown in Figure 3.7a.

Bias estimates (C) were subjected to ANOVA with Face Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed a significant main effect of Movement Direction [F(1, 99) = 5.615, p = .020, η^2_G = .015, BF01 = 0.463], whereby participants were more likely to report a distance change on move closer trials. No main effect of Face Orientation was observed [F(1, 99) = 2.267, p = .135, η^2_G = .004 , BF01 = 2.346], and there was a non-significant Face Orientation × Movement Direction interaction [F(1, 99) = 1.530, p = .219, η^2_G < .001, BF01 = 3.000]. Simple contrasts revealed participants were significantly less likely to report a distance change on move closer trials in the upright condition, than the inverted condition [M_{upr} = -0.23, SD_{upr} = 0.47, M_{inv} = -0.14, SD_{inv} = 0.44, t(99) = -1.991, p = .049, d_z = -0.20, BF01 = 1.361]. However, there was no effect of Dyad Orientation on bias scores in the move apart condition [M_{upr} = -0.31, SD_{upr} = 0.46, M_{inv} = -0.28, SD_{inv} = 0.36, t(99) = -0.714, p = .477, d_z = -0.07, BF01 = 7.050]. Participants' bias scores in the upright and inverted conditions exhibited significant correlation. This was evident in both parametric [move closer: r_p = .596,

$p < .001$; move apart: $r_p = .435$, $p < .001$] and non-parametric analyses [move closer: $r_s = .500$, $p < .001$; move apart: $r_s = .424$, $p < .001$].

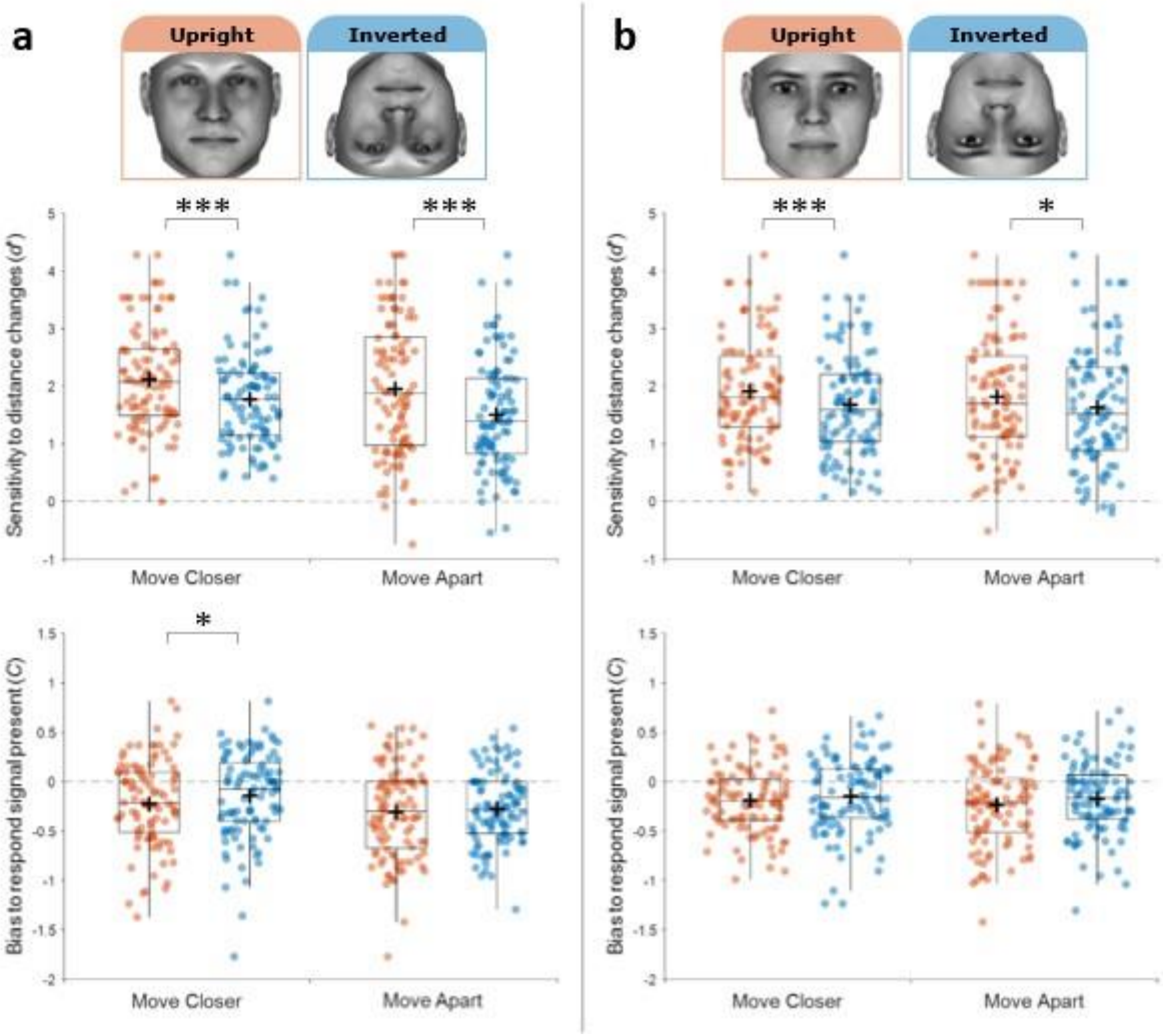

Figure 3.6: Results of Experiment 3. **(a)** Results for Experiment 3a obtained with male faces. **(b)** Results for Experiment 3b obtained with female faces. Boxplots denote median and interquartile range. Plus signs denote means. * denotes $p < .05$, ** denotes $p < .01$, *** denotes $p < .001$.

Experiment 3b

The results from Experiment 3b are shown in Figure 3.6b. Sensitivity estimates (d') were subjected to ANOVA with Face Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. No main effect of Movement Direction was observed [$F(1, 99) = 0.821$, $p = .367$, $\eta^2_G = .001$, $BF_{01} = 3.617$], indicating participants did not exhibit significant differences in sensitivity on move closer and move apart trials. However, the ANOVA did reveal a significant main effect of Face Orientation [$F(1, 99) = 12.115$, $p < .001$, $\eta^2_G = .012$, $BF_{01} = 0.025$], whereby participants were more sensitive to distance changes in the upright condition. There was no significant Face Orientation × Movement Direction interaction [$F(1, 99) = 0.300$, $p = .585$ $\eta^2_G < .001$, $BF_{01} = 5.970$]. Participants were significantly more sensitive to distance changes on move closer trials in the upright condition, than in the inverted condition [$M_{upr} = 1.91$, $SD_{\text{upr}} = 0.89$, $M_{\text{inv}} = 1.68$, $SD_{inv} = 0.90$, $t(99) = 3.457$, $p < .001$, $d_z = 0.35$, $BF_{01} < .001$]. Participants were also significantly more sensitive to distance changes on move apart trials in the upright condition, than in the inverted condition [$M_{\text{upr}} = 1.82$, $SD_{\text{upr}} = 1.05$, $M_{\text{inv}} = 1.63$, $SD_{\text{inv}} = 1.01$, $t(99) = 2.392$, $p = .019$, $d_z = 0.24$, $BF_{01} = 0.602$]. Participants' sensitivity scores in the upright and inverted conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .719$, $p < .001$; move apart: $r_p = .713$, $p < .001$] and non-parametric analyses [move closer: $r_s = .759$, $p < .001$; move apart: $r_s = .722$, $p < .001$]. Scatterplots of these relationships are shown in Figure 3.7b.

Bias estimates (C) were subjected to ANOVA with Face Orientation (upright, inverted) and Movement Direction (move closer, move apart) as within-subjects factors. The ANOVA revealed no main effect of Movement Direction [$F(1, 99) = 0.821$, $p = .367$, $\eta^2_G = .002$, $BF_{01} = 3.166$], indicating participants were equally likely to report a distance change on move closer and move apart trials. No main effect of Face Orientation was observed [$F(1, 99) =$

1.823, $p = .180$, $\eta^2_G = .005$, $BF_{01} = 2.248$], and there was a non-significant Face Orientation × Movement Direction interaction [$F(1, 99) = 0.300$, $p = .180$, $\eta^2_G = .005$, $BF_{01} = 6.250$]. Simple contrasts revealed no effect of Face Orientation on bias scores in the move closer condition [$M_{upr} = -0.19$, $SD_{upr} = 0.33$, $M_{inv} = -0.15$, $SD_{inv} = 0.38$, $t(99) = -1.078$, $p = .284$, $d_z = -0.11$, $BF_{01} = 5.150$] and the move apart condition [$M_{upr} = -0.24$, $SD_{upr} = 0.41$, $M_{inv} = -0.17$, $SD_{inv} = 0.37$, $t(99) = -1.309$, $p = .194$, $d_z = -1.13$, $BF_{01} = 3.952$]. Participants' bias scores in the upright and inverted conditions exhibited significant correlation. This was evident in both parametric [move closer: $r_p = .394$, $p < .001$; move apart: $r_p = .188$, p = .061] and non-parametric analyses [move closer: $r_s = .382$, $p < .001$; move apart: $r_s = .241$, $p = .016$].

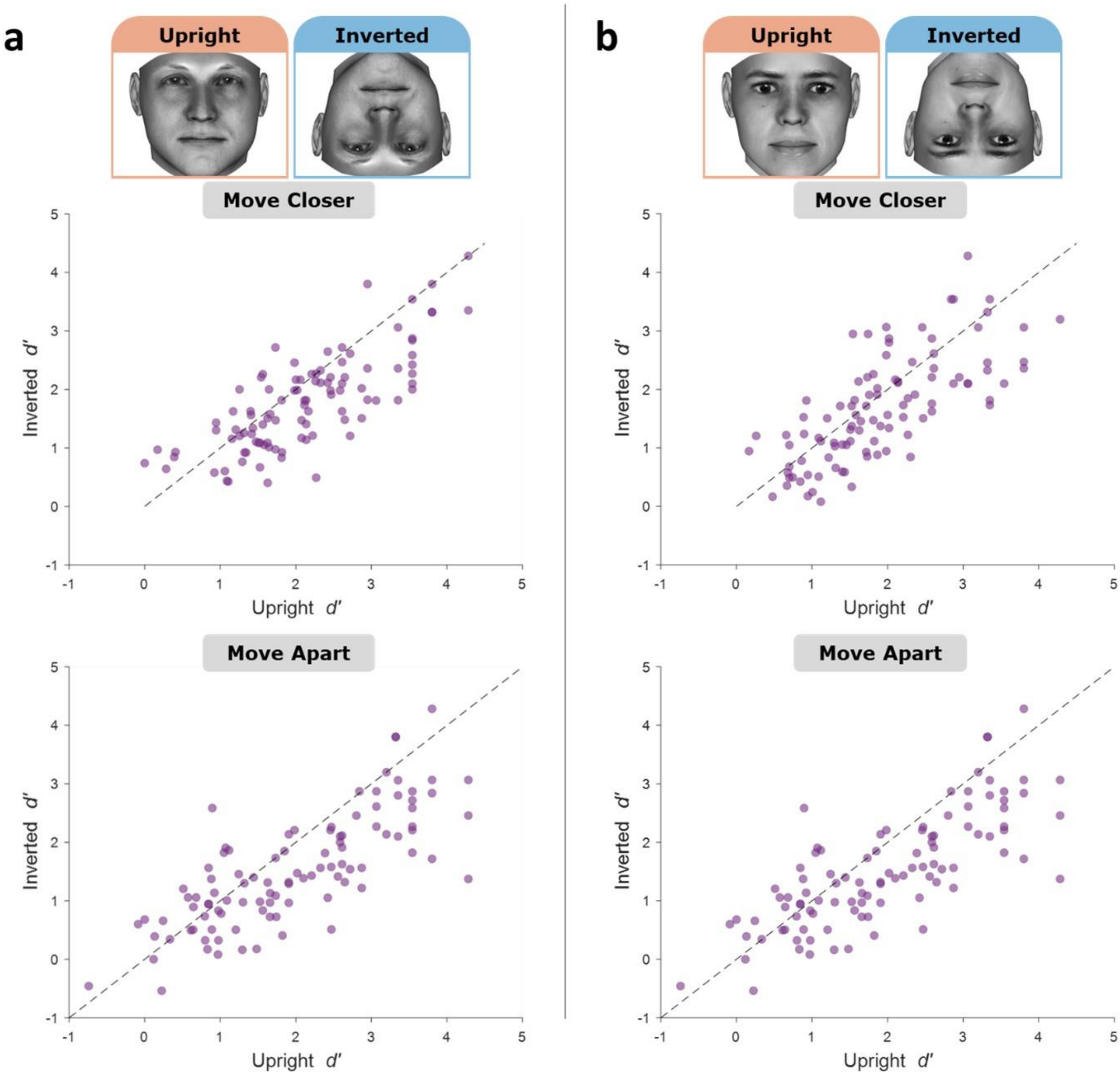

Figure 3.7: Scatterplots of sensitivity scores observed in Experiment 3. **(a)** Results for Experiment 3a obtained with upright and inverted male faces. **(b)** Results for Experiment 3b obtained with upright and inverted female faces. Dashed line represents unity.

3.5. Discussion

It has long been thought that upright faces engage configural or holistic processing that helps observers integrate information from local regions into a unified, coherent percept (Bukach et al., 2006; Farah et al., 1998; Maurer et al., 2002; McKone et al., 2007). One of the key advantages conveyed by this processing is thought to be heightened sensitivity to the spatial relationships between constituent elements; this is widely regarded as a hallmark of configural / holistic processing (Farah et al., 1998; Maurer et al., 2002; Piepers & Robbins, 2012). Consistent with this view, participants exhibit greater perceptual sensitivity to inter-feature relations when faces are shown upright, than when they are shown upside-down (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001a).

More recently, it has been suggested that pairs of upright individuals arranged face-to-face and viewed in profile may recruit further configural processing analogous to that engaged by upright faces (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). Importantly, this additional configural processing of dyads is thought to be gated, such that it is not recruited – or recruited less – when the constituent individuals are arranged back-to-back, or when facing dyads are shown upside-down. However, this account remains controversial. In particular, it has been argued that several effects cited as evidence for the configural processing hypothesis reflect the differential arrangement of attentional cues in facing and non-facing dyads (Vestner et al., 2020, 2021), and the fact that attention cueing by faces and bodies viewed in profile is greatly attenuated by orientation inversion (Langton & Bruce, 1999; Vestner et al., 2020, 2021).

The present study sought to test a key prediction of the configural processing hypothesis. If upright facing dyads engage a form of configural processing, that is i) analogous to that engaged by upright faces, and ii) not engaged by back-to-back or inverted dyads, then participants should show heightened sensitivity to the spatial relationships between the constituent individuals when dyads are arranged face-to-face and shown upright. In the first set of experiments, observers' ability to detect changes in interpersonal distance was compared when pairs of boxers (Experiment 1a) or dancers (Experiment 1b) were presented in face-to-face and back-to-back arrangements. In the second set of experiments, observers' ability to detect changes in interpersonal distance was compared when pairs of facing boxers (Experiment 2a) or facing dancers (Experiment 2b) were presented in upright and inverted orientations.

Contrary to the predictions of the configural processing hypothesis (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017), no overall increase in sensitivity to changes in interpersonal distance was observed when dyads were presented face-to-face (relative to back-to-back; Experiment 1) or upright (relative to upside-down; Experiment 2). These results argue against the configural processing hypothesis which predicts main effects of dyad arrangement (face-to-face > back-to-back) and orientation (upright > inverted) on sensitivity to distance changes. Note, the two main effects of Dyad Arrangement (Experiments 1a and 1b) and the two main effects of Orientation (Experiments 2a and 2b) yielded associated Bayes Factors ranging from 3.4 to 5.7 – substantial evidence for the null hypothesis (Jeffreys, 1998).

In Experiments 2a and 2b, the analyses revealed an unexpected Orientation × Movement Direction interaction. In Experiment 2b, greater sensitivity to distance changes was observed on move closer trials when dancer dyads were presented upright, relative to the inverted condition. However, no equivalent effect was observed in Experiment 2a with boxer dyads. Although this isolated finding of enhanced upright sensitivity aligns with the configural processing account, several factors urge caution in its interpretation. While the effect narrowly met the threshold for statistical significance ($p = .042$), its associated Bayes factor ($BF_{01} = 1.198$) provided anecdotal evidence in favour of the null hypothesis, suggesting that the effect may not be robust. This uncertainty is further compounded by the absence of a similar effect in Experiment 2a or in the move apart trials of Experiment 2b. It may be conceivable that dancer dyads moving in particular directions elicit greater engagement of configural processing than boxer dyads due to their social or aesthetic properties. Nevertheless, this inconsistency remains problematic for a hypothesis that predicts upright facing dyads should reliably engage such mechanisms.

Interestingly, the Orientation × Movement Direction interactions observed in Experiments 2a and 2b highlighted instances of superior sensitivity for inverted dyads. In both experiments, diminished sensitivity to distance changes was observed on move apart trials when dyads were presented upright, relative to the inverted condition. Once again, these findings are hard to reconcile with the configural processing hypothesis. The observation of diminished sensitivity to distance changes on move apart trials when dyads are upright does not accord with the recruitment of configural processing which ought to selectively augment the representation of interpersonal distance when viewing upright dyads.

The observation of superior sensitivity in these inverted conditions may at first appear counter-intuitive. However, one possible explanation is that participants experience a perceptual bias whereby actors appear closer together when viewed upright, but not when viewed inverted (see also: Vestner et al., 2019). This kind of bias might hinder the detection of distance changes in the move apart condition when stimuli are shown upright. When stimuli are shown inverted, however, participants – free from the interfering bias – may exhibit superior sensitivity. Such a bias might arise from perceptual priors acquired through previous visual experience of social interactions. It is also conceivable that a bias might arise from attention cueing; i.e., stimuli that cue attention might appear to drift in the direction implied. Given that attention cueing is greatly attenuated by inversion, this might manifest as an orientation-specific bias.

One might make the argument that the failure to replicate the feature-spacing effect with dyadic stimuli in Experiments 1 and 2 could be attributable to factors such as the online testing procedure or the working memory demands of the task. However, this explanation seems unlikely in light of the findings from Experiment 3, which successfully replicated the feature-spacing effect for faces using the same experimental paradigm employed in Experiments 1 and 2. In this set of experiments, participants were tasked with detecting changes in interocular distance when viewing individual faces presented upright and inverted. Experiment 3a featured a male face, and Experiment 3b featured a female face. In contrast to the null results obtained with dyadic stimuli, participants exhibited superior sensitivity to changes in interocular distance when faces were viewed in the upright condition. These results align with prior demonstrations of the feature-spacing effect for faces (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001a), affirming the validity of the sequential matching paradigm for capturing evidence of configural processing.

The pattern of C effects observed in Experiments 1 and 2 closely mirrored that seen in the *d*' analyses. In all four experiments, participants exhibited greater sensitivity on move closer trials (than on move apart trials), and a corresponding bias to report more distance changes in the move closer trials (than in the move apart trials). Similarly, greater sensitivity on move apart trials when facing dyads were shown inverted (relative to upright presentation) was accompanied by a greater bias to report distance changes. As described above, it is possible that the presence of a perceptual bias sometimes undermines sensitivity to distance changes – in particular, when facing dyads move apart. However, it is also possible that greater sensitivity affects the bias scores; for example, participants with high and low sensitivity may detect more / fewer distance changes, and exhibit different biases accordingly.

In all four dyad experiments a main effect of Movement Direction was observed, whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. The absolute difference between the distances presented in the first and second interval was held constant across move closer and move apart trials; i.e., in absolute terms, the distance changes in the move closer and move apart conditions was physically identical (±30 cm). However, the distance changes may not have been perceptually equivalent in the move closer and move apart conditions. The ratio of the larger distance to the smaller distance was greater on move closer trials (180 cm / 150 cm = 1.200) than on move apart trials (210 cm / 180 cm = 1.166). As a result, the distance change on move closer trials may have been more salient. The discriminability of two stimuli is known to vary as a function of the relative difference when the absolute difference is held constant – see Weber's Law (e.g., Algom, 2021; Pardo-Vazquez et al., 2019). For example, a difference in height of 3 cm is more obvious when viewing two short individuals, than when viewing two tall individuals. For a similar reason, a 30 cm reduction in interpersonal distance may be more obvious to an observer than a 30 cm increase.

The results described here suggest that the perceptual mechanisms recruited by facing and non-facing dyads may be more similar than is currently thought. At first glance, this conclusion is at odds with recent findings from neuroimaging. In particular, it has been reported that facing dyads elicit a stronger response in extrastriate body area (EBA), relative to dyads shown back-to-back (Abassi & Papeo, 2020, 2022; Bellot, Abassi, & Papeo, 2021). Moreover, dyadic arrangement (face-to-face vs. back-to-back) modulates the pattern of effective connectivity between EBA and posterior superior temporal sulcus (Bellot et al., 2021) – a region implicated in the interpretation of social interactions (Isik et al., 2017; Walbrin et al., 2018). It has been suggested that these neural effects reflect configural dyad processing (e.g., Abassi & Papeo, 2022). Once again, however, these effects may be easily understood in terms of the differential arrangement of attention cues in face-to-face and back-to-back arrangements.

Many regions of the human visual system are known to exhibit attentional modulation. For example, when viewing arrays depicting both moving and static dots, the instruction to attend to the moving dots induces stronger activation in MT (O’Craven et al., 1997). When viewing simultaneously presented images of faces and houses, “attend-face” and “attend-house” instructions increase activity in face-selective and house-selective visual cortex respectively (Bird et al., 2006). When viewing faces, instructions to attend preferentially to facial identity or gaze direction induces greater signal change in fusiform face area (FFA) and pSTS respectively (Hoffman & Haxby, 2000). Moreover, it is known that attentional manipulations modulate patterns of effective connectivity between regions-of-interest (e.g., Bird et al., 2006).

It is entirely plausible that stronger responses to face-to-face dyads in EBA (Abassi & Papeo, 2020, 2022; Bellot et al., 2021) and the reported modulation of effective connectivity between EBA and pSTS by dyadic arrangement (Bellot et al., 2021), reflects attentional modulation of single-actor processing. Faces and bodies viewed in profile cue participants’ visuospatial attention (Langton & Bruce, 1999; Vestner et al., 2021). When arranged face-to-face, the directionality of the lefthand actor cues observers’ attention towards the righthand actor, and vice versa, creating an ‘attention trap’ (Vestner et al., 2020, 2021). In back-to-back arrangements, the same cues direct observers’ attention towards the display periphery. Eye-tracking confirms that patterns of fixation differ for face-to-face vs. back-to-back dyads; in particular, observers spend more time looking at actors’ faces when viewing pairs of actors arranged face-to-face (Kujala et al., 2012). In light of these behavioural findings, it would be surprising if dyadic arrangement (face-to-face vs. back-to-back) did not induce attentional modulation of visual areas implicated in social perception (e.g., EBA).

In summary, this chapter describes four experiments that sought to test whether upright facing dyads recruit a form of configural processing analogous to that engaged by faces. Contrary to this view, no evidence for heightened perceptual sensitivity to the interpersonal distance between two upright actors arranged face-to-face was observed. Instead, participants showed similar perceptual sensitivity to changes in interpersonal distance irrespective of dyadic arrangement (face-to-face, back-to-back) or orientation (upright, inverted). These results contrast with those of two follow-up experiments, which revealed participants exhibited marked increases in sensitivity when detecting changes in inter-feature spatial relations for faces oriented upright compared to inverted. Taken together, these findings challenge the view that upright dyads arranged face-to-face selectively engage configural processing analogous to that engaged by upright faces.

Chapter 4: Typical sensitivity to changes in interpersonal distance in developmental prosopagnosia

Early findings from research aiming to elucidate the mechanisms underlying dyadic interaction perception have suggested that upright dyads arranged face-to-face engage neurocognitive processing similar to that recruited by upright faces. Like faces, facing dyads may engage configural representation and be processed with high priority within the visual system. Faces and facing dyads may also engage common regions of the occipitotemporal social perception network, including the fusiform face area. In light of the parallels between the visual processing of faces and facing dyads, the study described in this chapter sought to determine whether developmental prosopagnosics (DPs) – who have lifelong difficulties recognising faces – also exhibit impaired perception of facing dyads. Participants completed three distance change detection tasks. Two of the tasks depicted distance changes during dyadic social interactions – fighting and dancing. A third task depicted distance changes using non-social objects – a pair of grandfather clocks. If DP is associated with impoverished perception of dyadic interactions, it was reasoned that DPs should exhibit diminished sensitivity to distance changes on the dancers task and the boxers task, but not on the clocks task. Contrary to this prediction, however, the DPs and controls did not differ significantly in their ability to detect distance changes on any of the tasks (dancers, boxers, clocks). Given that DP is associated with lifelong face processing difficulties, these findings argue against the view that dyadic interactions engage face-like processing.

4.1. Introduction

For several decades, social perception research has sought to elucidate the visual perception of observed individuals. Consequently, much is known about the visual processing engaged by the faces (Duchaine & Yovel, 2015; Tsao & Livingstone, 2008), bodies (Peelen & Downing, 2007; Slaughter et al., 2004), facial expressions (Adolphs, 2002; Frith, 2009), and actions (Blake & Shiffrar, 2007; Cook et al., 2014) of lone actors. More recently, however, there has been growing interest in how we perceive dyadic interactions between people (Papeo, 2020; Quadflieg & Koldewyn, 2017). This emerging literature is still in its infancy. However, several early findings suggest that upright dyads arranged face-to-face may engage domain-specific neurocognitive processing analogous to that recruited by upright faces (Papeo, 2020; Abassi & Papeo, 2022).

When viewed upright, faces are thought to engage configural processing whereby information from local regions is integrated into a unified, coherent percept (Farah et al., 1998; Maurer et al., 2002). A key hallmark of this processing is that the content of one stimulus region informs the perception of another region; for example, the appearance of the mouth region biases observers' perception of the eye-region – the so-called composite face effect (Murphy et al., 2017; Rossion, 2013). It has been suggested that facing dyads engage a similar form of configural processing when viewed upright (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2019). Consistent with this view, the facial and bodily expressions of one actor bias the perception of the other actor's expression when dyads are arranged face-to-face (Abramson et al., 2021; Gray, Barber, et al., 2017).

Similarly, it is well-established that upright faces are processed with high priority within the human visual system. For example, upright faces capture observers' attention (Farroni et al., 2005; Langton et al., 2008; Lavie et al., 2003) and are detected in situations where other stimuli do not reach conscious awareness (Jiang et al., 2007; Stein et al., 2011). This may also be true of facing dyads. For example, dyadic targets shown face-to-face are found faster in visual search tasks than dyadic targets shown back-to-back (Papeo et al., 2017; Vestner et al., 2019). This search advantage for facing dyads is not seen when target and distractor dyads are shown upside-down (Vestner et al., 2019). Similarly, when dyads are presented briefly (30 ms) and subject to backwards masking, participants are also better able to detect upright face-to-face arrangements than inverted face-to-face arrangements. Conversely, little or no modulation-by-orientation is observed for back-to-back dyads (Papeo et al., 2017).

Neuroimaging studies also suggest that the visual analysis of facing dyads recruits cortical regions previously implicated in the perception of faces and bodies. For example, the extrastriate body area (EBA) and the fusiform face area (FFA) exhibit stronger univariate responses when observers view dyads arranged face-to-face than when viewing dyads arranged back-to-back (Abassi & Papeo, 2020, 2022). The same areas also respond more strongly when observers view semantically incongruous facing dyads, than when they view semantically congruous facing dyads (Quadflieg et al., 2015). Similarly, studies of social interaction perception suggest that posterior superior temporal sulcus (pSTS) plays an important role in the interpretation of dyadic stimuli (Isik et al., 2017; Walbrin et al., 2018). Interestingly, the pSTS has also been identified as an important hub in the processing of facial identity (e.g., Tsantani et al., 2019), the perception of facial motion (Pitcher, Dilks, et al., 2011), and whole-body actions (Blake & Shiffrar, 2007).

In light of the parallels between the visual processing of faces and facing dyads, the present study sought to determine whether individuals who have lifelong difficulties recognising faces – developmental prosopagnosia (DP) – also exhibit impaired perception of facing dyads. DP is a neurodevelopmental condition associated with difficulties recognising and distinguishing facial identities, that occurs in people with normal intelligence and typical visual acuity, and in the absence of manifest brain injury (Behrmann & Avidan, 2005; Cook & Biotti, 2016; Duchaine & Nakayama, 2006). Although DPs struggle to identify others based on their facial appearance, they exhibit typical recognition of others from vocal cues (Liu et al., 2015; Tsantani & Cook, 2020). Given their face recognition problems, individuals with DP are more reliant on non-facial cues (e.g., hairstyle, voice, clothing, walking gait) when identifying others (Cook & Biotti, 2016). As such, individuals can experience great difficulty when familiar people are encountered with new hairstyles or in situations where clothing is less diagnostic of identity; for example, where people are required to wear uniforms (Shah, Gaule, et al., 2015).

At the neurological level, DPs exhibit differences in cortical structure (Behrmann et al., 2007; Garrido et al., 2009), and structural (Gomez et al., 2015; Song et al., 2015; Thomas et al., 2009) and functional connectivity (Avidan & Behrmann, 2009, 2014) in occipital and inferotemporal regions. Aberrant connectivity between key hubs – including the fusiform (Kanwisher & Yovel, 2006) and occipital (Pitcher, Walsh, et al., 2011) face areas – may impair information exchange within the face processing network (e.g., Cook & Biotti, 2016). A popular cognitive account of DP argues that individuals with the condition struggle to process faces configurally / holistically (Avidan et al., 2011; Liu & Behrmann, 2014; Palermo et al., 2011), though this remains controversial (e.g., Biotti, Wu, et al., 2017; Tsantani et al., 2020).

The defining feature of DP is severe lifelong face-identification difficulties (Behrmann & Avidan, 2005; Cook & Biotti, 2016; Duchaine & Nakayama, 2006). Nevertheless, individuals with the condition often exhibit other social perception deficits. For example, at the group level, DPs show worse categorisation of facial expressions relative to typical controls (Biotti & Cook, 2016; Tsantani, Gray, et al., 2022). Similarly, DPs are less able to individuate human body shapes (Biotti, Gray, et al., 2017) and point-light displays of whole-body actions (Lange et al., 2009). Presently, very little is known about the ability of DPs to perceive facing dyads. However, the parallels that exist between the face and dyadic interaction literatures points to the possibility that DPs might well exhibit deficits in this facet of social perception.

The focus of this investigation was the perceptual sensitivity of individuals with DP to changes in interpersonal distance. The putative domain-specific dyad processing recently described in the social vision literature is thought to enhance observers' encoding of configural stimulus features (Papeo, 2020; Abassi & Papeo, 2022). Crucially, interpersonal distance is a key configural feature of dyadic interactions. This attribute cannot be inferred from one actor alone; rather, it is an emergent configural property of the presence of two actors. Therefore, perceptual decisions about interpersonal distance should in principle provide an ideal measure of the specialised dyad processing hypothesised by proponents of the face-like processing account (e.g., Papeo, 2020).

By way of analogy, the specialized visual processing engaged by upright faces is thought to increase perceptual sensitivity to inter-feature spatial relations. (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001b; Leder et al., 2001). For example, observers are more sensitive to the distance between the eyes when faces are shown upright – a condition that affords domain-specific face processing – then when faces are presented upside down – a condition that attenuates domain-specific processing (Chapter 3, Experiments 3a & 3b; Leder et al., 2001). DPs are well-documented to exhibit diminished sensitivity to spatial relationships between facial features relative to controls with intact face processing ability (e.g., Yovel & Duchaine, 2006). If the mechanisms underlying face and dyad processing overlap, as suggested by the face-like processing hypothesis, it follows that DPs should also exhibit diminished perceptual sensitivity to changes in interpersonal distance compared to controls.

4.2. Method

4.2.1. Participants

Forty-two adults with DP (23 female, 19 male; M_{age} = 41.64 years, SD_{age} = 13.01 years) were recruited via www.troublewithfaces.org. Diagnostic evidence for the presence of DP was collected using the Twenty-item Prosopagnosia Index (PI20; Gray, Bird, et al., 2017; Shah, Gaule, et al., 2015; Tsantani et al., 2021) – a 20-item self-report measure that assesses the presence of prosopagnosic traits – and two variants of the Cambridge Face Memory Test – the original (CFMT-O; Duchaine & Nakayama, 2006) and the Australian (CFMT-A; McKone et al., 2011) versions. All participants in the DP sample scored two or more standard deviations below the typical mean on both versions of the CMFT. All of the DPs scored above cut-off (65) on the PI20. DPs were also assessed on the Cambridge Car Memory Test (CCMT; Dennett et al., 2012), a measure of wider object recognition ability. Scores on this test ranged from 31.94 to 94.44 (M_{CCMT} = 64.62, SD_{CCMT} = 14.81). Diagnostic information for individual DPs is presented in Table 4.1.

Eighty-four typical individuals (51 female, 33 male, M_{age} = 42.06 years, SD_{age} = 9.99 years) were recruited through www.prolific.co to serve as controls. To be eligible, potential participants needed a Prolific approval rate of 85% or higher at the start of the study. Control participants were screened for signs of prosopagnosia using the PI20. Any who scored 65 or more were excluded and replaced (rule determined prior to analysis). Ten controls were replaced on this basis. As expected, the typical controls (M_{PI20} = 40.19, SD_{PI20} = 9.95) scored lower on the PI20 than the DPs (M_{PI20} = 81.48, SD_{PI20} = 6.69) [$t(124) = 24.270$, $p < .001$]. The groups did not differ significantly in terms of age [$t(124) = .199$, $p = .843$] or sex [$\chi^2 = .409$, $p = .522$]. All participants (DPs and controls) were required to be aged 18 years-old or above, to have normal or corrected-to-normal visual acuity, to have no history of psychiatric or neurological illness including diagnosis of autism or schizophrenia, and to reside in the United Kingdom.

A power analysis conducted using GPower 3.1 (Faul et al., 2009) revealed that an independent-samples *t*-test ($\alpha = 0.05$, two-tailed) has a 92.7% chance of detecting a medium-to-large effect size (Cohen's $d = 0.65$) with groups of 84 and 42. Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London. The experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent and were reimbursed for their time.

Table 4.1: Demographic and diagnostic information for the DP participants.

	Age	Sex	PI20	CFMT-O (%)	CFMT-A (%)	CCMT (%)	*z*PI20	*z*CFMT	*z*CFMT-A	*z*CCMT
1	48	F	88	56.9	55.6	59.7	5.49	-3.15	-2.42	-1.09
2	57	F	82	52.8	56.9	65.3	4.84	-3.62	-2.28	-0.65
3	56	M	90	54.2	52.8	86.1	5.71	-3.46	-2.69	1.00
4	27	M	76	38.9	58.3	51.4	4.18	-5.18	-2.14	-1.75
5	54	F	86	40.3	58.3	75.0	5.27	-5.02	-2.14	0.12
6	55	F	82	50.0	58.3	58.3	4.84	-3.93	-2.14	-1.20
7	47	F	69	58.3	50.0	69.4	3.41	-3.00	-2.96	-0.32
8	49	F	96	54.2	56.9	79.2	6.37	-3.46	-2.28	0.45
9	20	F	73	38.9	48.6	63.9	3.85	-5.18	-3.10	-0.76
10	20	M	84	45.8	44.4	61.1	5.05	-4.40	-3.51	-0.98
11	39	M	78	58.3	59.7	88.9	4.40	-3.00	-2.01	1.22
12	44	F	84	44.4	47.2	75.0	5.05	-4.56	-3.23	0.12
13	28	F	82	54.2	56.9	63.9	4.84	-3.46	-2.28	-0.76
14	49	M	80	50.0	58.3	86.1	4.62	-3.93	-2.14	1.00
15	23	M	76	58.3	54.2	75.0	4.18	-3.00	-2.55	0.12
16	39	M	71	55.6	58.3	65.3	3.63	-3.31	-2.14	-0.65
17	47	M	88	50.0	55.6	55.6	5.49	-3.93	-2.42	-1.42
18	50	M	84	29.2	33.3	37.5	5.05	-6.27	-4.60	-2.86
19	51	M	85	52.8	50.0	84.7	5.16	-3.62	-2.96	0.89
20	45	F	74	34.7	41.7	54.2	3.96	-5.65	-3.78	-1.53
21	48	F	73	41.7	59.7	50.0	3.85	-4.87	-2.01	-1.87
22	56	F	76	56.9	54.2	61.1	4.18	-3.15	-2.55	-0.98
23	23	M	90	40.3	48.6	61.1	5.71	-5.02	-3.10	-0.98
24	27	F	84	59.7	59.7	63.9	5.05	-2.84	-2.01	-0.76
25	24	F	74	33.3	34.7	47.2	3.96	-5.81	-4.46	-2.09
26	22	F	82	47.2	59.7	70.8	4.84	-4.24	-2.01	-0.21
27	22	F	88	50.0	58.3	61.1	5.49	-3.93	-2.14	-0.98
28	49	F	80	54.2	48.6	41.7	4.62	-3.46	-3.10	-2.53
29	23	F	80	51.4	59.7	55.6	4.62	-3.78	-2.01	-1.42
30	44	F	82	50.0	59.7	81.9	4.84	-3.93	-2.01	0.67
31	42	F	77	36.1	58.3	47.2	4.29	-5.49	-2.14	-2.09
32	28	M	83	55.6	45.8	94.4	4.95	-3.31	-3.37	1.66
33	29	F	89	41.7	56.9	44.4	5.60	-4.87	-2.28	-2.31
34	61	F	78	34.7	54.2	55.6	4.40	-5.65	-2.55	-1.42
35	43	F	88	55.6	48.6	56.9	5.49	-3.31	-3.10	-1.31
36	43	M	69	48.6	58.3	86.1	3.41	-4.09	-2.14	1.00
37	52	M	85	51.4	44.4	77.8	5.16	-3.78	-3.51	0.34
38	57	M	80	56.9	48.6	58.3	4.62	-3.15	-3.10	-1.20
49	58	M	82	52.8	55.6	80.6	4.84	-3.62	-2.42	0.56
40	38	M	70	45.8	48.6	58.3	3.52	-4.40	-3.10	-1.20
41	60	M	93	47.2	44.4	72.2	6.04	-4.24	-3.51	-0.10
42	52	M	91	33.3	41.7	31.9	5.82	-5.81	-3.78	-3.30
DP mean			81.5	48.1	52.5	64.6				
DP SD			6.7	8.3	7.0	14.8				
Comparison mean			38.0	85.0	80.2	73.5				
Comparison SD			9.1	8.9	10.2	12.6				

Nb. Comparison data (N = 54, M_{age} = 39.2; SD_{age} = 13.4; range: 20–69 years) for the PI20, and CFMT-O were taken from Biotti et al. (2019), *Neuropsychologia*. Comparison data (N = 75, M_{age} = 21.67; SD_{age} = 2.96; range: 18–32 years) for the CFMT-A were taken from McKone et al. (2011), *Cognitive Neuropsychology*. Comparison data (N = 61, M_{age} = 37.0; SD_{age} = 9.8; range: 27–60 years) for the CCMT were taken from Gray et al. (2019), *Cognitive Neuropsychology*.

4.2.2. Distance change detection tasks

Participants completed three distance change detection tasks in a counterbalanced order. Two of the tasks depicted distance changes during dyadic social interactions – fighting and dancing. In these tasks, participants had to judge whether pairs of boxers and dancers moved closer together or further apart. On half the trials (move closer trials), participants judged whether the stimulus elements moved closer together or whether the distance remained constant. On half the trials (move apart trials), participants judged whether the stimulus elements moved further apart or whether the distance remained constant. A third task depicted distance changes using non-social objects – a pair of grandfather clocks. The three tasks had an identical format (Figure 4.1) and were administered online via Gorilla (Anwyl-Irvine et al., 2020). The tasks had to be completed using a personal computer or laptop – they would not run on a tablet or mobile device. The experimental tasks are available as Open Materials at gorilla.sc (https://app.gorilla.sc/openmaterials/652716).

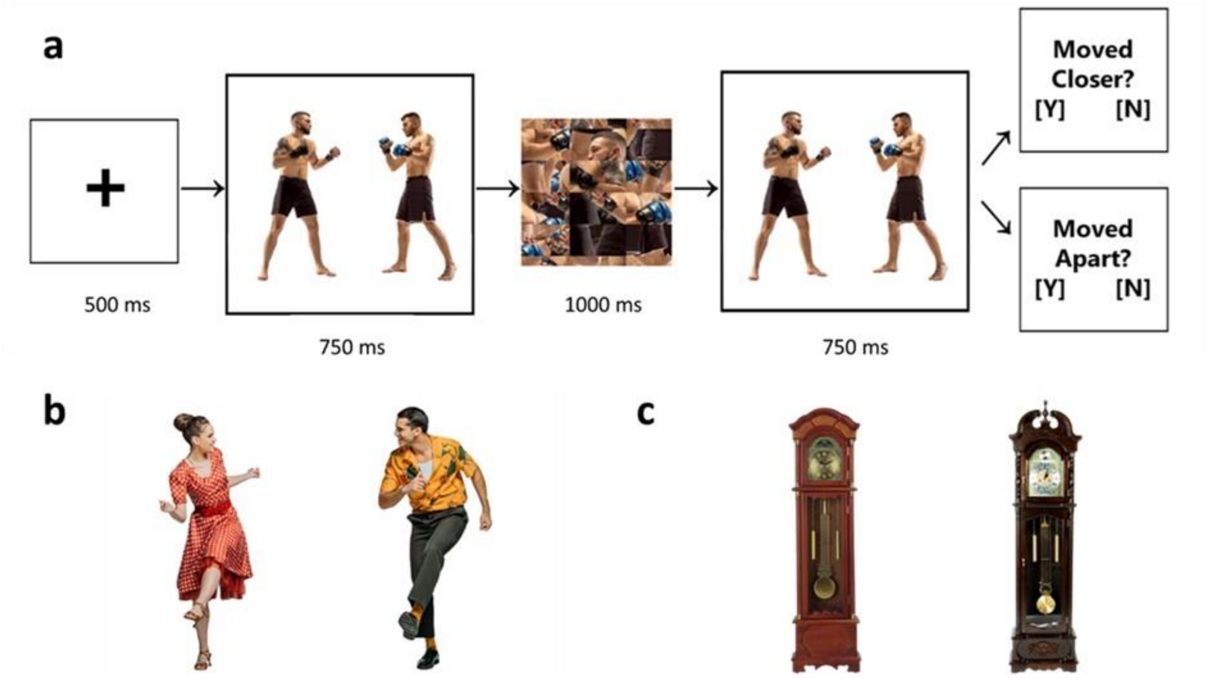

Figure 4.1: Overview of task format. **(a)** Schematic illustration of the sequence of an experimental trial in which participants viewed the boxer stimuli. **(b)** Example of the dancer stimuli. **(c)** Example of the clock stimuli. Interpersonal distances depicted are illustrative and not to scale.

Each of the three tasks consisted of 120 trials split into two blocks of 60 trials. Each block included 15 signal absent move closer trials (no distance change was depicted), 15 signal present move closer trials (the stimulus elements moved closer together), 15 signal absent move apart trials (no distance change was depicted), and 15 signal present move apart trials (the stimulus elements moved further apart). Trial order was randomized within each block. Participants could take a break midway through each of the blocks, and between blocks.

Trials began with a grey fixation cross (500 ms) which was followed by a stimulus image (e.g., an image of two dancers) presented for 750 ms each. The people / clocks shown in this first image always appeared ~180 cm apart (assuming the models and the clocks had an approximate height of 180 cm). A visual mask – constructed by scrambling elements of the stimulus images – was presented during an inter-stimulus-interval of 1000 ms. The second stimulus image was presented for 750 ms following mask offset. On signal absent trials, the same image was presented in the second stimulus interval. On signal present trials, a different image was presented. On signal present move closer trials the people / clocks would appear closer together (~150 cm). On signal present move apart trials the people / clocks would appear further apart (~210 cm). Finally, a question prompt would appear. On move closer trials participants were asked whether the two models had moved closer together in the second image relative to the first image. On move apart trials participants were asked if they had moved further apart. Participants made a binary 'yes' or 'no' response via keypress.

The stimuli presented first and second within a trial would always be shown on opposite sides of the screen (left or right). On 50% of trials the stimulus presented in the first interval would appear to the left of fixation, while the stimulus presented in the second interval would appear on the right. On 50% of trials the stimulus presented in the first interval would appear to the right of fixation, while the stimulus presented in the second interval would appear on the left. The precise positioning on the left and right was jittered to discourage participants from using distance to the display edge as a cue.

All stimulus images were presented overlaid against a greyscale gradient background. When viewed at 57.1 cm, the dyadic stimuli subtended between ~16° and ~19° of horizontal visual angle and ~13° of vertical visual angle. Mirror images (flipped about the vertical midline) of each stimulus image were created so that each actor / clock could be presented on the left and right equally often. The left-right arrangement of the exemplars was held constant within a trial sequence; i.e., if the female dancer was shown on the left in the first interval, she would also appear on the left in the second interval.

Eight attention checks were interspersed throughout the task. Participants were required to identify the shape (circle, square, triangle, or diamond) presented for 1000 ms immediately prior to the response prompt. Any participant who failed to respond correctly on at least 6 of the 8 attention checks were excluded and replaced (rule determined prior to analysis). Two controls were replaced on this basis.

4.2.3. Analysis

Performance was analysed using signal detection theory (Green & Swets, 1966). For each participant, separate measures of perceptual sensitivity (*d*') and bias (C) were calculated for move closer and move apart trials, based on their performance in each of the three tasks. Signal detection analyses were conducted in Matlab (The MathWorks Inc., Natick, USA) using routines from the Palamedes toolbox (Prins & Kingdom, 2009). Greater *d*' values reflect superior ability to distinguish signal present and absent trials. Positive C values reflect a greater proportion of distance change responses.

For the purpose of the group analyses, distributions of sensitivity (*d*') and bias (*C*) estimates were evaluated using both traditional null-hypothesis significance testing ($\alpha = 0.05$, two-tailed) and Bayesian methods (JASP-Team, 2022). Bayesian contrasts were conducted using default Cauchy priors (centre = 0, width = 0.707). A Bayes Factor (BF_{01}) larger than 1, 3, and 10 reflects anecdotal, substantial, and strong evidence, respectively, in favour of the null hypothesis. A Bayes Factor (BF_{01}) less than 1, 1/3, and 1/10 reflects anecdotal, substantial, and strong evidence, respectively, in favour of the alternative hypothesis. For the purpose of the correlational analyses described, Pearson correlation coefficients were computed. The supporting data are available via the Open Science Framework (https://osf.io/gbaqe/).

4.3. Results

4.3.1. Signal detection measures

Perceptual sensitivity (d')

Dancers. The *d*' estimates obtained (Figure 4.2a) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 7.634$, $p = .007$, $\eta_p^2 = .058$, $BF_{01} = 0.270$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 0.151$, $p = .698$, $\eta_p^2 = .001$, $BF_{01} = 4.076$], indicating that the DPs ($M = 2.34$, $SD = 0.53$) and controls ($M = 2.39$, $SD = 0.75$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [$F(1, 124) = 0.520$, $p = .472$, $\eta_p^2 = .004$, $BF_{01} = 3.255$]. When considered separately, no significant group difference was observed on move closer [$M_{DP} = 2.45$, $SD_{DP} = 0.71$, $M_{control} = 2.45$, $SD_{control} = 0.78$, $t(124) = 0.027$, $p = .979$, $d = 0.01$, $BF_{01} = 4.986$] or move apart trials [$M_{DP} = 2.21$, $SD_{DP} = 0.57$, $M_{control} = 2.31$, $SD_{control} = 0.75$, $t(124) = -0.732$, $p = .466$, $d = -0.14$, $BF_{01} = 3.922$].

Boxers. The *d*' estimates obtained (Figure 4.2b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) =$

4.004 $p = .048$, $\eta_p^2 = .031$, $\mathrm{BF}_{01} = 0.716$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 2.207$, $p = .140$, $\eta_p^2 = .017$, $\mathrm{BF}_{01} = 1.494$, indicating that the DPs ($M = 2.27$, $SD = 0.54$) and controls ($M = 2.45$, $SD = 0.77$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial type and Group [$F(1, 124) = 0.093$, $p = .761$, $\eta_p^2 < .001$, $\mathrm{BF}_{01} = 4.848$]. When considered separately, no significant group difference was observed on move closer [$M_{\mathrm{DP}} = 2.30$, $SD_{\mathrm{DP}} = 0.70$, $M_{\mathrm{control}} = 2.50$, $SD_{\mathrm{control}} = 0.71$, $t(124) = -1.505$, $p = .135$, $d = -0.28$, $\mathrm{BF}_{01} = 1.812$] or move apart trials [$M_{\mathrm{DP}} = 2.19$, $SD_{\mathrm{DP}} = 0.68$, $M_{\mathrm{control}} = 2.35$, $SD_{\mathrm{control}} = 0.79$, $t(124) = -1.132$, $p = .260$, $d = -0.21$, $\mathrm{BF}_{01} = 2.808$].

Clocks. The *d*’ estimates obtained (Figure 4.2c) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 5.599$, $p = .020$, $\eta_p^2 = .043$, $\mathrm{BF}_{01} = 0.350$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 2.758$, $p = .099$, $\eta_p^2 = .022$, $\mathrm{BF}_{01} = 1.257$], indicating that the DPs ($M = 2.35$, $SD = 0.52$) and controls ($M = 2.39$, $SD = 0.73$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [$F(1, 124) = 0.015$, $p = .903$, $\eta_p^2 < .001$, $\mathrm{BF}_{01} = 5.082$]. When considered separately, no significant group difference was observed on move closer [$M_{\mathrm{DP}} = 2.39$, $SD_{\mathrm{DP}} = 0.70$, $M_{\mathrm{control}} = 2.59$, $SD_{\mathrm{control}} = 0.71$, $t(124) = -1.514$, $p = .133$, $d = -0.29$, $\mathrm{BF}_{01} = 1.790$] or move apart trials [$M_{\mathrm{DP}} = 2.25$, $SD_{\mathrm{DP}} = 0.62$, $M_{\mathrm{control}} = 2.44$, $SD_{\mathrm{control}} = 0.73$, $t(124) = -1.415$, $p = .159$, $d = -0.27$, $\mathrm{BF}_{01} = 2.035$].

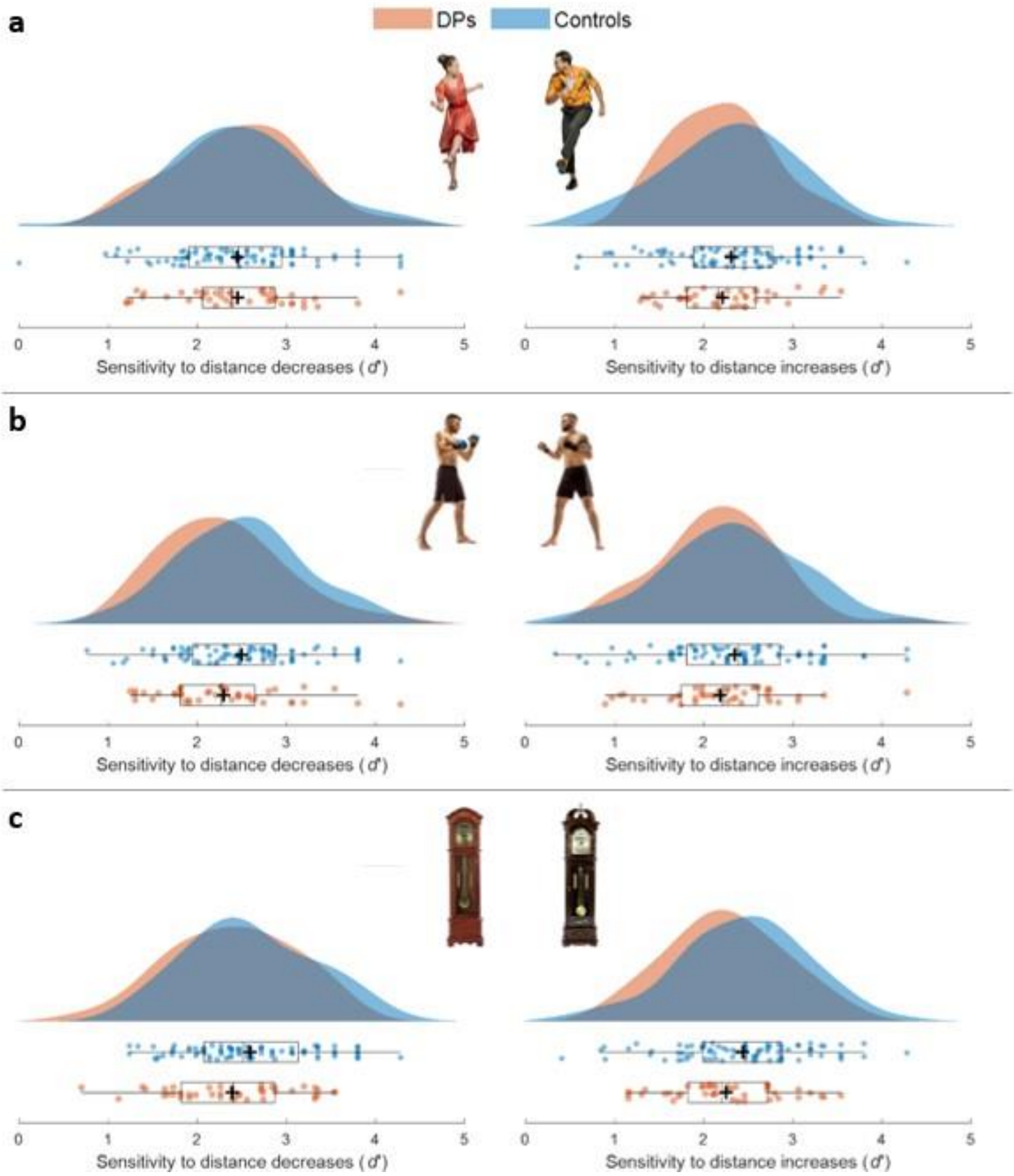

Figure 4.2: Perceptual sensitivity (*d*′) exhibited by DP and control participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent sensitivity on move closer trials; right-hand plots represent sensitivity on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher *d*’ values reflect superior sensitivity.

Bias (C)

Dancers. The C estimates obtained (Figure 4.3a) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 11.671$, $p < .001$, $\eta_p^2 = .086$, $BF_{01} = 0.021$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 0.020$, $p = .886$, $\eta_p^2 < .001$, $BF_{01} = 5.985$], indicating that the DPs ($M = -0.05$, $SD = 0.31$) and controls ($M = -0.04$, $SD = 0.44$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 124) = 1.042$, $p = .309$, $\eta_p^2 = .008$, $BF_{01} = 2.911$]. When considered separately, no significant group difference was observed on move closer trials [$M_{DP} = -0.21$, $SD_{DP} = 0.51$, $M_{control} = -0.13$, $SD_{control} = 0.63$, $t(124) = -0.752$, $p = .454$, $d = -0.14$, $BF_{01} = 3.870$] or move apart trials, [$M_{DP} = 0.11$, $SD_{DP} = 0.48$, $M_{control} = 0.05$, $SD_{control} = 0.46$, $t(124) = 0.727$, $p = .468$, $d = 0.14$, $BF_{01} = 3.933$].

Boxers. The C estimates obtained (Figure 4.3b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 34.754$, $p < .001$, $\eta_p^2 = .219$, $BF_{01} < .001$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 1.275$, $p = .261$, $\eta_p^2 = .010$, $BF_{01} = 3.872$], indicating that the DPs ($M = 0.06$, $SD = 0.28$) and controls ($M = 0.13$, $SD = 0.39$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 124) = 0.038$, $p = .845$, $\eta_p^2 < .001$, $BF_{01} = 4.705$]. When considered separately, no significant group difference was observed on move closer trials [$M_{DP} = 0.22$, $SD_{DP} = 0.39$, $M_{control} = 0.30$, $SD_{control} = 0.49$, $t(124) = -0.953$, $p = .343$, $d = -0.18$, $BF_{01} = 3.320$] or move apart trials [$M_{DP} = -0.13$, $SD_{DP} = 0.50$, $M_{control} = -0.07$, $SD_{control} = 0.45$, $t(124) = -0.671$, $p = .504$, $d = -0.13$, $BF_{01} = 4.075$].

Clocks. The C estimates obtained (Figure 4.3c) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 166.837$, $p < .001$, $\eta_p^2 = .574$, $BF_{01} < .001$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 124) = 1.430$, $p = .234$, $\eta_p^2 = .011$, $BF_{01} = 4.611$], indicating that the DPs ($M = 0.05$, $SD = 0.25$) and controls ($M = 0.12$, $SD = 0.36$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 124) = 0.557$, $p = .457$, $\eta_p^2 = .004$, $BF_{01} = 3.923$]. When considered separately, no significant group difference was observed on move closer trials [$M_{\text{DP}} = 0.44$, $SD_{\text{DP}} = 0.40$, $M_{\text{control}} = 0.46$, $SD_{\text{control}} = 0.41$, $t(124) = -0.315$, $p = .753$, $d = -0.06$, $BF_{01} = 4.770$] or move apart trials [$M_{\text{DP}} = -0.36$, $SD_{\text{DP}} = 0.50$, $M_{\text{control}} = -0.25$, $SD_{\text{control}} = 0.43$, $t(124) = -1.295$, $p = .198$, $d = -0.25$, $BF_{01} = 2.354$].

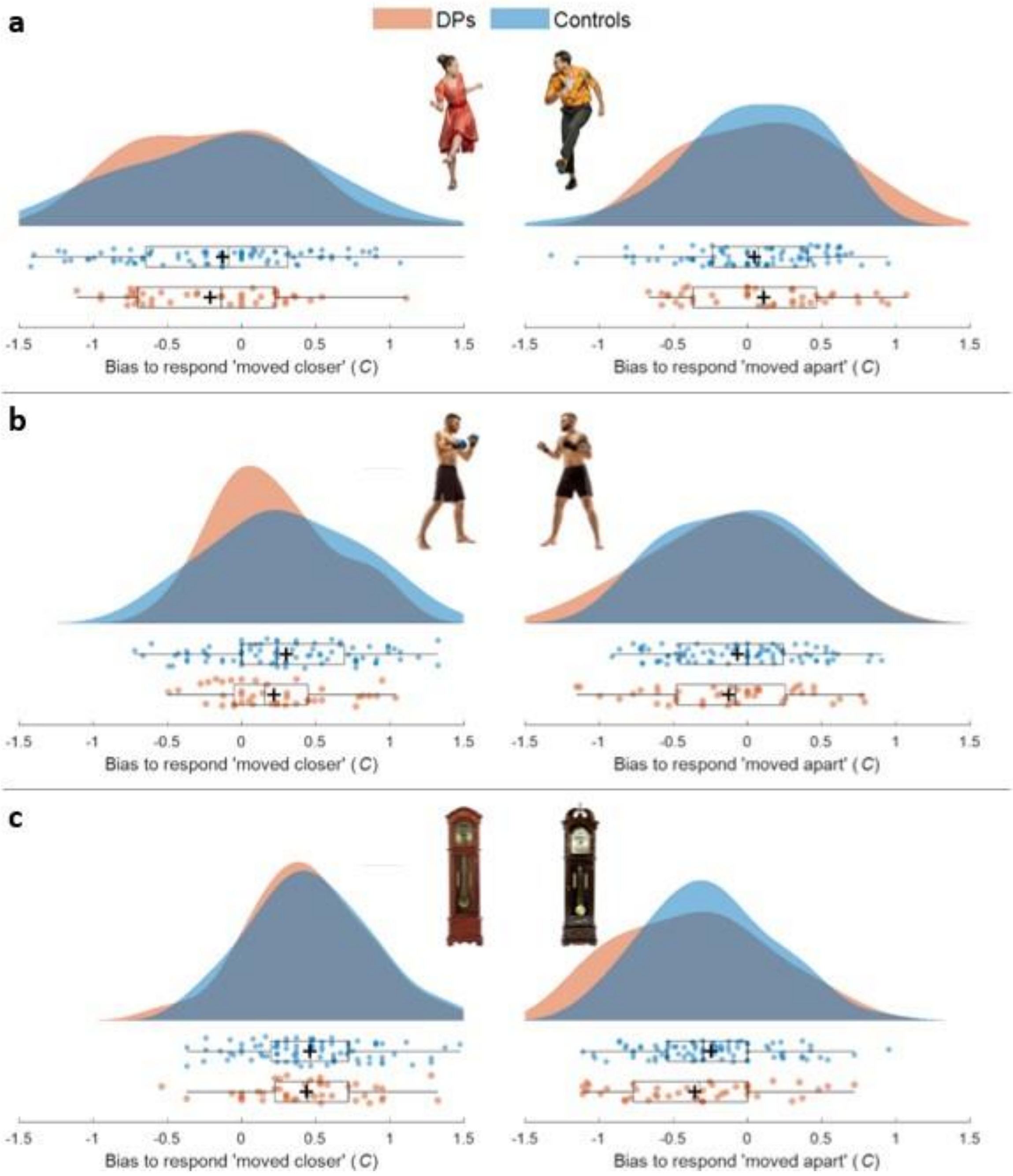

Figure 4.3: Bias (C) estimates for DP and control participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent bias on move closer trials; right-hand plots represent bias on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher C values reflect bias to report a distance change.

4.3.2. Omnibus ANOVA

To maximize statistical power in detecting group differences in the signal detection measures, an omnibus ANOVA was conducted that incorporated all three tasks (dancers, boxers, clocks) as a within-subjects factor. If the control group benefit from an overall perceptual sensitivity advantage to changes in dyadic distance over the DP group, a main effect of Group would be expected. However, as only dyadic stimuli depicting social interactions (dancers, boxers) are hypothesized to confer a perceptual sensitivity advantage under the face-like processing account (Papeo, 2020; Abassi & Papeo, 2022), the analysis was repeated with the clocks task data omitted. Consistent with the individual task analyses, no convincing evidence was found to support differences between DP and control participants in terms of perceptual sensitivity or response bias, regardless of the inclusion of the non-social control task.

Perceptual sensitivity (d')

<u>All tasks.</u> The *d*' estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 11.077$, $p = .001$, $\eta_p^2 = .082$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. There was no main effect of Stimulus Type [$F(2, 248) = 1.745$, $p = .177$, $\eta_p^2 = .014$], indicating sensitivity scores were similar across the dancers ($M = 2.36$, $SD = 0.73$), boxers ($M = 2.36$, $SD = 0.74$) and clocks tasks ($M = 2.45$, $SD = 0.71$). No significant main effect of Group was observed [$F(1, 124) = 1.769$, $p = .186$, $\eta_p^2 = .014$], indicating that DP and control participants exhibited

comparable perceptual sensitivity overall. Furthermore, Group did not significantly interact with Trial Type [*F*(1, 124) = 0.026, $p = .873$, $\eta_p^2 < .001$] or Stimulus Type [*F*(2, 248) = 1.463, $p = .234$, $\eta_p^2 = .012$]. No three-way interaction was observed [*F*(2, 248) = 0.442, $p = .643$, $\eta_p^2 = .004$].

Social tasks only: When the clocks task data was excluded, the results were largely consistent with the full model. The analysis revealed a significant main effect of Trial Type [*F*(1, 124) = 8.519, $p = .004$, $\eta_p^2 = .064$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Stimulus Type was observed [*F*(1, 124) = 0.253, $p = .616$, $\eta_p^2 = .002$], suggesting that sensitivity levels were similar across the boxers and dancers tasks. No significant main effect of Group was observed [*F*(1, 124) = 1.054, $p = .307$, $\eta_p^2 = .008$], indicating that DP and control participants exhibited comparable perceptual sensitivity on the social tasks. Furthermore, Group did not significantly interact with Trial Type [*F*(1, 124) = 0.075, $p = .785$, $\eta_p^2 < .001$] or Stimulus Type [*F*(1, 178) = 0.492, $p = .484$, $\eta_p^2 = .003$]. No three-way interaction was observed [*F*(1, 124) = 2.048, $p = .616$, $\eta_p^2 = .002$].

Bias (C)

All tasks: The C estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [*F*(1, 124) = 60.775, $p < .001$, $\eta_p^2 = .329$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. A main effect of Stimulus Type emerged [*F*(2, 248) = 5.607, $p = .004$, $\eta_p^2 = .043$], whereby participants were more likely to report a distance change on the boxers task (*M* = 0.09, *SD* = 0.49), followed by the clocks (*M* = 0.08, *SD* = 0.56), and dancers tasks (*M* = -0.04, *SD* = 0.54). The main effect of Group did not meet significance [*F*(1, 124) = 1.561, *p* = .214, η_p^2 = .012], indicating that DP and control participants exhibited comparable response biases across the tasks. Furthermore, Group did not significantly interact with Trial Type [*F*(1, 124) = 0.149, *p* = .700, η_p^2 = .001] or Stimulus Type [*F*(2, 248) = 0.320, *p* = .726, η_p^2 = .003]. No three-way interaction was observed [*F*(2, 248) = 0.835, *p* = .435, η_p^2 = .007].

Social tasks only: When the clocks task was excluded, results were largely consistent with the full model. The analysis revealed a non-significant main effect of Trial Type [*F*(1, 124) = 1.573, *p* = .212, η_p^2 = .013], indicating participants were equally likely to report a distance change on move closer trials as they would on move apart trials. A main effect of Stimulus Type emerged [*F*(1, 124) = 6.575, *p* = .012, η_p^2 = .050]. The main effect of Group did not meet significance [*F*(1, 124) = 0.841, *p* = .361, η_p^2 = .007], indicating that DP and control participants exhibited comparable response biases across both social tasks. No significant interaction was found between Group and Trial Type [*F*(1, 124) = 0.965, *p* = .328, η_p^2 = .008] or Group and Stimulus Type [*F*(1, 124) = 0.375, *p* = .541, η_p^2 = .003]. No three-way interaction was observed [*F*(1, 124) = 0.378, *p* = .540, η_p^2 = .003].

4.3.3. Correlational analyses

The group analyses did not yield convincing evidence that DP is associated with impoverished perception of interpersonal distance, challenging the notion that the visual processing of faces and facing dyads rely on overlapping configural mechanisms. To further evaluate the face-like processing hypothesis, individual differences in the diagnostic measures of face processing ability were correlated with performance on the two social tasks (dancers, boxers). Table 4.2. presents the correlation coefficients between face recognition scores (PI20, CFMT, CFMT-A) and distance change detection measures (*d*’, C) for each participant group (controls, DPs, DPs without object agnosia).

No correlations with PI20 scores remained significant after correcting for multiple comparisons. In the DP group, CFMT and CFMT-A scores showed a general trend toward positive associations with sensitivity scores in some conditions of the of the distance change tasks. However, none of these correlations survived correction for multiple comparisons. The only correlation that remained significant after correction was between CFMT-A and response bias in the DP sample (r_p = -.485, *p* = .001), which indicated those with poorer face recognition were less likely to report distance changes on move closer trials in the Dancers task. The theoretical importance of this isolated finding is likely to be low, however, given the broad pattern of non-significant results.

Table 4.2: Correlations between performance on the on the dancer and boxer distance change detection tasks and diagnostic measures of face recognition ability. Correlation coefficients (Pearson's *r*) shown in bold and marked with an asterisk remain significant once correction for multiple comparisons is applied. Note: the control groups' face recognition ability was only assessed on the PI20, not the CFMT or CFMT-A.

		Move closer		**Move apart**	
		d'	**C**	***d'***	**C**
Control participants (*N* = 84)					
Dancer task	PI20	-.081	-.059	-.059	-.026
Boxer task	PI20	-.189	-.168	-.204	-.061
DP participants (*N* = 42)					
Dancer task	PI20	-0.076	.006	-.028	-.009
	CFMT	.216	-.136	.095	-129
	CFMT-A	.290	**-.485***	.324	.058
Boxer task	PI20	-.035	.135	.055	.188
	CFMT	.300	.261	-.121	-.167
	CFMT-A	.075	.373	.142	.007
DP participants without object agnosia (*N* = 34)					
Dancer task	PI20	-.121	-.118	-.070	.031
	CFMT	.079	-.086	-.119	.228
	CFMT-A	.314	-.234	.405	.166
Boxer task	PI20	-.148	.162	-.036	.253
	CFMT	.098	.202	-.188	-.174
	CFMT-A	.183	.221	.253	-.026

4.4. Results excluding DPs with co-occurring object recognition problems

In the foregoing analyses, there was no evidence that sensitivity to distance changes – either between people or objects – differs significantly in DPs and typical controls. However, despite the relatively large sample of DPs ($N = 42$), the Bayesian analyses yielded only anecdotal evidence for the null hypothesis on two of the tasks (Boxers and Clocks). On these tasks, a non-significant trend in which the DP group were less sensitive to distance changes than the typical controls was observed.

It is well known that some DPs experience object recognition difficulties alongside their face recognition problems (Geskin & Behrmann, 2018; Gray et al., 2019; Gray & Cook, 2018). It is therefore no surprise that the DP sample included 8 individuals who exhibited significant impairment on the CCMT (*z*CFMTs < -1.545; Table 4.1). It can be reasoned that some individuals with non-specific object agnosias may show impoverished sensitivity to distance changes when viewing both social and non-social scenes. However, such deficits reveal little about whether dyadic arrangements recruit face-like processing.

To examine whether the inclusion of these 8 DPs was responsible for the non-significant trend seen on the Boxers and Clocks tasks, the analyses described in Section 4.3 were re-run with these individuals excluded. Once again, no significant effects of Group on either signal detection measure or task were found. In the case of sensitivity, however, substantial evidence for the null hypothesis ($BF_{01} > 3.0$) was observed on all three tasks (Table 4.3).

Table 4.3. Comparison of the Bayes Factors (BF_{01}) associated with each group contrast (DPs vs. typical controls) when the eight DPs who show signs of non-face object recognition problems are included in (*N* = 42) or excluded from (*N* = 34) the DP group. Bayes factors that exceed 3.0 represent substantial evidence for the null hypothesis (no group difference) and are emboldened and marked with an asterisk.

			Object agnosic DPs included (*N* = 42)	**Object agnosic DPs excluded (*N* = 34)**
Sensitivity (*d*’)	Dancers	Move closer	**4.986***	**4.232***
		Move apart	**3.922***	**4.675***
	Boxers	Move closer	1.812	**3.455***
		Move apart	2.808	**3.517***
	Clocks	Move closer	1.790	**3.772***
		Move apart	2.035	**3.936***
Bias (C)	Dancers	Move closer	**3.870***	**3.556***
		Move apart	**3.933***	**3.166***
	Boxers	Move closer	**3.320***	**3.730***
		Move apart	**4.075***	2.242
	Clocks	Move closer	**4.770***	**4.577***
		Move apart	2.354	2.880

4.4.1. Signal detection measures

Perceptual sensitivity (d')

Dancers. The *d*' estimates obtained (Figure 4.4a) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 5.630$, $p = .019$, $\eta_p^2 = .046$, $BF_{01} = 0.497$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116) = 0.076$, $p = .784$, $\eta_p^2 < .001$, $BF_{01} = 3.929$], indicating that the DPs ($M = 2.41$, $SD = 0.64$) and controls ($M = 2.38$, $SD = 0.63$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [$F(1, 116) = 0.253$, $p = .616$, $\eta_p^2 = .002$, $BF_{01} = 4.433$]. When considered separately, no significant group difference was observed on move closer [$M_{DP} = 2.52$, $SD_{DP} = 0.71$, $M_{control} = 2.45$, $SD_{control} = 0.78$, $t(116) = 0.475$, $p = .636$, $d = 0.10$, $BF_{01} = 4.232$] or move apart trials [$M_{DP} = 2.31$, $SD_{DP} = 0.59$, $M_{control} = 2.31$, $SD_{control} = 0.75$, $t(116) = -0.018$, $p = .986$, $d = -0.004$, $BF_{01} = 4.675$].

Boxers. The *d*' estimates obtained (Figure 4.4b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 5.028$, $p = .027$, $\eta_p^2 = .042$, $BF_{01} = 0.422$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116) = 0.837$, $p = .362$, $\eta_p^2 = .007$, $BF_{01} = 2.586$, indicating that the DPs ($M = 2.33$, $SD = 0.52$) and controls ($M = 2.45$, $SD = 0.82$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial type and Group [F(1,

116) = 0.003, p = .956, $\eta_p^2 < .001$, BF_{01} = 4.439]. When considered separately, no significant group difference was observed on move closer [M_{DP} = 2.38, SD_{DP} = 0.67, $M_{control}$ = 2.50, $SD_{control}$ = 0.71, $t(116) = -0.827$, p = .410, d = -0.17, BF_{01} = 3.455] or move apart trials [M_{DP} = 2.22, SD_{DP} = 0.71, $M_{control}$ = 2.35, $SD_{control}$ = 0.79, $t(116) = -0.802$, p = .424, d = -0.16, BF_{01} = 3.517].

Clocks. The *d*' estimates obtained (Figure 4.4c) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116)$ = 4.764, p = .031, η_p^2 = .039, BF_{01} = 0.442], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116)$ = 0.568, p = .453, η_p^2 = .005, BF_{01} = 3.064], indicating that the DPs (M = 2.44, SD = 0.49) and controls (M = 2.54, SD = 0.77) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [$F(1, 116)$ = 0.007, p = .933, $\eta_p^2 < .001$, BF_{01} = 4.857]. When considered separately, no significant group difference was observed on move closer [M_{DP} = 2.49, SD_{DP} = 0.69, $M_{control}$ = 2.59, $SD_{control}$ = 0.71, $t(116) = -0.696$, p = .488, d = -0.14, BF_{01} = 3.772] or move apart trials [M_{DP} = 2.35, SD_{DP} = 0.59, $M_{control}$ = 2.44, $SD_{control}$ = 0.73, $t(116) = -0.624$, p = .534, d = -0.13, BF_{01} = 3.936].

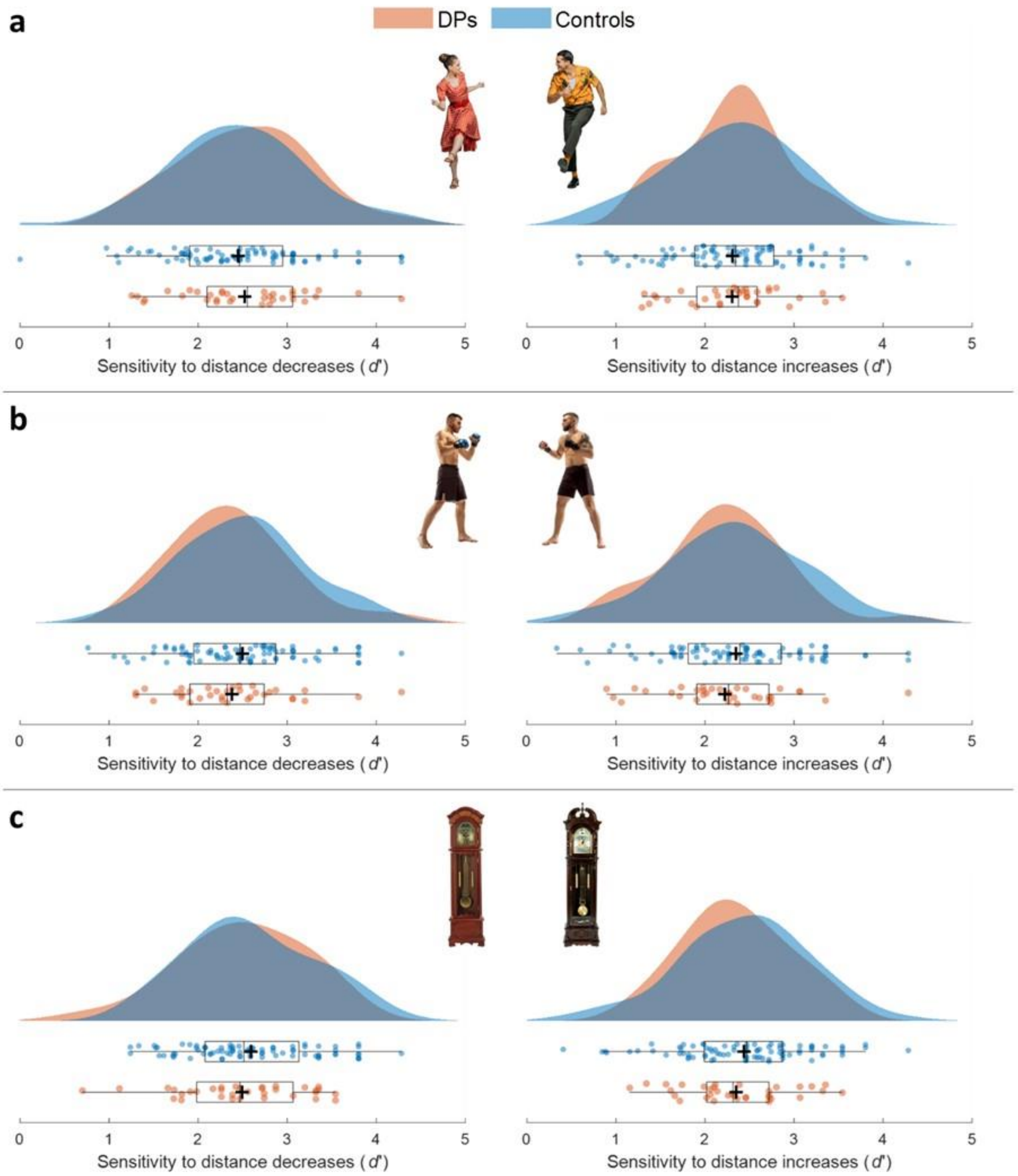

Figure 4.4: Perceptual sensitivity (*d′*) exhibited by non-object agnosic DP and control participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent sensitivity on move closer trials; right-hand plots represent sensitivity on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher *d*’ values reflect superior sensitivity.

Bias (C)

Dancers. The C estimates obtained (Figure 4.5a) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 11.589$, $p < .001$, $\eta_p^2 = .091$, $BF_{01} = 0.025$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116) < .001$, $p = .976$, $\eta_p^2 < .001$, $BF_{01} = 5.735$], indicating that the DPs ($M = -0.04$, $SD = 0.29$) and controls ($M = -0.41$, $SD = 0.46$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 116) = 1.372$, $p = .244$, $\eta_p^2 = .012$, $BF_{01} = 2.429$]. When considered separately, no significant group difference was observed on move closer trials [$M_{DP} = -0.22$, $SD_{DP} = 0.45$, $M_{control} = -0.13$, $SD_{control} = 0.63$, $t(116) = -0.786$, $p = .433$, $d = -0.16$, $BF_{01} = 3.556$] or move apart trials, [$M_{DP} = 0.14$, $SD_{DP} = 0.49$, $M_{control} = 0.05$, $SD_{control} = 0.46$, $t(116) = 0.939$, $p = .350$, $d = 0.19$, $BF_{01} = 3.166$].

Boxers. The C estimates obtained (Figure 4.5b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 37.012$, $p < .001$, $\eta_p^2 = .242$, $BF_{01} < .001$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116) = 1.976$, $p = .163$, $\eta_p^2 = .017$, $BF_{01} = 2.934$], indicating that the DPs ($M = 0.04$, $SD = 0.26$) and controls ($M = 0.14$, $SD = 0.41$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 116) = 0.182$, $p = .670$, $\eta_p^2 = .002$, $BF_{01} = 4.632$]. When considered separately, no significant group difference was observed on move closer trials [$M_{DP} = 0.24$, $SD_{DP} = 0.35$, $M_{control} = 0.30$, $SD_{control} = 0.49$,

$t(116) = -0.714$, $p = .476$, $d = -0.15$, $BF_{01} = 3.730$] or move apart trials [$M_{DP} = -0.19$, $SD_{DP} = 0.51$, $M_{control} = -0.07$, $SD_{control} = 0.45$, $t(116) = -1.290$, $p = .200$, $d = -0.26$, $BF_{01} = 2.242$].

Clocks. The C estimates obtained (Figure 4.5c) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 144.571$, $p < .001$, $\eta_p^2 = .555$, $BF_{01} < .001$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Group was observed [$F(1, 116) = 0.929$, $p = .337$, $\eta_p^2 = .008$, $BF_{01} = 4.927$], indicating that the DPs ($M = 0.06$, $SD = 0.23$) and controls ($M = 0.12$, $SD = 0.36$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 116) = 0.378$, $p = .540$, $\eta_p^2 = .003$, $BF_{01} = 4.432$]. When considered separately, no significant group difference was observed on move closer trials [$M_{DP} = 0.44$, $SD_{DP} = 0.35$, $M_{control} = 0.46$, $SD_{control} = 0.41$, $t(116) = -0.220$, $p = .826$, $d = -0.05$, $BF_{01} = 4.577$] or move apart trials [$M_{DP} = -0.34$, $SD_{DP} = 0.47$, $M_{control} = -0.25$, $SD_{control} = 0.43$, $t(116) = -1.047$, $p = .297$, $d = -0.21$, $BF_{01} = 2.880$].

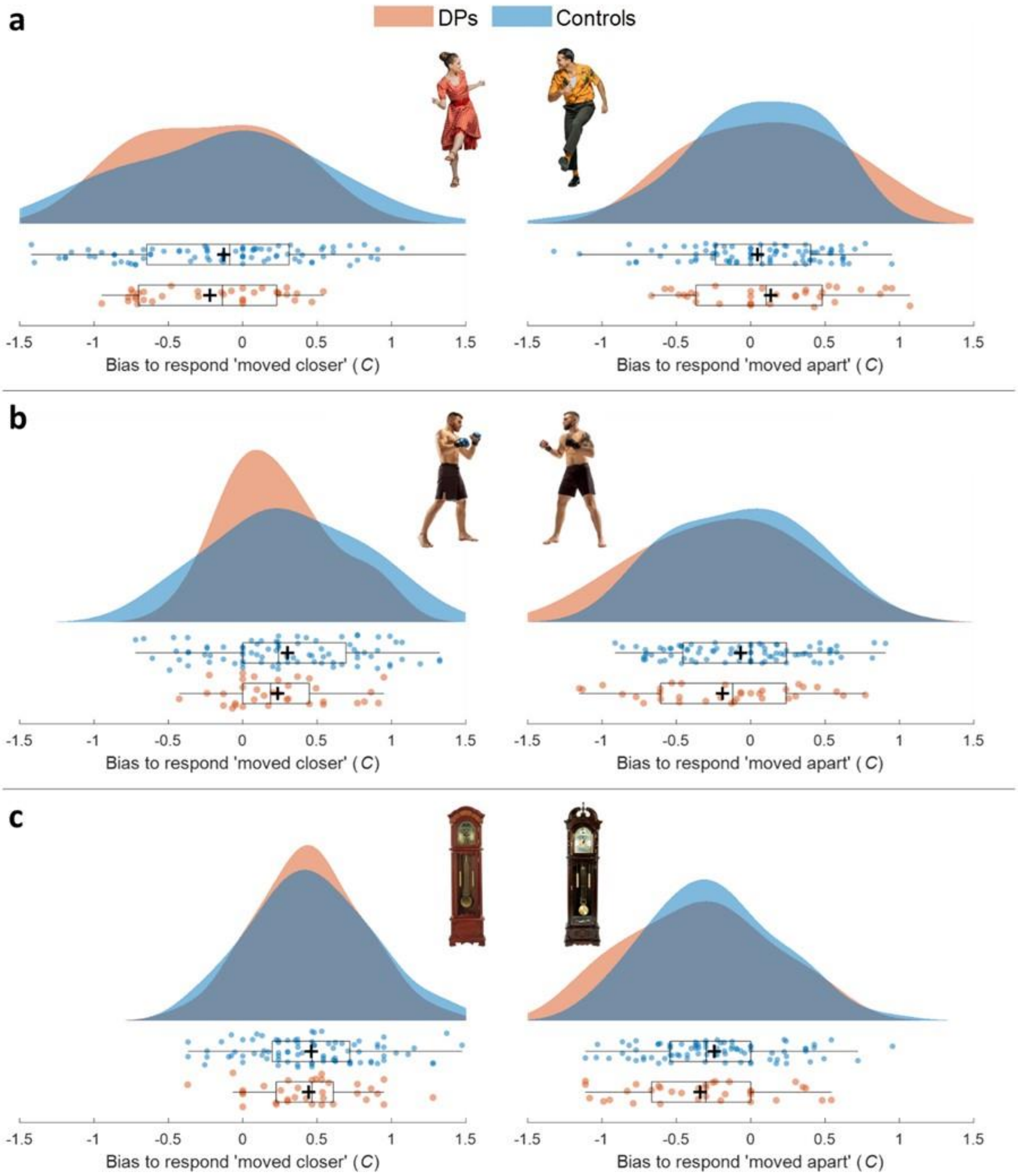

Figure 4.5: Bias (*C*) estimates for non-object agnosic DP and control participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent bias on move closer trials; right-hand plots represent bias on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher *C* values reflect bias to report a distance change.

4.4.2. Omnibus ANOVA

Perceptual sensitivity (d′)

All tasks. The *d′* estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 9.824$, $p = .002$, $\eta_p^2 = .078$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. There was no main effect of Stimulus Type [$F(2, 232) = 2.211$, $p = .112$, $\eta_p^2 = .019$], indicating sensitivity scores were similar across the dancers ($M = 2.39$, $SD = 0.74$), boxers ($M = 2.39$, $SD = 0.74$) and clocks tasks ($M = 2.49$, $SD = 0.70$). No significant main effect of Group was observed [$F(1, 116) = 0.276$, $p = .600$, $\eta_p^2 = .002$], indicating that DP and control participants exhibited comparable perceptual sensitivity overall. Furthermore, Group did not significantly interact with Trial Type [$F(1, 116) = 0.055$, $p = .815$, $\eta_p^2 < .001$] or Stimulus Type [$F(2, 232) = 1.309$, $p = .272$, $\eta_p^2 = .011$]. No three-way interaction was observed [$F(2, 232) = 0.148$, $p = .863$, $\eta_p^2 = .001$].

Social tasks only: When the clocks task data was excluded, the results were largely consistent with the full model. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 7.865$, $p = .006$, $\eta_p^2 = .063$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Stimulus Type was observed [$F(1, 116) = 0.455$, $p = .501$, $\eta_p^2 = .004$], suggesting that sensitivity levels were similar across the boxers and dancers tasks. No significant main effect of Group was observed [$F(1, 116) = 0.127$, $p = .722$, $\eta_p^2 = .001$], indicating that DP and control participants exhibited comparable perceptual sensitivity on the social tasks. Furthermore, Group did not significantly interact with Trial Type [$F(1, 116) = 0.124$, $p = .725$, $\eta_p^2 = .001$] or Stimulus Type [$F(1, 116) = 2.337$, $p = .129$, $\eta_p^2 = .020$]. No three-way interaction was observed [$F(1, 116) = 0.175$, $p = .676$, $\eta_p^2 = .002$].

Bias (C)

<u>All tasks</u>: The C estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (DP, control) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 53.007$, $p < .001$, $\eta_p^2 = .314$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. A main effect of Stimulus Type emerged [$F(2, 232) = 4.678$, $p = .010$, $\eta_p^2 = .039$], whereby participants were more likely to report a distance change on the clocks task ($M = 0.09$, $SD = 0.55$), followed by the boxers ($M = 0.09$, $SD = 0.50$), and dancers tasks ($M = -0.04$, $SD = 0.54$). The main effect of Group did not meet significance [$F(1, 116) = 1.406$, $p = .238$, $\eta_p^2 = .012$], indicating that DP and control participants exhibited comparable response biases across the tasks. Furthermore, Group did not significantly interact with Trial Type [$F(1, 116) = 0.044$, $p = .835$, $\eta_p^2 < .001$] or Stimulus Type [$F(2, 232) = 0.543$, $p = .582$, $\eta_p^2 = .005$]. No three-way interaction was observed [$F(2, 232) = 1.108$, $p = .332$, $\eta_p^2 = .009$].

<u>Social tasks only</u>: When the clocks task was excluded, results were largely consistent with the full model. The analysis revealed a non-significant main effect of Trial Type [$F(1, 116) = 1.908$, $p = .170$, $\eta_p^2 = .016$], indicating participants were equally likely to report a distance change on move closer trials as they would on move apart trials. A main effect of Stimulus Type emerged [$F(1, 116) = 4.637$, $p = .033$, $\eta_p^2 = .038$]. The main effect of Group did not

meet significance [$F(1, 116) = 1.009$, $p = .317$, $\eta_p^2 = .009$], indicating that DP and control participants exhibited comparable response biases across both social tasks. No significant interaction was found between Group and Trial Type [$F(1, 116) = 0.437$, $p = .510$, $\eta_p^2 = .004$] or Group and Stimulus Type [$F(1, 116) = 0.783$, $p = .378$, $\eta_p^2 = .007$]. No three-way interaction was observed [$F(1, 116) = 1.236$, $p = .269$, $\eta_p^2 = .011$].

4.5. Discussion

Compared with other facets of social vision, we know relatively little about the visual processing of social interactions. Recently, however, it has been suggested that upright dyads arranged face-to-face may engage specialised processing (Abassi & Papeo, 2020; Quadflieg & Koldewyn, 2017; Vestner et al., 2019). One perspective is that dyads recruit a form of configural processing, analogous to that recruited by individual faces (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). Like faces, facing dyads are also thought to be processed with high-priority within the visual system (Papeo et al., 2019; Vestner et al., 2019). Moreover, dyads and faces appear to engage common areas of the social perception network, including FFA (Abassi & Papeo, 2020, 2022; Quadflieg et al., 2015) and pSTS (Isik et al., 2017; Walbrin et al., 2018). In light of the foregoing similarities between the visual processing of faces and facing dyads, the study described in this chapter sought to determine whether individuals with DP – who experience life-long face recognition difficulties – show atypical perception of dyadic social interactions.

Participants completed three distance change detection tasks in a counterbalanced order. Two of the tasks depicted distance changes during dyadic social interactions – fighting and dancing. In these tasks, participants had to judge whether pairs of boxers and dancers moved closer together or further apart. On half the trials (move closer trials), participants judged whether the stimulus elements moved closer together or whether the distance remained constant. On half the trials (move apart trials), participants judged whether the stimulus elements moved further apart or whether the distance remained constant. A third task depicted distance changes using non-social objects – a pair of grandfather clocks.

If DP is associated with impoverished perception of dyadic interactions, it can be reasoned that DPs should exhibit diminished sensitivity to distance changes on the dancers task and the boxers task, but not on the clocks task. Contrary to this prediction, however, the DPs and controls did not differ significantly in their ability to detect distance changes on any of the tasks (dancers, boxers, clocks), irrespective of movement type (move closer, move apart). Bayesian analyses conducted on the overall sample (42 DPs, 84 typical controls) revealed substantial evidence ($BF_{01} > 3.0$; Jeffreys, 1998) for the null hypothesis (i.e., no group difference) in both the move closer and move apart conditions of the Dancers Task. On the Boxers Task and the Clocks Task, the evidence for the null hypothesis was anecdotal $BF_{01} < 3.0$) for both move closer and move apart conditions.

It is well-established that some individuals with DP exhibit signs of co-occurring object agnosia, in addition to their characteristic face recognition impairments (Geskin & Behrmann, 2018; Gray et al., 2019; Gray & Cook, 2018). Consistent with this view, 8 of the 42 DPs that took part in the study exhibited significantly impaired car identification on the CCMT at the single-case level. When these individuals were excluded – i.e., when the group comparisons were limited to the 34 DPs with (relatively) face-specific perceptual deficits – substantial evidence ($BF_{01} > 3.0$) for the null hypothesis (no group difference) was observed on all three tasks (dancers, boxers, clocks), irrespective of movement type.

Given that DP is associated with lifelong face processing difficulties, these findings argue against the view that dyadic interactions engage face-like processing (e.g., Papeo, 2020). Perceptual decisions about interpersonal distance provide a strong test of this hypothesis because this attribute is an emergent property of the presence of two actors. Judgements about interpersonal distance cannot be based on the cues extracted from one or the other individual; rather, interpersonal distance is a key configural feature of dyadic arrangements. The fact that DPs make broadly typical judgements about interpersonal distance implies that they are able to encode the configural features of facing dyads without impairment.

The view that facing dyads engage specialized visual processing has not gone unchallenged. Much of the evidence for this position has been obtained by comparing behavioural (Gray, Barber, et al., 2017; Papeo et al., 2017, 2019; Vestner et al., 2019) and neural (Abassi & Papeo, 2020, 2022; Quadflieg et al., 2015) markers seen when observers view dyads arranged face-to-face and back-to-back. The logic here is that non-facing arrangements contain the same face, body, and action cues to those seen in face-to-face arrangements, but unlike face-to-face arrangements, do not imply social interaction. However, this manipulation may also have unintended consequences for the way that observers attend to dyadic stimuli.

Individual faces and bodies viewed in profile cue observers' visuospatial attention leftwards or rightwards, in accordance with their directionality (Langton & Bruce, 1999; Vestner et al., 2021, 2022). Importantly, the arrangement of these attention cues is very different when viewing face-to-face and back-to-back dyadic arrangements (Vestner et al., 2020). In face-to-face arrangements, these attention cues form an 'attention trap': the face / body on the left of the dyad directs observers' attention to the face / body on the right, which in turn re-directs observers' attention back to the face / body on the left. When dyads are arranged back-to-back, however, the same face / body cues direct observers' attention toward the display periphery. Evidence from eye-tracking confirms that observers inspect face-to-face and back-to-back stimuli in different ways; in particular, observers spend more time fixating the actors' faces when viewing facing dyads (Kujala et al., 2012).

Together, these attentional / fixation differences may explain why facing dyads are found more quickly in visual search tasks (Papeo et al., 2019; Vestner et al., 2019) and are detected more often in backwards masking paradigms (Papeo et al., 2017), than back-to-back dyads. These differences may also explain why the expression cues of one actor alter the perceived emotion of another when the two are arranged face-to-face, but not back-to-back (Abramson et al., 2021; Gray, Barber, et al., 2017). Similarly, evidence that different cortical regions (e.g., EBA, FFA) respond more strongly when viewing facing dyads than when viewing non-facing dyads (e.g., Abassi & Papeo, 2020, 2022), may reflect attentional modulation of single actor processing, not specialized processing of facing dyads.

The origins of DP remain poorly understood. According to one view, DP is a product of a domain-general deficit processing feature configurations that hampers the individuation of faces and certain non-face objects (Avidan et al., 2011; Gerlach et al., 2017; Gerlach & Starrfelt, 2018; Tanzer et al., 2013). Consistent with this account, some authors have reported that DPs exhibit reduced global precedence effects when asked to identify compound ('Navon') letter stimuli (Avidan et al., 2011; Gerlach et al., 2017). The present results are somewhat inconsistent with this view, however. Where observers experience a domain-general difficulty processing feature configurations, one might expect to see impoverished judgments of spatial relations within visual scenes. Contrary to this view, the present findings suggest that the majority of individuals with DP exhibit broadly typical judgements of inter-actor and inter-object distance.

At least two caveats are with nothing, however. First, it remains possible that a domain-general deficit processing feature configurations may account for the perceptual difficulties experienced by certain individuals within the DP population; for example, some or all of those who exhibit signs of co-occurring object recognition difficulties. Second, it is possible that a domain-specific form of configural face processing is disrupted in DP (DeGutis et al., 2012, 2014). Such an impairment would not be expected to generalize to judgements of inter-actor and inter-object distance.

It remains possible that the DPs in the present study achieved the same levels of distance change discrimination as typical controls but did so via a different route. Many DPs are adept at developing strategies that allow them to infer the correct solution on perceptual tasks (e.g., matching facial photographs using specular highlights). If DPs and controls are using different mechanistic routes to make their perceptual decisions, dyadic arrangement manipulations – notably face-to-face vs. back-to-back presentation (Gray, Barber, et al., 2017; Papeo et al., 2017, 2019; Vestner et al., 2019) – might induce differential effects on the perceptual decisions of DPs and typical controls. In a similar vein, it may be useful to examine whether similar neural markers of dyadic processing (e.g., Abassi & Papeo, 2020; Isik et al., 2017) are observed in DPs and typical controls.

In summary, it was found that DPs – individuals who exhibit lifelong face processing difficulties – show typical sensitivity to changes in interpersonal distance, a key configural feature of dyadic arrangements. These findings cast doubt on the notion that dyadic interactions engage face-like visual processing mechanisms and suggest a dissociation between these facets of social vision.

Chapter 5: Autistic adults exhibit typical sensitivity to changes in interpersonal distance

The visual processing differences seen in autism often impede individuals' visual perception of the social world. In particular, many autistic people exhibit poor face recognition. The study described in this chapter sought to determine whether autistic adults also show impaired perception of dyadic social interactions – a class of stimulus thought to engage face-like visual processing. Participants completed distance change detection tasks, in which they had to make perceptual decisions about the distance between two boxers or two dancers. On half of the trials, participants judged whether the actors moved closer together; on the other half, whether they moved further apart. In a non-social control task, participants made similar judgements about two grandfather clocks. Participants' face recognition ability was also assessed using standardized measures. The autistic and non-autistic observers showed similar levels of perceptual sensitivity to changes in interpersonal distance when viewing social interactions. As expected, however, the autistic observers showed clear signs of impaired face recognition. Despite putative similarities between the visual processing of faces and dyadic social interactions, the results reported in the chapter suggest that these two facets of social vision may dissociate.

5.1. Introduction

Autism spectrum disorder (hereafter autism) is a neurodevelopmental condition associated with differences in social communication, together with focused patterns of behaviours and intensive interests (APA, 2013). For a substantial portion of the autistic population these core difficulties are thought to present alongside differences in visual processing (Behrmann, Avidan, et al., 2006; Dakin & Frith, 2005; Simmons et al., 2009). In certain contexts, the perceptual differences seen in autism may confer advantages (Bertone et al., 2005; Gliga et al., 2015; Mottron et al., 2006). However, the processing differences seen in autism often impede individuals' visual perception of the social world. In particular, many autistic people experience difficulties when asked to identify or match faces (Gehdu et al., 2022; Hedley et al., 2011; Minio-Paluello et al., 2020; Stantić et al., 2022). These difficulties may extend to other facets of social vision including the perception of facial motion (Keating et al., 2022; Shah et al., 2016) and the interpretation of whole-body actions (Atkinson, 2009).

It is widely thought that faces (e.g., Farah et al., 1998; Maurer et al., 2002; Piepers & Robbins, 2012) and bodies (Reed et al., 2003, 2006) engage configural processing, whereby information from local regions is integrated into a unified, coherent percept, facilitating accurate identification and interpretation. According to configural accounts, this processing affords greater sensitivity to the spatial relationships between component features (Farah et al., 1998; Maurer et al., 2002; Piepers & Robbins, 2012). For example, participants exhibit greater sensitivity to the distances between the eyes, nose, and mouth when faces are shown upright – a condition thought to afford configural processing – than when faces are shown upside-down – a condition thought to reduce configural processing (Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001b; Leder et al., 2001).

According to one prominent view, autistic observers exhibit poor perception of faces and bodies because of a local processing style undermines their ability to process social stimuli in a configural manner (Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Happé, 1996; Happé & Frith, 2006; Reed et al., 2007). Consistent with this suggestion, autistic observers sometimes show atypical composite face effects; a key behavioural marker of configural / holistic processing, whereby information from one stimulus region alters how observers perceive other regions (Gauthier et al., 2009; Shah et al., 2016; Teunisse & de Gelder, 2003).

Compared with other facets of social vision, we know relatively little about the visual processing of social interactions. However, several recent results suggest the possibility that upright face-to-face dyads engage specialised processing (Papeo, 2020; Quadflieg & Koldewyn, 2017). For example, when viewing dyads arranged face-to-face – but not back-to-back – the facial and bodily expressions of one actor bias how observers interpret the expressions of the other (Abramson et al., 2021; Gray, Barber, et al., 2017). Similarly, dyadic targets shown face-to-face are found faster in visual search tasks, than dyadic targets shown back-to-back (Papeo et al., 2019; Vestner et al., 2019). When dyads are presented briefly (30ms) and subject to backwards masking, participants are also better able to detect upright face-to-face arrangements, than inverted face-to-face arrangements – the so-called two-body inversion effect (Papeo et al., 2017). Conversely, little or no modulation-by-orientation is observed for back-to-back dyads.

These findings have led some authors to speculate that pairs of individuals shown upright and face-to-face engage face-like visual processing (Papeo, 2020). In particular, it has been suggested that facing dyads may recruit a form of configural processing, analogous to that engaged by individual faces (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). It is hypothesised that relations among body pairs – their configuration – are captured automatically, aiding the detection, discrimination, and interpretation of social interactions (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017). Drawing on domain-specific accounts of face processing (e.g., Farah et al., 1998), it is proposed that the configural processing engaged by dyads is gated such that it is selectively recruited when viewing upright facing dyads – dyads shown back-to-back or upside-down are not thought to be processed configurally (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017).

Potentially consistent with this account, findings from neuroimaging suggest that facing dyads engage several neural regions involved in the perception of faces. For example, the fusiform face area (FFA) – a region widely implicated in the perception and identification of faces (Kanwisher et al., 1997; Kanwisher & Yovel, 2006) – exhibits a stronger response when observers view dyads arranged face-to-face than when viewing dyads arranged back-to-back (Abassi & Papeo, 2020, 2022). Similarly, a stronger FFA response is seen when observers view semantically incongruous facing dyads than when they view semantically congruous facing dyads (Quadflieg et al., 2015). The posterior superior temporal sulcus (pSTS) also appears to contribute to the perception and interpretation of dyadic interactions (Isik et al., 2017; Walbrin et al., 2018) and faces (Pitcher, Walsh, et al., 2011; Pitcher & Ungerleider, 2021; Tsantani et al., 2019).

The study described in this chapter sought to determine if autistic observers exhibit impaired perception of dyadic social interactions. It is well-established that many autistic individuals exhibit atypical perception of faces (e.g., Gehdu et al., 2022; Hedley et al., 2011; Keating et al., 2022; Minio-Paluello et al., 2020; Shah et al., 2016; Stantić et al., 2022). In light of potential parallels between the visual processing recruited by faces and facing dyads – for example, the engagement of configural processing and common neural substrates – it was reasoned that the perception of dyads might also be atypical in this population.

In principle, atypical social interaction perception might contribute to the social and communicative difficulties experienced by autistic individuals. The interactions we observe around us are a rich source of information about social behaviour (Eggleston et al., 2021; Gray, Barber, et al., 2017; Over et al., 2020). To some extent, we may learn how to interact by observing the social interactions of others. For example, interaction observation affords opportunities to learn about turn-taking, interpersonal distance, verbal and non-verbal gestures, and the norms that govern these behaviours. Where observed, deficits of interaction perception may limit opportunities for this kind of learning.

To date, little is known about the perception of facing dyads in autism. However, recent results obtained with non-autistic participants suggest that dyad perception may vary as a function of autistic traits. For example, Abassi and Papeo (2022) reported a significant correlation between the strength of the two-body inversion effect exhibited by non-autistic participants (N = 22) and their scores on the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001). There is also some evidence that high-AQ observers may use head and body cues differently when appraising social interactions. In their second experiment (N = 104), Williams and Chakrabarti (2023) found that observers with higher AQ scores were influenced more by body orientation when judging whether or not two actors were interacting.

The focus of the present investigation was on whether autistic individuals showed impaired perception of interpersonal distance. Perceptual decisions about interpersonal distance are of interest because this attribute is an emergent property of the presence of two actors.

Judgements about interpersonal distance cannot be based on the cues extracted from one individual; rather, interpersonal distance is a key configural feature of dyadic arrangements.

If the visual detection and encoding of dyadic interactions is augmented by configural processing (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017), one would expect the perception of interpersonal distance to be enhanced in those with typical configural processing ability. By way of analogy, the perception of inter-feature distances are thought to be enhanced by configural processing when observing faces (e.g., Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001b; Leder et al., 2001). If i) dyadic social interactions recruit configural processing, and ii) this processing is aberrant in autistic observers (Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Happé, 1996; Happé & Frith, 2006), it can be reasoned that observers with autism ought to exhibit poor dyad perception relative to non-autistic observers. It was therefore hypothesised that autistic observers should be less sensitive to changes in interpersonal distance than non-autistic controls.

In addition to the perception of interpersonal distance, the face recognition ability of the autistic and non-autistic participants was also assessed. It is well-established that autistic observers exhibit worse face recognition than non-autistic controls (e.g., Gehdu et al., 2022; Hedley et al., 2011; Stantić et al., 2022). In the event that typical perception of interpersonal distance was observed in the autistic sample, it was reasoned that it would be valuable to replicate this group difference to establish whether the perceptual mechanisms recruited by faces and dyadic social interactions dissociate; that is, whether these mechanisms can be selectively impaired.

5.2. Method

5.2.1. Participants

Sixty participants with a clinical diagnosis of autism (M_{age} = 34.10 years, SD_{age} = 11.57 years) were recruited through www.ukautismresearch.org. All autistic participants exhibited typical levels of intelligence and verbal ability. Of the 19 individuals who described their sex as male, 16 described their gender identity as male, and 3 identified as non-binary. Of the 40 individuals who described their sex as female, 31 described their gender identity as female, 6 identified as non-binary, 2 identified as male, and 1 preferred not to state their gender identity. One participant preferred not to describe their sex and identified as non-binary. All autistic participants had received an autism diagnosis (e.g., Autism Spectrum Disorder, Asperger's Syndrome) from a clinical professional (General practitioner, Neurologist, Psychiatrist, or Clinical Psychologist) based in the UK. All participants in the autistic group also reached cut-off (a score $\geq$ 32) on the 50-item Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001).

One hundred and twenty non-autistic individuals (M_{age} = 33.09 years, SD_{age} = 8.47 years) were recruited through www.prolific.co to serve as a control group. Within this group, 42 participants described their sex and gender identity as male and 78 described their sex and gender identity as female. Any non-autistic participants who scored above cut-off on the AQ were replaced (in total, seven were replaced on this basis).

As expected, the mean AQ score of the non-autistic group (M = 17.91, SD = 5.45) was significantly different from that of the autistic group (M = 41.5, SD = 4.51) [t(178) = 29.010, p < .001]. The autistic and non-autistic groups did not differ significantly in terms of age

[$t(178) = 0.664$, $p = .508$] or sex [$\chi^2_{(1)} = 2.148$, $p = .342$]. However, they did differ significantly in terms of gender identity [$\chi^2_{(2)} = 23.474$, $p < .001$].

To ensure that the autistic and non-autistic participants were approximately matched for non-verbal intelligence, all participants completed a measure of abstract visuospatial reasoning. Forty items were selected from The Matrix Reasoning Item Bank (MaRs-IB; Chierchia et al., 2019). Participants were given 30 seconds to complete each puzzle by selecting the correct answer from four options. Participants responded using keyboard number keys (1-4), were given a 5-second warning before the end of each trial, and received no feedback. Each participant attempted all forty items. Participants had to complete 3 practice trials correctly before beginning the test. The scores of the autistic participants ($M = 25.78$, $SD = 5.23$, range: 14 to 37) and the non-autistic controls ($M = 24.53$, $SD = 6.99$, range: 8 to 38) did not differ significantly [$t(178) = 1.224$, $p = .223$].

To be eligible, all participants (autistic and non-autistic) were required to be aged between 18 and 65, to have normal or corrected-to-normal visual acuity, to have never received a diagnosis of schizophrenia, and to be a current UK resident. Non-autistic participants had to have a Prolific rating above 85%. Power analysis conducted *a priori* using G-Power 3.1 (Faul et al., 2009) indicated that the chances of detecting a medium-sized effect ($d = .5$) with two independent groups of $N = 60$ and $N = 120$, exceeded 85% (88.2%) when running an independent samples *t*-test (two-tailed, $\alpha = .05$).

Ethical clearance was granted by the Departmental Ethics Committee for Psychological Sciences, Birkbeck, University of London. The experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent and were reimbursed for their time.

5.2.2. Distance change detection tasks

Participants completed three distance change detection tasks in a counterbalanced order. Two of the tasks depicted distance changes during dyadic social interactions – fighting and dancing. In these tasks, participants had to judge whether pairs of boxers and dancers moved closer together or further apart. On half the trials (move closer trials), participants judged whether the stimulus elements moved closer together or whether the distance remained constant. On half the trials (move apart trials), participants judged whether the stimulus elements moved further apart or whether the distance remained constant. A third task depicted distance changes using non-social objects – a pair of grandfather clocks. The three tasks had an identical format (Figure 5.1) and were administered online via Gorilla (Anwyl-Irvine et al., 2020). The tasks had to be completed using a personal computer or laptop – they would not run on a tablet or mobile device. The experimental tasks are available as Open Materials at gorilla.sc (https://app.gorilla.sc/openmaterials/656322).

With the exception of the following details, the three distance change tasks were identical in format to those described in Chapter 4 (Section 4.2). The two stimulus images presented within each trial (e.g., images of the two dancers) were each presented for 500 ms instead of 750 ms. Consistent with the Chapter 4 tasks, the people / clocks shown in the first image always appeared ~180 cm apart. However, the magnitude of distance change on signal present trials was reduced by ~5 cm. On signal present move closer trials the people / clocks would appear ~155 cm apart, and on signal present move apart trials the people / clocks would appear ~205 cm apart.

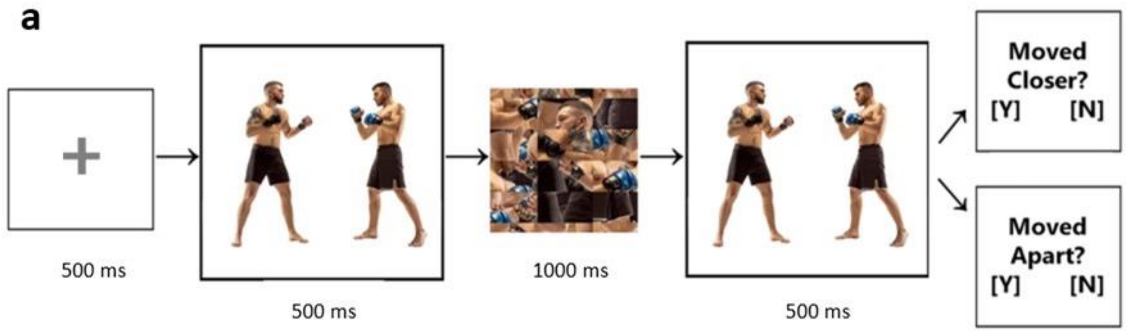

Figure 5.1: Overview of task format. **(a)** Schematic illustration of the sequence of an experimental trial in which participants viewed the Boxer stimuli. Interpersonal distances depicted are illustrative and not to scale.

Eight attention checks were interspersed throughout the task. Participants were required to identify which shape (a circle, square, triangle, or diamond) was presented for 1000 ms immediately prior to the response prompt. Participants who failed to respond correctly on 6 of the 8 attention checks were excluded and replaced (rule determined prior to analysis). One autistic participant and 2 non-autistic participants were replaced on this basis.

Performance was analysed using signal detection theory (Green & Swets, 1966). For each participant, separate measures of perceptual sensitivity (*d*′) and bias (C) were calculated for move closer and move apart trials, based on their performance in each of the three tasks. Signal detection analyses were conducted in Matlab (The MathWorks Inc., Natick, USA) using routines from the Palamedes toolbox (Prins & Kingdom, 2009). The supporting data are available via the Open Science Framework (https://osf.io/u54bk/).

5.2.3. Measures of face recognition ability

All participants completed two measures designed to assess their face recognition ability following the distance change tasks. Both assessments were completed online using Gorilla (Anwyl-Irvine et al., 2020).

The Twenty-item Prosopagnosia Index (PI20; Shah, Gaule, et al., 2015; Gray, Bird, et al., 2017; Tsantani et al., 2021) is a widely-used self-report questionnaire which measures the presence of traits associated with developmental prosopagnosia – a neurodevelopmental condition characterised by severe lifelong face recognition impairment (Chapter 4; Cook & Biotti, 2016; Susilo & Duchaine, 2013). Participants are tasked with responding to statements such as “I often mistake people I have met before for strangers” and “When people change their hairstyle, or wear hats, I have problems recognizing them” using a five-point scale (strongly agree to strongly disagree). Higher scores on this measure (scale: 0–100) reflect the presence of more prosopagnosic traits.

The Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006b) is a standardized objective measure of face recognition ability that is widely used to diagnose developmental prosopagnosia. On each trial (72 in total), participants are asked to identify recently learned target faces from a line-up of three options (a target and two foils). The addition of view-point changes and high-spatial frequency visual noise increases task difficulty in the later stages. Higher scores (% accuracy) on this measure reflect superior face recognition.

5.3. Results

5.3.1. Signal detection measures

Perceptual sensitivity (d')

Dancers. The d' estimates (Figure 5.2a) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [F(1, 178) = 55.097, $p < .001$, $\eta_p^2 = .236$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No effect of Group was observed [F(1, 178) = 0.071, $p = .791$, $\eta_p^2 < .001$], indicating that the autistic (M = 1.71, SD = 0.68) and non-autistic participants (M = 1.71, SD = 0.52) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [F(1, 178) = 0.048, $p = .828$, $\eta_p^2 < .001$]. When considered separately, no significant group difference was observed on move closer [$M_{\text{autisic}} = 1.88$, $SD_{\text{autistic}} = 0.75$, $M_{\text{non-autistic}} = 1.92$, $SD_{\text{non-autistic}} = 0.59$, $t(178) = 0.340$, $p = .734$, $d = 0.05$, $BF_{01} = 5.56$] or move apart trials [$M_{\text{autisic}} = 1.53$, $SD_{\text{autistic}} = 0.74$, $M_{\text{non-autistic}} = 1.55$, $SD_{\text{non-autistic}} = 0.62$, $t(178) = 0.131$, $p = .896$, $d = 0.02$, $BF_{01} = 5.82$].

Boxers. The d' estimates (Figure 5.2b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [F(1, 178) = 21.524, $p < .001$, $\eta_p^2 = .108$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No effect of Group was observed [F(1, 178) = 0.130, $p = .719$, $\eta_p^2 = .001$], indicating that the autistic (M = 1.67, SD = 0.58) and non-autistic participants (M = 1.64, SD = 0.62) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [F(1, 178) = 3.120, $p = .079$, $\eta_p^2 = .017$]. When considered separately, no significant group difference was observed on move closer [$M_{\text{autisic}} = 1.74$, $SD_{\text{autistic}} = 0.58$, $M_{\text{non-autistic}} = 1.79$, $SD_{\text{non-autistic}} = 0.65$, $t(178) = 0.460$, $p = .646$, $d = 0.07$, $BF_{01} = 5.32$] or move apart trials

[M_{autisic} = 1.61, SD_{autistic} = 0.73, $M_{\text{non-autistic}}$ = 1.49, $SD_{\text{non-autistic}}$ = 0.70, $t(178) = 1.025$, $p = .307$, $d = 0.16$, $BF_{01} = 3.61$].

Clocks. The *d′* estimates (Figure 5.2c) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 42.886$, $p < .001$, $\eta_p^2 = .194$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No effect of Group was observed [$F(1, 178) = 0.424$, $p = .515$, $\eta_p^2 = .002$], indicating that the autistic ($M = 1.80$, $SD = 0.62$) and non-autistic participants ($M = 1.74$, $SD = 0.60$) did not differ significantly in their sensitivity to distance changes. There was no interaction between Trial Type and Group [$F(1, 178) = 1.121$, $p = .291$, $\eta_p^2 = .006$]. When considered separately, no significant group difference was observed on move closer [M_{autisic} = 1.95, SD_{autistic} = 0.65, $M_{\text{non-autistic}}$ = 1.95, $SD_{\text{non-autistic}}$ = 0.70, $t(178) = 0.034$, $p = .973$, $d = 0.01$, $BF_{01} = 5.86$] or move apart trials [M_{autisic} = 1.65, SD_{autistic} = 0.74, $M_{\text{non-autistic}}$ = 1.53, $SD_{\text{non-autistic}}$ = 0.71, $t(178) = 1.067$, $p = .288$, $d = 0.17$, 0.48, $BF_{01} = 3.47$].

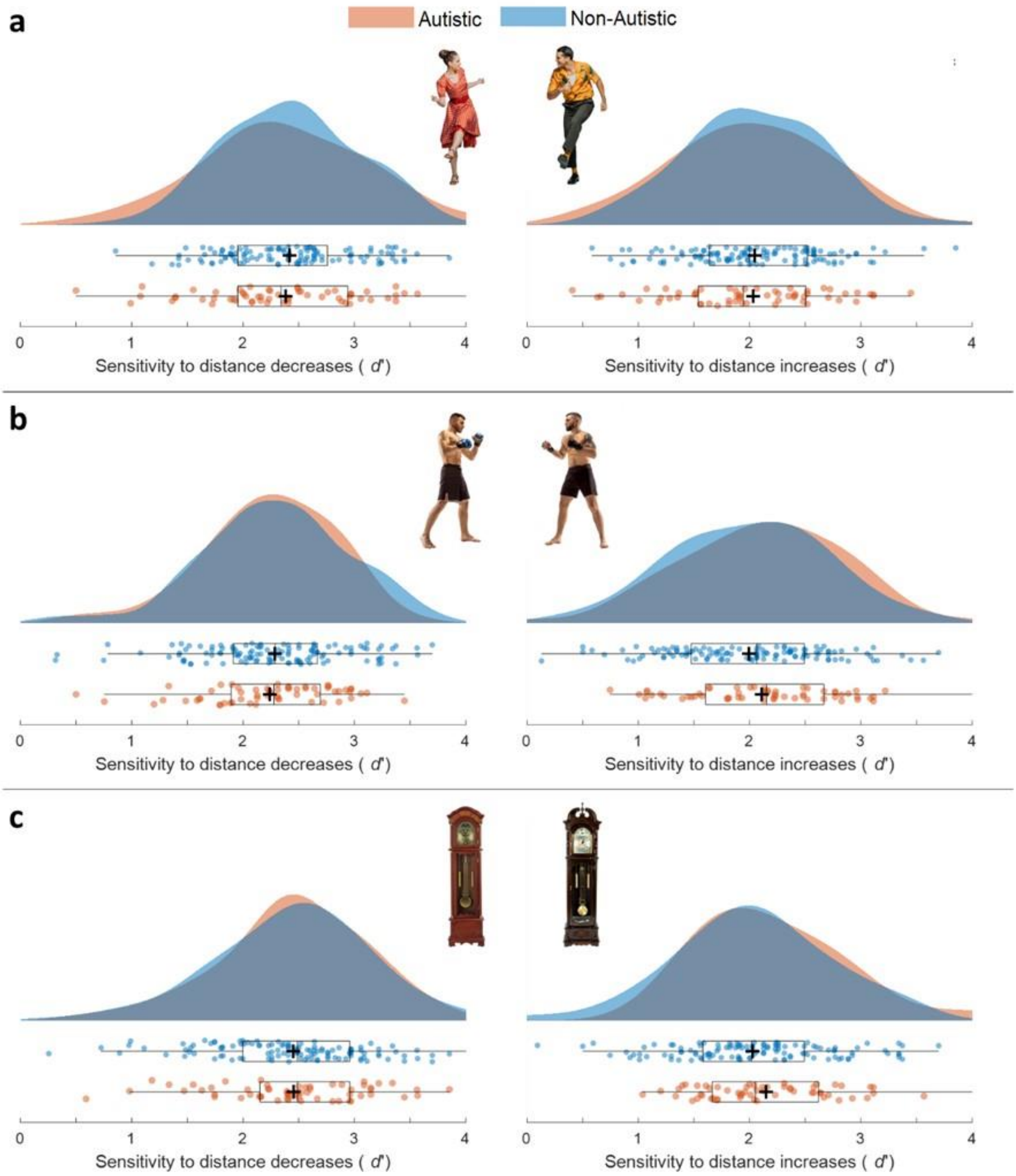

Figure 5.2: Perceptual sensitivity (*d*′) exhibited by autistic and non-autistic participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent sensitivity on move closer trials; right-hand plots represent sensitivity on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. No group contrast reached significance.

Bias (C)

Dancers. The C estimates (Figure 5.3a) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 138.097$, $p < .001$, $\eta_p^2 = .437$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No effect of Group was observed [$F(1, 178) = 0.355$, $p = .552$, $\eta_p^2 = .002$], indicating that the autistic ($M = 0.05$, $SD = 0.34$) and non-autistic participants ($M = 0.02$, $SD = 0.34$) did not differ significantly in their biases. There was no interaction between Trial Type and Group [$F(1, 178) = 1.781$, $p = .184$, $\eta_p^2 = .010$]. When considered separately, no significant group difference was observed on move closer trials [$M_{\text{autisic}} = 0.36$, $SD_{\text{autistic}} = 0.41$, $M_{\text{non-autistic}} = 0.26$, $SD_{\text{non-autistic}} = 0.48$, $t(178) = 1.317$, $p = .189$, $d = 0.21$, $BF_{01} = 2.64$] or on move apart trials, [$M_{\text{autisic}} = -0.26$, $SD_{\text{autistic}} = 0.45$, $M_{\text{non-autistic}} = -0.23$, $SD_{\text{non-autistic}} = 0.45$, $t(178) = -0.433$, $p = .666$, $d = -0.07$, $BF_{01} = 5.38$].

Boxers. The C estimates (Figure 5.3b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 105.249$, $p < .001$, $\eta_p^2 = .372$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. There was also a main effect of Group [$F(1, 178) = 5.199$, $p = .024$, $\eta_p^2 = .028$], whereby the autistic participants ($M = 0.11$, $SD = 0.35$) reported more distance changes than the non-autistic participants ($M = -0.02$, $SD = 0.35$). There was no interaction between Trial Type and Group [$F(1, 178) = 1.321$, $p = .252$, $\eta_p^2 = .007$]. When considered separately, there was a significant effect of Group on move closer trials [$M_{\text{autisic}} = 0.37$, $SD_{\text{autistic}} = 0.48$, $M_{\text{non-autistic}} = 0.19$, $SD_{\text{non-autistic}} = 0.42$, $t(178) = 2.607$, $p = .010$, $d = 0.41$, $BF_{01} = 0.26$]. However, there was no significant effect of Group on move apart trials [M_{autisic} = -0.16, SD_{autistic} = 0.42, $M_{\text{non-autistic}}$ = -0.23, $SD_{\text{non-autistic}}$ = 0.50, $t(178) = 0.970$, $p = .334$, $d = 0.15$, $BF_{01} = 3.80$].

<u>Clocks</u>. The C estimates (Figure 5.3c) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 255.511$, $p < .001$, $\eta_p^2 = .589$], whereby participants were more likely to report a distance change on move closer trials. Although the main effect of Group did not reach significance [$F(1, 178) = 3.615$, $p = .059$, $\eta_p^2 = .020$], there was a trend for the autistic participants ($M = 0.11$, $SD = 0.33$) to report more distance changes than the non-autistic participants ($M = 0.01$, $SD = 0.34$). There was no interaction between Trial Type and Group [$F(1, 178) = 2.894$, $p = .091$, $\eta_p^2 = .016$]. When considered separately, there was a significant effect of Group on move closer trials [M_{autisic} = 0.56, SD_{autistic} = 0.46, $M_{\text{non-autistic}}$ = 0.37, $SD_{\text{non-autistic}}$ = 0.46, $t(178) = 2.569$, $p = .011$, $d = 0.41$, $BF_{01} = 0.29$]. However, there was no significant effect of Group on move apart trials [M_{autisic} = -0.34, SD_{autistic} = 0.47, $M_{\text{non-autistic}}$ = -0.35, $SD_{\text{non-autistic}}$ = 0.46, $t(178) = 0.207$, $p = .836$, $d = 0.03$, $BF_{01} = 5.75$].

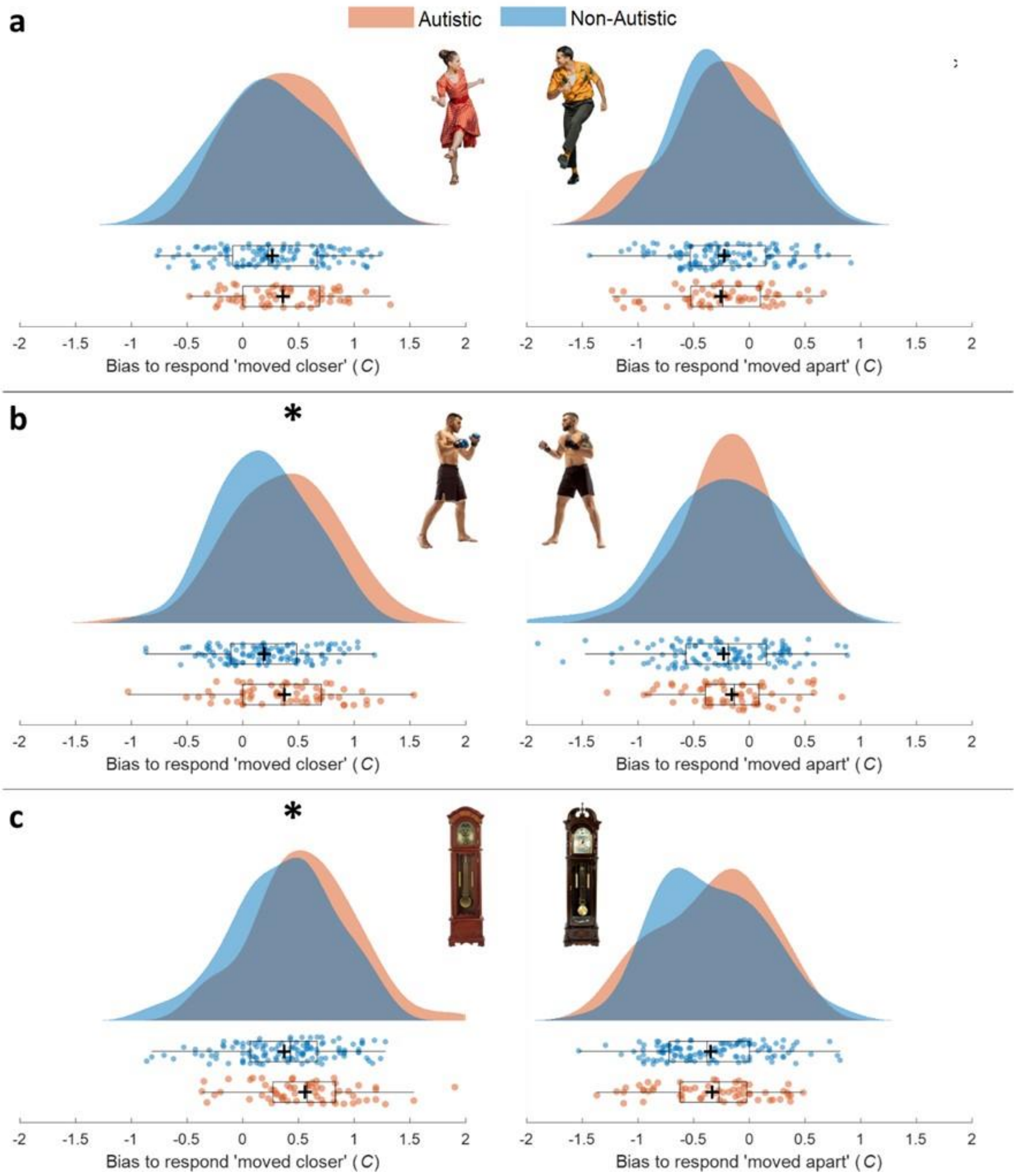

Figure 5.3: Bias (C) exhibited by autistic and non-autistic participants. **(a)** Results for the dancer task. **(b)** Results for the boxer task. **(c)** Results for the clock task. Left-hand plots represent bias on move closer trials; right-hand plots represent bias on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Asterisks denote significance (*$p < 0.05$, **$p < 0.01$, ***$p < .001$).

5.3.2. Omnibus ANOVA

To maximize statistical power in detecting group differences in the signal detection measures, an omnibus ANOVA was conducted that incorporated all three tasks (dancers, boxers, clocks) as a within-subjects factor. If non-autistic participants benefit from an overall perceptual sensitivity advantage to changes in dyadic distance over autistic participants, a main effect of Group would be expected. However, as only dyadic stimuli depicting social interactions (dancers, boxers) are hypothesized to confer a perceptual sensitivity advantage for those with intact configural processing under the dyad configural account (Papeo, 2020; Abassi & Papeo, 2022), the analysis was repeated with the clocks task data omitted. Consistent with the individual task analyses, no convincing evidence was found to support differences between autistic and non-autistic participants in terms of perceptual sensitivity or response bias, regardless of whether the non-social control task was included.

Perceptual sensitivity (d')

All tasks. The *d′* estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 81.217$, $p < .001$, $\eta_p^2 = .313$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. A main effect of Stimulus Type also emerged [$F(2, 356) = 3.605$, $p = .028$, $\eta_p^2 = .020$], with sensitivity being highest in the clocks task ($M = 1.76$, $SD = 0.73$), followed by the dancers ($M = 1.72$, $SD = 0.68$) and boxers tasks ($M = 1.65$, $SD = 0.68$). No significant main effect of Group was observed [$F(1, 178) = 0.090$, $p = .765$, $\eta_p^2 < .001$], indicating that autistic and non-autistic participants exhibited comparable perceptual sensitivity overall. Furthermore, Group did not significantly interact with Trial Type [$F(1, 178) = 2.089$, $p = .150$, $\eta_p^2 = .012$] or Stimulus Type [$F(2, 356) = 0.563$, $p = .570$, $\eta_p^2 = .003$]. No three-way interaction was observed [$F(2, 356) = 0.665$, $p = .515$, $\eta_p^2 = .004$].

Social tasks only: When the clocks task data was excluded, the results were largely consistent with the full model. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 60.726$, $p < .001$, $\eta_p^2 = .254$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. No main effect of Stimulus Type was observed [$F(1, 178) = 2.191$, $p = .141$, $\eta_p^2 = .012$], suggesting that sensitivity levels were similar across the boxers and dancers tasks. No significant main effect of Group was observed [$F(1, 178) = 0.004$, $p = .951$, $\eta_p^2 < .001$], indicating that autistic and non-autistic participants exhibited comparable perceptual sensitivity on the social tasks. Furthermore, Group did not significantly interact with Trial Type [$F(1, 178) = 1.552$, $p = .215$, $\eta_p^2 = .009$] or Stimulus Type [$F(1, 178) = 0.492$, $p = .484$, $\eta_p^2 = .003$]. No three-way interaction was observed [$F(1, 178) = 1.435$, $p = .232$, $\eta_p^2 = .008$].

Bias (C)

All tasks: The C estimates were subjected to ANOVA with Trial Type (move closer, move apart) and Stimulus Type (dancers, boxers, clocks) as within-subjects factors, and Group (autistic, non-autistic) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 178) = 240.916$, $p < .001$, $\eta_p^2 = .575$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Stimulus Type was observed [$F(2, 356) = 0.743$, $p = .476$, $\eta_p^2 = .004$]. The main effect of Group also did not meet significance [*F*(1, 178) = 3.263, *p* = .073, η_p^2 = .018], indicating that autistic and non-autistic participants exhibited comparable response biases across the tasks. Furthermore, Group did not significantly interact with Trial Type [*F*(1, 178) = 2.927, *p* = .089, η_p^2 = .016] or Stimulus Type [*F*(2, 356) = 2.541, *p* = .080, η_p^2 = .014]. No three-way interaction was observed [*F*(2, 356) = 0.247, *p* = .781, η_p^2 = .001].

Social tasks only: When the clocks task was excluded, results were largely consistent with the full model. The analysis revealed a significant main effect of Trial Type [*F*(1, 178) = 158.736, *p* < .001, η_p^2 = .471], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. No main effect of Stimulus Type was observed [*F*(1, 178) = 0.142, *p* = .707, η_p^2 < .001]. The main effect of Group also did not meet significance [*F*(1, 178) = 2.563, *p* = .111, η_p^2 = .014], indicating that autistic and non-autistic participants exhibited comparable response biases across both social tasks. No significant interaction was found between Group and Trial Type [*F*(1, 178) = 2.029, *p* = .156, η_p^2 = .024]; however, the interaction between Group and Stimulus Type did meet the significance threshold [*F*(1, 178) = 4.290, *p* = .040, η_p^2 = .024]. No three-way interaction was observed [*F*(1, 178) = 0.047, *p* = .829, η_p^2 < .001].

5.3.3. Face recognition measures

The results obtained with the PI20 and CFMT are shown in Figure 5.4. The autistic participants (*M* = 64.48, *SD* = 18.05) scored significantly higher on the PI20 than the non-autistic participants (*M* = 43.27, *SD* = 13.83), indicative of greater self-reported prosopagnosic traits [*t*(178) = 8.738, *p* < .001, *d* = 1.38, BF_{01} < 0.01]. The autistic participants (*M* = 70.07, *SD* = 13.13) also scored significantly lower on the CFMT than the non-autistic participants (*M* = 75.72, *SD* = 13.20), indicative of worse face recognition [$t(178) = 2.711$, $p = .007$, $d = 0.43$, $BF_{01} = 0.21$]. A significant negative correlation was found between the two measures [$r_p(178) = -.383$, $p < .001$], whereby higher self-reported prosopagnosic traits on the PI20 were associated with lower face recognition scores on the CFMT.

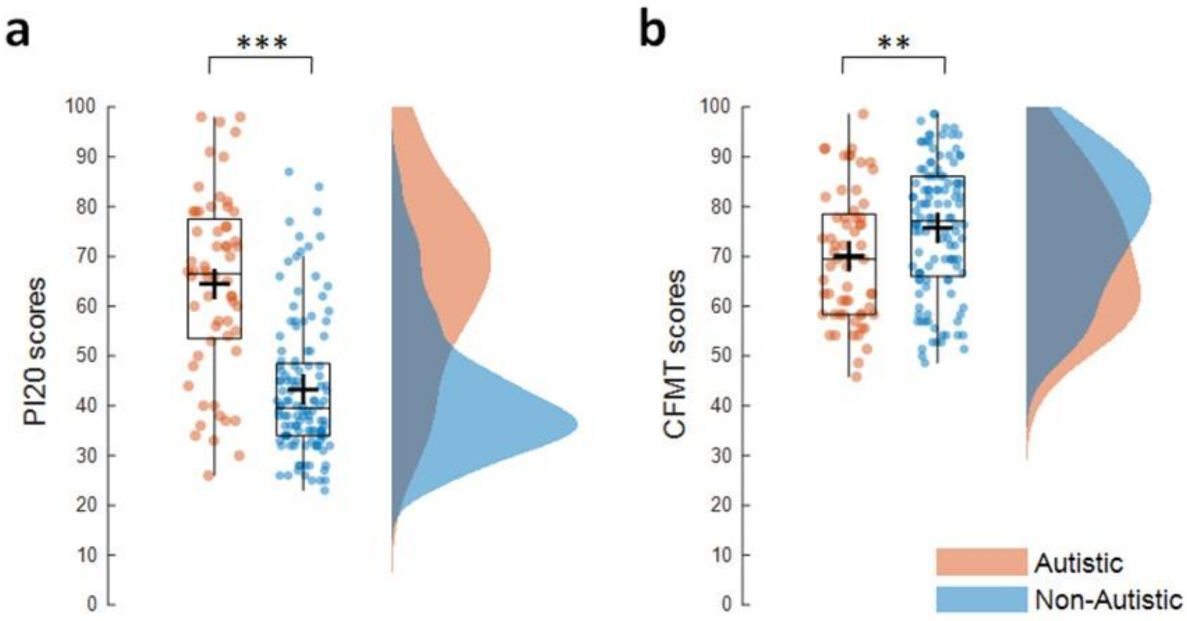

Figure 5.4: Group performance on the face recognition measures. **(a)** Performance on the 20-item Prosopagnosia Index (PI20). **(b)** Performance on the Cambridge Face Memory Test (CFMT). Boxplots denote median and interquartile range. Plus signs denote means. Asterisks denote significance (*$p < 0.05$, **$p < 0.01$, ***$p < .001$).

5.3.4. Correlational analyses

The correlations between performance on the face recognition measures and performance on the distance change detection tasks are shown in Table 5.1. None of the correlations with PI20 scores remained significant once correction for multiple comparisons was applied. There was a general trend whereby CFMT scores were positively associated with sensitivity to distance changes on all three tasks and two of these correlations remained significant after correction for multiple comparisons: the correlation between autistic participants' CFMT scores and their sensitivity to distance increases on the Clocks task ($r_p = .369$, $p = .004$), and the correlation between the non-autistic participants' CFMT scores and their sensitivity to distance increases on the Boxers task ($r_p = .297$, $p < .001$). Given the overall pattern, however, these significant correlations may well reflect the influence of general factors (e.g., motivation, conscientiousness) on task performance.

Table 5.1: Correlations between performance on the face recognition measures and performance on the distance change detection tasks. Correlation coefficients (Pearson's *r*) shown in bold and marked with an asterisk remain significant once correction for multiple comparisons is applied.

		Move closer		**Move apart**	
		d'	**C**	***d'***	**C**
Autistic participants (*N* = 60)					
Boxer task	CFMT	.167	-.089	.245	.237
	PI20	.104	-.029	-.111	-.104
Dancer task	CFMT	.223	-.033	.307	.275
	PI20	-.056	-.079	-.009	-.158
Clock task	CFMT	.256	-.199	**.369***	.085
	PI20	-.060	.153	-.114	-.068
Non-autistic participants (*N* = 120)					
Boxer task	CFMT	.175	-.040	**.297***	.061
	PI20	-.066	-.003	-.029	-.153
Dancer task	CFMT	.121	-.031	.061	.010
	PI20	.111	.028	-.044	.131
Clocks task	CFMT	.155	-.070	.197	.034
	PI20	.056	.036	-.024	-.025

5.4. Discussion

This chapter sought to determine whether autistic individuals exhibit impaired perception of interpersonal distance when viewing dyadic social interactions from a third-person perspective. Participants completed three distance change detection tasks in which they had to make perceptual decisions about the distance between two boxers, two dancers, or two grandfather clocks. On half the trials, participants judged whether the stimulus elements moved closer together; on the other half, participants judged whether the stimulus elements moved further apart. It was found that the autistic (*N* = 60) and non-autistic (*N* = 120) participants exhibited similar levels of perceptual sensitivity (*d′*) to distance changes in all three tasks. Similar results were seen for move closer and move apart trials. In each case, Bayesian analyses revealed substantial evidence (BFs > 3.0) for the null hypothesis (i.e., no group difference).

In addition to the perception of interpersonal distance, the face recognition ability of the autistic and non-autistic samples was also assessed. As expected, the autistic participants scored higher than non-autistic controls on a self-report measure of prosopagnosic traits – the PI20 questionnaire (Shah, Gaule, et al., 2015; Gray, Bird, et al., 2017; Tsantani et al., 2021) – and lower than non-autistic controls on a widely-used objective measure of face recognition ability – the CFMT (Duchaine & Nakayama, 2006b). It is well-established that autistic observers exhibit worse face recognition than non-autistic controls (Gehdu et al., 2022; Hedley et al., 2011; Minio-Paluello et al., 2020; Stantić et al., 2022). However, the fact that this effect was replicated demonstrates that the autistic participants that took part in this study do experience some social vision difficulties, despite their typical sensitivity when judging interpersonal distance.

In recent years, there has been much interest in the visual perception of dyadic social interactions (Gray, Barber, et al., 2017; Isik et al., 2017; Papeo et al., 2017; Quadflieg et al., 2015; Vestner et al., 2019). Much of the early work in this area has pointed towards parallels with face processing. In particular, faces (Farah et al., 1998; Maurer et al., 2002; Piepers &

Robbins, 2012) and facing dyads (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2017) are both thought to engage orientation-specific configural processing when viewed upright. Similarly, when viewing upright faces (Murphy et al., 2017; Rossion, 2013) and dyadic interaction displays (Abramson et al., 2021; Gray, Barber, et al., 2017), the perception of one stimulus region is biased by the content / nature of another. Several cortical regions that support face processing, including pSTS and FFA (Duchaine & Yovel, 2015; Haxby et al., 2000), have also been implicated in the perception of interactions (Abassi & Papeo, 2022; Isik et al., 2017; Quadflieg et al., 2015). Despite these parallels, however, the present findings imply dissociation between the visual processing of faces and dyadic interactions – that the visual processing of faces can be selectively impaired in autism without affecting the visual encoding of dyadic configurations.

The mechanisms of social vision have been the subject of research attention for over fifty years. Nevertheless, the overarching structure of social vision remains unclear. Certain results suggest that different social perception abilities may covary. For example, autism is thought to impair several aspects of social vision including face recognition (Gehdu et al., 2022; Hedley et al., 2011; Stantić et al., 2022), the analysis of facial motion (Keating et al., 2022; Shah et al., 2016), perception of body postures (Reed et al., 2007), and dynamic whole-body actions (Atkinson, 2009; Philip et al., 2010). Similarly, developmental prosopagnosics – who exhibit lifelong face recognition difficulties (Chapter 4; Cook & Biotti, 2016; Susilo & Duchaine, 2013) – also appear to perform poorly across a range of social vision tasks, including expression recognition (Biotti & Cook, 2016; Tsantani, Gray, et al., 2022), individuation of body shapes (Biotti, Gray, et al., 2017), and interpretation of dynamic whole-body actions (Lange et al., 2009). These findings are broadly consistent with the presence of a general ‘social vision’ factor that contributes to perceptual ability across these various domains.

However, many results – including those observed here – suggest dissociations between different facets of social vision. For example, several findings suggest that the recognition of facial expressions and facial identity can be selectively impaired in neuropsychological cases (Bate & Bennetts, 2015). Neuroimaging studies suggest that the extrastriate body area (EBA) responds strongly to body stimuli, but shows little or no face selectivity (Peelen & Downing, 2007). Similarly, the application of disruptive transcranial magnetic stimulation (TMS) to EBA and occipital face area (OFA) induces selective impairments of body and face perception, respectively (Pitcher et al., 2009). Overall, the emerging picture is a complex one. More work is required to understand the patterns of association and dissociation seen between different facets of social vision, and how the visual analysis of social interactions fits within this framework.

On the boxer task, the criterion (C) analyses revealed differences in the biases exhibited by autistic and non-autistic participants: the autistic participants were more likely to report a distance change on move closer trials, relative to the non-autistic controls. It is possible that this effect has a perceptual origin. For example, autistic and non-autistic observers may have different expectations (priors) about interpersonal distance or how interpersonal distance is likely to change (e.g., Pellicano & Burr, 2012; Van de Cruys et al., 2014). Alternatively, the application of these perceptual priors may differ in autistic and non-autistic observers (e.g., Lawson et al., 2014). Three features of the data undermine a perceptual account, however.

First, the effect of Group on criterion scores was seen on the boxer task, but not on the dancer task. In principle, it is not impossible to reconcile these differential results with a perceptual account. For example, the particular dancers used may not afford strong expectations about interpersonal distance and likely changes thereof. Conversely, when viewing boxers, there may be a strong expectation that the two actors will approach one another. Nevertheless, the fact that the effect is seen on one of the interaction tasks but not the other calls the robustness of the effect into question.

Second, some signs of a similar criterion effect was observed on the clocks task. On this task, neither the main effect of Group (p = .059) nor the Group × Trial Type interaction (p = .091) reached significance. Once again, however, a significant effect of Group was observed on move closer trials (p = .011, BF_{01} = .29, d = .41), whereby autistic participants reported more distance changes than non-autistic participants, but not on move apart trials (p = .836, BF_{01} = .5.75, d = .03). Signs that the effect of Group on criterion scores is also seen on the non-social clocks task undermines a perceptual account that invokes expectations about interpersonal distance or social interaction.

Third, if the effect of Group on criterion scores seen on the boxer task had a perceptual origin (e.g., different distance priors), one might expect the bias to vary depending on the nature of the question (‘Move closer?’ vs. ‘Move apart?’). If autistic observers were more likely to report distance changes on both types of trial, this would suggest a theoretically uninteresting response bias, whereby participants were simply more likely to respond ‘Yes’ irrespective of the question. In this sense, the absence of a significant Group × Trial Type interaction (p = .184) on the boxer task is problematic for the perceptual account. It is conceivable that autistic observers might expect more changes in their environment and thus tended to perceive both types of movement more often. In this case, however, one might expect to see evidence of a change bias on the dancer task as well.

In sum, the finding that autistic participants were more likely to report distance changes on the boxer task is curious and worthy of further investigation. In light of the foregoing considerations, however, clear interpretation is not possible. At present, the possibility that this difference reflects a theoretically uninteresting response bias (e.g., a tendency to respond 'Yes') that manifested on the boxers task, and to some extent on the clocks task, cannot be excluded.

In the future, it will be important to determine whether the present findings generalise to other perceptual decisions about dyadic social interactions viewed from third-person perspectives. Having assessed the perception of interpersonal distance, no evidence of impaired sensitivity in autism was found. It is possible, however, that other kinds of perceptual decision – for example, judgements that require more interpretative processing – may differ in this population. It remains possible that autistic individuals experience difficulties using proxemic cues to infer interaction valence, the relationship between interactants, the presence of rapport, and so on. High-alexithymic autistic participants are known to experience problems when asked to interpret the emotional content of facial expressions (Cook et al., 2013; Gehdu et al., 2023) and vocal stimuli (Heaton et al., 2012). It would be interesting to examine whether these individuals also struggle to appraise the emotional content of dyadic social interactions.

It also might also be useful to examine the developmental trajectory of interaction perception in autistic participants. The present results suggest that autistic and non-autistic adults exhibit similar sensitivity to changes in interpersonal distance. However, it is possible that perceptual expertise for social interaction stimuli develops more slowly in autistic individuals than in non-autistic individuals. Several aspects of face perception are thought to develop incrementally over many years, shaped by perceptual experience (Cook et al., 2022; Germine et al., 2011; Johnston et al., 2011; Mondloch et al., 2002). Young infants who show reduced interest in social stimuli, including those who may later receive an ASD diagnosis (Klin et al., 2009; Maestro et al., 2002; Osterling & Dawson, 1994; Swettenham et al., 1998), might therefore take longer to develop perceptual expertise for social interactions.

To conclude, the results of this chapter indicate that autistic and non-autistic observers exhibit similar perceptual sensitivity to changes in interpersonal distance when viewing dyadic social interactions from third-person perspectives. As expected, however, the autistic observers showed clear signs of impaired face recognition – relative to non-autistic controls, the autistic group described more prosopagnosic traits on the PI20 and achieved lower scores on the CFMT. Despite putative similarities between the visual processing of faces and dyadic social interactions (Papeo, 2020; Papeo et al., 2017; Gray, Barber, et al., 2017), the findings of this chapter provide further support for the view that these two facets of social vision dissociate.

Chapter 6: General Discussion

Interpersonal distance holds a fundamental role in our social lives. How we choose to position ourselves relative to our interaction partners is deeply revealing of our attitudes towards them and the underlying nature of our relationships (Hall, 1963, 1966; Worthington, 1974; Bessenoff & Sherman, 2000; Dotsch & Wigboldus, 2008; McCall et al., 2009; McCall & Singer, 2015). Moreover, proxemic cues have been shown to significantly influence our evaluations of the social interactions we observe from a third-person perspective (Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; McCall & Singer, 2015). Despite the wealth of information conveyed by proxemic cues, however, strikingly little is known about the representation of this attribute within the human visual system. This thesis presents four empirical investigations that sought to elucidate the visual mechanisms underlying the perception of interpersonal distance. This final chapter will summarize the key findings from these investigations, discuss their implications, acknowledge limitations, and propose potential avenues for future research.

6.1. Summary of findings

The study described in Chapter 2 aimed to determine whether the Müller-Lyer illusion, a visual bias traditionally studied in domains outside of social perception, could distort the perception of interpersonal distance. In classic demonstrations of this illusion, the distance between two points is misperceived as expanded or compressed depending on whether pairs of arrows, with their tips coinciding with the target points, point inward or outward, respectively (Müller-Lyer, 1889). While the illusion remains robust when the arrow pairs are replaced with various other geometric shapes like diamonds (Howe & Purves, 2005), no prior research had explored whether higher-level stimulus elements, such as faces, are capable of inducing the illusion.

In nine experiments, separate groups of participants (each *N* = 30) were asked to judge which of two simultaneously presented intervals was the longest. One of these intervals was presented with contextual elements positioned around its boundaries in various arrangements. When these contextual elements consisted of pairs of arrows and diamonds, the results aligned with classic demonstrations of the Müller-Lyer effect. Interestingly, this pattern also held when face stimuli were employed as contextual elements: pairs of faces positioned interior and exterior of the target points induced a bias to judge the interval as compressed and expanded, respectively. Moreover, it was established that these illusory biases endured irrespective of the relative facing direction of the face pairs (face-to-face, back-to-back), and whether the face pairs were presented in the context of full bodies.

Chapters 3, 4 and 5 sought to test recent theories of social interaction perception that posit an overlap in the visual mechanisms involved in processing dyadic interactions and faces (Papeo, 2020; Abassi & Papeo, 2022). This claim has been supported by a growing body of research demonstrating that ostensibly face- and body-specific behavioural and neural markers can be observed in paradigms employing dyadic stimuli (for review, see Section 1.2.4; Abassi & Papeo, 2022; Papeo et al., 2017; Papeo & Abassi, 2019; Vestner et al., 2019). A key aspect of face processing that distinguishes it from other visual processes is the engagement of configural / holistic mechanisms, thought to afford enhanced sensitivity to inter-feature spatial relationships (Freire et al., 2000; Maurer et al., 2002; Piepers & Robbins, 2012). Preliminary support for the recruitment of analogous mechanisms when observing dyadic interactions comes from studies that have documented inversion effects for dyadic stimuli (Papeo et al., 2017; Abassi & Papeo, 2022).

The feature-spacing effect is a behavioural marker thought to provide compelling evidence for configural processing in face perception (Farah et al., 1998; Maurer et al., 2002; Piepers & Robbins, 2012). When viewing faces in their canonical upright configuration, typical observers tend to show enhanced sensitivity to changes in the spatial positioning of facial features, such as the distance between the eyes (Leder & Bruce, 1998, 2000; Freire et al., 2000; Leder et al., 2001; Barton et al., 2001). If similar configural mechanisms are engaged during the perception of dyadic interactions, one would expect typical observers to exhibit heightened sensitivity to changes in spatial relations between interactants (i.e., interpersonal distance) when presented in their canonical configuration.

Across four well-powered experiments (each N = 100) described in Chapter 3, no evidence was found to support the notion that participants exhibit increased perceptual sensitivity when detecting changes in interpersonal distance for upright face-to-face dyads compared to dyads presented in back-to-back (Experiments 1a and 1b) or inverted (Experiments 2a and 2b) configurations. This pattern of results generally remained consistent when task demands required detection of both decreases and increases in interpersonal distance. Furthermore, the pattern held for dyadic stimuli depicting different types of social interaction—dancing and fighting. In contrast to the findings observed with dyadic stimuli, two follow-up experiments (3a and 3b) employing face stimuli in a closely matched paradigm were able to show a clear upright advantage (vs. inverted) when participants were tasked with detecting changes in interocular distance. Consequently, no evidence of dyadic configural processing was found in this series of experiments.

Chapters 4 and 5 sought to further examine the claim dyadic interactions recruit ‘face-like’ visual processing by determining whether individuals with neurodevelopmental conditions known to be associated with face processing deficits exhibit similar deficits in their ability to process changes in dyadic spatial relations relative to neurotypical individuals. The experiment reported in Chapter 4 shows that a group of developmental prosopagnosic (DPs; N = 42) participants exhibited comparable perceptual sensitivity to changes in interpersonal and inter-object distance to a control group with intact face processing ability (N = 84). The experiment reported in Chapter 5 similarly shows that autistic participants (N = 60) exhibit comparable perceptual sensitivity to a group of non-autistic participants (N = 120). Crucially, these studies were able to confirm that both the DP and autistic samples used in these experiments experienced face recognition difficulties relative to their respective control groups through standardised tests. Given existing evidence suggesting that both neurodevelopmental groups exhibit aberrant configural / holistic processing ability for faces (Avidan et al., 2011; Behrmann, Avidan, et al., 2006; Behrmann, Thomas, et al., 2006; Liu & Behrmann, 2014; Palermo et al., 2011), these findings cast further doubt on the notion that the perception of dyadic interactions recruits specialised visual processing analogous to that seen in face perception.

6.2. Implications

Understanding of how the human visual system processes scenes of social interaction remains limited compared to what is currently known about other facets of social perception, such as individual face and body processing. A central, unresolved debate within this emerging field of study concerns whether specialised mechanisms mediate the perception of visual features of social interactions – such as interpersonal distance – when observing dyads presented in upright, face-to-face configurations. Proponents of the domain-specific view contend that dyadic interactions are processed in a manner that is qualitatively distinct from the processing of dyadic stimuli that do not as strongly imply the presence of social interaction (Abassi & Papeo, 2020, 2022; Vestner et al., 2019). In contrast, the opposing perspective argues that any differences observed in the processing of such dyadic displays can instead be attributed to domain-general perceptual and attentional phenomena (Vestner et al., 2021, 2022). The findings in this thesis hold significant implications for this ongoing debate.

Throughout the experiments detailed in this thesis, a recurring pattern emerges: the mechanisms involved in perceiving upright, facing dyads do not appear to differ from those involved in the perception of upright non-facing dyads, inverted facing dyads, or even pairs of non-social objects. The Müller-Lyer illusion was shown to distort the perception of distance between pairs of faces and pairs of geometric shapes to a similar degree, regardless of how stimulus elements were arranged in terms of directionality (Chapter 2). No substantial evidence was found to support the notion that upright face-to-face dyadic configuration confers perceptual advantages when detecting changes in interpersonal distance (Chapter 3). Comparable levels of perceptual sensitivity were observed when participants were tasked with detecting changes in spatial relations for human-human and object-object dyads (Chapters 4 and 5). Moreover, neither group-level nor individual differences analyses were able to uncover meaningful evidence that face processing ability mediates performance on the dyadic distance change detection tasks (Chapters 4 and 5).

Taken together, the findings of these chapters do not align with the domain-specific account, particularly the idea that dyadic interactions benefit from configural or other ‘face-like’ modes of visual processing. The configural hypothesis has provided an appealing framework for interpreting a wide range of curious behavioural (Gray, Barber, et al., 2017; Papeo et al., 2017, 2019; Vestner et al., 2019) and neural (Abassi & Papeo, 2020, 2022; Quadflieg et al., 2015) markers that appear to manifest as a consequence of observers viewing dyads in configurations that imply social interaction. However, given the present challenges to this account, a critical question arises concerning how these various strands of research can be collectively understood if not through the lens of configural processing.

An alternative explanation, one not reliant on the existence of gated configural mechanisms, posits that these effects are born from domain-general attentional phenomena (Vestner et al., 2020, 2021). Individual faces and bodies viewed in profile are known to induce shifts in observers' visuospatial attention, leftwards or rightwards, in accordance with their directionality (Langton & Bruce, 1999; Vestner et al., 2021, 2022). Within the context of a face-to-face dyad, these attention cues are theorized to create an 'attention trap', where each face / body redirects attention to the other face / body (Vestner et al., 2020). When positioned back-to-back, these same attention cues guide observers' attention towards the display periphery. Eye-tracking research further substantiates these differences in viewing patterns, revealing that observers disproportionately fixate on the faces of actors presented within face-to-face dyads (Kujala et al., 2012).

Compelling evidence supports the idea these differential arrangements of attention cues within dyadic displays may underlie why facing dyads are detected more efficiently in visual search tasks (Vestner et al., 2020, 2021). Notably, recent research has shown similar search advantages for object pairs that are arranged upright and front-to-front, including arrows, desk fans, desk lamps, power drills, and cars (Vestner et al., 2020, 2021). These findings pose a challenge for the configural hypothesis, which would predict that such effects should only emerge for dyads comprised of human faces / bodies (Papeo, 2020; Papeo et al., 2017; Abassi

& Papeo, 2022). In contrast, the attentional account predicts that any stimulus capable of cueing attention should induce the search advantage. Vestner et al. (2021) have supported this hypothesis by demonstrating a close correlation between a stimulus category's ability to cue attention and the extent to which it is able to produce a front-to-front search advantage when paired with a conspecific.

In principle, the attentional account may be capable of providing domain-general explanations for various other effects often cited in support of the configural hypothesis (Papeo, 2020). For instance, increased attention to face regions when viewing facing dyads (Kujala et al., 2012) may explain why the facial expressions of one actor can alter the perceived emotion of the other (Abramson et al., 2021; Gray, Barber, et al., 2017). The differential arrangement of attention cues in facing dyads may also account for higher detection rates in backward masking procedures (Papeo et al., 2017). Furthermore, differential attention deployment may be responsible for findings from neuroimaging, where certain cortical regions such as extrastriate body area (EBA) and fusiform face area (FFA) respond more strongly when viewing facing dyads compared to non-facing dyads (Abassi & Papeo, 2020, 2022; Bellot et al., 2021; Isik et al., 2017; Walbrin & Koldewyn, 2019). Instead of signifying dyadic configural processing (e.g., Abassi & Papeo, 2022), these differential activation patterns may reflect attentional modulation driven by single actor processing (Hoffman & Haxby, 2000; Bird et al., 2006).

The findings of the empirical chapters in this thesis, together with domain-general explanations of prior effects described in the social interaction literature, pose a severe challenge to the face-like configural hypothesis proposed by Papeo and colleagues in its strongest form (Papeo, 2020; Abassi & Papeo, 2022). However, it may still be possible to sustain a weaker version of this theory, one that does not depend on strict mechanistic overlap between domains of social vision (i.e., face and dyadic interaction processing). This weaker account can be illustrated through the example of individual face and body processing. It is generally understood these domains share functional similarities, including behavioural markers thought to signify configural / holistic processing (Yin, 1969; Reed et al., 2003, 2006; Slaughter et al., 2004). Both are also thought to engage common regions within the social perception network, such as the fusiform gyrus and superior temporal sulcus (Bernstein et al., 2014). Evidence for a shared neurocognitive basis of configural mechanisms across domains comes from studies showing that behavioural face and body inversion effects may rely on overlapping neural substrates within the face processing network (Brandman & Yovel, 2010).

On the other hand, these facets of social vision also show clear dissociations. For example, EBA is a region that responds selectively to body stimuli while showing minimal face selectivity (Peelen & Downing, 2007). Disruption of the EBA and occipital face area (OFA) via transcranial magnetic stimulation (TMS) induces selective impairments in body and face perception, respectively (Pitcher et al., 2009). Furthermore, the developmental trajectories of face and body processing differ markedly, with expertise in face perception emerging much earlier than expertise in body perception (Bushnell, 2001; Farah et al., 2000; Simion & Giorgio, 2015; Slaughter et al., 2002; Slaughter & Heron, 2004). The functional significance of configural processing may also differ across these domains. For faces, configural mechanisms are thought to enhance the perception of individual identity and emotional states (Maurer et al., 2002; Piepers & Robbins, 2012), while in bodies, they may play a greater role in action recognition and postural analysis (Slaughter et al., 2004; Reed et al., 2006).

In a similar vein, it is plausible that dyadic interaction processing could involve some form of domain-specialised configural mechanisms that are functionally, developmentally, and structurally independent from those used in face processing. If so, this would suggest the need for a revision of the current theory to account for this additional complexity. Future research should investigate whether the putative configural processing of dyadic interactions relies on unique neurocognitive pathways and further examine whether spatial distance plays analogous or distinct roles in the perception of faces and interactions.

6.3. Limitations & suggestions for future research direction

A weakness of the experiments presented in this thesis is that they were conducted online. There are numerous drawbacks to online experimentation, including reduced experimenter control over the testing environment, participants' viewing distance, and their monitor settings. However, a counterpoint to this criticism is that carefully-designed online tests of cognitive and perceptual processing have been shown to yield high-quality data that is indistinguishable from that collected in traditional lab settings (Crump et al., 2013; Germine et al., 2012; Woods et al., 2015). The successful replication of classic variants of the Müller-Lyer illusion (Chapter 2, Experiments 1 & 2) and the feature-spacing effect for faces (Chapter 3, Experiments 3a and 3b) in an online format further supports the validity of the findings from the dyadic social interaction variants of these tasks (Chapter 2, Experiments 3-9; Chapter 3, Experiments 1a, 1b, 2a and 2c). Similarly, Chapters 4 and 5 reproduced findings from prior research showing DP and autistic observers exhibit poor face recognition relative to matched controls, indicating that the online experimentation did not introduce confounding systematic differences between typical and atypical groups.

Another potential limitation that should be acknowledged is that all the described experiments were conducted in the months and years following an outbreak of coronavirus (COVID-19). This period was marked by government and healthcare agencies promoting social distancing and quarantine guidelines in an effort to mitigate transmission. As a result, it may be possible that the data collected during this timeframe might be influenced by the unique social circumstances of the pandemic (e.g., participants may have been hyperaware of interpersonal distance or been experiencing some form of social deprivation). Conducting follow-up studies in a post-pandemic context could offer valuable insights into the generalizability of the findings.

Throughout the various experiments detailed in Chapters 3-5, no substantial evidence was found to support the configural account of dyadic interaction perception. One possible explanation for the null findings observed in these chapters is that the employed distance change paradigm was not sensitive enough to tap into configural processing. Faces are complex visual stimuli housing multiple salient visual features (e.g., eyes, nose, mouth) from which spatial interrelations can be derived. Previous studies investigating the ability to detect subtle spatial displacements of these features have revealed that participants tend to be more sensitive to certain relationships over others. For example, participants often demonstrate greater sensitivity to vertical shifts in mouth position compared to horizontal shifts in interocular distance (Haig, 1984). Similarly, the findings of the dyadic distance change tasks in these chapters indicate that participants tend to exhibit varying sensitivity depending on the direction of the displacement: participants were more likely to detect inwards shifts in interpersonal distance (move closer trials) than outward shifts (move apart trials).

The distance change tasks used here were designed to focus solely on a single spatial dimension: interpersonal distance. It is conceivable that this particular spatial manipulation happened to be one that does not robustly trigger configural processing. While interpersonal distance undeniably plays a crucial role in perceiving and evaluating social interactions (Burgoon, 1991; Goldring, 1967; Haase & Tepper, 1972; McCall & Singer, 2015), other spatial aspects may carry greater social and/or perceptual relevance when observing interactions in the real-world; for instance, the relative positions of interactants’ limbs or the trajectories of their eye gaze. By broadening the scope of spatial manipulations to encompass various aspects of dyadic interactions beyond interpersonal distance, researchers may increase their chances of capturing evidence of dyadic configural processing.

The static nature of the stimuli used in these experiments may also contribute to the absence of sensitivity effects. Static snapshots of interactions have been shown to modulate activity in cortical regions implicated in the visual processing of social interactions, such as EBA and FFA (Abassi & Papeo, 2020, 2022). Likewise, putative markers of dyadic configural processing, like the two-body inversion effect and search advantage for facing dyads, have been elicited using static displays (Abassi & Papeo, 2022; Papeo et al., 2017, 2019; Vestner et al., 2019). However, certain other neural regions, such as posterior superior temporal sulcus, are known to exhibit stronger activation and increased effective connectivity with other social perceptual regions in response to viewing dynamic displays over static ones (Bellot et al., 2021). Therefore, it remains a possibility that differential results would be obtained from these experiments had they employed dynamic stimuli. If it is determined that the presence of motion cues is a necessary condition to elicit dyadic configural processing, existing theoretical accounts of dyadic interaction perception will need to be revised accordingly (Papeo, 2020; Abassi & Papeo, 2022).

Besides potentially being an important factor for the engagement of configural processing, another advantage of employing dynamic depictions of interactions in studies aiming to measure perception of interpersonal distance (or social interactions more generally) is the increase in ecological validity. In real-world settings, the interactions we observe are rich in dynamic information. Interpersonal distance will in many cases serve as a dynamic visual cue, as the relative positioning of interactants' bodies tends to fluctuate over the course of an interaction due to various factors, such as the affective states of each interactant (Argyle & Dean, 1965; Bailenson et al., 2003; Kroczek et al., 2020; McCall & Singer, 2015). However, it should be noted that it may not always be straightforward to interpret the impact of interpersonal distance on measures of interest when employing dynamic stimuli (e.g., any observed effect could be driven by the average positions of the actors across a sequence or the closest distance between the actors that occurs within a sequence).

Another limitation of the stimuli used in these experiments is that they consisted of two-dimensional images. Future research may wish to explore whether the findings in this thesis can be replicated when participants view dyadic stimuli in immersive virtual reality. In addition to enhancing ecological validity, the use of virtual reality could be theoretically valuable for further investigations into the social variant of the Müller-Lyer illusion described in Chapter 2, as depth-based explanations have been proposed to explain traditional variants of the illusion (Day, 1989; Gregory, 1966; Howe & Purves, 2005).

Lastly, future research may find it fruitful to delve further into the social cognitive aspects of interpersonal distance. The findings from Chapter 2 shed light on the specific conditions under which illusory spatial distortions can be enacted on the perception of interpersonal distance. However, the real-world implications of these biases remain unclear, especially in scenarios where veridical assessments of social scenes are crucial (e.g., when providing eyewitness testimony in legal proceedings).

Furthermore, there is an opportunity to examine whether individuals with conditions associated with socio-cognitive atypicalities interpret changes in interpersonal distance differently. Although the current investigations suggest that individuals with DP (Chapter 4) and autism (Chapter 5) exhibit an intact ability to perceive interpersonal distance, it remains possible that individuals with these conditions may differ in their ability to utilise proxemic cues to inform their appraisals of social scenes. In other words, DP / autistic observers may be as effective as neurotypical observers in noticing changes in spatial relations between interactants but nevertheless infer different social meanings concerning interaction valence, the nature of the relationship between interactants, the presence of rapport, and so on. This could be explored in a study measuring how descriptive labels of social interactions, in terms of content (e.g., conflict vs. cooperation) or emotional context (happy vs. sad), change as a function of the magnitude of interpersonal distance.

6.4. Conclusion

Recent years have witnessed a burgeoning interest in the visual mechanisms that facilitate our perception of social interactions. This thesis delved into a fundamental aspect of dyadic interaction perception often overlooked in the literature: interpersonal distance. Chapter 2 demonstrates that the perception of this visual cue is not always veridical; it can be subject to distortion through visual illusions of length that have previously only been observed in domains outside of social perception (the Müller-Lyer illusion). Chapter 3 challenges prevailing theories of dyadic interaction perception that argue for the existence of specialised configural processes which should grant heightened perceptual sensitivity to changes in spatial relationships (i.e., interpersonal distance) when viewing upright, face-to-face dyads.

The final two empirical chapters cast even further doubt on claims that dyadic interaction perception leverages ‘face-like’ visual processes by showing that participants with neurodevelopmental conditions associated with face processing impairments – developmental prosopagnosia (Chapter 4) and autism (Chapter 5) – exhibit perceptual sensitivity to changes in dyadic spatial relations at a level comparable to that of neurotypical control groups. Overall, the findings reported in this thesis favour a domain-general model of interpersonal distance and dyadic interaction perception that does not rely on specialised or gated configural mechanisms.

References

Abassi, E., & Papeo, L. (2020). The Representation of Two-Body Shapes in the Human Visual Cortex. *Journal of Neuroscience*, *40*(4), 852–863. https://doi.org/10.1523/JNEUROSCI.1378-19.2019

Abassi, E., & Papeo, L. (2022). Behavioral and neural markers of visual configural processing in social scene perception. *NeuroImage*, *260*, 119506. https://doi.org/10.1016/j.neuroimage.2022.119506

Abramson, L., Petranker, R., Marom, I., & Aviezer, H. (2021). Social interaction context shapes emotion recognition through body language, not facial expressions. *Emotion*, *21*(3), 557–568. https://doi.org/10.1037/emo0000718

Adolphs, R. (2002). Recognizing Emotion from Facial Expressions: Psychological and Neurological Mechanisms. *Behavioral and Cognitive Neuroscience Reviews*, *1*(1), 21–62. https://doi.org/10.1177/1534582302001001003

Aiello, J. R., & De Carlo Aiello, T. (1974). The development of personal space: Proxemic behavior of children 6 through 16. *Human Ecology*, *2*(3), 177–189. https://doi.org/10.1007/BF01531420

Algom, D. (2021). The Weber–Fechner law: A misnomer that persists but that should go away. *Psychological Review*, *128*(4), 757–765. https://doi.org/10.1037/rev0000278

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

Argyle, M., & Dean, J. (1965). Eye-Contact, Distance and Affiliation. *Sociometry*, *28*(3), 289–304. https://doi.org/10.2307/2786027

Asada, K., Tojo, Y., Osanai, H., Saito, A., Hasegawa, T., & Kumagaya, S. (2016). Reduced Personal Space in Individuals with Autism Spectrum Disorder. *PLOS ONE, 11*(1), e0146306. https://doi.org/10.1371/journal.pone.0146306

Atkinson, A. P. (2009). Impaired recognition of emotions from body movements is associated with elevated motion coherence thresholds in autism spectrum disorders. *Neuropsychologia*, *47*(13), 3023–3029. https://doi.org/10.1016/j.neuropsychologia.2009.05.019

Avidan, G., & Behrmann, M. (2009). Functional MRI reveals compromised neural integrity of the face processing network in congenital prosopagnosia. *Current Biology*, *19*(13), 1146–1150. https://doi.org/10.1016/j.cub.2009.04.060

Avidan, G., & Behrmann, M. (2014). Impairment of the face processing network in congenital prosopagnosia. *Frontiers in Bioscience (Elite Edition)*, *6*(2), 236–257. https://doi.org/10.2741/E705

Avidan, G., Tanzer, M., & Behrmann, M. (2011). Impaired holistic processing in congenital prosopagnosia. *Neuropsychologia*, *49*(9), 2541–2552. https://doi.org/10.1016/j.neuropsychologia.2011.05.002

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2003). Interpersonal Distance in Immersive Virtual Environments. *Personality and Social Psychology Bulletin*, *29*(7), 819–833. https://doi.org/10.1177/0146167203029007002

Bandura, A. (1977). *Social Learning Theory*. Prentice Hall.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Prentice-Hall.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/a:1005653411471

Bartlett, J. C., & Searcy, J. (1993). Inversion and Configuration of Faces. *Cognitive Psychology*, *25*(3), 281–316. https://doi.org/10.1006/cogp.1993.1007

Barton, J. J. S. (2008). Structure and function in acquired prosopagnosia: Lessons from a series of 10 patients with brain damage. *Journal of Neuropsychology*, *2*(1), 197–225. https://doi.org/10.1348/174866407X214172

Barton, J. J. S., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology (London, England: 1953)*, *92 Part 3*, 527–549.

Barton, R. A. (1997). Neocortex size and behavioural ecology in primates. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *263*(1367), 173–177. https://doi.org/10.1098/rspb.1996.0028

Barton, R. A. (1998). Visual specialization and brain evolution in primates. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *265*(1409), 1933–1937. https://doi.org/10.1098/rspb.1998.0523

Bate, S., & Bennetts, R. (2015). The independence of expression and identity in face-processing: Evidence from neuropsychological case studies. *Frontiers in Psychology*, *6*. https://www.frontiersin.org/articles/10.3389/fpsyg.2015.00770

Bauser, D. A. S., Suchan, B., & Daum, I. (2011). Differences between perception of human faces and body shapes: Evidence from the composite illusion. *Vision Research*, *51*(1), 195–202. https://doi.org/10.1016/j.visres.2010.11.007

Behrmann, M., & Avidan, G. (2005). Congenital prosopagnosia: Face-blind from birth. *Trends in Cognitive Sciences*, *9*(4), 180–187. https://doi.org/10.1016/j.tics.2005.02.011

Behrmann, M., Avidan, G., Gao, F., & Black, S. (2007). Structural imaging reveals anatomical alterations in inferotemporal cortex in congenital prosopagnosia. *Cerebral Cortex (New York, N.Y.: 1991)*, *17*(10), 2354–2363. https://doi.org/10.1093/cercor/bhl144

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia*, *44*(1), 110–129. https://doi.org/10.1016/j.neuropsychologia.2005.04.002

Behrmann, M., Thomas, C., & Humphreys, K. (2006). Seeing it differently: Visual processing in autism. *Trends in Cognitive Sciences*, *10*(6), 258–264. https://doi.org/10.1016/j.tics.2006.05.001

Bellot, E., Abassi, E., & Papeo, L. (2021). Moving Toward versus Away from Another: How Body Motion Direction Changes the Representation of Bodies and Actions in the Visual Cortex. *Cerebral Cortex*, *31*(5), 2670–2685. https://doi.org/10.1093/cercor/bhaa382

Bernieri, F., Davis, J. M., Rosenthal, R., & Knee, C. (1994). Interpersonal Synchrony and Rapport: Measuring Synchrony in Displays Devoid of Sound and Facial Affect. *Personality and Social Psychology Bulletin*, *20*(3), 303–311.

Bernieri, F. J., Gillis, J. S., Davis, J. M., & Grahe, J. E. (1996). Dyad rapport and the accuracy of its judgment across situations: A lens model analysis. *Journal of Personality and Social Psychology*, *71*(1), 110–129. https://doi.org/10.1037/0022-3514.71.1.110

Bernstein, M., Erez, Y., Blank, I., & Yovel, G. (2018). An Integrated Neural Framework for Dynamic and Static Face Processing. *Scientific Reports*, *8*(1), Article 1. https://doi.org/10.1038/s41598-018-25405-9

Bernstein, M., Oron, J., Sadeh, B., & Yovel, G. (2014). An Integrated Face–Body Representation in the Fusiform Gyrus but Not the Lateral Occipital Cortex. *Journal of Cognitive Neuroscience*, *26*(11), 2469–2478. https://doi.org/10.1162/jocn_a_00639

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2005). Enhanced and diminished visuo-spatial information processing in autism depends on stimulus complexity. *Brain: A Journal of Neurology*, *128*(Pt 10), 2430–2441. https://doi.org/10.1093/brain/awh561

Bessenoff, G. R., & Sherman, J. W. (2000). Automatic and controlled components of prejudice toward fat people: Evaluation versus stereotype activation. *Social Cognition*, *18*(4), 329–353. https://doi.org/10.1521/soco.2000.18.4.329

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 1076–1096. https://doi.org/10.1037/0096-1523.25.4.1076

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, *94*, 115–147. https://doi.org/10.1037/0033-295X.94.2.115

Bindemann, M., Burton, A. M., Hooge, I. T., Jenkins, R., & de Haan, E. H. (2005). Faces retain attention. *Psychonomic Bulletin & Review*, *12*(6). https://doi.org/10.3758/bf03206442

Bindemann, M., Burton, A. M., Langton, S. R. H., Schweinberger, S. R., & Doherty, M. J. (2007). The control of attention to faces. *Journal of Vision*, *7*(10), 15.1-8. https://doi.org/10.1167/7.10.15

Biotti, F., & Cook, R. (2016). Impaired perception of facial emotion in developmental prosopagnosia. *Cortex*, *81*, 126–136. https://doi.org/10.1016/j.cortex.2016.04.008

Biotti, F., Gray, K. L. H., & Cook, R. (2017). Impaired body perception in developmental prosopagnosia. *Cortex*, *93*, 41–49. https://doi.org/10.1016/j.cortex.2017.05.006

Biotti, F., Gray, K. L. H., & Cook, R. (2019). Is developmental prosopagnosia best characterised as an apperceptive or mnemonic condition? *Neuropsychologia*, *124*, 285–298. https://doi.org/10.1016/j.neuropsychologia.2018.11.014

Biotti, F., Wu, E., Yang, H., Jiahui, G., Duchaine, B., & Cook, R. (2017). Normal composite face effects in developmental prosopagnosia. *Cortex*, *95*, 63–76. https://doi.org/10.1016/j.cortex.2017.07.018

Bird, G., Catmur, C., Silani, G., Frith, C., & Frith, U. (2006). Attention does not modulate neural responses to social stimuli in autism spectrum disorders. *NeuroImage*, *31*(4). https://doi.org/10.1016/j.neuroimage.2006.02.037

Blake, R., & Shiffrar, M. (2007). Perception of Human Motion. *Annual Review of Psychology*, *58*(1), 47–73. https://doi.org/10.1146/annurev.psych.57.102904.190152

Brandman, T., & Yovel, G. (2010). The Body Inversion Effect Is Mediated by Face-Selective, Not Body-Selective, Mechanisms. *The Journal of Neuroscience*, *30*(31), 10534–10540. https://doi.org/10.1523/JNEUROSCI.0911-10.2010

Brewer, R., Bird, G., Gray, K. L. H., & Cook, R. (2019). Face perception in autism spectrum disorder: Modulation of holistic processing by facial emotion. *Cognition*, *193*, 104016. https://doi.org/10.1016/j.cognition.2019.104016

Bruner, J. S., & Goodman, C. C. (1947). Value and need as organizing factors in perception. *The Journal of Abnormal and Social Psychology*, *42*, 33–44. https://doi.org/10.1037/h0058484

Bruyer, R. (2011). Configural face processing: A meta-analytic survey. *Perception*, *40*(12), 1478–1490. https://doi.org/10.1068/p6928

Buiatti, M., Di Giorgio, E., Piazza, M., Polloni, C., Menna, G., Taddei, F., Baldo, E., & Vallortigara, G. (2019). Cortical route for facelike pattern processing in human newborns. *Proceedings of the National Academy of Sciences*, *116*(10), 4625–4630. https://doi.org/10.1073/pnas.1812419116

Bukach, C. M., Gauthier, I., & Tarr, M. J. (2006). Beyond faces and modularity: The power of an expertise framework. *Trends in Cognitive Sciences*, *10*(4), 159–166. https://doi.org/10.1016/j.tics.2006.02.004

Bunce, C., Gehdu, B. K., Press, C., Gray, K. L. H., & Cook, R. (2024). Autistic adults exhibit typical sensitivity to changes in interpersonal distance. *Autism Research*, *17*(7), 1464–1474. https://doi.org/10.1002/aur.3164

Bunce, C., Gray, K. L. H., & Cook, R. (2021). The perception of interpersonal distance is distorted by the Müller-Lyer illusion. *Scientific Reports*, *11*(1), Article 1. https://doi.org/10.1038/s41598-020-80073-y

Bunce, C., Press, C., Gray, K., & Cook, R. (2024). Perceptual sensitivity to changes in interpersonal distance when observing social interactions: The effects of dyad arrangement and orientation.

Quarterly Journal of Experimental Psychology, 17470218241275595. https://doi.org/10.1177/17470218241275595

Bunce, C., Tsantani, M., Yon, D., & Cook, R. (unpublished). *Neural representations of observed interpersonal and person-object motion synchrony in the social perception network*.

Burgoon, J. K. (1991). Relational message interpretations of touch, conversational distance, and posture. *Journal of Nonverbal Behavior*, *15*(4), 233–259. https://doi.org/10.1007/BF00986924

Burton, A. M., & Bindemann, M. (2009). The role of view in human face detection. *Vision Research*, *49*(15), 2026–2036. https://doi.org/10.1016/j.visres.2009.05.012

Bushneil, I. W. R., Sai, F., & Mullin, J. T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology*, *7*(1), 3–15. https://doi.org/10.1111/j.2044-835X.1989.tb00784.x

Bushnell, I. W. R. (2001). Mother's face recognition in newborn infants: Learning and memory. *Infant and Child Development*, *10*(1–2), 67–74. https://doi.org/10.1002/icd.248

Candini, M., Battaglia, S., Benassi, M., di Pellegrino, G., & Frassinetti, F. (2021). The physiological correlates of interpersonal space. *Scientific Reports*, *11*(1), Article 1. https://doi.org/10.1038/s41598-021-82223-2

Carter, L. F., & Schooler, K. (1949). Value, need, and other factors in perception. *Psychological Review*, *56*, 200–207. https://doi.org/10.1037/h0060745

Centelles, L., Assaiante, C., Nazarian, B., Anton, J.-L., & Schmitz, C. (2011). Recruitment of Both the Mirror and the Mentalizing Networks When Observing Social Interactions Depicted by Point-Lights: A Neuroimaging Study. *PLOS ONE*, *6*(1), e15749. https://doi.org/10.1371/journal.pone.0015749

Chard, J., Cook, R., & Press, C. (2022). Impaired sensitivity to spatial configurations in healthy aging. *Cortex*, *155*, 347–356. https://doi.org/10.1016/j.cortex.2022.05.026

Chierchia, G., Fuhrmann, D., Knoll, L. J., Pi-Sunyer, B. P., Sakhardande, A. L., & Blakemore, S.-J. (2019). The matrix reasoning item bank (MaRs-IB): Novel, open-access abstract reasoning items for adolescents and adults. *Royal Society Open Science*, *6*(10), 190232. https://doi.org/10.1098/rsos.190232

Chin, M. D., Evans, K. K., Wolfe, J. M., Bowen, J., & Tanaka, J. W. (2018). Inversion effects in the expert classification of mammograms and faces. *Cognitive Research: Principles and Implications*, *3*(1), 31. https://doi.org/10.1186/s41235-018-0123-6

Christ, O., Schmid, K., Lolliot, S., Swart, H., Stolle, D., Tausch, N., Al Ramiah, A., Wagner, U., Vertovec, S., & Hewstone, M. (2014). Contextual effect of positive intergroup contact on outgroup prejudice. *Proceedings of the National Academy of Sciences*, *111*(11), 3996–4000. https://doi.org/10.1073/pnas.1320901111

Cook, R., & Biotti, F. (2016). Developmental prosopagnosia. *Current Biology*, *26*(8), R312–R313. https://doi.org/10.1016/j.cub.2016.01.008

Cook, R., Bird, G., Catmur, C., Press, C., & Heyes, C. (2014). Mirror neurons: From origin to function. *The Behavioral and Brain Sciences*, *37*(2), 177–192. https://doi.org/10.1017/S0140525X13000903

Cook, R., Brewer, R., Shah, P., & Bird, G. (2013). Alexithymia, not autism, predicts poor recognition of emotional facial expressions. *Psychological Science*, *24*(5), 723–732. https://doi.org/10.1177/0956797612463582

Cook, R., Eggleston, A., & Over, H. (2022). The cultural learning account of first impressions. *Trends in Cognitive Sciences*, *26*(8), 656–668. https://doi.org/10.1016/j.tics.2022.05.007

Coren, S., & Girgus, J. S. (1980). Principles of perceptual organization and spatial distortion: The gestalt illusions. *Journal of Experimental Psychology: Human Perception and Performance*, *6*, 404–412. https://doi.org/10.1037/0096-1523.6.3.404

Corrow, S. L., Dalrymple, K. A., & Barton, J. J. (2016). Prosopagnosia: Current perspectives. *Eye and Brain*, *8*, 165–175. https://doi.org/10.2147/EB.S92838

Costanzo, M., & Archer, D. (1989). Interperting the expressive behavior of others: The Interpersonal Perception Task. *Journal of Nonverbal Behavior*, *13*(4), 225–245. https://doi.org/10.1007/BF00990295

Crouzet, S. M., Kirchner, H., & Thorpe, S. J. (2010). Fast saccades toward faces: Face detection in just 100 ms. *Journal of Vision*, *10*(4), 16. https://doi.org/10.1167/10.4.16

Crump, M. J. C., McDonnell, J. V., & Gureckis, T. M. (2013). Evaluating Amazon's Mechanical Turk as a Tool for Experimental Behavioral Research. *PLOS ONE*, *8*(3), e57410. https://doi.org/10.1371/journal.pone.0057410

Curby, K. M., Huang, M., & Moerel, D. (2019). Multiple paths to holistic processing: Holistic processing of Gestalt stimuli do not overlap with holistic face processing in the same manner as do objects of expertise. *Attention, Perception, & Psychophysics*, *81*(3), 716–726. https://doi.org/10.3758/s13414-018-01643-x

Curby, K. M., & Moerel, D. (2019). Behind the face of holistic perception: Holistic processing of Gestalt stimuli and faces recruit overlapping perceptual mechanisms. *Attention, Perception, & Psychophysics*, *81*(8), 2873–2880. https://doi.org/10.3758/s13414-019-01749-w

Dakin, S., & Frith, U. (2005). Vagaries of Visual Perception in Autism. *Neuron*, *48*(3), 497–507. https://doi.org/10.1016/j.neuron.2005.10.018

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology*, *27*(3), 403–424. https://doi.org/10.1207/s15326942dn2703_6

Day, R. H. (1989). In *Human Information Processing: Measures, Mechanisms, and Models (eds. Vickers, D. & Smith, P. L.)*. Elsevier.

DeGutis, J., Cohan, S., Mercado, R. J., Wilmer, J., & Nakayama, K. (2012). Holistic processing of the mouth but not the eyes in developmental prosopagnosia. *Cognitive Neuropsychology*, *29*(5–6), 419–446. https://doi.org/10.1080/02643294.2012.754745

DeGutis, J., Cohan, S., & Nakayama, K. (2014). Holistic face training enhances face processing in developmental prosopagnosia. *Brain*, *137*(6), 1781–1798. https://doi.org/10.1093/brain/awu062

Dennett, H. W., McKone, E., Tavashmi, R., Hall, A., Pidcock, M., Edwards, M., & Duchaine, B. (2012). The Cambridge Car Memory Test: A task matched in format to the Cambridge Face Memory Test, with norms, reliability, sex differences, dissociations from face memory, and expertise effects. *Behavior Research Methods*, *44*(2), 587–605. https://doi.org/10.3758/s13428-011-0160-2

Deus, V., & Jokić-Begić, N. (2006). Personal space in schizophrenic patients. *Psychiatria Danubina*, *18*(3–4), 150–158.

Devue, C., Laloyaux, C., Feyers, D., Theeuwes, J., & Brédart, S. (2009). Do pictures of faces, and which ones, capture attention in the inattentional-blindness paradigm? *Perception*, *38*(4), 552–568. https://doi.org/10.1068/p6049

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology. General*, *115*(2), 107–117. https://doi.org/10.1037//0096-3445.115.2.107

Dotsch, R., & Wigboldus, D. H. J. (2008). Virtual prejudice. *Journal of Experimental Social Psychology*, *44*(4), 1194–1198. https://doi.org/10.1016/j.jesp.2008.03.003

Downing, P. E., Bray, D., Rogers, J., & Childs, C. (2004). Bodies capture attention when nothing is expected. *Cognition*, *93*(1), B27–B38. https://doi.org/10.1016/j.cognition.2003.10.010

Downing, P. E., & Peelen, M. V. (2011). The role of occipitotemporal body-selective regions in person perception. *Cognitive Neuroscience*, *2*(3–4), 186–203. https://doi.org/10.1080/17588928.2011.582945

Downing, P. E., & Peelen, M. V. (2016). Body selectivity in occipitotemporal cortex: Causal evidence. *Neuropsychologia*, *83*, 138–148. https://doi.org/10.1016/j.neuropsychologia.2015.05.033

Downing, P. E., Peelen, M. V., Wiggett, A. J., & Tew, B. D. (2006). The role of the extrastriate body area in action perception. *Social Neuroscience*, *1*(1), 52–62. https://doi.org/10.1080/17470910600668854

Duchaine, B. C. (2000). Developmental prosopagnosia with normal configural processing. *Neuroreport*, *11*(1), 79–83. https://doi.org/10.1097/00001756-200001170-00016

Duchaine, B. C., & Nakayama, K. (2006a). Developmental prosopagnosia: A window to content-specific face processing. *Current Opinion in Neurobiology*, *16*(2), 166–173. https://doi.org/10.1016/j.conb.2006.03.003

Duchaine, B. C., & Nakayama, K. (2006b). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia*, *44*(4), 576–585. https://doi.org/10.1016/j.neuropsychologia.2005.07.001

Duchaine, B., & Yovel, G. (2015). A Revised Neural Framework for Face Processing. *Annual Review of Vision Science*, *1*, 393–416. https://doi.org/10.1146/annurev-vision-082114-035518

Dunbar, R. I. M. (2009). The social brain hypothesis and its implications for social evolution. *Annals of Human Biology*, *36*(5), 562–572. https://doi.org/10.1080/03014460902960289

Duncan, B. L. (1976). Differential social perception and attribution of intergroup violence: Testing the lower limits of sterotyping of blacks. *Journal of Personality and Social Psychology*, *34*(44), 590–598.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review*, *16*(5), 964–969. https://doi.org/10.3758/PBR.16.5.964

Eberts, E. H. (1972). Social and personality correlates of personal space. In W. J. Mitchel (Ed.), *Environmental design: Research and practice (Proceedings of the EDRA 11/AR VIII Conference).* University of California Press.

Eggleston, A., Geangu, E., Tipper, S. P., Cook, R., & Over, H. (2021). Young children learn first impressions of faces through social referencing. *Scientific Reports*, *11*(1), 14744. https://doi.org/10.1038/s41598-021-94204-6

Eimer, M. (2011). The Face-Sensitivity of the N170 Component. *Frontiers in Human Neuroscience, 5*, 119. https://doi.org/10.3389/fnhum.2011.00119

Ellis, H. D. (1986). Processes underlying face recognition. *The Neuropsychology of Face Perception and Facial Expression*. https://cir.nii.ac.jp/crid/1570854175227744000

Farah, M. J., Rabinowitz, C., Quinn, G. E., & Liu, G. T. (2000). Early commitment of neural substrates for face recognition. *Cognitive Neuropsychology*, *17*(1), 117–123. https://doi.org/10.1080/026432900380526

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance*, *21*(3), 628–634. https://doi.org/10.1037/0096-1523.21.3.628

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is ‘special’ about face perception? *Psychological Review, 105*(3), 482–498. https://doi.org/10.1037/0033-295X.105.3.482

Farkas, K., Pesthy, O., Guttengéber, A., Weigl, S., Komoróczy, E., Szuromi, B., Réthelyi, J., & Németh, D. (2022). Altered interpersonal distance regulation in autism spectrum disorder. *European Psychiatry*, *65*(S1), S732–S733. https://doi.org/10.1192/j.eurpsy.2022.1892

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborns’ preference for face-relevant stimuli: Effects of contrast polarity. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(47), 17245–17250. https://doi.org/10.1073/pnas.0502205102

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Feinman, S., & Entwisle, D. R. (1976). Children's ability to recognize other children's faces. *Child Development, 47*(2), 506–510.

Field, T. M., Cohen, D., Garcia, R., & Greenberg, R. (1984). Mother-stranger face discrimination by the newborn. *Infant Behavior and Development*, *7*(1), 19–25. https://doi.org/10.1016/S0163-6383(84)80019-3

Filliter, J. H., Glover, J. M., McMullen, P. A., Salmon, J. P., & Johnson, S. A. (2016). The DalHouses: 100 new photographs of houses with ratings of typicality, familiarity, and degree of similarity to faces. *Behavior Research Methods*, *48*(1), 178–183. https://doi.org/10.3758/s13428-015-0561-8

Firestone, C. (2013). How "Paternalistic" Is Spatial Perception? Why Wearing a Heavy Backpack Doesn't—and Couldn't—Make Hills Look Steeper. *Perspectives on Psychological Science, 8*(4), 455–473. https://doi.org/10.1177/1745691613489835

Firestone, C., & Scholl, B. J. (2014). 'Top-down' effects where none should be found: The El Greco fallacy in perception research. *Psychological Science, 25*(1), 38–46. https://doi.org/10.1177/0956797613485092

Firestone, C., & Scholl, B. J. (2016). Cognition does not affect perception: Evaluating the evidence for 'top-down' effects. *The Behavioral and Brain Sciences, 39*, e229. https://doi.org/10.1017/S0140525X15000965

Forgas, J. P. (1993). On Making Sense of Odd Couples: Mood Effects on the Perception of Mismatched Relationships. *Personality and Social Psychology Bulletin, 19*(1), 59–70. https://doi.org/10.1177/0146167293191007

Forgas, J. P. (1995). Strange Couples: Mood Effects on Judgments and Memory about Prototypical and Atypical Relationships. *Personality and Social Psychology Bulletin, 21*(7), 747–765. https://doi.org/10.1177/0146167295217009

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception*, *29*(2), 159–170. https://doi.org/10.1068/p3012

Freitag, G. (1970). An experimental study of the social responsiveness of children with autistic behaviors. *Journal of Experimental Child Psychology*, *9*(3), 436–453. https://doi.org/10.1016/0022-0965(70)90030-5

Freiwald, W., Duchaine, B., & Yovel, G. (2016). Face Processing Systems: From Neurons to Real-World Social Perception. *Annual Review of Neuroscience*, *39*, 325–346. https://doi.org/10.1146/annurev-neuro-070815-013934

Frith, C. (2009). Role of facial expressions in social interactions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3453–3458. https://doi.org/10.1098/rstb.2009.0142

Gabay, S., Nestor, A., Dundas, E., & Behrmann, M. (2014). Monocular advantage for face perception implicates subcortical mechanisms in adult humans. *Journal of Cognitive Neuroscience*, *26*(5), 927–937. https://doi.org/10.1162/jocn_a_00528

Gallotti, M., Fairhurst, M. T., & Frith, C. D. (2017). Alignment in social interactions. *Consciousness and Cognition*, *48*, 253–261. https://doi.org/10.1016/j.concog.2016.12.002

Garrido, L., Furl, N., Draganski, B., Weiskopf, N., Stevens, J., Tan, G. C.-Y., Driver, J., Dolan, R. J., & Duchaine, B. (2009). Voxel-based morphometry reveals reduced grey matter volume in the temporal cortex of developmental prosopagnosics. *Brain: A Journal of Neurology*, *132*(Pt 12), 3443–3455. https://doi.org/10.1093/brain/awp271

Gauthier, I., & Bukach, C. (2007). Should we reject the expertise hypothesis? *Cognition*, *103*(2), 322–330. https://doi.org/10.1016/j.cognition.2006.05.003

Gauthier, I., Klaiman, C., & Schultz, R. T. (2009). Face composite effects reveal abnormal face processing in Autism spectrum disorders. *Vision Research*, *49*(4), 470–478. https://doi.org/10.1016/j.visres.2008.12.007

Gauthier, I., Williams, P., Tarr, M. J., & Tanaka, J. (1998). Training ‘greeble’ experts: A framework for studying expert object recognition processes. *Vision Research*, *38*(15), 2401–2428. https://doi.org/10.1016/S0042-6989(97)00442-2

Gehdu, B. K., Gray, K. L. H., & Cook, R. (2022). Impaired grouping of ambient facial images in autism. *Scientific Reports*, *12*(1), Article 1. https://doi.org/10.1038/s41598-022-10630-0

Gehdu, B. K., Tsantani, M., Press, C., Gray, K. L. H., & Cook, R. (2023). Recognition of facial expressions in autism: Effects of face masks and alexithymia. *Quarterly Journal of Experimental Psychology*, *0*(0). https://doi.org/10.1177/174702182311630

Gerlach, C., Klargaard, S. K., Petersen, A., & Starrfelt, R. (2017). Delayed processing of global shape information in developmental prosopagnosia. *PLOS ONE*, *12*(12), e0189253. https://doi.org/10.1371/journal.pone.0189253

Gerlach, C., & Starrfelt, R. (2018). Global precedence effects account for individual differences in both face and object recognition performance. *Psychonomic Bulletin and Review*, *25*(4), 1365–1372. https://doi.org/10.3758/s13423-018-1458-1

Germine, L., Nakayama, K., Duchaine, B. C., Chabris, C. F., Chatterjee, G., & Wilmer, J. B. (2012). Is the Web as good as the lab? Comparable performance from Web and lab in cognitive/perceptual experiments. *Psychonomic Bulletin & Review*, *19*(5), 847–857. https://doi.org/10.3758/s13423-012-0296-9

Germine, L. T., Duchaine, B. C., & Nakayama, K. (2011). Where cognitive development and aging meet: Face learning ability peaks after age 30. *Cognition*, *118*(2), 201–210. https://doi.org/10.1016/j.cognition.2010.11.002

Geskin, J., & Behrmann, M. (2018). Congenital prosopagnosia without object agnosia? A literature review. *Cognitive Neuropsychology*, *35*(1–2), 4–54. https://doi.org/10.1080/02643294.2017.1392295

Gessaroli, E., Santelli, E., Pellegrino, G. di, & Frassinetti, F. (2013). Personal Space Regulation in Childhood Autism Spectrum Disorders. *PLOS ONE*, *8*(9), e74959. https://doi.org/10.1371/journal.pone.0074959

Gifford, R. (1983). The experience of personal space: Perception of interpersonal distance. *Journal of Nonverbal Behavior*, *7*(3), 170–178. https://doi.org/10.1007/BF00986947

Givon-Benjio, N., Oren-Yagoda, R., Aderka, I. M., & Okon-Singer, H. (2020). Biased distance estimation in social anxiety disorder: A new avenue for understanding avoidance behavior. *Depression and Anxiety*, *37*(12), 1243–1252. https://doi.org/10.1002/da.23086

Gliga, T., Bedford, R., Charman, T., Johnson, M. H., & BASIS Team. (2015). Enhanced Visual Search in Infancy Predicts Emerging Autism Symptoms. *Current Biology*, *25*(13), 1727–1730. https://doi.org/10.1016/j.cub.2015.05.011

Goffaux, V., & Rossion, B. (2007). Face inversion disproportionately impairs the perception of vertical but not horizontal relations between features. *Journal of Experimental Psychology. Human Perception and Performance*, *33*(4), 995–1002. https://doi.org/10.1037/0096-1523.33.4.995

Goffman, E. (1963). *Behavior in Public Places*. Free Press.

Goldring, P. (1967). Role of distance and posture in the evaluation of interactions. *Proceedings of the Annual Convention of the American Psychological Association*, *2*, 2–2.

Gomez, J., Pestilli, F., Witthoft, N., Golarai, G., Liberman, A., Poltoratski, S., Yoon, J., & Grill-Spector, K. (2015). Functionally defined white matter reveals segregated pathways in human ventral temporal cortex associated with category-specific processing. *Neuron*, *85*(1), 216–227. https://doi.org/10.1016/j.neuron.2014.12.027

Goren, C. C., Sarty, M., & Wu, P. Y. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, *56*(4), 544–549.

Gray, K. L. H., Barber, L., Murphy, J., & Cook, R. (2017). Social interaction contexts bias the perceived expressions of interactants. *Emotion*, *17*(4), 567–571. https://doi.org/10.1037/emo0000257

Gray, K. L. H., Biotti, F., & Cook, R. (2019). Evaluating object recognition ability in developmental prosopagnosia using the Cambridge Car Memory Test. *Cognitive Neuropsychology*, *36*(1–2), 89–96. https://doi.org/10.1080/02643294.2019.1604503

Gray, K. L. H., Bird, G., & Cook, R. (2017). Robust associations between the 20-item prosopagnosia index and the Cambridge Face Memory Test in the general population. *Royal Society Open Science*, *4*(3), 160923. https://doi.org/10.1098/rsos.160923

Gray, K. L. H., & Cook, R. (2018). Should developmental prosopagnosia, developmental body agnosia, and developmental object agnosia be considered independent neurodevelopmental conditions? *Cognitive Neuropsychology*, *35*(1–2), 59–62. https://doi.org/10.1080/02643294.2018.1433153

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics* (pp. xi, 455). John Wiley.

Gregory, R. L. (1966). *Eye and brain: The psychology of seeing*. McGraw-Hill.

Greist-Bousquet, S., & Schiffman, H. R. (1981). The Many Illusions of the Müller-Lyer: Comparisons of the Wings-in and Wings-out Illusions and Manipulations of Standard and Dot Forms. *Perception*, *10*(2), 147–154. https://doi.org/10.1068/p100147

Grill-Spector, K. (2003). The neural basis of object perception. *Current Opinion in Neurobiology*, *13*(2), 159–166. https://doi.org/10.1016/s0959-4388(03)00040-0

Grill-Spector, K., Knouf, N., & Kanwisher, N. (2004). The fusiform face area subserves face perception, not generic within-category identification. *Nature Neuroscience*, *7*(5), 555–562. https://doi.org/10.1038/nn1224

Grill-Spector, K., Kourtzi, Z., & Kanwisher, N. (2001). The lateral occipital complex and its role in object recognition. *Vision Research*, *41*(10), 1409–1422. https://doi.org/10.1016/S0042-6989(01)00073-6

Haase, R. F., & Tepper, D. T. (1972). Nonverbal components of empathic communication. *Journal of Counseling Psychology*, *19*(5), 417–424. https://doi.org/10.1037/h0033188

Haig, N. D. (1984). The effect of feature displacement on face recognition. *Perception*, *13*(5), 505–512. https://doi.org/10.1068/p130505

Hall, E. T. (1963). A System for the Notation of Proxemic Behavior. *American Anthropologist*, *65*(5), 1003–1026. https://doi.org/10.1525/aa.1963.65.5.02a00020

Hall, E. T. (1966). *The hidden dimension*. Doubleday.

Hall, J. A. (1984). *Nonverbal sex differences: Communication accuracy and expressive style*. https://www.semanticscholar.org/paper/Nonverbal-sex-differences-%3A-communication-accuracy-Hall/723859e778e27c04e8bf79246078bd9cafe67e31

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *36*(1), 5–25. https://doi.org/10.1007/s10803-005-0039-0

Happé, F. G. E. (1996). Studying Weak Central Coherence at Low Levels: Children with Autism do not Succumb to Visual Illusions. A Research Note. *Journal of Child Psychology and Psychiatry*, *37*(7), 873–877. https://doi.org/10.1111/j.1469-7610.1996.tb01483.x

Harris, A., Vyas, D. B., & Reed, C. L. (2016). Holistic processing for bodies and body parts: New evidence from stereoscopic depth manipulations. *Psychonomic Bulletin & Review*, *23*(5), 1513–1519. https://doi.org/10.3758/s13423-016-1027-4

Hautus, M. J. (1995). Corrections for extreme proportions and their biasing effects on estimated values ofd′. *Behavior Research Methods, Instruments, & Computers*, *27*(1), 46–51. https://doi.org/10.3758/BF03203619

Haxby, J. V., & Gobbini, M. I. (2011). Distributed Neural Systems for Face Perception. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *Oxford Handbook of Face Perception* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199559053.013.0006

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science (New York, N.Y.), 293*(5539), 2425–2430. https://doi.org/10.1126/science.1063736

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*(6), 223–233. https://doi.org/10.1016/s1364-6613(00)01482-0

Hayduk, L. (1978). Personal space: An evaluative and orienting overview. *Psychological Bulletin*, *85*(1), 117–134.

Hayduk, L. A. (1981). The shape of personal space: An experimental investigation. *Canadian Journal of Behavioural Science*, *13*, 87–93. https://doi.org/10.1037/h0081114

Hayduk, L. A. (1983). Personal space: Where we now stand. *Psychological Bulletin*, *94*, 293–335. https://doi.org/10.1037/0033-2909.94.2.293

Heaton, P., Reichenbacher, L., Sauter, D., Allen, R., Scott, S., & Hill, E. (2012). Measuring the effects of alexithymia on perception of emotional vocalizations in autistic spectrum disorder and typical development. *Psychological Medicine*, *42*(11), 2453–2459. https://doi.org/10.1017/S0033291712000621

Hecht, H., Welsch, R., Viehoff, J., & Longo, M. R. (2019). The shape of personal space. *Acta Psychologica*, *193*, 113–122. https://doi.org/10.1016/j.actpsy.2018.12.009

Hedley, D., Brewer, N., & Young, R. (2011). Face recognition performance of individuals with Asperger syndrome on the Cambridge Face Memory Test. *Autism Research*, *4*(6), 449–455. https://doi.org/10.1002/aur.214

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, *33*(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X

Hershler, O., Golan, T., Bentin, S., & Hochstein, S. (2010). The wide window of face detection. *Journal of Vision*, *10*(10), 21. https://doi.org/10.1167/10.10.21

Hobson, R. P., Ouston, J., & Lee, A. (1988). What’s in a face? The case of autism. *British Journal of Psychology (London, England : 1953)*, *79 (Pt 4)*. https://doi.org/10.1111/j.2044-8295.1988.tb02745.x

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84. https://doi.org/10.1038/71152

Howe, C. Q., & Purves, D. (2005). The Müller-Lyer illusion explained by the statistics of image–source relationships. *Proceedings of the National Academy of Sciences*, *102*(4), 1234–1239. https://doi.org/10.1073/pnas.0409314102

Iachini, T., Coello, Y., Frassinetti, F., Senese, V. P., Galante, F., & Ruggiero, G. (2016). Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age. *Journal of Environmental Psychology*, *45*, 154–164. https://doi.org/10.1016/j.jenvp.2016.01.004

Isik, L., Koldewyn, K., Beeler, D., & Kanwisher, N. (2017). Perceiving social interactions in the posterior superior temporal sulcus. *Proceedings of the National Academy of Sciences*, *114*(43), E9145–E9152. https://doi.org/10.1073/pnas.1714471114

Jeffreys, H. (1998). *The Theory of Probability*. OUP Oxford.

Jiang, Y., Costello, P., & He, S. (2007). Processing of Invisible Stimuli: Advantage of Upright Faces and Recognizable Words in Overcoming Interocular Suppression. *Psychological Science*, *18*(4), 349–355. https://doi.org/10.1111/j.1467-9280.2007.01902.x

Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews. Neuroscience*, *6*(10), 766–774. https://doi.org/10.1038/nrn1766

Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two-process theory of face processing: Modifications based on two decades of data from infants and adults. *Neuroscience and Biobehavioral Reviews*, *50*, 169–179. https://doi.org/10.1016/j.neubiorev.2014.10.009

Johnston, P. J., Kaufman, J., Bajic, J., Sercombe, A., Michie, P. T., & Karayanidis, F. (2011). Facial emotion and identity processing development in 5- to 15-year-old children. *Frontiers in Psychology*, *2*, 26. https://doi.org/10.3389/fpsyg.2011.00026

Joseph, R. M., & Tanaka, J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *44*(4), 529–542. https://doi.org/10.1111/1469-7610.00142

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The Fusiform Face Area: A Module in Human Extrastriate Cortex Specialized for Face Perception. *Journal of Neuroscience*, *17*(11), 4302–4311. https://doi.org/10.1523/JNEUROSCI.17-11-04302.1997

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: A cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *361*(1476), 2109–2128. https://doi.org/10.1098/rstb.2006.1934

Keating, C. T., Sowden, S., & Cook, J. L. (2022). Comparing internal representations of facial expression kinematics between autistic and non-autistic adults. *Autism Research*, *15*(3), 493–506. https://doi.org/10.1002/aur.2642

Kennedy, D. P., Gläscher, J., Tyszka, J. M., & Adolphs, R. (2009). Personal Space Regulation by the Human Amygdala. *Nature Neuroscience*, *12*(10), 1226–1227. https://doi.org/10.1038/nn.2381

Keys, R. T., Taubert, J., & Wardle, S. G. (2021). A visual search advantage for illusory faces in objects. *Attention, Perception, & Psychophysics*, *83*(5), 1942–1953. https://doi.org/10.3758/s13414-021-02267-4

Kimura, M., & Daibo, I. (2006). Interactional Synchrony in Conversations about Emotional Episodes: A Measurement by “the Between-Participants Pseudosynchrony Experimental Paradigm”. *Journal of Nonverbal Behavior*, *30*(3), 115–126. https://doi.org/10.1007/s10919-006-0011-5

Kleinke, C. L., Meeker, F. B., & Fong, C. L. (1974). Effects of gaze, touch, and use of name on evaluation of "Engaged" couples. *Journal of Research in Personality, 7*(4), 368–373. https://doi.org/10.1016/0092-6566(74)90058-0

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature*, *459*(7244), 257–261. https://doi.org/10.1038/nature07868

Kroczek, L. O. H., Pfaller, M., Lange, B., Müller, M., & Mühlberger, A. (2020). Interpersonal Distance During Real-Time Social Interaction: Insights From Subjective Experience, Behavior, and Physiology. *Frontiers in Psychiatry*, *11*. https://doi.org/10.3389/fpsyt.2020.00561

Kujala, M. V., Carlson, S., & Hari, R. (2012). Engagement of amygdala in third-person view of face-to-face interaction. *Human Brain Mapping*, *33*(8), 1753–1762. https://doi.org/10.1002/hbm.21317

Kunz, B. R., Wouters, L., Smith, D., Thompson, W. B., & Creem-Regehr, S. H. (2009). Revisiting the effect of quality of graphics on distance judgments in virtual environments: A comparison of verbal reports and blind walking. *Attention, Perception, & Psychophysics*, *71*(6), 1284–1293. https://doi.org/10.3758/APP.71.6.1284

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face perception in high-functioning autistic adults: Evidence for superior processing of face parts, not for a configural face-processing deficit. *Neuropsychology, 20*(1), 30–41. https://doi.org/10.1037/0894-4105.20.1.30

Landis, D., Jones, J. M., & Reiter, J. (1966). Two experiments on perceived size of coins. *Perceptual and Motor Skills*, *23*(3), 719–729. https://doi.org/10.2466/pms.1966.23.3.719

Langdell, T. (1978). Recognition of Faces: An Approach to the Study of Autism. *Journal of Child Psychology and Psychiatry, 19*(3), 255–268. https://doi.org/10.1111/j.1469-7610.1978.tb00468.x

Lange, J., de Lussanet, M., Kuhlmann, S., Zimmermann, A., Lappe, M., Zwitserlood, P., & Dobel, C. (2009). Impairments of Biological Motion Perception in Congenital Prosopagnosia. *PLoS ONE*, *4*(10), e7414. https://doi.org/10.1371/journal.pone.0007414

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition and Emotion*, *24*(8), 1377–1388. https://doi.org/10.1080/02699930903485076

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, *6*(5), 541–567. https://doi.org/10.1080/135062899394939

Langton, S. R. H., Law, A. S., Burton, A. M., & Schweinberger, S. R. (2008). Attention capture by faces. *Cognition*, *107*(1), 330–342. https://doi.org/10.1016/j.cognition.2007.07.012

Latif, N., Barbosa, A. V., Vatiokiotis-Bateson, E., Castelhano, M. S., & Munhall, K. G. (2014). Movement Coordination during Conversation. *PLOS ONE*, *9*(8), e105036. https://doi.org/10.1371/journal.pone.0105036

Lavie, N., Ro, T., & Russell, C. (2003). The role of perceptual load in processing distractor faces. *Psychological Science*, *14*(5), 510–515. https://doi.org/10.1111/1467-9280.03453

Lawson, R. P., Rees, G., & Friston, K. J. (2014). An aberrant precision account of autism. *Frontiers in Human Neuroscience*, *8*. https://www.frontiersin.org/articles/10.3389/fnhum.2014.00302

Le Grand, R., Cooper, P. A., Mondloch, C. J., Lewis, T. L., Sagiv, N., de Gelder, B., & Maurer, D. (2006). What aspects of face processing are impaired in developmental prosopagnosia? *Brain and Cognition*, *61*(2), 139–158. https://doi.org/10.1016/j.bandc.2005.11.005

Le Grand, R., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001a). Early visual experience and face processing. *Nature*, *410*(6831), Article 6831. https://doi.org/10.1038/35073749

Le Grand, R., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001b). Early visual experience and face processing. *Nature*, *410*(6831), Article 6831. https://doi.org/10.1038/35073749

Leder, H., & Bruce, V. (1998). Local and Relational Aspects of Face Distinctiveness. *The Quarterly Journal of Experimental Psychology Section A*, *51*(3), 449–473. https://doi.org/10.1080/713755777

Leder, H., & Bruce, V. (2000). When Inverted Faces are Recognized: The Role of Configural Information in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *53*(2), 513–536. https://doi.org/10.1080/713755889

Leder, H., Candrian, G., Huber, O., & Bruce, V. (2001). Configural features in the context of upright and inverted faces. *Perception*, *30*(1), 73–83. https://doi.org/10.1068/p2911

Levine, D. N., & Calvanio, R. (1989). Prosopagnosia: A defect in visual configural processing. *Brain and Cognition*, *10*(2), 149–170. https://doi.org/10.1016/0278-2626(89)90051-1

Little, K. B. (1965). Personal space. *Journal of Experimental Social Psychology*, *1*(3), 237–247. https://doi.org/10.1016/0022-1031(65)90028-4

Liu, J., Li, J., Feng, L., Li, L., Tian, J., & Lee, K. (2014). Seeing Jesus in toast: Neural and behavioral correlates of face pareidolia. *Cortex*, *53*, 60–77. https://doi.org/10.1016/j.cortex.2014.01.013

Liu, R. R., Corrow, S. L., Pancaroglu, R., Duchaine, B., & Barton, J. J. S. (2015). The processing of voice identity in developmental prosopagnosia. *Cortex*, *71*, 390–397. https://doi.org/10.1016/j.cortex.2015.07.030

Liu, T. T., & Behrmann, M. (2014). Impaired holistic processing of left-right composite faces in congenital prosopagnosia. *Frontiers in Human Neuroscience*, *8*. https://www.frontiersin.org/articles/10.3389/fnhum.2014.00750

López, B., Donnelly, N., Hadwin, J., & Leekam, S. (2004). Face processing in high-functioning adolescents with autism: Evidence for weak central coherence. *Visual Cognition*, *11*(6), 673–688. https://doi.org/10.1080/13506280344000437

Maestro, S., Muratori, F., Cavallaro, M. C., Pei, F., Stern, D., Golse, B., & Palacio-Espasa, F. (2002). Attentional skills during the first 6 months of age in autism spectrum disorder. *Journal of the*

American Academy of Child and Adolescent Psychiatry, *41*(10), 1239–1245. https://doi.org/10.1097/00004583-200210000-00014

Matheson, H., Moore, C., & Akhtar, N. (2013). The development of social learning in interactive and observational contexts. *Journal of Experimental Child Psychology*, *114*(2), 161–172. https://doi.org/10.1016/j.jecp.2012.09.003

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, *6*(6), 255–260. https://doi.org/10.1016/S1364-6613(02)01903-4

McCall, C. (2017). Mapping Social Interactions: The Science of Proxemics. In M. Wöhr & S. Krach (Eds.), *Social Behavior from Rodents to Humans: Neural Foundations and Clinical Implications* (pp. 295–308). Springer International Publishing. https://doi.org/10.1007/7854_2015_431

McCall, C., Blascovich, J., Young, A., & Persky, S. (2009). Proxemic behaviors as predictors of aggression towards Black (but not White) males in an immersive virtual environment. *Social Influence*, *4*(2), 138–154. https://doi.org/10.1080/15534510802517418

McCall, C., & Singer, T. (2015). Facing Off with Unfair Others: Introducing Proxemic Imaging as an Implicit Measure of Approach and Avoidance during Social Interaction. *PLOS ONE*, *10*(2), e0117532. https://doi.org/10.1371/journal.pone.0117532

McCurdy, H. G. (1956). Coin perception studies and the concept of schemata. *Psychological Review*, *63*(3), 160–168. https://doi.org/10.1037/h0046614

McKone, E., Hall, A., Pidcock, M., Palermo, R., Wilkinson, R. B., Rivolta, D., Yovel, G., Davis, J. M., & O’Connor, K. B. (2011). Face ethnicity and measurement reliability affect face recognition performance in developmental prosopagnosia: Evidence from the Cambridge Face Memory Test–Australian. *Cognitive Neuropsychology*, *28*(2), 109–146. https://doi.org/10.1080/02643294.2011.616880

McKone, E., Kanwisher, N., & Duchaine, B. C. (2007). Can generic expertise explain special processing for faces? *Trends in Cognitive Sciences*, *11*(1), 8–15. https://doi.org/10.1016/j.tics.2006.11.002

McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. *Psychonomic Bulletin & Review*, *16*(5), 778–797. https://doi.org/10.3758/PBR.16.5.778

Minio-Paluello, I., Porciello, G., Pascual-Leone, A., & Baron-Cohen, S. (2020). Face individual identity recognition: A potential endophenotype in autism. *Molecular Autism*, *11*(1), 81. https://doi.org/10.1186/s13229-020-00371-0

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception*, *31*(5), 553–566. https://doi.org/10.1068/p3339

Morgan, M. J., Hole, G. J., & Glennerster, A. (1990). Biases and sensitivities in geometrical illusions. *Vision Research*, *30*(11), 1793–1810. https://doi.org/10.1016/0042-6989(90)90160-M

Morris, D. (2002). *Peoplewatching*. Random House.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: A two-process theory of infant face recognition. *Psychological Review*, *98*(2), 164–181. https://doi.org/10.1037/0033-295x.98.2.164

Moscovitch, M., Winocur, G., & Behrmann, M. (1997). What Is Special about Face Recognition? Nineteen Experiments on a Person with Visual Object Agnosia and Dyslexia but Normal Face Recognition. *Journal of Cognitive Neuroscience*, *9*(5), 555–604. https://doi.org/10.1162/jocn.1997.9.5.555

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception. *Journal of*

Autism and Developmental Disorders, *36*(1), 27–43. https://doi.org/10.1007/s10803-005-0040-7

Müller-Lyer, F. C. (1889). Optische urteilstauschungen. *Arch. Anatom. Physiol. Physiol. Abteilung*, *2*, 263–270.

Murphy, J., Gray, K. L. H., & Cook, R. (2017). The composite face illusion. *Psychonomic Bulletin & Review*, *24*(2), 245–261. https://doi.org/10.3758/s13423-016-1131-5

Nandrino, J.-L., Ducro, C., Iachini, T., & Coello, Y. (2017). Perception of Peripersonal and Interpersonal Space in Patients with Restrictive-type Anorexia. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, *25*(3), 179–187. https://doi.org/10.1002/erv.2506

Nijhawan, R. (1991). Three-dimensional Müller-Lyer illusion. *Perception & Psychophysics*, *49*(4), 333–341. https://doi.org/10.3758/BF03205989

Nisbet, R. A., & Perrin, R. (1977). *The Social Bond*. Knopf.

Nishimura, M., Rutherford, M. D., & Maurer, D. (2008). Converging evidence of configural processing of faces in high-functioning adults with autism spectrum disorders. *Visual Cognition*, *16*(7), 859–891. https://doi.org/10.1080/13506280701538514

O’Craven, K. M., Rosen, B. R., Kwong, K. K., Treisman, A., & Savoy, R. L. (1997). Voluntary attention modulates fMRI activity in human MT-MST. *Neuron*, *18*(4), 591–598. https://doi.org/10.1016/s0896-6273(00)80300-1

Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism and Developmental Disorders*, *24*(3), 247–257. https://doi.org/10.1007/BF02172225

Over, H., & Carpenter, M. (2015). Children infer affiliative and status relations from watching others imitate. *Developmental Science*, *18*(6), 917–925. https://doi.org/10.1111/desc.12275

Over, H., Eggleston, A., & Cook, R. (2020). Ritual and the origins of first impressions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1805), 20190435. https://doi.org/10.1098/rstb.2019.0435

Palermo, R., Willis, M. L., Rivolta, D., McKone, E., Wilson, C. E., & Calder, A. J. (2011). Impaired holistic coding of facial expression and facial identity in congenital prosopagnosia. *Neuropsychologia*, *49*(5), 1226–1235. https://doi.org/10.1016/j.neuropsychologia.2011.02.021

Papeo, L. (2020). Twos in human visual perception. *Cortex*, *132*, 473–478. https://doi.org/10.1016/j.cortex.2020.06.005

Papeo, L., & Abassi, E. (2019). Seeing social events: The visual specialization for dyadic human–human interactions. *Journal of Experimental Psychology: Human Perception and Performance*, *45*(7), 877–888. https://doi.org/10.1037/xhp0000646

Papeo, L., Goupil, N., & Soto-Faraco, S. (2019). Visual Search for People Among People. *Psychological Science*, *30*(10), 1483–1496. https://doi.org/10.1177/0956797619867295

Papeo, L., Stein, T., & Soto-Faraco, S. (2017). The Two-Body Inversion Effect. *Psychological Science*, *28*(3), 369–379. https://doi.org/10.1177/0956797616685769

Pardo-Vazquez, J. L., Castiñeiras-de Saa, J. R., Valente, M., Damião, I., Costa, T., Vicente, M. I., Mendonça, A. G., Mainen, Z. F., & Renart, A. (2019). The mechanistic foundation of Weber's law. *Nature Neuroscience*, *22*(9), Article 9. https://doi.org/10.1038/s41593-019-0439-7

Parker, N. I., & Newbigging, P. L. (1963). Magnitude and decrement of the Muller-Lyer illusion as a function of pre-training. *Canadian Journal of Psychology*, *17*, 134–140. https://doi.org/10.1037/h0083262

Parr, L. A. (2011). The evolution of face processing in primates. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1571), 1764–1777. https://doi.org/10.1098/rstb.2010.0358

Pascalis, O., & de Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *Neuroreport*, *5*(14), 1721–1724. https://doi.org/10.1097/00001756-199409080-00008

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior and Development*, *18*(1), 79–85. https://doi.org/10.1016/0163-6383(95)90009-8

Pedersen, J., Livoir-Petersen, M. F., & Schelde, J. T. (1989). An ethological approach to autism: An analysis of visual behaviour and interpersonal contact in a child versus adult interaction. *Acta Psychiatrica Scandinavica*, *80*(4), 346–355. https://doi.org/10.1111/j.1600-0447.1989.tb02991.x

Peelen, M. V., & Downing, P. E. (2007). The neural basis of visual body perception. *Nature Reviews. Neuroscience*, *8*(8), 636–648. https://doi.org/10.1038/nrn2195

Pellicano, E., & Burr, D. (2012). When the world becomes 'too real': A Bayesian explanation of autistic perception. *Trends in Cognitive Sciences*, *16*(10), 504–510. https://doi.org/10.1016/j.tics.2012.08.009

Perry, A., Levy-Gigi, E., Richter-Levin, G., & Shamay-Tsoory, S. G. (2015). Interpersonal distance and social anxiety in autistic spectrum disorders: A behavioral and ERP study. *Social Neuroscience*, *10*(4), 354–365. https://doi.org/10.1080/17470919.2015.1010740

Perry, A., Rubinsten, O., Peled, L., & Shamay-Tsoory, S. G. (2013). Don't stand so close to me: A behavioral and ERP study of preferred interpersonal distance. *NeuroImage*, *83*, 761–769. https://doi.org/10.1016/j.neuroimage.2013.07.042

Philip, R. C. M., Whalley, H. C., Stanfield, A. C., Sprengelmeyer, R., Santos, I. M., Young, A. W., Atkinson, A. P., Calder, A. J., Johnstone, E. C., Lawrie, S. M., & Hall, J. (2010). Deficits in facial, body movement and vocal emotional processing in autism spectrum disorders. *Psychological Medicine*, *40*(11), 1919–1929. https://doi.org/10.1017/S0033291709992364

Piepers, D., & Robbins, R. (2012). A Review and Clarification of the Terms “holistic,” “configural,” and “relational” in the Face Perception Literature. *Frontiers in Psychology, 3*. https://www.frontiersin.org/article/10.3389/fpsyg.2012.00559

Pitcher, D., Charles, L., Devlin, J. T., Walsh, V., & Duchaine, B. (2009). Triple dissociation of faces, bodies, and objects in extrastriate cortex. *Current Biology*, *19*(4), 319–324. https://doi.org/10.1016/j.cub.2009.01.007

Pitcher, D., Dilks, D. D., Saxe, R. R., Triantafyllou, C., & Kanwisher, N. (2011). Differential selectivity for dynamic versus static information in face-selective cortical regions. *NeuroImage*, *56*(4), 2356–2363. https://doi.org/10.1016/j.neuroimage.2011.03.067

Pitcher, D., & Ungerleider, L. G. (2021). Evidence for a Third Visual Pathway Specialized for Social Perception. *Trends in Cognitive Sciences*, *25*(2), 100–110. https://doi.org/10.1016/j.tics.2020.11.006

Pitcher, D., Walsh, V., & Duchaine, B. (2011). The role of the occipital face area in the cortical face perception network. *Experimental Brain Research*, *209*(4), 481–493. https://doi.org/10.1007/s00221-011-2579-1

Plötner, M., Over, H., Carpenter, M., & Tomasello, M. (2016). What Is a Group? Young Children’s Perceptions of Different Types of Groups and Group Entitativity. *PLoS ONE*, *11*(3), e0152001. https://doi.org/10.1371/journal.pone.0152001

Pomerantz, J. R., & Portillo, M. C. (2011). Grouping and emergent features in vision: Toward a theory of basic Gestalts. *Journal of Experimental Psychology: Human Perception and Performance*, *37*, 1331–1349. https://doi.org/10.1037/a0024330

Prins, N., & Kingdom, F. A. A. (2009). *Palamedes: Matlab routines for analyzing psychophysical data*. http://www.palamedestoolbox.org

Proffitt, D. R. (2006). Embodied Perception and the Economy of Action. *Perspectives on Psychological Science*, *1*(2), 110–122. https://doi.org/10.1111/j.1745-6916.2006.00008.x

Quadflieg, S., Gentile, F., & Rossion, B. (2015). The neural basis of perceiving person interactions. *Cortex, 70,* 5–20. https://doi.org/10.1016/j.cortex.2014.12.020

Quadflieg, S., & Koldewyn, K. (2017). The neuroscience of people watching: How the human brain makes sense of other people's encounters. *Annals of the New York Academy of Sciences, 1396*(1), 166–182. https://doi.org/10.1111/nyas.13331

Quadflieg, S., & Penton-Voak, I. S. (2017). The Emerging Science of People-Watching: Forming Impressions From Third-Party Encounters. *Current Directions in Psychological Science, 26*(4), 383–389. https://doi.org/10.1177/0963721417694353

Quadflieg, S., & Westmoreland, K. (2019). Making Sense of Other People's Encounters: Towards an Integrative Model of Relational Impression Formation. *Journal of Nonverbal Behavior, 43*(2), 233–256. https://doi.org/10.1007/s10919-019-00295-1

Reed, C. L., Beall, P. M., Stone, V. E., Kopelioff, L., Pulham, D. J., & Hepburn, S. L. (2007). Brief report: Perception of body posture--what individuals with autism spectrum disorder might be missing. *Journal of Autism and Developmental Disorders, 37*(8). https://doi.org/10.1007/s10803-006-0220-0

Reed, C. L., Stone, V. E., Bozova, S., & Tanaka, J. (2003). The Body-Inversion Effect. *Psychological Science, 14*(4), 302–308. https://doi.org/10.1111/1467-9280.14431

Reed, C. L., Stone, V. E., Grubb, J. D., & McGoldrick, J. E. (2006). Turning configural processing upside down: Part and whole body postures. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(1), 73–87. https://doi.org/10.1037/0096-1523.32.1.73

Restle, F., & Decker, J. (1977). Size of the Mueller-Lyer illusion as a function of its dimensions: Theory and data. *Perception & Psychophysics*, *21*(6), 489–503. https://doi.org/10.3758/BF03198729

Rhodes, G., Byatt, G., Michie, P. T., & Puce, A. (2004). Is the fusiform face area specialized for faces, individuation, or expert individuation? *Journal of Cognitive Neuroscience*, *16*(2), 189–203. https://doi.org/10.1162/089892904322984508

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic Processing Predicts Face Recognition. *Psychological Science*, *22*(4), 464–471. https://doi.org/10.1177/0956797611401753

Richler, J., Palmeri, T., & Gauthier, I. (2012). Meanings, Mechanisms, and Measures of Holistic Processing. *Frontiers in Psychology*, *3*. https://www.frontiersin.org/articles/10.3389/fpsyg.2012.00553

Ro, T., Friggel, A., & Lavie, N. (2007). Attentional biases for faces and body parts. *Visual Cognition*, *15*(3), 322–348. https://doi.org/10.1080/13506280600590434

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science*, *12*(1), 94–99. https://doi.org/10.1111/1467-9280.00317

Robbins, R. A., & Coltheart, M. (2012). Left–right holistic integration of human bodies. *Quarterly Journal of Experimental Psychology*, *65*(10), 1962–1974. https://doi.org/10.1080/17470218.2012.674145

Roger, D. B. (1982). Body-image, personal space and self-esteem: Preliminary evidence for ‘focusing’ effects. *Journal of Personality Assessment*, *46*(5). https://doi.org/10.1207/s15327752jpa4605_4

Rossion, B. (2013). The composite face illusion: A whole window into our understanding of holistic face perception. *Visual Cognition*, *21*(2), 139–253. https://doi.org/10.1080/13506285.2013.772929

Schirmer, A., Reece, C., Zhao, C., Ng, E., Wu, E., & Yen, S.-C. (2015). Reach out to one and you reach out to many: Social touch affects third-party observers. *British Journal of Psychology*, *106*(1), 107–132. https://doi.org/10.1111/bjop.12068

Segall, M. H., Campbell, D. T., & Herskovits, M. J. (1966). *The influence of culture on visual perception*. Bobbs-Merrill Co.

Shah, P., Bird, G., & Cook, R. (2016). Face processing in autism: Reduced integration of cross-feature dynamics. *Cortex*, *75*, 113–119. https://doi.org/10.1016/j.cortex.2015.11.019

Shah, P., Gaule, A., Sowden, S., Bird, G., & Cook, R. (2015). The 20-item prosopagnosia index (PI20): A self-report instrument for identifying developmental prosopagnosia. *Royal Society Open Science*, *2*(6), 140343. https://doi.org/10.1098/rsos.140343

Shah, P., Happé, F., Sowden, S., Cook, R., & Bird, G. (2015). Orienting Toward Face-Like Stimuli in Early Childhood. *Child Development*, *86*(6), 1693–1700. https://doi.org/10.1111/cdev.12441

Simion, F., & Giorgio, E. D. (2015). Face perception and processing in early infancy: Inborn predispositions and developmental changes. *Frontiers in Psychology*, *6*, 969. https://doi.org/10.3389/fpsyg.2015.00969

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Research*, *49*(22), 2705–2739. https://doi.org/10.1016/j.visres.2009.08.005

Skinner, A. L., & Hudac, C. M. (2017). “Yuck, you disgust me!” Affective bias against interracial couples. *Journal of Experimental Social Psychology*, *68*, 68–77. https://doi.org/10.1016/j.jesp.2016.05.008

Slaughter, V., & Heron, M. (2004). Origins and early development of human body knowledge. *Monographs of the Society for Research in Child Development*, *69*(2), vii, 1–102. https://doi.org/10.1111/j.0037-976X.2004.00286.x

Slaughter, V., Heron, M., & Sim, S. (2002). Development of preferences for the human body shape in infancy. *Cognition*, *85*(3), B71-81. https://doi.org/10.1016/s0010-0277(02)00111-7

Slaughter, V., Stone, V. E., & Reed, C. (2004). Perception of Faces and Bodies: Similar or Different? *Current Directions in Psychological Science*, *13*(6), 219–223. https://doi.org/10.1111/j.0963-7214.2004.00312.x

Song, S., Garrido, L., Nagy, Z., Mohammadi, S., Steel, A., Driver, J., Dolan, R. J., Duchaine, B., & Furl, N. (2015). Local but not long-range microstructural differences of the ventral temporal cortex in developmental prosopagnosia. *Neuropsychologia*, *78*, 195–206. https://doi.org/10.1016/j.neuropsychologia.2015.10.010

Sorokin, P. A. (1928). *Contemporary Sociological Theories*. Harper & Brothers.

Sorokowska, A., Sorokowski, P., Hilpert, P., Cantarero, K., Frackowiak, T., Ahmadi, K., Alghraibeh, A. M., Aryeetey, R., Bertoni, A., Bettache, K., Blumen, S., Błażejewska, M., Bortolini, T., Butovskaya, M., Castro, F. N., Cetinkaya, H., Cunha, D., David, D., David, O. A., … Pierce, J. D. (2017). Preferred Interpersonal Distances: A Global Comparison. *Journal of Cross-Cultural Psychology*, *48*(4), 577–592. https://doi.org/10.1177/0022022117698039

Stantić, M., Ichijo, E., Catmur, C., & Bird, G. (2022). Face memory and face perception in autism. *Autism*, *26*, 276–280.

Stein, T., Peelen, M. V., & Sterzer, P. (2011). Adults' awareness of faces follows newborns' looking preferences. *PloS One*, *6*(12), e29361. https://doi.org/10.1371/journal.pone.0029361

Summerfield, C., Egner, T., Mangels, J., & Hirsch, J. (2006). Mistaking a house for a face: Neural correlates of misperception in healthy humans. *Cerebral Cortex (New York, N.Y.: 1991)*, *16*(4), 500–508. https://doi.org/10.1093/cercor/bhi129

Sun, Z., Ye, C., Sun, T., Yu, W., & Li, X. (2022). The spatial distance compression effect is due to social interaction and not mere configuration. *Psychonomic Bulletin & Review*, *29*(3), 828–836. https://doi.org/10.3758/s13423-021-02045-1

Sundstrom, E., & Altman, I. (1976). Interpersonal relationships and personal space: Research review and theoretical model. *Human Ecology*, *4*(1), 47–67. https://doi.org/10.1007/BF01531456

Susilo, T., & Duchaine, B. (2013). Advances in developmental prosopagnosia research. *Current Opinion in Neurobiology*, *23*(3), 423–429. https://doi.org/10.1016/j.conb.2012.12.011

Susilo, T., McKone, E., Dennett, H., Darke, H., Palermo, R., Hall, A., Pidcock, M., Dawel, A., Jeffery, L., Wilson, C. E., & Rhodes, G. (2010). Face recognition impairments despite normal holistic processing and face space coding: Evidence from a case of developmental prosopagnosia. *Cognitive Neuropsychology*, *27*(8), 636–664. https://doi.org/10.1080/02643294.2011.613372

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., Rees, L., & Wheelwright, S. (1998). The frequency and distribution of spontaneous attention shifts between social and nonsocial stimuli in autistic, typically developing, and nonautistic developmentally delayed infants. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *39*(5). https://pubmed.ncbi.nlm.nih.gov/9690937/

Tanaka, J., & Gauthier, I. (1997). Expertise in object and face recognition. In *Perceptual learning* (pp. 83–125). Academic Press.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology*, *46*(2), 225–245. https://doi.org/10.1080/14640749308401045

Tanzer, M., Freud, E., Ganel, T., & Avidan, G. (2013). General holistic impairment in congenital prosopagnosia: Evidence from Garner's speeded-classification task. *Cognitive Neuropsychology*, *30*(6), 429–445. https://doi.org/10.1080/02643294.2013.873715

Tennis, G. H., & Dabbs, J. M. (1975). Sex, Setting and Personal Space: First Grade Through College. *Sociometry*, *38*(3), 385–394. https://doi.org/10.2307/2786172

Teunisse, J. P., & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: The inversion and composite effects. *Brain and Cognition*, *52*(3), 285–294. https://doi.org/10.1016/S0278-2626(03)00042-3

Thayer, S., & Schiff, W. (1974). Observer judgement of social interaction: Eye contact and relationship inferences. *Journal of Personality and Social Psychology*, *30*(1), 110–114.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition*, *13*(6), 657–665. https://doi.org/10.1080/13506280500410949

Thomas, C., Avidan, G., Humphreys, K., Jung, K., Gao, F., & Behrmann, M. (2009). Reduced structural connectivity in ventral visual cortex in congenital prosopagnosia. *Nature Neuroscience*, *12*(1), 29–31. https://doi.org/10.1038/nn.2224

Tiedens, L. Z., & Fragale, A. R. (2003). Power moves: Complementarity in dominant and submissive nonverbal behavior. *Journal of Personality and Social Psychology, 84*, 558–568.

Tomalski, P., Csibra, G., & Johnson, M. H. (2009). Rapid orienting toward face-like stimuli with gaze-relevant contrast information. *Perception*, *38*(4), 569–578. https://doi.org/10.1068/p6137

Tomalski, P., Johnson, M. H., & Csibra, G. (2009). Temporal-nasal asymmetry of rapid orienting to face-like stimuli. *Neuroreport*, *20*(15), 1309–1312. https://doi.org/10.1097/WNR.0b013e32832f0acd

Trout, D. L., & Rosenfeld, H. M. (1980). The effect of postural lean and body congruence on the judgment of psychotherapeutic rapport. *Journal of Nonverbal Behavior*, *4*(3), 176–190. https://doi.org/10.1007/BF00986818

Tsantani, M., & Cook, R. (2020). Normal recognition of famous voices in developmental prosopagnosia. *Scientific Reports*, *10*(1), 19757. https://doi.org/10.1038/s41598-020-76819-3

Tsantani, M., Gray, K. L. H., & Cook, R. (2020). Holistic processing of facial identity in developmental prosopagnosia. *Cortex*, *130*, 318–326. https://doi.org/10.1016/j.cortex.2020.06.003

Tsantani, M., Gray, K. L. H., & Cook, R. (2022). New evidence of impaired expression recognition in developmental prosopagnosia. *Cortex*, *154*, 15–26. https://doi.org/10.1016/j.cortex.2022.05.008

Tsantani, M., Kriegeskorte, N., McGettigan, C., & Garrido, L. (2019). Faces and voices in the brain: A modality-general person-identity representation in superior temporal sulcus. *NeuroImage, 201*, 116004. https://doi.org/10.1016/j.neuroimage.2019.07.017

Tsantani, M., Vestner, T., & Cook, R. (2021). The Twenty Item Prosopagnosia Index (PI20) provides meaningful evidence of face recognition impairment. *Royal Society Open Science*, *8*(11), 202062. https://doi.org/10.1098/rsos.202062

Tsantani, M., Yon, D., & Cook, R. (2022). *Neural representations of observed interpersonal synchrony/asynchrony in the social perception network*. PsyArXiv. https://doi.org/10.31234/osf.io/pjvke

Tsao, D. Y., & Livingstone, M. S. (2008). Mechanisms of face perception. *Annual Review of Neuroscience, 31*, 411–437. https://doi.org/10.1146/annurev.neuro.30.051606.094238

Valenza, E., Simion, F., Cassia, V. M., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology. Human Perception and Performance*, *22*(4), 892–903. https://doi.org/10.1037//0096-1523.22.4.892

Van de Cruys, S., Evers, K., Van der Hallen, R., Van Eylen, L., Boets, B., de-Wit, L., & Wagemans, J. (2014). Precise minds in uncertain worlds: Predictive coding in autism. *Psychological Review*, *121*(4), 649–675. https://doi.org/10.1037/a0037665

Vestner, T., Gray, K. L. H., & Cook, R. (2020). Why are social interactions found quickly in visual search tasks? *Cognition, 200,* 104270. https://doi.org/10.1016/j.cognition.2020.104270

Vestner, T., Gray, K. L. H., & Cook, R. (2021). Visual search for facing and non-facing people: The effect of actor inversion. *Cognition, 208*, 104550. https://doi.org/10.1016/j.cognition.2020.104550

Vestner, T., Gray, K. L. H., & Cook, R. (2022). Sensitivity to orientation is not unique to social attention cueing. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-09011-4

Vestner, T., Tipper, S. P., Hartley, T., Over, H., & Rueschemeyer, S.-A. (2019). Bound Together: Social binding leads to faster processing, spatial distortion and enhanced memory of interacting partners. *Journal of Experimental Psychology: General*, 1251–1268.

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure–ground organization. *Psychological Bulletin*, *138,* 1172–1217. https://doi.org/10.1037/a0029333

Walbrin, J., Downing, P., & Koldewyn, K. (2018). Neural responses to visually observed social interactions. *Neuropsychologia*, *112*, 31–39. https://doi.org/10.1016/j.neuropsychologia.2018.02.023

Walbrin, J., & Koldewyn, K. (2019). Dyadic interaction processing in the posterior temporal cortex. *NeuroImage*, *198*, 296–302. https://doi.org/10.1016/j.neuroimage.2019.05.027

Wallace, S., Coleman, M., & Bailey, A. (2008). Face and object processing in autism spectrum disorders. *Autism Research*, *1*(1), 43–51. https://doi.org/10.1002/aur.7

Webb, J. D., & Weber, M. J. (2003). Influence of sensory abilities on the interpersonal distance of the elderly. *Environment and Behavior*, *35*, 695–711. https://doi.org/10.1177/0013916503251473

Weidner, R., & Fink, G. R. (2007). The Neural Mechanisms Underlying the Müller-Lyer Illusion And Its Interaction with Visuospatial Judgments. *Cerebral Cortex*, *17*(4), 878–884. https://doi.org/10.1093/cercor/bhk042

Weigelt, S., Koldewyn, K., & Kanwisher, N. (2012). Face identity recognition in autism spectrum disorders: A review of behavioral studies. *Neuroscience and Biobehavioral Reviews*, *36*(3), 1060–1084. https://doi.org/10.1016/j.neubiorev.2011.12.008

Weller, M., Takahashi, K., Watanabe, K., Bülthoff, H. H., & Meilinger, T. (2018). The Object Orientation Effect in Exocentric Distances. *Frontiers in Psychology*, *9*, 1374. https://doi.org/10.3389/fpsyg.2018.01374

Welsch, R., Castell, C. von, Rettenberger, M., Turner, D., Hecht, H., & Fromberger, P. (2020). Sexual attraction modulates interpersonal distance and approach-avoidance movements towards virtual agents in males. *PLOS ONE*, *15*(4), e0231539. https://doi.org/10.1371/journal.pone.0231539

Welsch, R., Hecht, H., & von Castell, C. (2018). Psychopathy and the Regulation of Interpersonal Distance. *Clinical Psychological Science*, *6*(6), 835–847. https://doi.org/10.1177/2167702618788874

Willems, S., Vrancken, L., Germeys, F., & Verfaillie, K. (2014). Holistic processing of human body postures: Evidence from the composite effect. *Frontiers in Psychology*, *5*. https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00618

Williams, E. H., & Chakrabarti, B. (2023). The integration of head and body cues during the perception of social interactions. *Quarterly Journal of Experimental Psychology (2006)*, 17470218231181001. https://doi.org/10.1177/17470218231181001

Williams, J. L. (1971). Personal space and its relation to extraversion-introversion. *Canadian Journal of Behavioural Science / Revue Canadienne Des Sciences Du Comportement*, *3*, 156–160. https://doi.org/10.1037/h0082257

Woloszyn, M. R. (2010). Contrasting Three Popular Explanations for the Muller-Lyer Illusion. *Current Research in Psychology*, *1*(2), 102–107. https://doi.org/10.3844/crpsp.2010.102.107

Wong, A. C.-N., Palmeri, T. J., & Gauthier, I. (2009). Conditions for Facelike Expertise With Objects: Becoming a Ziggerin Expert—but Which Type? *Psychological Science*, *20*(9), 1108–1117. https://doi.org/10.1111/j.1467-9280.2009.02430.x

Woods, D. L., Wyma, J. M., Yund, E. W., Herron, T. J., & Reed, B. (2015). Factors influencing the latency of simple reaction time. *Frontiers in Human Neuroscience*, *9*. https://doi.org/10.3389/fnhum.2015.00131

Word, C. O., Zanna, M. P., & Cooper, J. (1974). The nonverbal mediation of self-fulfilling prophecies in interracial interaction. *Journal of Experimental Social Psychology*, *10*(2), 109–120. https://doi.org/10.1016/0022-1031(74)90059-6

Wormith, J. S. (1984). Personal space of incarcerated offenders. *Journal of Clinical Psychology*, *40*, 815–827. https://doi.org/10.1002/1097-4679(198405)40:3<815::AID-JCLP2270400332>3.0.CO;2-G

Worthington, M. E. (1974). Personal space as a function of the stigma effect. *Environment and Behavior*, *6*(3), 289–294. https://doi.org/10.1177/001391657400600302

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141–145. https://doi.org/10.1037/h0027474

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception*, *16*(6), 747–759. https://doi.org/10.1068/p160747

Yovel, G. (2016). Neural and cognitive face-selective markers: An integrative review. *Neuropsychologia*, *83*, 5–13. https://doi.org/10.1016/j.neuropsychologia.2015.09.026

Yovel, G., & Duchaine, B. (2006). Specialized face perception mechanisms extract both part and spacing information: Evidence from developmental prosopagnosia. *Journal of Cognitive Neuroscience*, *18*(4), 580–593. https://doi.org/10.1162/jocn.2006.18.4.580

Yovel, G., & Kanwisher, N. (2005). The neural basis of the behavioral face-inversion effect. *Current Biology*, *15*(24), 2256–2262. https://doi.org/10.1016/j.cub.2005.10.072

Yovel, G., & Kanwisher, N. (2008). The representations of spacing and part-based information are associated for upright faces but dissociated for objects: Evidence from individual differences. *Psychonomic Bulletin & Review*, *15*(5), 933–939. https://doi.org/10.3758/PBR.15.5.933

Zhang, J., Liu, J., & Xu, Y. (2015). Neural decoding reveals impaired face configural processing in the right fusiform face area of individuals with developmental prosopagnosia. *The Journal of Neuroscience*, *35*(4), 1539–1548. https://doi.org/10.1523/JNEUROSCI.2646-14.2015

Zhao M, Bülthoff, H., & Bülthoff I. (2016). Beyond Faces and Expertise: Facelike Holistic Processing of Nonface Objects in the Absence of Expertise. *Psychological Science*, *27*(2). https://doi.org/10.1177/0956797615617779