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Typical perceptual sensitivity to changes in interpersonal distance in developmental prosopagnosia

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Abstract

Social perception research has traditionally sought to elucidate the visual processing engaged by the faces and bodies of individuals. Recently, however, there has been growing interest in how we perceive dyadic interactions between people. Early findings suggest that dyads arranged face-to-face may engage neurocognitive processing similar to that recruited by faces. Given these parallels, we sought to determine whether developmental prosopagnosics (DPs), who exhibit lifelong face recognition difficulties, also exhibit impaired perception of facing dyads. The focus of our investigation was interpersonal distance – a key visual feature of dyadic social interactions. 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, we 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, DPs and typical controls did not differ significantly in their ability to detect distance changes on any of the tasks. Although the visual processing of faces and facing dyads exhibit certain similarities, these findings suggest that the underlying perceptual mechanisms may dissociate.

Keywords:

Developmental prosopagnosia; Social interaction; Dyadic perception; Face recognition; Interpersonal distance.

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 (McMahon & Isik, 2023; Papeo, 2020; Quadflieg & Koldewyn, 2017). This emerging literature is still in its infancy. However, it has been suggested that upright dyads arranged face-to-face engage domain-specific neurocognitive processing analogous to that recruited by upright faces (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2019). This face-like processing hypothesis accords with several lines of evidence.

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). Facing dyads may 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; Barzy et al., 2025; 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, 2012). 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 – the so-called search advantage for facing dyads (Papeo et al., 2019; Vestner et al., 2019).

When shown upright, faces are thought to engage domain-specific visual processing that affords high levels of visual sensitivity to facial cues, rapid discrimination, and the spontaneous recruitment of attention. When shown upside-down, however, the same face stimuli fail to engage this processing, or engage it to a lesser extent (Farah et al., 1998; Maurer et al., 2002; McKone et al., 2007; McKone & Yovel, 2009; Murphy et al., 2017;

Rossion, 2008). Consistent with this view, observers' perceptual decisions tend to be more accurate when judging upright faces, than when judging inverted faces (Murphy et al., 2017; Prkachin, 2003; Schwaninger et al., 2005; Thompson, 1980; Yin, 1969). Thus, orientation sensitivity is widely regarded as a key hallmark of domain-specific face processing (Farah et al., 1998; Maurer et al., 2002; McKone et al., 2007; McKone & Yovel, 2009; Murphy et al., 2017; Rossion, 2008). It is noteworthy, therefore, that aspects of dyadic processing also exhibit sensitivity to orientation (Papeo, 2020). For example, the 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 (30ms) and subject to backwards masking, participants are also better able to detect upright face-to-face arrangements, than inverted face-to-face arrangements. However, 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 may recruit cortical regions previously implicated in the perception of faces. For example, the fusiform face area (FFA) exhibits 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 area also responds more strongly when observers view semantically incongruous facing dyads – i.e., two agents acting in an unrelated manner, such as an office-worker greeting a burglar – than when they view semantically congruous facing dyads – i.e., two agents acting in a related manner, such as two people dancing together (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; Tsantani et al., 2024; Walbrin et al., 2018). Interestingly, the pSTS has also been identified as an important hub in the processing of facial identity (Tsantani et al., 2019), facial motion (Pitcher, Dilks, et al., 2011), and facial expressions (Sliwinska & Pitcher, 2018).

Developmental prosopagnosia

Developmental prosopagnosia (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). Given their face recognition problems, individuals with DP are more reliant on non-face cues (e.g., hairstyle, voice, clothing, walking gait) when identifying others. 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 (Cook & Biotti, 2016; Shah et al., 2015).

At the neurological level, DPs exhibit differences in cortical structure(Behrmann et al., 2007; Garrido et al., 2009), structural (Gomez et al., 2015; Song et al., 2015; Thomas et al., 2009) and functional connectivity (Avidan & Behrmann, 2009; Avidan et al., 2014) in occipital and inferotemporal regions. Aberrant connectivity between key hubs – including the fusiform (Kanwisher & Yovel, 2006) and occipital face areas (Pitcher, Walsh, et al., 2011) – may impair information exchange within the face processing network (e.g., Thomas et al., 2009). Electrophysiological studies have also revealed differences in certain event-related potentials (ERPs) in DP, including the N170 (Fisher et al., 2016; Towler et al., 2012), N250 (Towler et al., 2018) and P600f (Parketny et al., 2015).

A popular cognitive account of DP argues that individuals with the condition struggle to process faces configurally (Avidan et al., 2011; Liu & Behrmann, 2014; Palermo et al., 2011), though this remains controversial (e.g., Biotti et al., 2017; Tsantani et al., 2020). One line of evidence for this view is that DPs exhibit diminished sensitivity to the spatial relationships between facial features. For example, Yovel and Duchaine (2006) found that DPs were less to able to detect changes in interocular and nose-mouth spacing than matched typical controls, yet showed typical performance when detecting equivalent spatial changes in houses (windows and doors).

The defining feature of DP is severe lifelong face recognition 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 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).

Despite their social vision deficits, the wider social cognition of DPs is frequently unaffected. For example, 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). In particular, typical recognition of famous voices is noteworthy as this finding suggests intact social learning (Tsantani & Cook, 2020). Many DPs also demonstrate typical levels of anthropomorphism and are adept at social interaction (Duchaine et al., 2009).

Present study

In light of recent claims that facing dyads recruit face-like visual processing (Abassi & Papeo, 2022; Papeo, 2020; Papeo et al., 2019), the present study sought to determine whether individuals with DP, who have lifelong difficulties recognising faces, also exhibit impaired perception of facing dyads. To-date, little is known about the ability of DPs to perceive facing dyads. However, the parallels seen between the processing engaged by faces and facing dyads, suggest the possibility that DPs might well exhibit differences in this facet of social perception. Because this field of study is relatively new, there is not an “off the shelf” test available to quantify individual differences in dyadic perception ability. We therefore sought to develop a bespoke task that would measure the dyadic processing hypothesised by proponents of the face-like processing account (e.g., Papeo, 2020). For this purpose, we elected to focus on perceptual judgements of interpersonal distance.

Interpersonal distance is an important cue when appraising the nature and content of social interactions. For example, we tend to stand closer to those we know well, or those with whom we have intimate relationships, but stand further away from strangers or those with whom we have formal relationships (Hall, 1963, 1966; McCall & Singer, 2015). Similarly, people tend to distance themselves from members of ethnic out-groups (Dotsch & Wigboldus, 2008; McCall et al., 2009), otherwise stigmatized individuals (Bessenoff & Sherman, 2000; Worthington, 1974), and people who have recently treated us unfairly (McCall & Singer, 2015). As such, it is possible to infer a great deal about an observed social interaction – and the interacting individuals – from the distance between the actors (Bunce et al., 2021).

The putative domain-specific dyad processing recently described in the social vision literature is thought to augment observers’ representation of configural stimulus features (Abassi & Papeo, 2020, 2022; Papeo et al., 2019). 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. Thus, one would expect perceptual decisions about interpersonal distance to be affected should observers exhibit impoverished configural dyad processing.

By way of analogy, the specialized visual processing engaged by upright *faces* is thought to increase perceptual sensitivity to inter-feature spatial relations (Bunce et al., 2024; Freire et al., 2000; Goffaux & Rossion, 2007; Le Grand et al., 2001; 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 viewed upside-down – a condition that attenuates domain-specific face processing (Leder et al., 2001). Similarly, as noted above, DPs are less sensitive to inter-feature spatial relations than typical observers (Yovel & Duchaine, 2006).

Research transparency and openness

Neither the study procedure nor the intended analyses were pre-registered prior to the start of the research. In the following sections we report how we determined our sample size, all data exclusions, all inclusion criteria, and whether inclusion/exclusion criteria were established prior to data analysis. All manipulations and all measures in the study are reported. The experimental task is available here: https://app.gorilla.sc/openmaterials/652716. The Twenty-Item Prosopagnosia Index (PI20) is freely available (see: Shah et al., 2015). Legal copyright restrictions prevent public archiving of the Cambridge Face Memory Tests (Duchaine & Nakayama, 2006b; McKone et al., 2011) and the Cambridge Car Memory Test (Dennett et al., 2012), which can be obtained from the authors and copyright holders. The supporting data are available via the Open Science Framework (https://osf.io/gbaqe/).

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 provided informed consent.

Method

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; Shah et al., 2015; Gray, Bird, et al., 2017; 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, 2006b) 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 31.9% to 94.4% (M_{CCMT} = 64.6, SD_{CCMT} = 14.8). Diagnostic information for individual DPs is presented in Table 1.

Table 1. Demographic and diagnostic information for the DP participants.

	Age	Sex	PI20	CFMT-O (%)	CFMT-A (%)	CCMT (%)	zPI20	zCFMT-O	zCFMT-A	zCCMT
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*. For the CFMT-A, comparison data (*N* = 75, M_{age} = 21.67; SD_{age} = 2.96; range: 18–32 years) were taken from McKone et al. (2011), *Cognitive Neuropsychology*. For the CCMT, comparison data (*N* = 61, M_{age} = 37.0; SD_{age} = 9.8; range: 27–60 years) were taken from Gray et al. (2019), *Cognitive Neuropsychology*.

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 (criterion 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) [$t(124) = 24.27$, $p < .001$]. The groups did not differ significantly in terms of age [$t(124) = .20$, $p = .84$] or sex [$\chi^2 = .41$, $p = .52$]. 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 (criteria determined prior to analysis).

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. Participants were asked 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. The images used in these tasks closely resemble those used in previous neuroimaging (e.g., Abassi & Papeo, 2020; Gandolfo et al., 2024; Quadflieg et al., 2015) and behavioural (Papeo et al., 2017, 2019; Vestner et al., 2019) studies that have sought to elucidate the representation of facing dyads in the human visual system. A third task depicted distance changes using non-social objects – a pair of grandfather clocks. We opted to use images of grandfather clocks because they were of similar height to the actors. The clocks were shown facing the observer so that they were easily recognisable. The three tasks had an identical format (Figure 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.

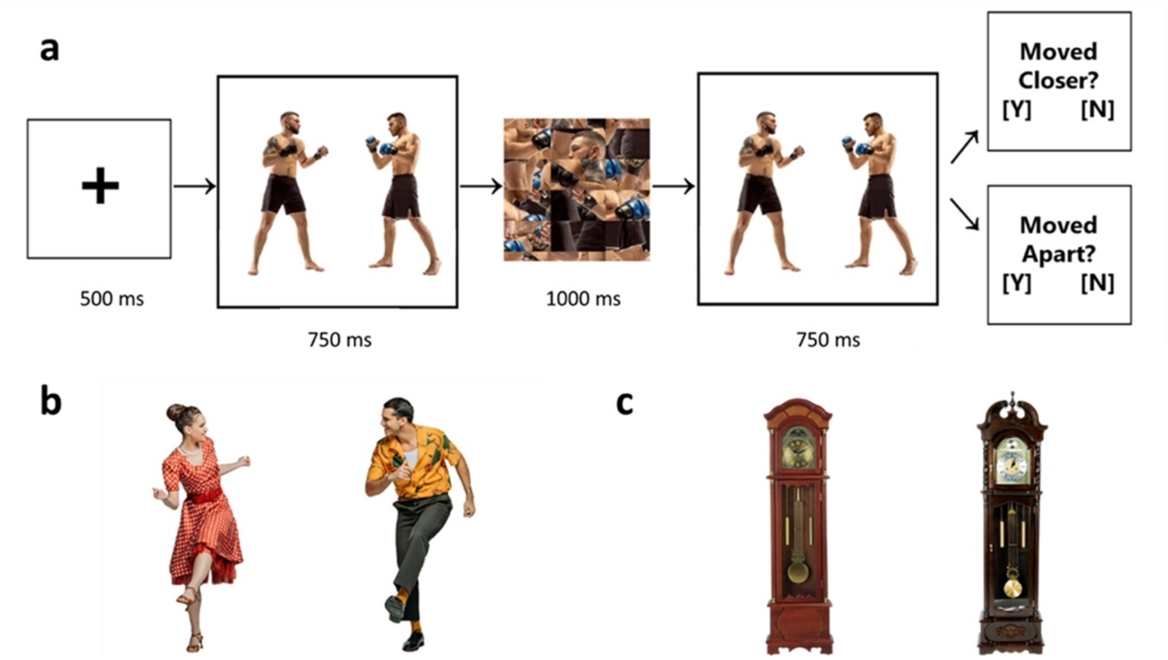

Figure 1. Overview of task format. (a) Schematic illustration of the sequence of an experimental trial in which participants viewed the boxer stimuli. (b) Example of the dancer stimuli. (c) Example of the clock stimuli.

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 500 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 in an open-ended response window.

The stimuli presented first and second 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 we could present each actor / clock on the left and right. 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 which shape (circle, square, triangle, or diamond) was presented (1000 ms) immediately prior to the response prompt. Any participant who failed to respond correctly on at least 6 of the 8 attention checks was excluded and replaced (criterion determined prior to analysis). Two controls were replaced on this basis.

Performance was analysed using signal detection theory (Green & Swets, 1966). For each participant we calculated separate measures of perceptual sensitivity (*d′*) and bias (C) 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). Log-linear corrections (e.g., Hautus, 1995) were applied to guard against extreme values in hit (HR) and false alarm (FAR) rates. Positive bias values reflect a greater proportion of distance change responses. The resulting distributions of *d′* and *C* estimates were normally distributed.

Results

For the purpose of the group analyses, distributions of sensitivity (*d′*) and bias (*C*) estimates were evaluated using both traditional null-hypothesis significance testing ($\alpha = 0.05$, twotailed) and Bayesian methods (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. Bayesian contrasts were conducted using default Cauchy priors (centre = 0, width = 0.707).

Perceptual sensitivity (d')

Dancers. The d' estimates obtained (Figure 2a) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 7.63$, $p = .007$, $\eta_p^2 = .058$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 124) = 0.15$, $p = .70$, $\eta_p^2 = .001$], 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 [$F(1, 124) = 0.52$, $p = .47$, $\eta_p^2 = .004$]. When considered separately, we observed no significant group difference on move closer [$M_{DP} = 2.45$, $SD_{DP} = 0.71$, $M_{control} = 2.45$, $SD_{control} = 0.78$, $t(124) = 0.03$, $p = .98$, $d = 0.01$, $BF_{01} = 4.99$] or move apart trials [$M_{DP} = 2.21$, $SD_{DP} = 0.57$, $M_{control} = 2.31$, $SD_{control} = 0.75$, $t(124) = -0.73$, $p = .47$, $d = -0.14$, $BF_{01} = 3.92$].

Boxers. The d' estimates obtained (Figure 2b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 4.00$, $p = .048$, $\eta_p^2 = .031$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 124) = 2.21$, $p = .14$, $\eta_p^2 = .017$], 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 [$F(1, 124) = 0.09$, $p = .76$, $\eta_p^2 < .001$]. When considered separately, we observed no significant group difference on move closer [$M_{DP} = 2.30$, $SD_{DP} = 0.70$, $M_{control} = 2.50$, $SD_{control} = 0.71$, $t(124) = -1.51$, $p = .14$, $d = -0.28$, $BF_{01} = 1.81$] or move apart trials [$M_{DP} = 2.19$, $SD_{DP} = 0.68$, $M_{control} = 2.35$, $SD_{control} = 0.79$, $t(124) = -1.13$, $p = .26$, $d = -0.21$, $BF_{01} = 2.81$].

Clocks. The d' estimates obtained (Figure 2c) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 5.60$,

p = .020, η_p^2 = .043], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [F(1, 124) = 2.76, p = .099, η_p^2 = .022], 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) = 0.02, p = .90, η_p^2 < .001]. When considered separately, we observed no significant group difference on move closer [M_{DP} = 2.39, SD_{DP} = 0.70, M_{control} = 2.59, SD_{control} = 0.71, t(124) = -1.51, p = .13, d = -0.29, BF_{01} = 1.79] or move apart trials [M_{DP} = 2.25, SD_{DP} = 0.62, M_{control} = 2.44, SD_{control} = 0.73, t(124) = -1.42, p = .16, d = -0.27, BF_{01} = 2.04].

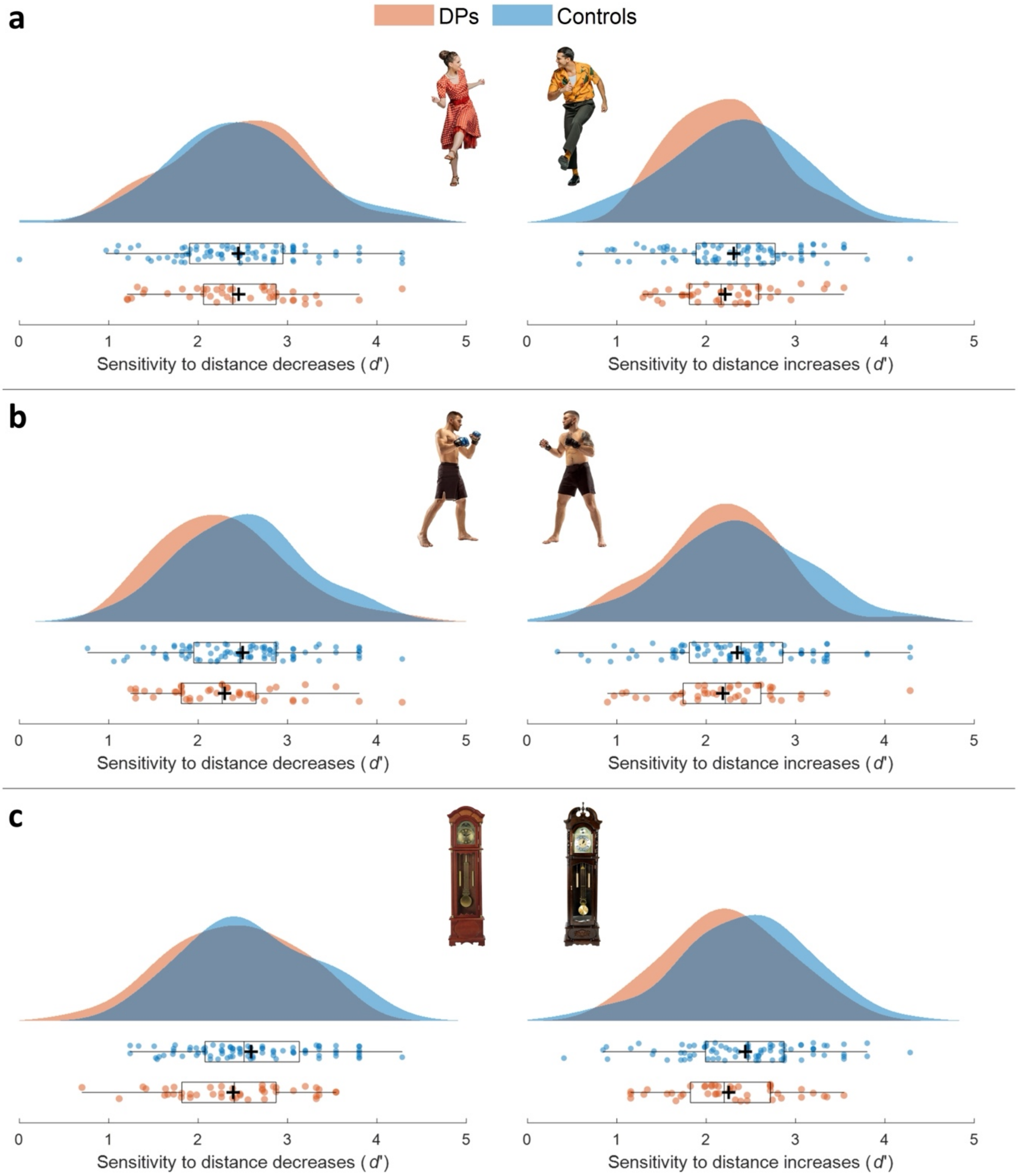

Figure 2. Perceptual sensitivity (*d*′) exhibited by DP and control participants. (a) Results for the dancer task. (b) Results for the boxer task. (c) Results for the clock task. Left-hand plots represent sensitivity on move closer trials; right-hand plots represent sensitivity on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher *d*′ values reflect superior sensitivity.

Bias (C)

Dancers. The C estimates obtained (Figure 3a) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 11.67$, $p < .001$, $\eta_p^2 = .086$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 124) = 0.02$, $p = .89$, $\eta_p^2 < .001$], 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 [$F(1, 124) = 1.04$, $p = .31$, $\eta_p^2 = .008$]. When considered separately, we observed no significant group difference on move closer trials [$M_{\mathrm{DP}} = -0.21$, $SD_{\mathrm{DP}} = 0.51$, $M_{\mathrm{control}} = -0.13$, $SD_{\mathrm{control}} = 0.63$, $t(124) = -0.75$, $p = .45$, $d = -0.14$, $\mathrm{BF}_{01} = 3.87$] or move apart trials, [$M_{\mathrm{DP}} = 0.11$, $SD_{\mathrm{DP}} = 0.48$, $M_{\mathrm{control}} = 0.05$, $SD_{\mathrm{control}} = 0.46$, $t(124) = 0.73$, $p = .47$, $d = 0.14$, $\mathrm{BF}_{01} = 3.93$].

Boxers. The C estimates obtained (Figure 3b) were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 34.75$, $p < .001$, $\eta_p^2 = .219$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 124) = 1.28$, $p = .26$, $\eta_p^2 = .010$], 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 [$F(1, 124) = 0.04$, $p = .85$, $\eta_p^2 < .001$]. When considered separately, we observed no group difference on move closer trials [$M_{\mathrm{DP}} = 0.22$, $SD_{\mathrm{DP}} = 0.39$, $M_{\mathrm{control}} = 0.30$, $SD_{\mathrm{control}} = 0.49$, $t(124) = -0.95$, $p = .34$, $d = -0.18$, $\mathrm{BF}_{01} = 3.32$] or move apart trials [$M_{\mathrm{DP}} = -0.13$, $SD_{\mathrm{DP}} = 0.50$, $M_{\mathrm{control}} = -0.07$, $SD_{\mathrm{control}} = 0.45$, $t(124) = -0.67$, $p = .50$, $d = -0.13$, $\mathrm{BF}_{01} = 4.08$].

Clocks. The C estimates obtained (Figure 3c) were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 124) = 166.84$, $p < .001$, $\eta_p^2 = .57$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [*F*(1, 124) = 1.43, *p* = .23, η_p^2 = .011], 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) = 0.56, *p* = .46, η_p^2 = .004]. When considered separately, we observed no group difference on move closer trials [M_{DP} = 0.44, SD_{DP} = 0.40, M_{control} = 0.46, SD_{control} = 0.41, *t*(124) = -0.32, *p* = .75, *d* = -0.06, BF_{01} = 4.77] or move apart trials [M_{DP} = -0.36, SD_{DP} = 0.50, M_{control} = -0.25, SD_{control} = 0.43, *t*(124) = -1.30, *p* = .20, *d* = -0.25, BF_{01} = 2.35].

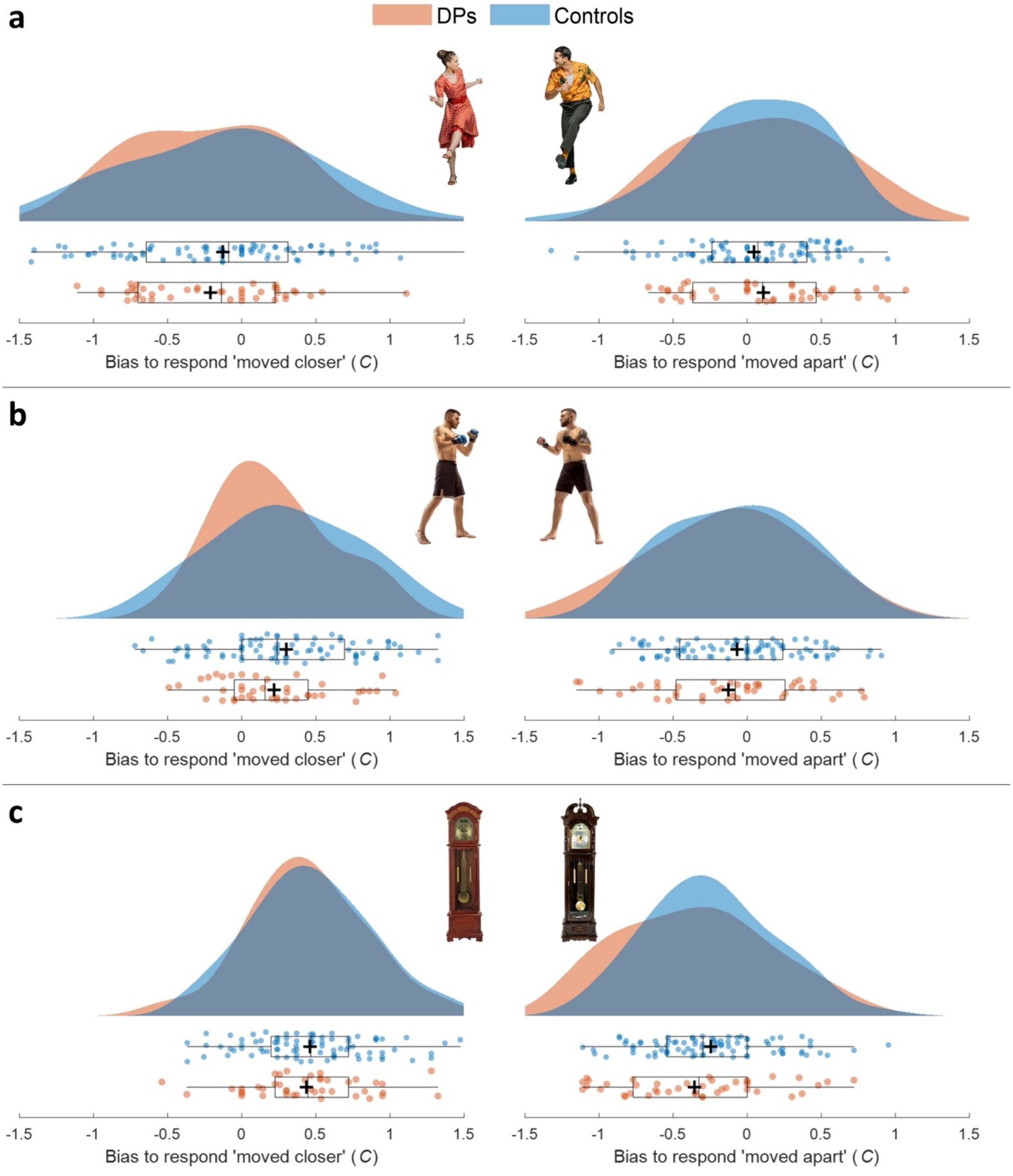

Figure 3. Bias (C) estimates for DP and control participants. (a) Results for the dancer task. (b) Results for the boxer task. (c) Results for the clock task. Left-hand plots represent bias on move closer trials; right-hand plots represent bias on move apart trials. Boxplots denote median and interquartile range. Plus signs denote means. Higher C values reflect bias to report a distance change.

DPs with co-occurring object recognition problems

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

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 our sample of *N* = 42 included 8 individuals who exhibited significant impairment on the CCMT (zCFMTs < -1.645, Table-1). We reasoned that some individuals with non-specific visual agnosias may show impoverished sensitivity to distance changes when viewing 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, we re-ran the analyses described above with these individuals excluded. The results of these exploratory analyses are described in detail in the Appendix. Once again, we found no significant effects of Group on either measure (sensitivity or bias). In the case of sensitivity, however, we observed substantial evidence for the null hypothesis (BF_{01} > 3.0; Jeffreys, 1998) on all three tasks (Table 2).

Table 2. 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 and are emboldened.

			Object agnosic DPs included (N = 42)	Object agnosic DPs excluded (N = 34)
Sensitivity	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	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

General Discussion

It has recently been argued that upright dyads arranged face-to-face engage specialised processing analogous to that engaged by upright faces (e.g., Papeo, 2020). For example, it has been suggested that facing 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 thought to be processed with high-priority within the visual system (Papeo et al., 2019; Vestner et al., 2019). Dyads and faces also 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, we asked 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, participants judged whether the stimulus elements moved closer together or whether the distance remained constant. On half the 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, we 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 Dancer 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 our 42 DPs 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 – we observed substantial evidence ($BF_{01} > 3.0$) for the null hypothesis (no group difference) on all three tasks (Dancers, Boxers, Clocks), irrespective of task or movement type.

Dissociation of face and dyad processing

Many facets of social vision are thought to dissociate. For example, convergent evidence from neuroimaging (Peelen & Downing, 2007) and studies employing disruptive transcranial magnetic stimulation (Pitcher et al., 2009) suggest that the visual processing of faces and bodies is mediated by dissociable neurocognitive mechanisms. Similarly, several findings suggest that the recognition of facial expressions and facial identity can be selectively impaired in neuropsychological cases (Bate & Bennetts, 2015). The present findings further elucidate the structure of social vision insofar as they suggest a potential dissociation between the visual processing engaged by faces and facing dyads.

The putative domain-specific visual mechanisms engaged by facing dyads are thought to affect all levels of perception, from early processing that occurs outside of awareness, to later interpretative processing (Abassi & Papeo, 2020, 2022; Papeo et al., 2017, 2019). The associated processing is ‘face-like’ insofar as it is obligatory and is thought to aid the representation of feature configurations (e.g., Papeo, 2020). Our distance-change detection paradigm would appear to be an appropriate means to assess individual differences in dyadic processing, as characterized above. Interpersonal distance is a key configural feature of dyadic stimuli and is an important cue for the interpretation of social interactions (Bunce et al., 2021). Our stimuli closely resemble those used in neuroimaging studies to reveal neural markers of dyad processing (e.g., Abassi & Papeo, 2020, 2022; Quadflieg et al., 2015). Furthermore, the ability to detect changes in the spacing between *facial* features (e.g., interocular distance) is known to be impaired in DP (e.g., Yovel & Duchaine, 2006).

It remains possible, however, that DPs may yet exhibit subtle deficits of dyadic processing that were not detected by our distance-change detection task. For example, 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). As such, it is possible that the DPs in our study achieved the same levels of distance change discrimination as typical controls but did so via a different route. In this context, it may prove useful to compare neural markers of dyadic processing (e.g., Abassi & Papeo, 2020; Isik et al., 2017; Oomen et al., 2022; Quadflieg et al., 2015; Tsantani et al., 2024) to establish whether DPs and controls are using different mechanistic routes when evaluating dyadic stimuli.

It is also important that future research establish whether other aspects of dyadic perception are intact in DP. For example, previous findings suggest that facing dyad targets are found faster in visual search tasks than non-facing dyad targets (Papeo et al., 2019; Vestner et al., 2019). Similarly, the facial and bodily expressions of one actor bias the perception of the other actor’s expression when dyads are arranged face-to-face, but not back-to-back (Abramson et al., 2021; Barzy et al., 2025; Gray, Barber, et al., 2017). It might be informative to compare these effects in typical observers and those with DP and thereby assess whether dyadic processing is qualitatively similar. If the mechanisms underlying these effects dissociate from those responsible for the perception of interpersonal distance, it is possible that such comparisons may yield different findings.

Configural processing in developmental prosopagnosia

According to one view, DP is a product of a domain-general configural processing deficit that hampers the individuation of faces and certain non-face objects (Avidan et al., 2011; Gerlach et al., 2017; Gerlach & and 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).

Similarly, it has been reported that some DPs fail to exhibit Garner interference when asked to judge the width of simple shapes while ignoring their height, and vice versa, unlike typical observers (Tanzer et al., 2013).

The present results are somewhat inconsistent with this domain-general configural hypothesis, however. Inter-actor and / or inter-object distance is a key configural feature of dyadic arrangements. Where observed, a domain-general difficultly processing feature configurations would be expected to cause impoverished judgements of these spatial relations. However, the present findings suggest that the majority of individuals with DP exhibit broadly typical judgements of inter-actor and inter-object distance. The fact that DPs make typical judgements about interpersonal distance implies that they are able to encode these configural properties without impairment.

Two caveats are worth noting, however. First, the DP population is thought to be heterogenous (e.g., Bennetts et al., 2022; Biotti & Cook, 2016). Thus, it remains possible that a domain-general configural processing deficit 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 face-specific form of configural face processing is disrupted in DP (e.g., DeGutis et al., 2012, 2014; Yovel & Duchaine, 2006). Such an impairment would not be expected to generalize to judgements of inter-actor and inter-object distance.

Distance change detection

Our results revealed two further features of distance-change detection that are noteworthy. First, participants were consistently better at detecting a decrease in interpersonal distance, than an increase. This was seen for all three tasks (including the non-social Clocks Task) and did not vary as a function of participant group. In absolute terms, the distance change was always the same: a decrease or increase of ~30 cm, relative to a starting distance of ~180 cm (assuming the actors / clocks had an approximate height of 180 cm). However, the discriminability of two stimuli is known to vary as a function of the relative difference when the absolute difference is held constant. For example, a difference in height of 3 cm is more obvious when viewing two short individuals, than when viewing two tall individuals – see Weber’s Law (e.g., Algom, 2021; Pardo-Vazquez et al., 2019). For a similar reason, a 30 cm reduction in distance (from ~180 cm to ~150 cm) may be more salient than a 30 cm increase (from ~180 cm to ~210 cm).

Second, we found that participants exhibited a systematic bias whereby they were more likely to report a distance change on move closer trials than move apart trials. Once again, this feature was seen for all three tasks and did not vary as a function of participant group. The interpretation of criterion measures under conditions where sensitivity is known to differ is not straightforward. Although sensitivity measures are generally regarded as meaningful across conditions that differ in bias, the reverse is not necessarily true (e.g., Wixted & Stretch, 2000). It is possible that participants' greater sensitivity in the move closer condition induced a shift in the associated criterion distributions – participants may have detected more distance changes on the move closer trials, and made more change responses accordingly.

Conclusion

In summary, we find that DPs – individuals who exhibit lifelong face processing difficulties – show typical sensitivity to changes in interpersonal distance, a key configural feature of dyadic arrangements. Although the visual processing of faces and facing dyads may exhibit certain similarities (Papeo, 2020; Abassi & Papeo, 2022; Papeo et al., 2017), these findings suggest that the perceptual mechanisms recruited by upright faces and facing dyads may dissociate.

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Appendix

Exploratory analysis excluding object agnosic DPs

The analyses described in the main text were conducted on a sample of 42 developmental prosopagnosics (DPs). Eight of these DPs showed significant impairment on the Cambridge Car Memory Test (CCMT), suggestive of co-occurring object agnosia. The analyses described below replicate those in the main-text having excluded these 8 DPs.

Perceptual sensitivity (d')

Dancers*.* The *d'* estimates obtained were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 5.63$, $p = .019$, $\eta_p^2 = .046$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) = 0.08$, $p = .78$, $\eta_p^2 < .001$], 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 [$F(1, 116) = 0.25$, $p = .62$, $\eta_p^2 = .002$]. When considered separately, we observed no significant group difference on move closer [$M_{DP} = 2.52$, $SD_{DP} = 0.71$, $M_{control} = 2.45$, $SD_{control} = 0.78$, $t(116) = 0.48$, $p = .64$, $d = 0.10$, $BF_{01} = 4.23$] or move apart trials [$M_{DP} = 2.31$, $SD_{DP} = 0.59$, $M_{control} = 2.31$, $SD_{control} = 0.75$, $t(116) = -0.02$, $p = .986$, $d = -0.004$, $BF_{01} = 4.68$].

Boxers. The *d'* estimates obtained were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 5.03$, $p = .027$, $\eta_p^2 = .042$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) = 0.84$, $p = .36$, $\eta_p^2 = .007$], 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 [$F(1, 116) < 0.01$, $p = .96$, $\eta_p^2 < .001$]. When considered separately, we observed no significant group difference on move closer [$M_{DP} = 2.38$, $SD_{DP} = 0.67$, $M_{control} = 2.50$, $SD_{control} = 0.71$, $t(116) = -0.83$, $p = .41$, $d = -0.17$, $BF_{01} = 3.46$] or move apart trials [$M_{DP} = 2.22$, $SD_{DP} = 0.71$, $M_{control} = 2.35$, $SD_{control} = 0.79$, $t(116) = -0.80$, $p = .42$, $d = -0.16$, $BF_{01} = 3.52$].

Clocks. The d' estimates obtained were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 4.76$, $p = .03$, $\eta_p^2 = .039$], whereby participants exhibited greater sensitivity to distance changes on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) = 0.57$, $p = .45$, $\eta_p^2 = .005$], 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 [$F(1, 116) = 0.01$, $p = .93$, $\eta_p^2 < .001$]. When considered separately, we observed no significant group difference on move closer [$M_{\mathrm{DP}} = 2.49$, $SD_{\mathrm{DP}} = 0.69$, $M_{\mathrm{control}} = 2.59$, $SD_{\mathrm{control}} = 0.71$, $t(116) = -0.70$, $p = .49$, $d = -0.14$, $\mathrm{BF}_{01} = 3.77$] or move apart trials [$M_{\mathrm{DP}} = 2.35$, $SD_{\mathrm{DP}} = 0.59$, $M_{\mathrm{control}} = 2.44$, $SD_{\mathrm{control}} = 0.73$, $t(116) = -0.62$, $p = .53$, $d = -0.13$, $\mathrm{BF}_{01} = 3.94$].

Bias (C)

Dancers. The C estimates obtained were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 11.59$, $p < .001$, $\eta_p^2 = .091$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) < 0.01$, $p = .98$, $\eta_p^2 < .001$], 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 [$F(1, 116) = 1.37$, $p = .24$, $\eta_p^2 = .012$]. When considered separately, we observed no significant group difference on move closer trials [$M_{\mathrm{DP}} = -0.22$, $SD_{\mathrm{DP}} = 0.45$, $M_{\mathrm{control}} = -0.13$, $SD_{\mathrm{control}} = 0.63$, $t(116) = -0.79$, $p = .43$, $d = -0.16$, $\mathrm{BF}_{01} = 3.56$] or move apart trials, [$M_{\mathrm{DP}} = 0.14$, $SD_{\mathrm{DP}} = 0.49$, $M_{\mathrm{control}} = 0.05$, $SD_{\mathrm{control}} = 0.46$, $t(116) = 0.94$, $p = .35$, $d = 0.19$, $\mathrm{BF}_{01} = 3.17$].

Boxers. The C estimates obtained were subjected to ANOVA with Trial Type (move closer, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 37.01$, $p < .001$, $\eta_p^2 = .24$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) = 1.98$, $p = .16$, $\eta_p^2 = .017$], 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 [$F(1, 116) = 0.18$, $p = .67$, $\eta_p^2 = .002$]. When considered separately, we observed no group difference on move closer trials [$M_{\text{DP}} = 0.24$, $SD_{\text{DP}} = 0.35$, $M_{\text{control}} = 0.30$, $SD_{\text{control}} = 0.49$, $t(116) = -0.71$, $p = .48$, $d = -0.15$, $\text{BF}_{01} = 3.73$] or move apart trials [$M_{\text{DP}} = -0.19$, $SD_{\text{DP}} = 0.51$, $M_{\text{control}} = -0.07$, $SD_{\text{control}} = 0.45$, $t(116) = -1.29$, $p = .20$, $d = -0.26$, $\text{BF}_{01} = 2.24$].

Clocks. The C estimates obtained were subjected to ANOVA with Trial Type (move close, move apart) as a within-subjects factor and Group (DP, controls) as a between-subjects factor. The analysis revealed a significant main effect of Trial Type [$F(1, 116) = 144.57$, $p < .001$, $\eta_p^2 = .56$], whereby participants were more likely to report a distance change on move closer trials than on move apart trials. We observed no effect of Group [$F(1, 116) = 0.93$, $p = .34$, $\eta_p^2 = .008$], 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 [$F(1, 116) = 0.38$, $p = .54$, $\eta_p^2 = .003$]. When considered separately, we observed no group difference on move closer trials [$M_{\text{DP}} = 0.44$, $SD_{\text{DP}} = 0.35$, $M_{\text{control}} = 0.46$, $SD_{\text{control}} = 0.41$, $t(116) = -0.22$, $p = .83$, $d = -0.05$, $\text{BF}_{01} = 4.58$] or move apart trials [$M_{\text{DP}} = -0.34$, $SD_{\text{DP}} = 0.47$, $M_{\text{control}} = -0.25$, $SD_{\text{control}} = 0.43$, $t(116) = -1.05$, $p = .297$, $d = -0.21$, $\text{BF}_{01} = 2.88$].