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Searching for people: non-facing distractor pairs hinder the visual search of social scenes more than facing distractor pairs

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Abstract

There is growing interest in the visual and attentional processes recruited when human observers view social scenes containing multiple people. Findings from visual search paradigms have helped shape this emerging literature. Previous research has established that, when hidden amongst pairs of individuals facing in the same direction (leftwards or rightwards), pairs of individuals arranged front-to-front are found faster than pairs of individuals arranged back-to-back. Here, we describe a second, closely-related effect with important theoretical implications. When searching for a pair of individuals facing in the same direction (leftwards or rightwards), target dyads are found faster when hidden amongst distractor pairs arranged front-to-front, than when hidden amongst distractor pairs arranged back-to-back. This distractor arrangement effect was also obtained with target and distractor pairs constructed from arrows and types of common objects that cue visuospatial attention. These findings argue against the view that pairs of people arranged front-to-front capture exogenous attention due to a domain-specific orienting mechanism. Rather, it appears that salient direction cues (e.g., gaze direction, body orientation, arrows) hamper systematic search and impede efficient interpretation, when distractor pairs are arranged back-to-back.

Keywords:

Social perception, Social interaction, Visual search, Direction cues, Visuospatial attention

1. Introduction

The traditional focus of social perception research has been the visual processing of individual faces and bodies (Blake & Shiffrar, 2007; Duchaine & Yovel, 2015; Peelen & Downing, 2007). Recently, however, there has been growing interest in how human observers perceive and attend to social scenes containing multiple people (Bunce, Gray, & Cook, 2021; Gray, Barber, Murphy, & Cook, 2017; Isik, Koldewyn, Beeler, & Kanwisher, 2017; Papeo, Stein, & Soto-Faraco, 2017; Quadflieg, Gentile, & Rossion, 2015). One of the interesting findings to emerge from this new literature is the search advantage for facing dyads: when hidden amongst pairs of individuals facing in the same direction, pairs of individuals arranged front-to-front are found faster in visual search tasks than pairs of individuals arranged back-to-back (Vestner, Gray, & Cook, 2020, 2021; Vestner, Over, Gray, & Cook, in press; Vestner, Tipper, Hartley, Over, & Rueschemeyer, 2019). Similarly, front-to-front targets hidden amongst back-to-back distractors are found faster than back-to-back targets hidden amongst front-to-front distractors (Papeo, Goupil, & Soto-Faraco, 2019; Vestner et al., 2021).

According to one view, pairs of individuals arranged front-to-front are processed as social interactions, and engage domain-specific processing that allows stimuli to compete effectively for limited attentional and perceptual resources (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019). The hypothesized attentional capture by facing dyads is thought to be an innate adaptation of the visual system (Papeo, 2020), and is likened to the attentional capture by face stimuli (Langton, Law, Burton, & Schweinberger, 2008; Lavie, Ro, & Russell, 2003; Papeo, 2020). A tendency to orient towards facing dyads may help individuals learn about social interactions and canalise the emergence of perceptual expertise (Papeo, Nicolas, & Hochmann, 2020). Conversely, individuals arranged back-to-back are not thought to engage domain-specific social interaction processing (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019). According to this perspective, the search advantage for facing dyads reflects a tendency for front-to-front arrangements to capture observers' exogenous attention in a way that back-to-back arrangements do not (Papeo, 2020).

An alternative view is that effects of the front-to-front vs. back-to-back manipulation are attributable to the differential configuration of direction cues present in front-to-front and back-to-back arrangements (Vestner et al., 2020, 2021). Human faces and bodies are salient direction cues that exert a strong influence on how observers distribute their attention (Frischen, Bayliss, & Tipper, 2007; Langton, Watt, & Bruce, 2000; Nummenmaa & Calder, 2009). Front-to-front arrangements create a relatively small focal region to which attention is directed by two sets of gaze and body-orientation cues. The presence of this region may help observers attend to a dyad stimulus and process its features (Vestner et al., 2020, 2021). Conversely, the individual elements in back-to-back arrangements direct observers' attention away from the target location. As a result, observers find the target location faster in a serial visual search when target dyads are arranged front-to-front, than when targets are arranged back-to-back.

Here we describe a series of experiments that sought to further elucidate the differential processing engaged by pairs of individuals arranged front-to-front and back-to-back. Specifically, we examined the ability of distractor items arranged front-to-front and back-to-back to interfere with visual search. In the visual search tasks previously employed in this field, participants are typically asked to find front-to-front or back-to-back targets hidden amongst distractor dyads that face the same direction, either leftwards or rightwards (Vestner et al., 2020, 2021; Vestner et al., in press; Vestner et al., 2019). Here we inverted this design: participants were asked to find a target dyad facing in the same direction (leftwards or rightwards), when hidden amongst distractor dyads, either arranged front-to-front or back-to-back.

The domain-specific account argues that pairs of individuals arranged front-to-front capture observers' exogenous attention, while dyads arranged back-to-back do not (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019). For example, it has been suggested that "facing dyads fall in the same biologically relevant category as faces or bodies, which are stimuli associated with high visual sensitivity, rapid discrimination, and spontaneous recruitment of attention" (Papeo et al., 2019, p1493). By extension, this account predicts that front-to-front arrangements should be more effective distractors than back-to-back arrangements (e.g., Langton et al., 2008). In other words, it should be harder to find two people facing in the same direction, when hidden amongst front-to-front distractors, than when hidden amongst back-to-back distractors, because observers' attention should be drawn away from the target location.

The direction cueing account is not tied to this prediction. Instead, this account raises the possibility that back-to-back distractors may hinder visual search to a greater degree than front-to-front distractors. Importantly, the direction cues contained within back-to-back dyads direct observers' attention towards other locations in the search display. This might have two consequences: First, it may take more time and effort to process and reject back-to-back distractors than front-to-front distractors. Second, the presence of multiple back-to-back arrangements may serve to scatter observers' attention around the search display, hindering a systematic search of the available options. As a result, observers may be more likely to attend to a previously-searched location when distractors are arranged back-to-back than when arranged front-to-front.

2. Online testing and participant recruitment

All the experiments described were conducted online, an approach that 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, McDonnell, & Gureckis, 2013; Germine et al., 2012; Woods, Velasco, Levitan, Wan, & Spence, 2015). The experiments were coded using Unity3D (Version 2018.3.7f1), compiled to WebGL, and hosted on an Amazon Lightsail server. Response times (RTs) were recorded locally on participants' computers without being influenced by variations in data transmission speed to the server. We have previously confirmed that this method produces similar RT distributions to those seen in the lab (Vestner et al., 2020).

Participants were recruited through Prolific (www.prolific.co). All were native English speakers with a prolific approval rate of at least 75%. The sample size for each experiment was determined *a priori* using a power analysis, assuming a moderate effect size (d_z = 0.5) and a target power of 0.8. This analysis yielded a target sample size of 34, which was rounded up to 40. Ethical clearance was granted by the local ethics committee and the experiment conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent. Data for all experiments can be found here: https://osf.io/mwvfu/.

3. Upright bodies and faces

To begin our investigation, we sought to compare the ability of front-to-front and back-to-back distractors to interfere with a search task, when the target and distractor dyads were constructed from images of upright people. In two experiments, we used either whole bodies (Vestner et al., 2019) or cropped images of faces only (Vestner et al., 2020, 2021).

All the experiments described in this paper employed the same visual search procedure (Figure 1a) and differed only in terms of the stimuli used to construct the target and distractor pairings. In our first experiments, we used 8 images of human bodies (Figure 1b) and 8 images of human faces (Figure 1c) to construct the target and distractor pairs. The images used in the body experiment were sourced from the Adobe Stock Service. The images of faces were sourced from the Radboud Face Database (Langner et al., 2010). We created mirror images of each exemplar so that it could be presented facing left or right. Images were standardized to a height of 350 pixels. Because the experiments were conducted online, we could not control viewing distance. We anticipate that the stimulus elements typically subtended between 6° and 8° of visual angle vertically.

Target pairs presented two actors facing the same direction (rightwards or leftwards). Distractor pairs consisted of the same elements as the target pair. In one condition, the three distractor pairs were arranged front-to-front. In a second condition, they were arranged back-to-back. In terms of their physical resemblance, the front-to-front and back-to-back dyads were equally similar to the target dyads. In other words, the same transformation (rotating one of the elements 180° about its vertical axis) was necessary to convert a target dyad to a front-to-front dyad or to a back-to-back dyad.

Figure-1

Experimental trials began with an empty screen divided into four quadrants. Participants initiated the trial in their own time by holding down spacebar, causing four stimulus pairings to appear, one in each quadrant. Experimental trials presented three distractor pairs and a target pair. Participants were instructed to release spacebar as soon as they had found the target. Releasing spacebar caused all four pairs to disappear, preventing participants from continuing their search. The stimulus pairings were then replaced by a keyboard key in each section. Participants indicated the target location by pressing the corresponding key. RTs were measured from stimulus onset until the moment the participant released spacebar. On catch trials distractor pairs appeared in all four quadrants. In the absence of a target, participants were instructed to keep holding down spacebar until the trial timed-out (after 5 s). At the end of each trial, participants were given feedback (correct or incorrect). Participants completed 100 trials (45 front-to-front distractors, 45 back-to-back distractors, 10 catch trials) in a randomised order.

3.1 Upright Bodies

Forty participants (26 female, 13 male, 1 non-binary) with an age range of 19 to 60 years (M_{age} = 31.5, SD_{age} = 12.0) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.9%), or where they took longer than 5 s to respond (1.3%), were excluded from the analysis. The distributions of RTs are shown in Figure 2a. There was a significant effect of distractor arrangement for upright bodies: targets were found faster when hidden amongst front-to-front distractors (M = 1.84 s, SD = 0.53 s) than when hidden amongst back-to-back distractors (*M* = 1.98 s, *SD* = 0.52 s) [*t*(39) = 5.00, $p < .001$, $d_z = 0.79$, $CI_{95\%} = 0.08, 0.20$].

3.2 Faces

Forty participants (22 female, 18 male) with an age range of 18 to 56 years ($M_{age} = 28.6$, $SD_{age} = 9.0$) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.5%), or where they took longer than 5 s to respond (1.0%), were excluded from the analysis. The distributions of RTs are shown in Figure 2a. There was a significant effect of distractor arrangement for upright faces: targets were found faster when hidden amongst front-to-front distractors (*M* = 1.61 s, *SD* = 0.46 s) than when hidden amongst back-to-back distractors (*M* = 1.73 s, *SD* = 0.48 s) [*t*(39) = 6.56, $p < .001$, $d = 1.03$, $CI_{95\%} = 0.08, 0.15$].

Figure-2

3.3. Discussion

These results indicate that distractor dyads arranged back-to-back interfere more with participants' visual search than distractor dyads arranged front-to-front. This finding does not accord with the view that front-to-front arrangements capture observers' exogenous attention while back-to-back arrangements do not. Instead, this finding is more consistent with the direction cueing account; with the view that the key difference between front-to-front and back-to-back dyads is the arrangement of salient direction cues. Because the direction cues contained within back-to-back dyads direct observers' attention towards other locations in the search display, it may take more time and effort to process and reject a back-to-back distractor, than a front-to-front distractor. Similarly, the presence of multiple back-to-back arrangements may serve to scatter observers' attention around the search display, hindering a systematic search of the available options.

4. Inverted bodies and faces

It is well established that profile views of individual faces and bodies cue observers' attention in the implied direction when stimuli are shown upright (Frischen et al., 2007; Langton et al., 2000; Nummenmaa & Calder, 2009). However, when images are shown upside-down direction cueing effects are attenuated or abolished (Langton & Bruce, 1999; Vestner et al., 2021). If the distractor arrangement effect is attributable to the cueing of visuospatial attention, it should be possible to eliminate the effect by inverting the orientation of the target and distractor dyads. To test this possibility, we employed an identical search procedure to that described above, except that target and distractor dyads were constructed from upside-down bodies (Figure 1d) and upside-down faces (Figure 1e).

4.1 Inverted bodies

Forty participants (24 female, 16 male) with an age range of 18 to 56 years (M_{age} = 31.1, SD_{age} = 10.9) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (2.1%), or where they took longer than 5 s to respond (1.7%), were excluded from the analysis. The distributions of RTs are shown in Figure 2b. There was no effect of distractor arrangement for inverted bodies: the speed with which observers found targets hidden amongst front-to-front distractors (M = 2.19 s, SD = 0.61 s) and back-to-back distractors (M = 2.24 s, SD = 0.66 s) did not differ significantly [$t(39)$ = 1.40, p = .171, d_z = 0.22, $CI_{95\%}$ = -0.02, 0.12].

4.2 Inverted faces

Forty participants (17 female, 23 male) with an age range of 18 to 52 years (M_{age} = 28.4, SD_{age} = 9.4) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.8%), or where they took longer than 5 s to respond (1.6%), were excluded from the analysis. The distributions of RTs are shown in Figure 2b. There was no effect of distractor arrangement for inverted faces: the speed with which observers found targets hidden amongst front-to-front distractors (M = 1.71 s, SD = 0.52 s) and back-to-back distractors (M = 1.73 s, SD = 0.60 s) did not differ significantly [$t(39)$ = 0.46, p = .649, d_z = 0.07, $CI_{95\%}$ = -0.06, 0.11].

4.3 Inversion effects

To determine whether the effect of distractor arrangement was significantly greater for dyads constructed from upright bodies, than for dyads constructed from inverted bodies, we analysed RTs from the two body tasks using ANOVA with Distractor Arrangement (front-to-front, back-to-back) as a within-subjects factor and Orientation (upright, inverted) as a between-subjects factor. This analysis revealed a significant Distractor Arrangement × Orientation interaction whereby the effect of Distractor Arrangement was significantly greater in the upright version of the task [$F(1, 78)$ = 4.12, p = .046, ηp^2 = .05]. The analysis also revealed a main effect of Distractor Arrangement [$F(1, 78)$ = 17.74, p < .001, ηp^2 = .19], whereby participants found targets more quickly amongst front-to-front distractors, and a main effect of Orientation [$F(1, 78)$ = 5.63, p = .020, ηp^2 = .07], whereby participants found targets faster in the upright task.

Similarly, to determine whether the effect of distractor arrangement was significantly greater for dyads constructed from upright faces, than for dyads constructed from inverted faces, we analysed RTs from the two face tasks using ANOVA with Distractor Arrangement (front-to-front, back-to-back) as a within-subjects factor and Orientation (upright, inverted) as a between-subjects factor. This analysis revealed a significant Distractor Arrangement × Orientation interaction whereby the effect of Distractor Arrangement was significantly greater in the upright version of the task [$F(1, 78) = 4.28$, $p = .042$, $\eta p^2 = .05$]. The analysis also revealed a main effect of Distractor Arrangement [$F(1, 78) = 8.51$, $p < .001$, $\eta p^2 = .10$], whereby participants found targets more quickly amongst front-to-front distractors. The main effect of Orientation was non-significant [$F(1, 78) = 0.24$, $p = .623$, $\eta p^2 = .003$].

4.4 Discussion

In our first experiments, we found that distractor dyads arranged back-to-back interfered more with participants' visual search than distractor dyads arranged front-to-front. In these experiments, target and distractor pairs were constructed using images of people shown upright. When target and distractor pairs were constructed using images of people shown upside-down, front-to-front and back-to-back distractors interfered with visual search to the same degree. Insofar as upright faces and bodies cue spatial attention, and inverted faces and bodies do not, these findings accord well with the direction cueing hypothesis. This finding is important as inverted faces and bodies share their low-level visual properties with upright exemplars. The orientation-specificity of the distractor arrangement effect thus argues against any explanation based on low-level features, including symmetry (Wolfe & Friedman-Hill, 1992); inverted arrangements preserve these properties but do not produce the effect.

5. Arrows

The domain-specific account attributes effects of dyad arrangement (front-to-front vs. back-to-back) to the fact that front-to-front arrangements are processed as social interactions, while back-to-back arrangements are not. This kind of explanation predicts that an effect should only be seen with 'social' stimuli (e.g., faces or bodies). Conversely, the direction cueing account is domain-general. Thus, where an effect of dyad arrangement is the product of direction cueing, it should be possible to replicate the effect with non-social stimuli that also direct observers' attention.

If the distractor arrangement effect described above is a product of domain-general direction cueing, it should be possible to replicate the effect with arrows. Like eye-gaze and body-orientation, arrows cue observers' attention rapidly and automatically; i.e., in a way that is hard to inhibit (Kuhn & Kingstone, 2009; Tipples, 2002). To test this possibility, we employed an identical procedure to that described above, except that target and distractor pairs were constructed from a pool of 8 arrows (Figure 3a). Images were standardized to a height of 350 pixels, and likely subtended between 6° and 8° of visual angle vertically.

Figure-3

5.1 Results

Forty participants (19 female, 21 male) with an age range of 18 to 48 years (M_{age} = 28.3, SD_{age} = 8.7) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.4%), or where they took longer than 5 s to respond (0.7%), were excluded from the analysis. The distributions of RTs are shown in Figure 3b. A significant effect of distractor arrangement was seen for arrows: targets were found faster when hidden amongst front-to-front distractors (M = 1.85 s, SD = 0.58 s) than when hidden amongst back-to-back distractors (M = 1.96 s, SD = 0.69 s) [$t(39) = 3.04$, $p = .004$, $d_z = 0.48$, $CI_{95\%}$ = 0.04, 0.18].

5.2 Discussion

Participants were able to find pairs of arrows pointing in the same direction (leftwards or rightwards) faster when targets were hidden amongst distractor pairs arranged front-to-front, than when arranged back-to-back. This effect mirrors closely that seen with target and distractor pairs created using images of people. Insofar as arrows are non-social, this finding suggests that the effect of distractor arrangement is a product of domain-general attentional mechanisms, not the fact that front-to-front arrangements are processed as social interactions.

6. Common objects that cue attention

The status of arrows as "non-social" has been contested (Furlanetto, Becchio, Samson, & Apperly, 2016). It is well established that, under certain conditions, adults and children anthropomorphise geometric shapes (Abell, Happe, & Frith, 2000; Heider & Simmel, 1944; Over & Carpenter, 2009). Importantly, arrows may have stronger social connotations than most geometric shapes because they are a symbolic instruction from one human mind to another to attend in a particular direction. As a result, children learn to understand them as ostensive or communicative cues (Wu, Tummeltshammer, Gliga, & Kirkham, 2014).

Consistent with this view, 3- to 4-year-old children are able to infer an actor's desire for a particular food item from observing an arrow cue (Pellicano & Rhodes, 2003). Indeed, the children inferred the mental state of an actor more reliably from an arrow than from a gaze cue. Thus, it is conceivable that pairs of arrows arranged point-to-point may be processed as a social interaction (Vestner et al., in press).

In order to provide additional evidence that non-social stimuli produce the distractor arrangement effect, we sought to replicate the effect with common objects that cue attention. We have previously found that several types of object with a front-back axis direct observers' spatial attention: participants are faster to find target letters, when they appeared at locations cued by the orientation of desk lamps, desk fans, cameras, power drills, bicycles, and cars, than when they appeared at non-cued locations (Vestner et al., in press). If the effect of distractor arrangement (front-to-front, back-to-back) on search efficiency seen with upright people and arrows, is the product of domain-general direction cueing, it should be possible to replicate the effect with these objects. Except for the stimuli employed (Figure 4), the procedure was identical to that described above. Images were standardized to a height of 350 pixels (desk lamps, desk fans, cameras, power drills) or 180 pixels (bicycles, cars), likely subtending 6° to 8° and 3° to 4°, respectively.

Figure-4

6.1 Desk lamps

Forty participants (21 female, 18 male, 1 non-binary) with an age range of 18 to 59 years (M_{age} = 30.4, SD_{age} = 11.5) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.8%), or where they took longer than 5 s to respond (1.5%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for desk lamps: targets were found faster when hidden amongst front-to-front distractors (M = 1.95 s, SD = 0.41 s) than when hidden amongst back-to-back distractors (M = 2.07 s, SD = 0.57 s) [$t(39) = 2.86$, $p = .007$, $d_z = 0.45$, $CI_{95\%}$ = 0.03, 0.20].

6.2 Desk fans

Forty participants (25 female, 15 male) with an age range of 18 to 60 years (M_{age} = 30.9, SD_{age} = 10.5) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.6%), or where they took longer than 5 s to respond

(1.1%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for desk fans: targets were found faster when hidden amongst front-to-front distractors (M = 1.96 s, SD = 0.55 s) than when hidden amongst back-to-back distractors (M = 2.07 s, SD = 0.63 s) [$t(39) = 3.32$, $p = .002$, $d_z = 0.53$, $CI_{95\%}$ = 0.05, 0.19].

6.3 Cameras

Forty participants (26 female, 14 male) with an age range of 18 to 60 years (M_{age} = 28.9, SD_{age} = 10.6) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (2.1%), or where they took longer than 5 s to respond (1.5%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for cameras: targets were found faster when hidden amongst front-to-front distractors (M = 2.46 s, SD = 0.65 s) than when hidden amongst back-to-back distractors (M = 2.58 s, SD = 0.71 s) [$t(39) = 4.15$, $p < .001$, $d_z = 0.66$, $CI_{95\%}$ = 0.06, 0.17].

6.4 Power drills

Forty participants (25 female, 15 male) with an age range of 20 to 59 years (M_{age} = 34.0, SD_{age} = 10.8) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.6%), or where they took longer than 5 s to respond (1.1%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for power drills: targets were found faster when hidden amongst front-to-front distractors (M = 1.91 s, SD = 0.44 s) than when hidden amongst back-to-back distractors (M = 2.06 s, SD = 0.56 s) [$t(39) = 4.49$, $p < .001$, $d_z = 0.71$, $CI_{95\%}$ = 0.08, 0.22].

6.5 Bicycles

Forty participants (20 female, 20 male) with an age range of 18 to 49 years (M_{age} = 28.0, SD_{age} = 8.2) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.9%), or where they took longer than 5 s to respond (1.7%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for bicycles: targets were found faster when hidden amongst front-to-front distractors (M = 1.98 s, SD = 0.56 s) than when hidden amongst back-to-back distractors (*M* = 2.07 s, *SD* = 0.60 s) [$t(39) = 3.13$, $p = .003$, $d_z = 0.51$, $CI_{95\%} = 0.03, 0.15$].

6.6 Cars

Forty participants (18 female, 22 male) with an age range of 19 to 52 years ($M_{age} = 34.1$, $SD_{age} = 9.6$) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 7 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.7%), or where they took longer than 5 s to respond (1.4%), were excluded from the analysis. The distributions of RTs are shown in Figure 5. A significant effect of distractor arrangement was seen for cars: targets were found faster when hidden amongst front-to-front distractors (*M* = 2.21 s, *SD* = 0.66 s) than when hidden amongst back-to-back distractors (*M* = 2.40 s, *SD* = 0.74 s) [$t(39) = 5.31$, $p < .001$, $d_z = 0.71$, $CI_{95\%} = 0.12, 0.26$].

Figure-5

7. Common objects that do not cue attention

We have previously found that several types of object with a front-back axis direct observers' spatial attention (Vestner et al., in press). Consistent with a direction cueing account, the same objects (desk fans, desk lamps, cameras, power drills, bicycles, and cars) produced superior interference effects for back-to-back arrangements. However, not all objects with a front-back axis direct observers' spatial attention. Guns, chairs, and shoes possess a canonical 'front' and 'back' but do not produce cueing effects; target letters are found equally quickly at locations cued by their directionality, and at non-cued locations (Vestner et al., in press). It is possible that guns are so salient ("weapon focus") that participants find it hard to disengage and orient their attention in the implied direction (Loftus & Messo, 1987; Steblay, 1992). Chairs and shoes may be ineffective cues because they afford downward motion that potentially interferes with attentional orienting to the left or right (Vestner et al., in press).

The direction cueing account predicts that these types of objects should not produce the distractor arrangement effect. This was the hypothesis we sought to test in our final three experiments. Example stimuli are shown in Figure 6a. Images were standardized to a height of 350 pixels (chairs) or 180 pixels (guns, shoes), likely subtending 6° to 8° and 3° to 4°, respectively.

Figure-6

7.1 Chairs

Forty participants (18 female, 21 male, 1 non-binary) with an age range of 18 to 59 years (M_{age} = 29.5, SD_{age} = 10.6) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.6%), or where they took longer than 5 s to respond (1.3%), were excluded from the analysis. The distributions of RTs are shown in Figure 6b. There was no effect of distractor arrangement for chairs: the speed with which observers found targets hidden amongst front-to-front distractors (M = 1.80 s, SD = 0.47 s) and back-to-back distractors (M = 1.81 s, SD = 0.57 s) did not differ significantly [$t(39) = 0.28$, $p = .784$, $d_z = 0.04$, $CI_{95\%}$ = -0.06, 0.08].

7.2 Guns

Forty participants (23 female, 17 male) with an age range of 18 to 52 years (M_{age} = 29.9, SD_{age} = 8.9) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.4%), or where they took longer than 5 s to respond (0.9%), were excluded from the analysis. The distributions of RTs are shown in Figure 6b. There was no effect of distractor arrangement for guns: the speed with which observers found targets hidden amongst front-to-front distractors (M = 1.94 s, SD = 0.49 s) and back-to-back distractors (M = 1.94 s, SD = 0.54 s) did not differ significantly [$t(39) = 0.02$, $p = .984$, $d_z = 0.00$, $CI_{95\%}$ = -0.06, 0.06].

7.3 Shoes

Forty participants (20 female, 20 male) with an age range of 20 to 59 years (M_{age} = 35.1, SD_{age} = 10.9) were recruited through Prolific. No-one was replaced or excluded. All participants completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (1.8%), or where they took longer than 5 s to respond (1.3%), were excluded from the analysis. The distributions of RTs are shown in Figure 6b. There was no effect of distractor arrangement for shoes: the speed with which observers found targets hidden amongst front-to-front distractors (M = 1.92 s, SD = 0.57 s) and back-to-back distractors (M = 1.89 s, SD = 0.58 s) did not differ significantly [$t(39) = 1.10$, $p = .279$, $d_z = 0.17$, $CI_{95\%}$ = -0.09, 0.03].

8. Attentional cueing and the distractor arrangement effect

The patterns of significance and non-significance observed in the foregoing experiments suggest that the ability of a stimulus class to produce the distractor arrangement effect is closely related to its ability to direct participants' visuospatial attention. Next, we sought direct statistical evidence for this relationship. To this end, we sought to correlate the strength of the various distractor arrangement effects described here, with the strength of direction cueing effects produced by same stimuli (Figure 7).

The cueing effects produced by upright bodies, desk lamps, desk fans, cameras, power drills, bicycles, cars, chairs, guns, and shoes were taken from Vestner, Over, et al. (in press). The cueing effects produced by upright and inverted faces were taken from Vestner, Gray, et al. (2021). The cueing effects produced by arrows and inverted bodies were taken from previously unpublished data, the details of which are provided as Supplementary Material. All cueing effects were measured using the same online procedure, using samples of the same size (N = 40), sourced via Prolific using the same criteria.

We found that the strength of the cueing effects produced by the fourteen stimulus categories correlated closely with the strength of the associated distractor arrangement effects [r_p = .793, p < .001]. This correlation remained significant when we restricted the analysis to the nine non-social object categories [r_p = .697, p = .037]. Thus, there is no sense in which the correlation is being driven by the presence of a social or pseudo-social category.

Figure-7

9. General discussion

Previous research has established that, when hidden amongst pairs of individuals facing in the same direction (leftwards or rightwards), pairs of individuals arranged front-to-front are found faster than pairs of individuals arranged back-to-back (Vestner et al., 2020, 2021; Vestner et al., in press; Vestner et al., 2019). Here, we have described a second, closely-related effect with important theoretical implications. When searching for a pair of faces or bodies facing in the same direction (leftwards or rightwards), target dyads are found faster when hidden amongst distractor pairs arranged front-to-front, than distractor pairs arranged back-to-back. This distractor arrangement effect was also seen for a range of non-social stimuli known to direct visuospatial attention (arrows, desk lamps, desk fans, cameras, power drills, bicycles, and cars). In contrast, stimuli that are known to be ineffective attentional cues (inverted human bodies and faces, chairs, guns, and shoes) failed to produce the effect. A correlational analysis indicated a strong association between the strength of the distractor arrangement effect produced by 14 stimulus categories, and the ability of those stimuli to direct visuospatial attention in a cueing paradigm.

9.1 Effects of dyadic arrangement of the recruitment and distribution of attention

It has been suggested that facing dyads capture observers' exogenous attention in a way that back-to-back arrangements do not. According to this view, pairs of individuals arranged front-to-front engage domain-specific social interaction processing that allows stimuli to compete effectively for limited attentional resources (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019). An innate tendency to orient towards facing individuals may help individuals learn about social interactions and canalise the emergence of perceptual expertise (Papeo et al., 2020). Conversely, individuals arranged back-to-back are not thought to engage domain-specific social interaction processing (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019).

This domain-specific account is potentially consistent with the search advantage for facing dyads. If facing dyads were able to capture observers' exogenous attention in a way that back-to-back arrangements were not, one might well expect front-to-front targets to be found faster in visual search paradigms, than back-to-back targets. By extension, however, this account predicts that front-to-front arrangements should also be more effective distractors than back-to-back arrangements (Langton et al., 2008). It should be harder to find two people facing in the same direction (leftwards or rightwards), when hidden amongst front-to-front distractors, than when hidden amongst back-to-back distractors, because observers' attention should be drawn away from the target location. In fact, we found the opposite: back-to-back distractors hindered visual search more than front-to-front distractors.

An alternative view is that effects of the front-to-front vs. back-to-back manipulation are attributable to the differential configuration of direction cues present in front-to-front and back-to-back arrangements (Vestner et al., 2020). Human faces and bodies are salient direction cues that exert a strong influence on how observers distribute their attention (Frischen et al., 2007; Langton et al., 2000; Nummenmaa & Calder, 2009). When pairs of individuals are arranged back-to-back, these gaze and body-orientation cues direct observers' visuospatial attention to other locations in the search display. Conversely, front-to-front arrangements create a relatively small focal region to which attention is directed by two sets of gaze and body-orientation cues (Vestner et al., 2020).

Unlike the domain-specific view (Papeo, 2020; Papeo et al., 2019; Papeo et al., 2020), the direction cueing account offers an explanation for both of the visual search effects described. According to this view, front-to-front targets are found faster than back-to-back targets because front-to-front targets are easier to attend to, process, and identify, whereas back-to-back targets direct observers' attention away from the target location. Front-to-front distractors produce less search interference because they are easier to attend to, process, and reject, whereas back-to-back distractors scatter observers' attention around the display, hindering systematic search.

The direction cueing account is supported by the fact that both effects are obtained with target and distractor displays created from non-social stimuli that also cue attention. For example, relative to front-to-front arrangements, pairs of arrows arranged back-to-back interfere more with visual search when used as distractors, and are found slower when used as targets (Vestner et al., 2020). The same is true of non-social objects that cue visuospatial attention, such as desk fans and lamps (Vestner et al., in press). Tellingly, however, neither of these visual search effects are seen when target and distractor pairs are constructed from elements that do not direct observers' attention, such as chairs, guns, and inverted bodies (Vestner et al., 2021; Vestner et al., in press). Correlational analyses confirm that the ability of a stimulus category to produce the search advantage for facing dyads (Vestner et al., in press), and the distractor arrangement effect (see Section 8), is closely related to its ability to direct participants' visuospatial attention.

9.2 An alternative account?

When searching for pairs of individuals facing in the same direction (leftwards or rightwards), participants found target dyads faster when hidden amongst distractor pairs arranged front-to-front, than when hidden amongst distractor pairs arranged back-to-back. We have argued that this effect is a product of the differential configuration of salient direction cues contained within these arrangements. However, an alternative explanation for our results is that individuals arranged front-to-front constitute a social interaction, while individuals facing in the same direction (leftwards or rightwards) or arranged back-to-back do not. As such, leftwards and rightwards facing targets may 'pop-out' when hidden amongst front-to-front distractors – because of target-distractor dissimilarity – but not when hidden amongst back-to-back distractors.

We find this explanation unlikely for three reasons. First, two individuals facing in the same direction (leftwards or rightwards) may well represent a social stimulus; for example, relative status can be inferred from the presence of a leader and follower (Over & Carpenter, 2015; Thomsen, 2020). While leftwards and rightwards facing arrangements might imply social interaction less strongly than front-to-front arrangements, they imply interaction more strongly than back-to-back arrangements. Thus, the front-to-front and back-to-back conditions appear to be well-matched in terms of target-distractor similarity. Second, putative target-distractor differences based on degree of implied 'social interaction' cannot explain the distractor arrangement effects produced by arrows and common objects (desk lamps, desk fans, cameras, power drills, bicycles, and cars). Third, this account does not explain the strong correlation seen between the ability of a stimulus to produce the distractor arrangement effect and its ability to direct participants' attention in a cueing paradigm (Section 8).

9.3 Broader implications for the study of interaction perception

The back-to-back vs. front-to-front manipulation has been used by several authors to isolate the visuo-cognitive processing recruited by interacting – but not non-interacting – individuals (Abassi & Papeo, 2020; Gray et al., 2017; Papeo et al., 2019; Papeo et al., 2017; Quadflieg et al., 2015; Vestner et al., 2019). Domain-specific explanations typically assume that differences seen between these conditions reflects additional social interaction processing recruited by front-to-front arrangements (Papeo, 2020; Papeo & Abassi, 2019; Papeo et al., 2019; Papeo et al., 2017). Thus, the focus of explanation is on one side of the face-to-face vs. back-to-back contrast. If correct, the direction cueing account suggests that the back-to-back condition is more than a mere 'baseline' condition. Rather, this account argues that salient direction cues exert considerable influence in both front-to-front and back-to-back conditions, potentially facilitating and impeding visual processing, respectively.

The direction cueing account has been developed to explain findings from visual search paradigms. However, this account has far-reaching implications that extend beyond visual search phenomena. To take one example, it has been reported that a region of occipital cortex shows a stronger fMRI response when observers view individuals arranged front-to-front, than when observers view individuals arranged back-to-back (Abassi & Papeo, 2020). It is conceivable that this region is not sensitive to dyad arrangement *per se*. Instead, the different levels of response in the front-to-front and back-to-back condition may reflect attentional modulation (Chawla, Rees, & Friston, 1999; Reynolds & Chelazzi, 2004; Treue & Maunsell, 1996). Relative to front-to-front arrangements, back-to-back arrangements might induce a weaker signal change by directing observers' attention away from the people in the stimulus display.

Several studies have compared the effects of the front-to-front vs. back-to-back manipulation on markers of cognitive and perceptual processing engaged by people and objects (Papeo & Abassi, 2019; Papeo et al., 2017; Vestner et al., 2019). The rationale behind this approach is that a disproportionate effect of front-to-front vs. back-to-back presentation during the perception of people, is suggestive of domain-specific social interaction processing (Papeo, 2020). The present results underscore how the choice of object may alter the results from this kind of experiment. Crucially, some objects with a front-back axis cue visuospatial attention (e.g., desk fans, power drills), while some (e.g., chairs, shoes) do not (Vestner et al., in press). It is increasingly clear that this distinction has a strong influence on the effects induced by the front-to-front vs. back-to-back manipulation. Where authors choose non-social comparison objects that do not cue attention, such as chairs (Papeo & Abassi, 2019; Papeo et al., 2017), it may prove impossible to distinguish the effects of domain-specific social interaction processing from the unintended consequences of attention cueing.

9.4 Conclusion

In summary, this paper describes a new visual search effect whereby target dyads (pairs of individuals facing in the same direction) are found faster when hidden amongst distractor pairs arranged front-to-front, than when hidden amongst distractor pairs arranged back-to-back. Similar effects were produced by arrows and objects that cue visuospatial attention. Our findings suggest that when viewing crowded social scenes, systematic visual search may be easier where a large proportion of the people depicted are facing partners. Scenes containing numerous individuals standing back-to-back may be harder to search because salient direction cues (gaze direction, body orientation) divert our attention back to previously searched locations.

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CRediT author statement

Tim Vestner: Conceptualization, Methodology, Software, Investigation, Formal analysis, Writing- Original draft preparation. Harriet Over: Conceptualization, Writing - Review & Editing. Katie Gray: Conceptualization, Writing - Review & Editing. Steven Tipper: Conceptualization, Writing - Review & Editing. Richard Cook: Conceptualization, Resources, Writing - Review & Editing, Supervision.

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Figures

Figure 1

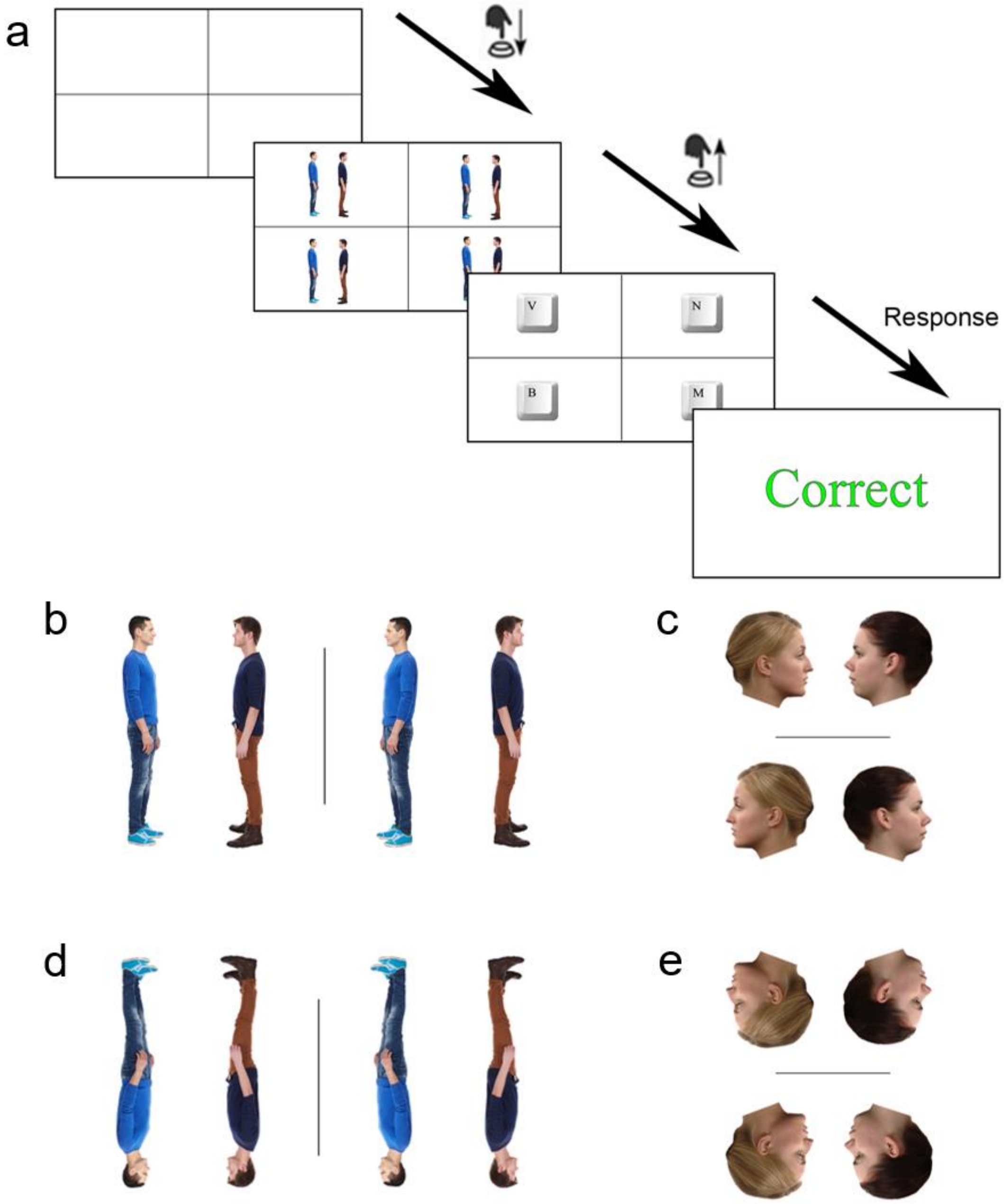

Figure 1. (a) Structure of a trial from the visual search procedure. (b – c) Examples of the stimulus pairs employed in the upright body and face experiments. (d – e) Examples of the stimulus pairs employed in the inverted body and face experiments.

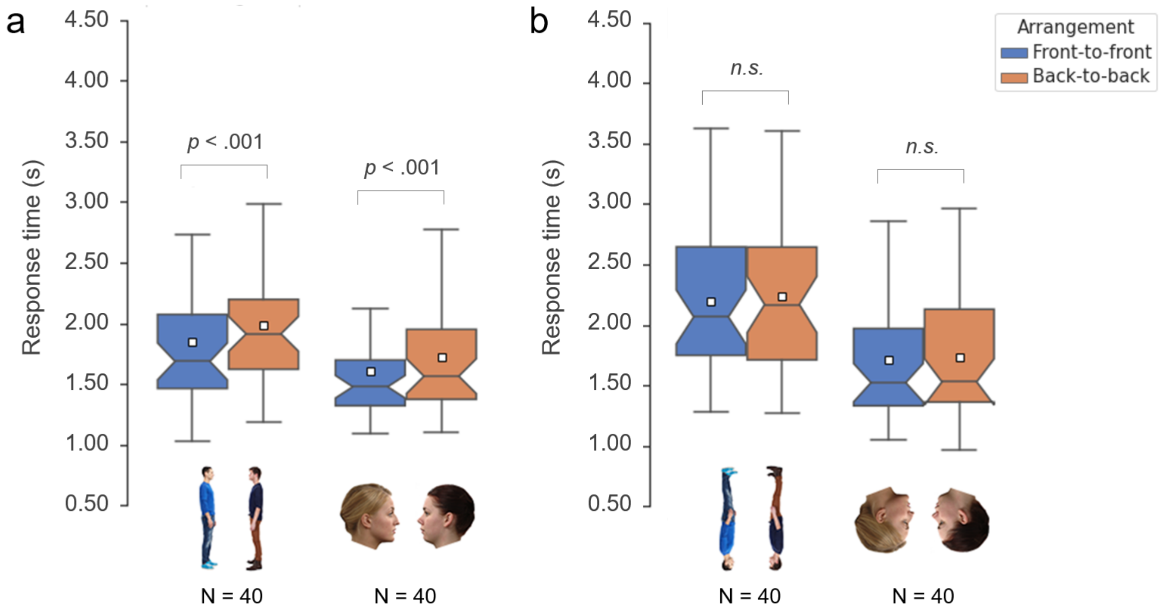

Figure 2. (a) Results from the upright body and face experiments. (b) Results from the inverted body and face experiments. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

Figure 3

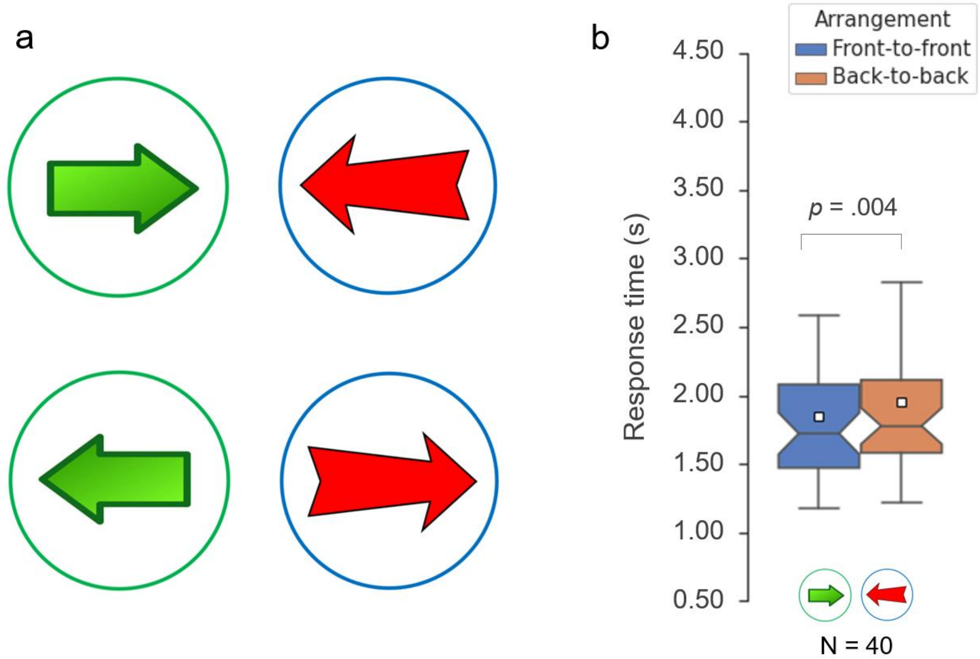

Figure 3. (a) Examples of the stimulus pairs employed in the arrows experiment. (b) Results from the arrows experiments. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

Figure 4

Figure 4. (a – f) Examples of the stimulus pairs employed in the desk lamp, desk fan, camera, power drill, bicycle, and car experiments.

Figure 5

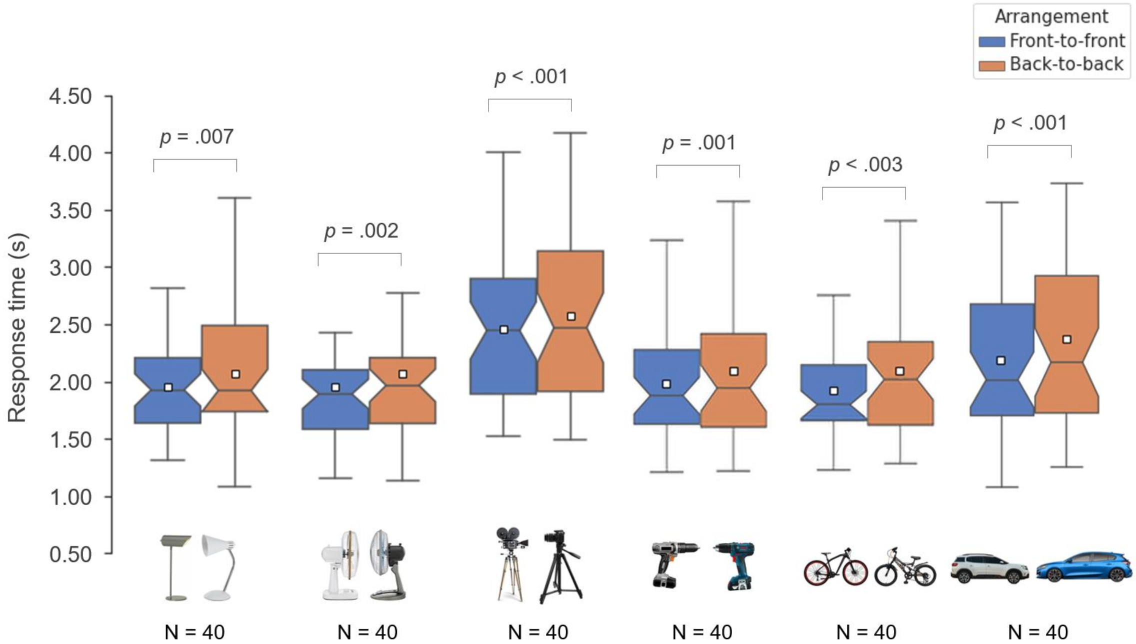

Figure 5. Results from the desk lamp, desk fan, camera, power drill, bicycle, and car experiments. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

Figure 6

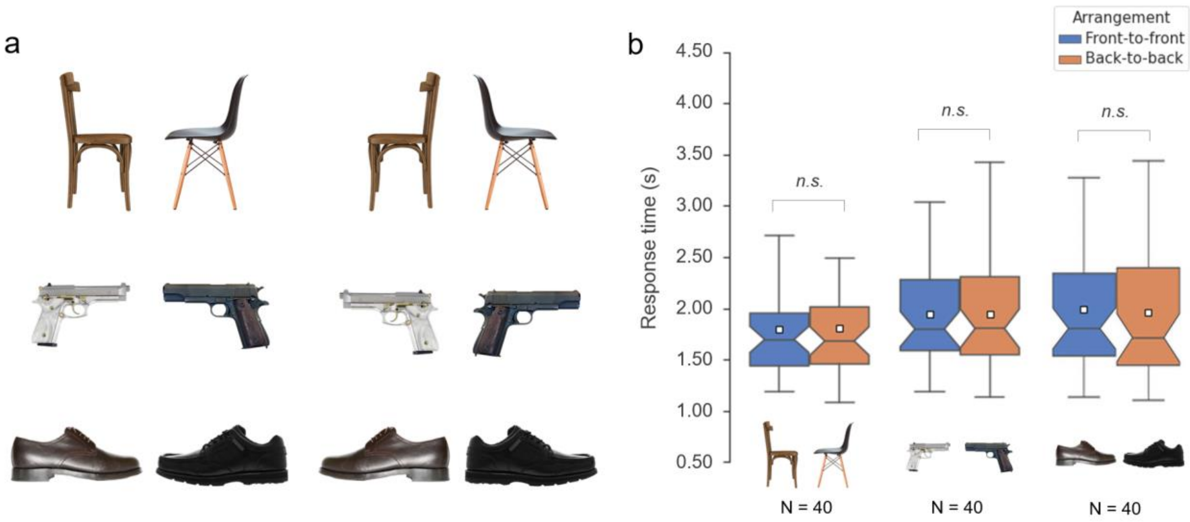

Figure 6. (a) Examples of the stimulus pairs employed in the chair, gun, and shoe experiments. (b) Results from the chair, gun, and shoe experiments. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

Figure 7

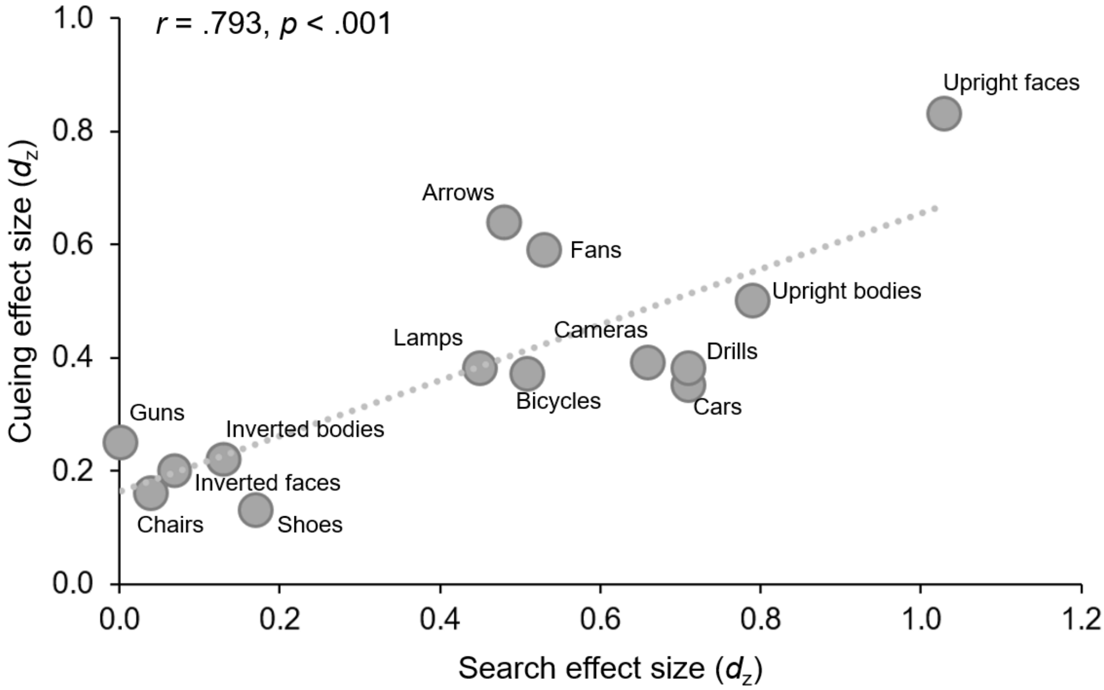

Figure 7. Scatterplot showing the relationship between the strength of the visual search effect (i.e., the effect of distractor arrangement) and the strength of the attentional cueing effect produced by the different stimulus types. The cueing effects produced by upright bodies, desk lamps, desk fans, cameras, power drills, bicycles, cars, chairs, guns, and shoes were taken from Vestner, Over, et al. (in press). The cueing effects produced by upright and inverted faces were taken from Vestner, Gray, et al. (2021). The cueing effects produced by arrows and inverted bodies were taken from previously unpublished data (see Supplementary Material).

Searching for people: non-facing distractor pairs hinder the visual search of social scenes more than facing distractor pairs

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Supplementary material

In the main text, we reference the results of two further online experiments that examined the ability of arrows and inverted bodies to cue participants' visuospatial attention. The resulting effect sizes are included in the correlational analysis described in Section 8. A detailed description of the methods and results is provided below as supplementary material.

Stimuli
Each experiment used cueing stimuli drawn from a particular category: either arrows or inverted human bodies. The pool of stimulus images was the same as those employed in the visual search experiments described in the main text. Images were standardized to a height of 400 pixels (inverted human bodies) or 200 pixels (arrows).

Procedure
Experimental trials began with a fixation cross in the centre of the screen. After 2 s, a cueing stimulus appeared in the centre, replacing the fixation cross (Figure S1). On 50% of trials this stimulus faced rightwards, on 50% of trials this stimulus faced leftwards. After a further 500 ms, two letter arrays appeared on screen, one on the left and one on the right, each consisting of 6 letters arranged vertically. Target letters were chosen randomly from a pool of 13 letters [E, F, H, K, L, M, N, T, V, W, X, Y, Z] chosen for their linear components and angular features. The remaining letters were used to populate the arrays. In total, the procedure consisted of eight blocks of 24 trials. Each block comprised 8 valid trials (the central stimulus cued the array containing the target letter), 8 invalid trials (the central stimulus cued the array that did not contain the target letter), and 8 catch trials (the target letter was not present).

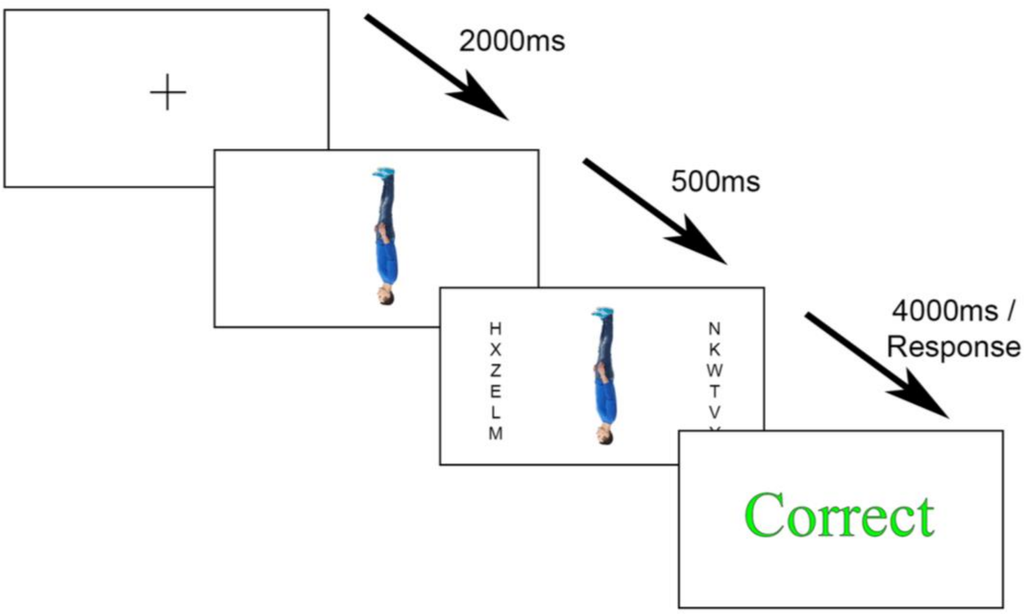

Figure S1. Structure of a trial from the cueing procedure

At the start of each block, participants were given a target letter to find on each trial of that block. Participants were asked to press spacebar as quickly as possible if the target letter was present in one of the arrays. Where the target letter was not present (catch trials), participants were instructed to simply wait until the trial timed-out (after 4 s). At the end of each trial, participants were given feedback in the form of the word 'correct' (following a spacebar response during target-present trials or no response during target-absent trials), the word 'incorrect' (following a spacebar response during target-absent trial), or the phrase 'too slow' (following a failure to respond within 4 s on target-present trials). Where participants responded incorrectly or too slowly, they were then reminded of the target letter.

Results

Arrows

Forty participants (18 female, 22 male) with an age range of 19 to 46 years (M_{age} = 27.2, SD_{age} = 6.4) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (1.2%) were excluded from the analysis. All participants performed correctly on at least 62 of the 64 catch trials. A cueing effect was seen for arrows. Participants responded significantly faster on valid trials (M = 1.18 s, SD = 0.20 s) than on invalid trials (M = 1.32 s, SD = 0.27 s) [$t(39) = 4.08$, $p < .001$, $d_z = 0.64$, $CI_{95\%}$ = 0.07 s, 0.21 s].

Inverted bodies

Forty participants (18 female, 21 male, 1 non-binary) with an age range of 18 to 58 years (M_{age} = 30.12, SD_{age} = 11.9) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (1.5%) were excluded from the analysis. All participants performed correctly on at least 60 of the 64 catch trials. No cueing effect was seen for inverted bodies. The RTs on valid trials (M = 1.23 s, SD = 0.26 s) and on invalid trials (M = 1.24 s, SD = 0.25 s) did not differ significantly [$t(39) = 0.81$, $p = .421$, $d_z = 0.13$, $CI_{95\%}$ = -0.02 s, 0.04 s].