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Visual search for facing and non-facing people: The effect of actor inversion

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ABSTRACT

In recent years, there has been growing interest in how human observers perceive, attend to, and recall, social interactions viewed from third-person perspectives. 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. Interestingly, the search advantage for facing dyads appears to be sensitive to the orientation of the people depicted. While front-to-front target pairs are found faster than back-to-back targets when target and distractor pairings are shown upright, front-to-front and back-to-back targets are found equally quickly when pairings are shown upside-down. In the present study, we sought to better understand why the search advantage for facing dyads is sensitive to the orientation of the people depicted. To begin, we show that the orientation sensitivity of the search advantage is seen with dyads constructed from faces only, and from bodies with the head and face occluded. We replicate these effects using two different visual search paradigms. We go on to show that individual faces and bodies, viewed in profile, produce strong attentional cueing effects when shown upright, but not when presented upside-down. Together with recent evidence that arrows arranged front-to-front also produce the search advantage for facing dyads, these findings support the view that the search advantage is a by-product of the ability of constituent elements to direct observers' visuo-spatial attention.

1. Introduction

Traditionally, social perception research has focussed on the visual processing of individual faces (Duchaine & Yovel, 2015; Freiwald, Duchaine, & Yovel, 2016) and bodies (Peelen & Downing, 2007; Ramsey, 2018). In recent years, however, there has been growing interest in how human observers perceive, attend to, and recall, social interactions viewed from third-person perspectives (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 (Papeo, Goupil, & Soto-Faraco, 2019; Vestner, Tipper, Hartley, Over, & Rueschemeyer, 2019). 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 et al., 2019; hereafter, the Vestner paradigm). 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 et al., 2019; hereafter, the Papeo paradigm).

According to one account, this search advantage reflects the fact that front-to-front targets are processed as social interactions, and therefore engage domain-specific social interaction processing that helps stimuli compete more effectively for limited attentional and perceptual resources (Papeo et al., 2019; Vestner et al., 2019). Conversely, back-to-back arrangements are not thought to be processed as social interactions, and thus do not benefit from domain-specific processing (Papeo et al., 2019). This domain-specific account accords with two closely-related suggestions: i) that front-to-front arrangements engage distinct regions of visual cortex not recruited by back-to-back arrangements (Abassi & Papeo, 2020), and ii) that infants have an innate preference for front-to-front arrangements that helps canalise the emergence of perceptual expertise for social interactions (Papeo, 2020).

Alternatively, it has been argued that front-to-front arrangements are found faster in visual search tasks because of the differential configuration of direction cues present in these arrangements (Vestner, Gray, & Cook, 2020). Human faces and bodies are salient directional cues that exert a strong influence on how observers distribute their attention

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(Frischen, Bayliss, & Tipper, 2007; Langton, Watt, & Bruce, 2000; Nummenmaa & Calder, 2009). Front-to-front arrangements may create a 'hot-spot' – a small focal region of space to which attention is directed by both sets of face and body cues. These hot-spots may help observers find front-to-front targets relatively early in a serial visual search. Conversely, the individual elements in back-to-back arrangements direct observers' attention away from the target location. As a result, observers may find the target location later in a serial visual search. Consistent with this view, pairs of arrows are also found faster in visual search tasks when arranged front-to-front, than when arranged back-to-back, when hidden amongst pairs of arrows pointing the same direction (Vestner et al., 2020).

Interestingly, the search advantage for facing dyads appears to be sensitive to the orientation of the people depicted. While front-to-front targets are found faster than back-to-back targets when targets and distractors are shown upright, front-to-front and back-to-back targets are found equally quickly when dyads are shown upside-down (Vestner et al., 2019). This finding is important as inverted faces and bodies share their low-level visual properties with upright exemplars, and retain a canonical "front" and "back". The orientation-specificity of the search advantage thus argues against any explanation of the search advantage based on low-level features – including symmetry (Wolfe & Friedman-Hill, 1992) – or the presence of a front-back axis; inverted arrangements preserve these properties but do not produce the search advantage.

Importantly, the orientation-specificity of the search advantage for facing dyads has also been cited as evidence against a directional cueing account of the effect (Vestner et al., 2019). This line of argument assumes that images of people facing leftward or rightward direct observers' visuo-spatial attention both when presented upright and upside-down. On this basis, it was argued that the directional cueing account predicts a search advantage for facing dyads irrespective of target and distractor orientation (upright or inverted). Thus, orientation sensitivity of the search advantage was thought to be more consistent with domain-specific processing of social interactions (Vestner et al., 2019).

The present study sought to better understand why the search advantage for facing dyads is sensitive to the orientation of the people depicted. To begin, we replicate and extend previous findings by showing that the search advantage is highly sensitive to orientation, both when dyads are constructed from faces only, and from bodies with the head and face occluded. First, we show these effects using the Vestner dyadic search paradigm. We go on to show that identical results are obtained with the Papeo dyadic search paradigm. We then show that individual faces and bodies, viewed in profile, produce strong attentional cueing effects when shown upright, but not when presented upside-down. These findings accord well with the view that it is the ability of the constituent faces and bodies to direct visuo-spatial attention that produces the search advantage for facing dyads (Vestner et al., 2020).

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%. Each experiment was completed by separate groups of participants (i.e., each sample was completely independent). The sample size for each experiment was determined a priori using a power analysis, assuming a moderate effect size ($d = 0.5$) and a target power of 0.8 for each pairwise comparison. 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 was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent.

3. Effects of stimulus inversion in the Vestner dyadic search paradigm

Previous research suggests that the search advantage for facing dyads is orientation-specific; that front-to-front targets are found faster than back-to-back targets only when the people depicted are shown upright (Vestner et al., 2019). This initial finding was obtained using the Vestner dyadic search paradigm (participants are tasked with finding front-to-front or back-to-back targets hidden amongst distractors that face the same direction). In their original demonstration, Vestner et al. (2019) used naturalistic whole-body stimuli in which actors' faces and bodies were visible. To better understand this result, we first examined the influence of orientation inversion on the search advantage for two types of dyad stimuli: face-only (only the actors' faces were visible) and body-only (the whole body was visible but the head and face were occluded).

3.1. Methods

The four experiments described employed the Vestner dyadic search paradigm (Fig. 1a) and differed only in terms of the stimuli used to construct the target and distractor pairings (Fig. 2). So that we had a common point of comparison across the different experiments, all participants also completed a variant of the search task with arrow stimuli. We were able to replicate the search advantage for pairs of arrows arranged front-to-front in all four experiments. For the sake of brevity, however, these results are described in the supplementary materials.

3.1.1. Stimuli

Each stimulus category comprised eight different exemplars. 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. The images of faces were sourced from the Radboud Face Database (Langner et al., 2010). The images used in the body experiment were sourced from the Adobe Stock Service. A gray oval was placed over the head and face of the body stimuli.

3.1.2. Procedure

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. Target pairs could appear front-to-front or back-to-back. The three distractor pairings consisted of the same elements as the target pair but both elements pointed in the same direction (leftwards or rightwards). The three distractors always included at least one rightward and one leftward facing pairing. Participants were instructed to release spacebar as soon as they had found the target. They were asked to respond as quickly as possible without sacrificing accuracy. 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 quadrant. 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).

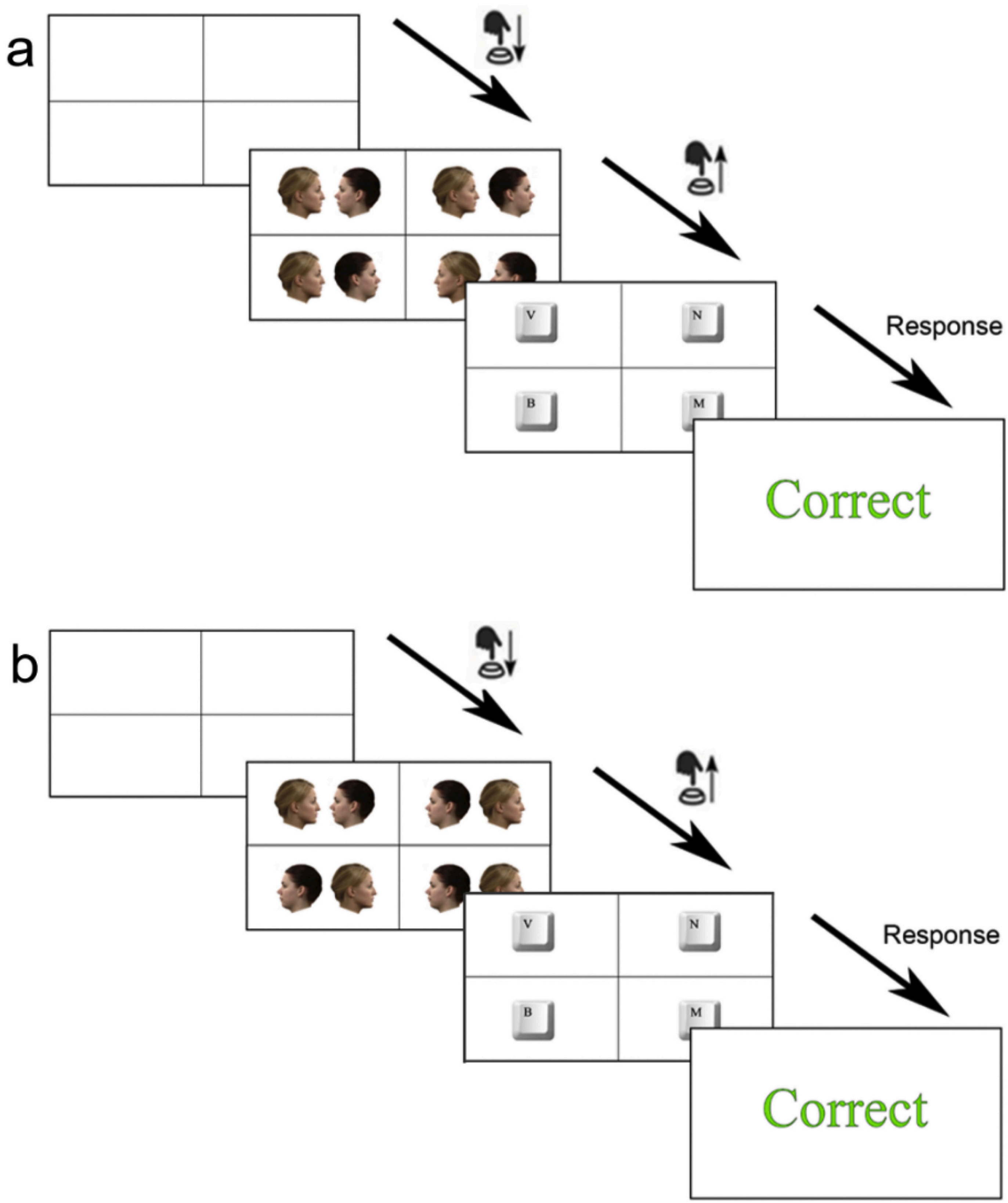

Fig. 1. (a) Structure of a trial from the Vestner dyadic search paradigm. (b) Structure of a trial from the Papeo dyadic search paradigm.

In each experiment, participants completed two blocks (front-to-front, back-to-back) in a counterbalanced order. Each block consisted of 50 trials (45 experimental trials, 5 catch trials). Participants were told the target for the visual search at the beginning of each block and shown an example stimulus pair. For the purposes of the instructions, we used the terms "front-to-front" and "back-to-back".

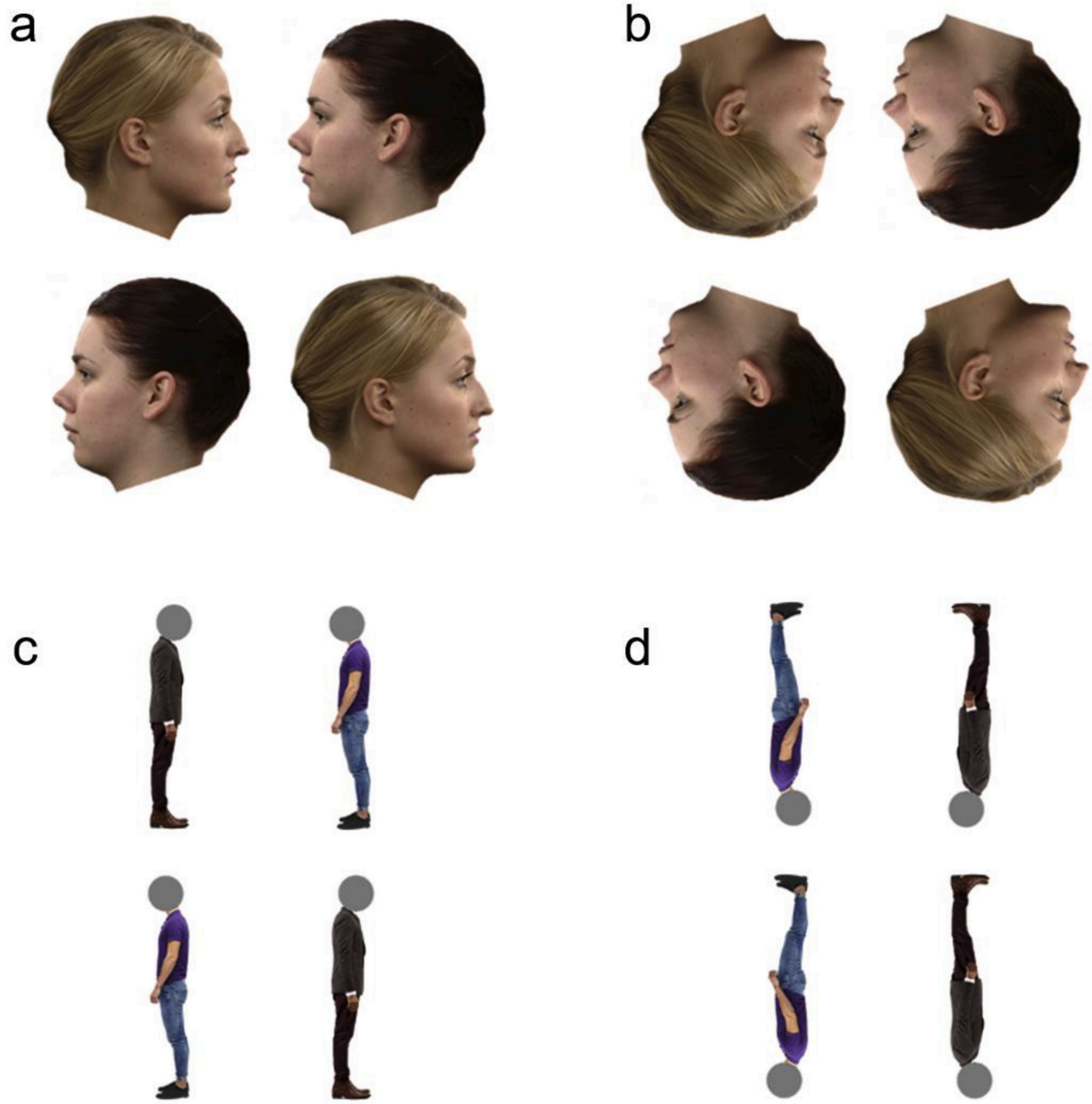

Fig. 2. Examples of the target dyads employed in the (a) upright faces, (b) inverted faces, (c) upright bodies, and (d) inverted bodies experiments.

3.2. Results

The results from these experiments are depicted in Fig. 3a. Raw data can be accessed at: https://osf.io/ezb34/. The search advantage for facing dyads is inferred from faster RTs when target pairings are arranged front-to-front, than back-to-back. Any trials where participants took longer than 5 s to respond, or where participants responded incorrectly were excluded from the analyses. Any participant who responded on four or more of the 10 catch trials was replaced. These criteria were agreed a priori.

3.2.1. Upright faces

Forty participants (26 female, 14 male) with an age range of 18 to 50 years ($M_{age} = 29.3$, $SD_{age} = 8.3$) 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 (1.7%), or where they took longer than 5 s to respond (0.9%), were excluded from the analysis. A search advantage for facing dyads was seen for the upright faces. Front-to-front targets ($M = 1.56$ s, $SD = 0.36$ s) were found significantly faster than back-to-back targets ($M = 1.85$ s, $SD = 0.49$ s) [$t(39) = 6.21$, $p < .001$, $d = 0.98$, $CI_{95\%} = 0.20, 0.39$].

3.2.2. Inverted faces

Forty participants (21 female, 19 male) with an age range of 18 to 57 years ($M_{age} = 31.0$, $SD_{age} = 11.4$) 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 (2.4%), or where they took longer than 5 s to respond (1.7%), were excluded from the analysis. A search advantage for facing dyads was not seen for inverted faces. RTs for front-to-front targets ($M = 1.93$ s, $SD = 0.39$ s) and back-to-back targets ($M = 1.99$ s, $SD = 0.42$ s) did not differ significantly [$t(39) = 1.33$, $p = .190$, $d = 0.21$, $CI_{95\%} = -0.03, 0.15$].

3.2.3. Upright bodies

Forty participants (15 female, 24 male, 1 non-binary) with an age range of 18 to 56 years ($M_{age} = 36.6$, $SD_{age} = 8.1$) 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 (2.6%), or where they took longer than 5 s to respond (1.6%), were excluded from the analysis. A search

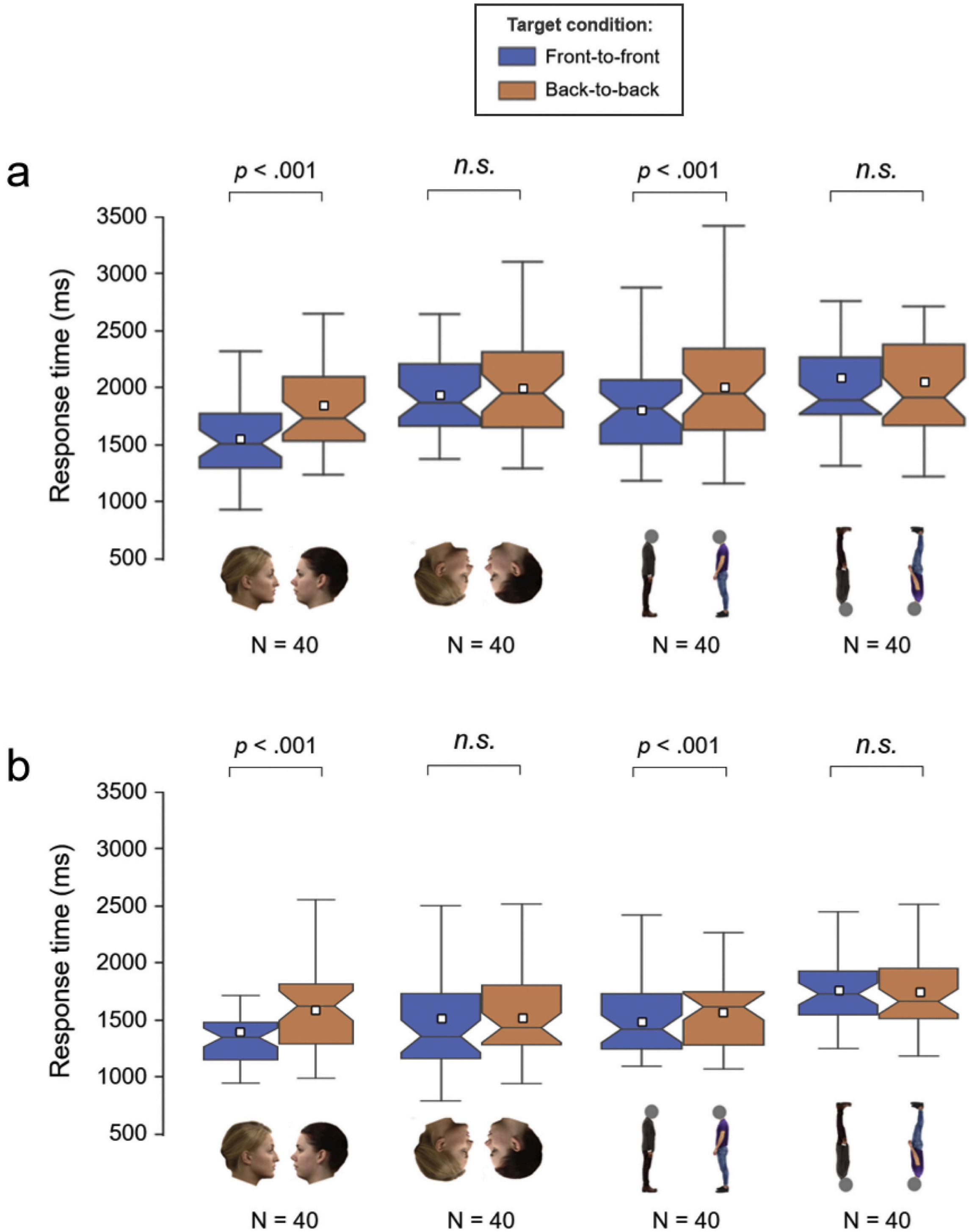

Fig. 3. (a) Results from the visual search experiments conducted with the Vestner dyadic search paradigm. (b) Results from the visual search experiments conducted with the Papeo dyadic search paradigm. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

advantage for facing dyads was seen for upright bodies. Front-to-front targets (M = 1.80 s, SD = 0.40 s) were found significantly faster than back-to-back targets (M = 2.00 s, SD = 0.49 s) [$t(39) = 4.40$, $p < .001$, $d = 0.69$, $CI_{95\%} = 0.11, 0.29$].

3.2.4. *Inverted bodies*

Forty participants (22 female, 18 male) with an age range of 18 to 55 years ($M_{age} = 29.3$, $SD_{age} = 9.5$) 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 (2.7%), or where they took longer than 5 s to respond (1.9%), were excluded from the analysis. A search advantage for facing dyads was not seen for inverted bodies. RTs for front-to-front targets (M = 2.08 s, SD = 0.55 s) and back-to-back targets (M = 2.05 s, SD = 0.55 s) did not differ significantly [$t(39) = 1.11$, $p = .272$, $d = 0.18$, $CI_{95\%} = -0.09, 0.02$].

3.2.5. Inversion effects

To determine whether the search advantage for facing dyads constructed from upright faces was significantly greater than that for facing dyads constructed from inverted faces, we analysed the RTs from the two face tasks using ANOVA with 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 Arrangement × Orientation interaction whereby the effect of Arrangement was significantly greater in the upright task [$F(1, 78) = 12.66$, $p = .001$, $\eta p^2 = 0.14$]. The analysis also revealed main effects of Arrangement [$F(1, 78) = 29.20$, $p < .001$, $\eta p^2 = 0.27$], whereby participants found front-to-front targets more quickly, and Orientation [$F(1, 78) = 8.53$, $p = .005$, $\eta p^2 = 0.10$], whereby participants generally found upright targets more quickly.

Similarly, to determine whether the search advantage for facing dyads constructed from upright bodies was significantly greater than that for facing dyads constructed from inverted bodies, we analysed the RTs from the two body tasks using ANOVA with 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 Arrangement × Orientation interaction whereby the effect of Arrangement was significantly greater in the upright task [$F(1, 78) = 18.45$, $p < .001$, $\eta p^2 = 0.19$]. The analysis also revealed a main effect of Arrangement [$F(1, 78) = 9.51$, $p = .003$, $\eta p^2 = 0.109$], whereby participants found front-to-front targets more quickly. There was no main effect of Orientation [$F(1, 78) = 2.23$, $p = .139$, $\eta p^2 = 0.03$].

4. Effects of stimulus inversion in the Papeo dyadic search paradigm

In the Vestner dyadic search paradigm, participants are tasked with finding front-to-front or back-to-back targets hidden amongst distractors that face the same direction. It is clear that the search advantage for facing dyads revealed by this paradigm is orientation specific. The search advantage seen with whole-bodies, faces, and bodies with faces occluded, is greatly reduced when target and distractor dyads are shown upside-down. Next, we sought to confirm that this is also true of the search advantage revealed by the Papeo dyadic search paradigm, whereby front-to-front target dyads hidden amongst back-to-back distractors are found faster than back-to-back targets hidden amongst front-to-front distractors. Except for the configuration of the distractors, the procedure was identical to the first set of experiments (Fig. 1b).

Once again, all participants also completed a variant of the search task with arrow stimuli. In these conditions, we also employed the Papeo dyadic search paradigm. We found a search advantage for pairs of arrows arranged front-to-front in all four experiments. For the sake of brevity, these results are described in the supplementary materials.

4.1. Results

The results from these experiments are depicted in Fig. 3b. The search advantage for facing dyads is inferred from faster RTs when target pairings are arranged front-to-front, than back-to-back.

4.1.1. Upright faces

Forty participants (26 female, 14 male) with an age range of 18 to 58 years ($M_{age} = 33.7$, $SD_{age} = 10.7$) 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 (1.9%), or where they took longer than 5 s to respond (1%), were excluded from the analysis. A search advantage for facing dyads was seen for the upright faces. Front-to-front targets ($M = 1.38$ s, $SD = 0.37$ s) were found significantly faster than back-to-back targets ($M = 1.59$ s, $SD = 0.37$ s) [$t(39) = 4.72$, $p < .001$, $d = 0.75$, $CI_{95\%} = 0.12, 0.29$].

4.1.2. Inverted faces

Forty participants (17 female, 22 male, 1 non-binary) with an age range of 20 to 56 years ($M_{age} = 32.9$, $SD_{age} = 11$) 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 (2.6%), or where they took longer than 5 s to respond (1.1%), were excluded from the analysis. A search advantage for facing dyads was not seen for inverted faces. RTs for front-to-front targets ($M = 1.45$ s, $SD = 0.33$ s) and back-to-back targets ($M = 1.46$ s, $SD = 0.45$ s) did not differ significantly [$t(39) = 0.17$, $p = .866$, $d = 0.03$, $CI_{95\%} = -0.11, 0.13$].

4.1.3. Upright bodies

Forty participants (21 female, 18 male, 1 non-binary) with an age range of 18 to 59 years ($M_{age} = 36.4$, $SD_{age} = 10.8$) 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 (2.7%), or where they took longer than 5 s to respond (1.2%), were excluded from the analysis. A search advantage for facing dyads was seen for the upright faces. Front-to-front targets ($M = 1.48$ s, $SD = 0.26$ s) were found significantly faster than back-to-back targets ($M = 1.55$ s, $SD = 0.29$ s) [$t(39) = 4.00$, $p < .001$, $d = 0.63$, $CI_{95\%} = 0.04, 0.12$].

4.1.4. Inverted bodies

Forty participants (19 female, 21 male) with an age range of 18 to 58 years ($M_{age} = 32.3$, $SD_{age} = 11.0$) were recruited through Prolific. Two participants were replaced having responded on 4 of the 10 catch trials. All participants in the final sample completed at least 8 of the 10 catch trials correctly. Those trials where participants responded incorrectly (2.5%), or where they took longer than 5 s to respond (1.3%), were excluded from the analysis. A search advantage for facing dyads was not seen for inverted faces. RTs for front-to-front targets ($M = 1.68$ s, $SD = 0.32$ s) and back-to-back targets ($M = 1.68$ s, $SD = 0.33$ s) did not differ significantly [$t(39) = 0.24$, $p = .809$, $d = 0.04$, $CI_{95\%} = -0.05, 0.07$].

4.1.5. Inversion effects

To determine whether the search advantage for facing dyads constructed from upright faces was significantly greater than that for facing dyads constructed from inverted faces, we analysed the RTs on the two face tasks using ANOVA with 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 Arrangement × Orientation interaction whereby the effect of Arrangement was significantly greater in the upright task [$F(1, 78) = 6.79$, $p = .011$, $\eta p^2 = 0.08$]. The analysis also revealed a main effect of Arrangement [$F(1, 78) = 8.31$, $p = .005$, $\eta p^2 = 0.10$], whereby participants found front-to-front targets more quickly. There was no main effect of Orientation [$F(1, 78) = 0.15$, $p = .699$, $\eta p^2 = 0.002$] .

Similarly, to determine whether the search advantage for facing dyads constructed from upright bodies was significantly greater than that for facing dyads constructed from inverted bodies, we analysed the RTs from the two body tasks using ANOVA with 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 Arrangement × Orientation interaction whereby the effect of Arrangement was significantly greater in the upright task [$F(1, 78) = 5.22$, $p = .025$, $\eta p^2 = 0.06$]. The analysis also revealed a marginal main effect of Arrangement [$F(1, 78) = 3.49$, $p = .065$, $\eta p^2 = 0.04$], whereby participants found front-to-front targets more quickly, and a significant main effect of Orientation [$F(1, 78) = 6.83$, $p = .011$, $\eta p^2 = 0.08$], whereby participants generally found upright targets more quickly.

5. Directional cueing of visuo-spatial attention by single exemplars

In the foregoing experiments we observed a search advantage for facing dyads when the individuals depicted were shown upright, but not when they were shown upside-down. This inversion effect was first described using naturalistic stimuli in which actors' faces and bodies were visible (Vestner et al., 2019). We were able to replicate these effects using dyads constructed from images of faces only, and with dyads constructed from images of bodies with the head and face occluded. Identical effects were obtained using the Vestner dyadic search paradigm (front-to-front and back-to-back targets are hidden amongst distractor pairs that face in the same direction) and the Papeo dyadic search paradigm (front-to-front and back-to-back targets are hidden amongst back-to-back and front-to-front distractors, respectively).

Evidence that the search advantage for facing dyads is disrupted by orientation inversion has previously been used to argue against the directional cueing account of this effect (Vestner et al., 2019). However, the inversion effects observed would accord well with a directional cueing account if inverted faces and bodies cued observers' visuo-spatial attention less effectively than upright faces and bodies. According to the directional cueing account, it is the ability of a stimulus to direct visuo-spatial attention in a rapid, automatic (hard-to-inhibit) manner, that determines whether it produces the search advantage for facing dyads (Vestner et al., 2020).

In our final set of experiments, we employed an attentional cueing paradigm to examine the ability of the stimuli used in the foregoing dyadic search tasks to direct participants' visuo-spatial attention. Little is known about the relative ability of upright and inverted bodies to cue attention. Interestingly, however, Langton and Bruce (1999) found that eye-gaze / head direction cued attention more effectively when stimuli were shown upright than when inverted.

5.1. Methods

The four experiments described employed a common attentional cueing procedure (Fig. 4a) and differed only in terms of the type of cueing stimulus presented (Fig. 4b–e).

5.1.1. Stimuli

Each experiment used cueing stimuli drawn from a particular category: upright faces, inverted faces, upright bodies, or inverted bodies. The pool of stimulus images was the same as those employed in the visual search experiments described earlier. Stimulus images were standardized to a height of 400 pixels.

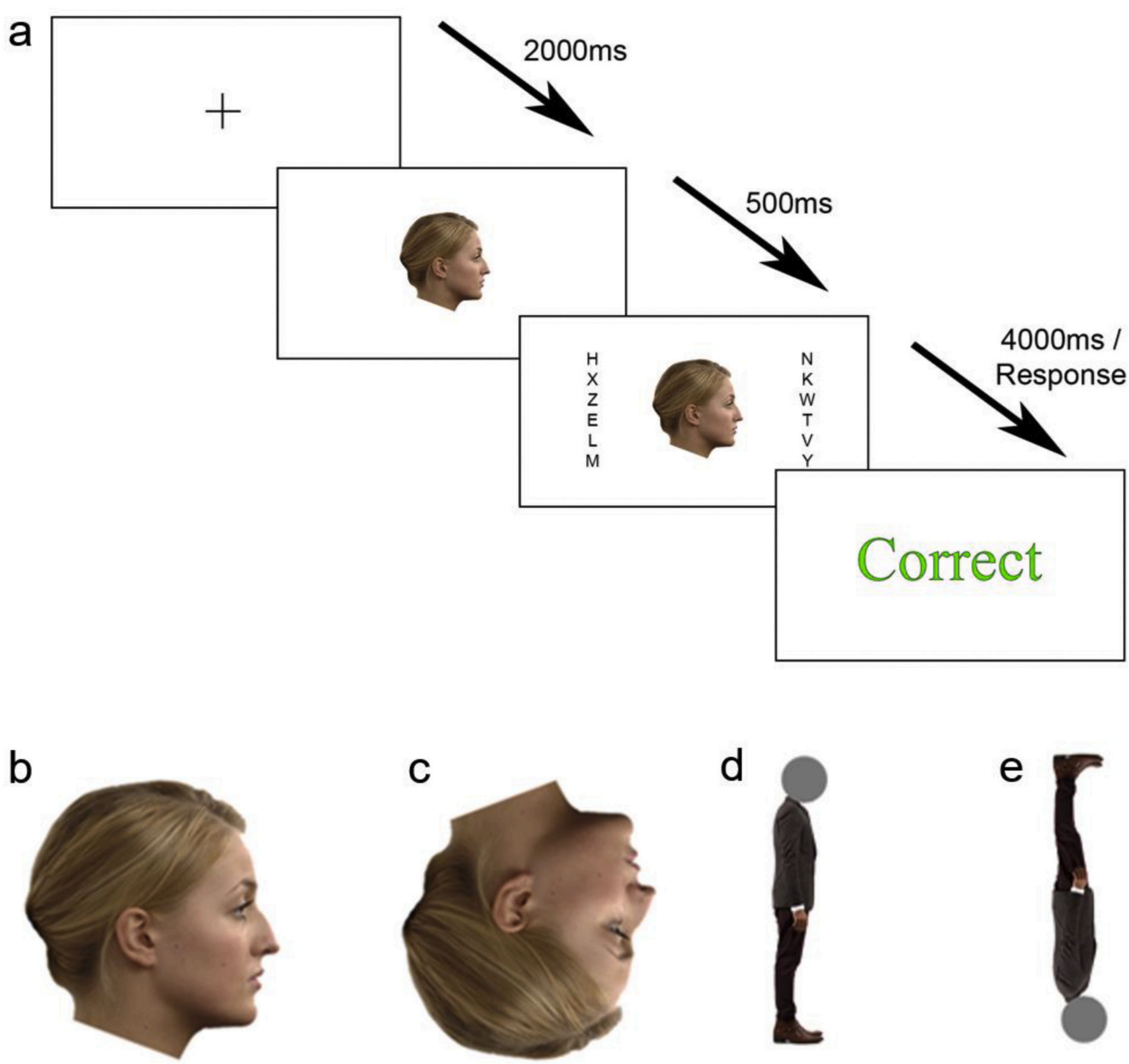

Fig. 4. (a) Structure of a trial from the attentional cueing procedure. (b – e) Examples of the cueing stimuli employed in the upright faces, inverted faces, upright bodies, and inverted bodies experiments, respectively.

5.1.2. Procedure

Experimental trials began with a fixation cross in the centre of the screen. After 2 s, a cueing stimulus appeared in the centre (either an upright face, an inverted face, an upright body, or an inverted body), replacing the fixation cross. 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. The position of the two arrays was held constant in all experiments. 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. The target letter was equally likely to appear at any of the 12 locations. 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).

At the start of each block, participants were given a target letter to find on each trial of that block. Participants were instructed to press spacebar if the target letter was present in one of the arrays. They were asked to respond as quickly as possible without sacrificing accuracy. 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' shown in green (following a spacebar response during target-present trials or no response during target-absent trials), the word 'incorrect' shown in red (following a spacebar response during target-absent trials), or the phrase 'too slow' shown in red (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.

5.2. Results

The results from our final series of experiments are depicted in Fig. 5. For each type of stimulus, a directional cueing effect is inferred from faster RTs on valid trials than on invalid trials. Trials where participants took longer than 4 s to respond or where participants responded incorrectly were excluded from the analyses. These criteria were agreed a priori. At the outset we agreed to exclude anyone who responded on more than eight of the catch trials, however no-one was replaced on this basis.

5.2.1. Upright faces

Forty participants (17 female, 21 male, 2 non-binary) with an age range of 18 to 55 years (M_{age} = 29.7, SD_{age} = 10.0) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (1.6%) were excluded from the analysis. All participants performed correctly on at least 61 of the 64 catch trials. Participants responded significantly faster on valid trials (M = 1.16 s, SD = 0.22 s) than on invalid trials (M = 1.28 s, SD = 0.23 s), [$t(39) = 5.32$, $p < .001$, $d = 0.84$, $CI_{95\%}$ = 0.07, 0.16].

5.2.2. Inverted faces

Forty participants (20 female, 20 male) with an age range of 22 to 60 years (M_{age} = 33.7, SD_{age} = 9.7) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (2.1%) were excluded from the analysis. All participants performed correctly on at least 59 of the 64 catch trials. There was no significant difference between RTs on valid trials (M = 1.17 s, SD = 0.25 s) and on invalid trials (M = 1.20 s, SD = 0.23 s), [$t(39) = 1.29$, $p = .203$, $d = 0.20$, $CI_{95\%}$ = −0.02, 0.07].

5.2.3. Upright bodies

Forty participants (19 female, 21 male) with an age range of 18 to 56

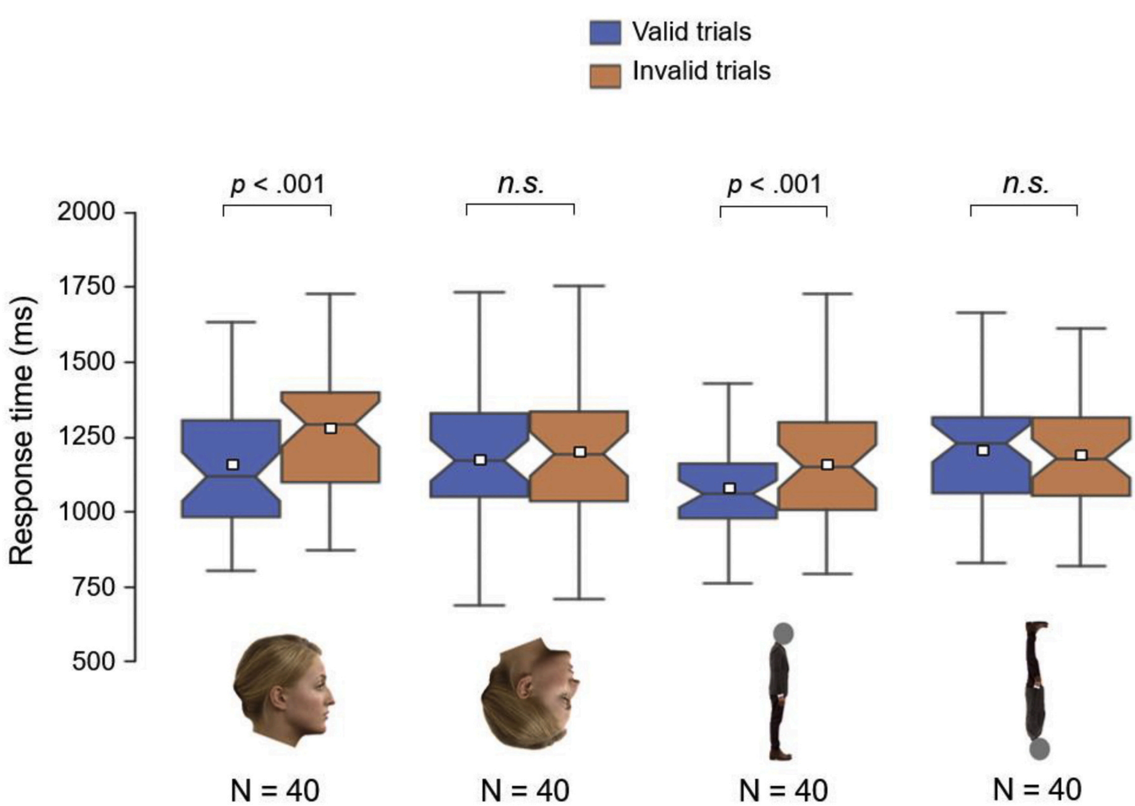

Fig. 5. Results from the direction cueing experiments. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5 * interquartile range. White squares denote the mean.

years ($M_{age} = 28.5$, $SD_{age} = 9.5$) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (1.8%) were excluded from the analysis. All participants performed correctly on at least 61 of the 64 catch trials. Participants responded significantly faster on valid trials ($M = 1.08$ s, $SD = 0.17$ s) than on invalid trials ($M = 1.16$ s, $SD = 0.22$ s), [$t(39) = 3.99$, $p < .001$, $d = 0.63$, $CI_{95\%} = 0.04, 0.12$].

5.2.4. Inverted bodies

Forty participants (15 female, 25 male) with an age range of 18 to 57 years ($M_{age} = 26.5$, $SD_{age} = 7.7$) were recruited through Prolific. No-one was replaced or excluded. Those trials where participants responded incorrectly (1%) were excluded from the analysis. All participants performed correctly on at least 62 of the 64 catch trials. There was no significant difference between RTs on valid trials ($M = 1.21$ s, $SD = 0.20$ s) and invalid trials ($M = 1.19$ s, $SD = 0.20$ s) [$t(39) = 1.22$, $p = .229$, $d = 0.19$, $CI_{95\%} = -0.04, 0.01$].

5.2.5. Inversion effects

To determine whether the directional cueing effect seen for upright faces was significantly greater than that for inverted faces, we analysed RTs from the two face tasks using ANOVA with Cue Validity (valid, invalid) as a within-subjects factor and Orientation (upright, inverted) as a between-subjects factor. This analysis revealed a significant Cue Validity × Orientation interaction whereby the effect of Cue Validity was significantly greater in the upright task [$F(1, 78) = 8.89$, $p = .004$, $\eta p^2 = 0.10$]. The analysis also revealed a main effect of Cue Validity [$F(1, 78) = 22.63$, $p < .001$, $\eta p^2 = 0.23$], whereby participants responded faster on valid trials. There was no main effect of Orientation [$F(1, 78) = 0.47$, $p = .494$, $\eta p^2 = 0.01$].

Similarly, to determine whether the directional cueing effect seen for upright bodies was significantly greater than that for inverted bodies, we analysed RTs from the two body tasks using ANOVA with Cue Validity (valid, invalid) as a within-subjects factor and Orientation (upright, inverted) as a between-subjects factor. This analysis revealed a significant Cue Validity × Orientation interaction whereby the effect of Cue Validity was significantly greater in the upright task [$F(1, 78) = 15.37$, $p < .001$, $\eta p^2 = 0.17$]. The analysis also revealed a significant main effect of Cue Validity [$F(1, 78) = 6.01$, $p = .016$, $\eta p^2 = 0.07$], whereby participants responded faster on valid trials, and a marginal main effect of Orientation [$F(1, 78) = 3.26$, $p = .075$, $\eta p^2 = 0.04$], whereby participants responded faster on upright trials.

6. General discussion

In recent years there has been considerable interest in the visual processing of social interactions (Gray et al., 2017; Isik et al., 2017; Papeo et al., 2017; Quadflieg et al., 2015). An interesting finding to emerge from this new field is the search advantage for facing dyads (Papeo et al., 2019; Vestner et al., 2019). 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 et al., 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 et al., 2019). The present findings advance our understanding of these effects.

6.1. Inversion effects and the search advantage for facing dyads

Vestner, Tipper and colleagues (2019) reported that the search advantage for facing dyads was disrupted by orientation inversion. When stimuli were shown upright, target pairs arranged front-to-front were found faster than target pairs arranged back-to-back when hidden amongst distractor pairs that faced the same direction. When stimuli were shown upside-down, however, front-to-front and back-to-back targets were found equally quickly. This initial finding was obtained with whole body stimuli in which the faces were visible, using the Vestner dyadic search paradigm. We were able to replicate this inversion effect with dyadic stimuli constructed from images of upright faces only, and with images of upright bodies with their face occluded. We were also able to replicate these effects using the Papeo dyadic search paradigm: When stimuli were shown upright, front-to-front target pairs hidden amongst back-to-back distractor pairs were found faster than back-to-back targets hidden amongst front-to-front distractors. However, when stimulus orientation was inverted, the search advantage for facing targets was lost.

Faces and bodies viewed in profile are salient cues to direction that influence how participants orient their visuo-spatial attention. It is possible that the search advantage for facing dyads is a product of these cues. This suggestion has gained empirical support from the fact that a front-to-front search advantage is also seen with arrows: pairs of arrows arranged front-to-front are found faster than pairs arranged back-to-back when hidden amongst distractor pairs that point in the same direction (Vestner et al., 2020). However, Vestner, Tipper, and colleagues (2019) cited evidence that the search advantage for facing dyads was disrupted by orientation inversion as an argument against the direction cueing account. Instead, it was suggested that the effect was more consistent with the view that pairs of people arranged front-to-front engage domain-specific social interaction processing that aids rapid detection and interpretation.

The view that inversion effects are suggestive of domain-specific social interaction processing assumes that the ability of faces and bodies to cue attention is unaffected by orientation inversion. By employing an attentional cueing paradigm, we were able to show that this assumption is incorrect. Faces and bodies with the face occluded were effective cues to attention when shown upright (target letters were found faster at cued locations than at non-cued locations) but not when shown upside-down (target letters were found equally quickly at cued and non-cued locations). These findings indicate that the orientation specificity of the search advantage for facing dyads is entirely consistent with the directional cueing hypothesis: inverted faces and bodies do not cue attention and would therefore not be expected to produce the search advantage under this account.

Taken together, the present results and our previous findings with arrow stimuli suggest that the search advantage for facing dyads is a by-product of the ability of faces, bodies, and arrows to direct participants' visuo-spatial attention. When arranged front-to-front, strong directional cues – including upright faces, upright bodies, and arrows (Vestner et al., 2020) – may create a small focal region to which observers' attention is guided. The presence of these hot-spots may aid the serial visual search for front-to-front targets. Conversely, when the same elements are arranged back-to-back, upright faces and bodies direct observers' attention away from the target location, hindering visual search (Vestner et al., 2020). Because inverted faces and inverted bodies do not direct visuo-spatial attention in the same way, the front-to-front vs. back-to-back manipulation exerts little or no influence on observers' visual search.

We have shown that upright bodies and faces direct participants' visuo-spatial attention and produce the search advantage for facing dyads, while inverted faces and bodies do not direct attention and do not produce the search advantage. These observations by themselves do not unequivocally demonstrate that attentional cueing is the crucial ingredient that produces the search advantage for facing dyads. Our aim in this work was more modest and more specific – to interrogate a particular argument that has been made against the directional cueing hypothesis. By resolving this key objection to the direction cueing account, these findings represent an important advance in our understanding of the search advantage for facing dyads.

6.2. Inversion effects and the visual processing of dyads

There has been considerable interest in the detrimental effects of orientation inversion on the ability of people to identify and discriminate faces (McKone & Yovel, 2009; Murphy, Gray, & Cook, 2020; Rossion, 2008; Yin, 1969). Traditionally, these effects have been understood in terms of configural processing (Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Le Grand, & Mondloch, 2002; McKone & Yovel, 2009; Rossion, 2008). While upright faces are thought to be processed configurally – whereby local features are integrated in to a coherent unified representation (also referred to as holistic processing) – inverted faces are thought to be processed in a piecemeal fashion. The piecemeal processing engaged by inverted faces is characterised as slow, effortful, and error-prone. In contrast, configural processing may afford fast and accurate interpretation (for a different perspective, see: Murphy et al., 2020).

This configural account of the face inversion effect owes much to related evidence from the composite face illusion (Gray et al., 2020; Hole, 1994; Young, Hellawell, & Hay, 1987). When the upper half of one face ('target region') is spatially aligned with the lower half of another ('distractor region'), the two halves appear to fuse together perceptually, changing observers' subjective perception of the target region. Importantly, the illusion manifests strongly when composite arrangements are shown upright, however, the distractor region induces much less perceptual distortion when arrangements are shown upside-down. These findings are consistent with the operation of whole-face integration processes that are engaged by upright faces only (Murphy, Gray, & Cook, 2017; Rossion, 2013).

Drawing on these ideas, some authors have suggested that front-to-front dyads may engage qualitatively different visual processing when shown upright and upside-down (Papeo, 2020; Papeo et al., 2017). Upright facing dyads are thought to engage configural processing whereby the two bodies are processed as a single structure. Conversely, pairs of facing individuals shown upside-down, and pairs of upright individuals shown back-to-back are thought to be processed as separate individuals. Consistent with this view, orientation inversion impairs the detection and perception of facing dyads, but has little effect on the perception of back-to-back dyads (the two body inversion effect; Papeo et al., 2017). Insofar as inversion is thought to disrupt configural processing, the orientation sensitivity of dyads shown front-to-front may suggest they are processed configurally (Papeo, 2020; Papeo et al., 2017).

Our findings indicate that there may be other important differences between the processing of upright and inverted dyads, beyond the engagement of configural processing. As described above, the front-to-front arrangement of upright individuals creates a small focal region to which observers' attention is directed by multiple highly-effective attention cues. We have argued that this attentional focus facilitates visual search (Vestner et al., 2020). When stimuli are presented upright, these attention cues may also aid encoding and interpretation of facing dyads, relative to pairs of individuals shown back-to-back. Conversely, profile views of faces and bodies do not direct attention when stimuli are shown upside-down. Consequently, front-to-front dyads may not induce the same attentional focus when shown upside-down, possibly with detrimental consequences for their encoding and interpretation.

6.3. Inversion effects and the visual processing of bodies

It is well established that the perception of faces is greatly impaired when stimuli are turned upside-down (McKone & Yovel, 2009; Rossion, 2008; Yin, 1969). Although similar effects have been reported with bodies (Cook & Duchaine, 2011; Reed, Stone, Bozova, & Tanaka, 2003), there is some debate about whether the processing of bodies is disrupted by orientation inversion, or whether performance decrements are in fact caused by the inversion of the face and head region (Yovel, Pelc, & Lubetzky, 2010). In the context of this debate, it is striking that the directional cueing by our body stimuli was so clearly modulated by stimulus orientation despite the fact that the face and head were occluded. This finding is suggestive of a body – not head – inversion effect. One possibility is that bodies, like faces, engage some form of configural processing (Reed et al., 2003; Willems, Vrancken, Germeys, & Verfaillie, 2014).

More broadly, there appears to be number of parallels between the visual processing of faces and bodies (Peelen & Downing, 2007; Slaughter, Stone, & Reed, 2004). For example, faces and bodies engage adjacent regions of fusiform cortex (Peelen & Downing, 2005) and induce similar event related potentials, the N170 and N190 respectively (Stekelenburg & de Gelder, 2004; Thierry et al., 2006). Similarly, faces and bodies capture participants' attention in conditions where other stimuli do not (Downing, Bray, Rogers, & Childs, 2004). There is also evidence that body stimuli produce effects comparable with the composite face illusion (Willems et al., 2014). The fact that orientation inversion disrupts the ability of both faces and bodies to orient participants' visuo-spatial attention is a further addition to this list of similarities.

6.4. Why does orientation inversion disrupt attentional cueing effects?

When viewing other people, the direction of their gaze, head and body, are powerful cues that direct our visuo-spatial attention (Frischen et al., 2007; Langton et al., 2000; Nummenmaa & Calder, 2009). However, relatively little is known about the orientation-sensitivity of these cueing effects. It has previously been shown that cueing by eye gaze and head direction is attenuated by orientation inversion (Langton & Bruce, 1999). The present findings indicate that cueing by body direction is also sensitive to stimulus orientation. As described above, perceptual deficits caused by orientation inversion are often attributed to disrupted configural processing (McKone & Yovel, 2009; Murphy et al., 2017; Rossion, 2008). It remains to be seen whether diminished attentional cueing by head and body direction are caused by disrupted configural processing.

Configural face processing is thought to help participants make fine-grained, within-category distinctions between visually similar stimuli (e.g., distinguishing between a true celebrity and an impersonator). According to theories of configural face processing, this type of judgement is much easier when stimuli are shown upright because configural processing improves the quality of the target face representation (Maurer et al., 2002; McKone & Yovel, 2009; Rossion, 2008). However, it is relatively easy to determine whether a face or body is facing rightwards or leftwards irrespective of stimulus orientation. Under free-viewing conditions, it seems likely that most participants would achieve perfect or close-to-perfect classification performance even where stimuli were shown upside-down. In this sense, it is hard to see how configural processing could drastically improve the accuracy with which head / body direction is encoded.

While there may be little scope to enhance the accuracy with which actor direction is represented, it is possible that configural processing may increase the speed with which this attribute is encoded. Configural processing is characterised as fast and efficient (e.g., Farah et al., 1998; Maurer et al., 2002). In contrast, the piecemeal processing of inverted stimuli may be slow and effortful. Consistent with this view, evidence from EEG suggests that the processing of faces and bodies may be delayed by inversion (Jacques, d'Arripe, & Rossion, 2007; Stekelenburg & de Gelder, 2004). Less efficient stimulus processing may afford weaker attentional cueing effects.

6.5. Conclusion

There is now considerable evidence that observers are better at finding target pairs in visual search paradigms, when dyads are arranged front-to-front, than when arranged back-to-back. However, this bias does not appear to reflect a domain-specific mechanism for the detection of social interactions. Together with recent evidence that arrows arranged front-to-front also produce the search advantage for facing dyads, our findings support the view that the search advantage is a by-product of the ability of constituent elements to direct observers' visuo-spatial attention. Importantly, heads and bodies direct observers' visuo-spatial attention when shown upright, but not when shown upside-down. This may be why front-to-front dyads are found faster than back-to-back dyads when shown upright, but why front-to-front and back-to-back dyads are found equally quickly when shown upside-down.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

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