# Eye Configuration Influences the Detection Advantage of Direct Gaze

Jiaying Shi, Ting Wu, Lei Chen, Zhe Wang, Linlin Yan, Yu-Hao P. Sun*, Haiyang Jin

Department of Psychology, Zhejiang Sci-Tech University

Correspondence concerning this article should be addressed to Yu-Hao P. Sun, Department of Psychology, Zhejiang Sci-Tech University, 928 Second Avenue, Hangzhou, Zhejiang, China, 310018. Tel.: +86-571-86843237.

E-mail: sunyuhao@zstu.edu.cn.

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**Abstract**

Research has shown that individuals detect direct eyes (those directed to the observer) more quickly and accurately than averted eyes (those directed elsewhere), a phenomenon known as the direct-gaze advantage (Conty et al., 2016; Hu et al., 2013; von Grünau & Anston, 1995). However, the underlying mechanisms of this advantage remain poorly understood. The current study employed the visual search task (Dunn et al., 2018) to investigate whether the direct-gaze advantage in capturing attention is contingent upon a specific configuration (face configuration or eyes configuration). In two experiments, participants were presented with four images and asked to judge whether there was a target with a direct or averted gaze. Experiment 1 revealed that participants showed the direct-gaze advantage across three image types: intact faces (maintaining both two-eye and face configuration), scrambled faces with intact eyes (disrupting the face configuration while preserving the two-eye configuration), and fully scrambled faces (preserving only the single eye configuration). Experiment 2 further demonstrated that participants showed the direct-gaze advantage for scrambled faces with intact eyes and fully scrambled faces under the upright condition. Interestingly, under the inverted condition, participants only showed the direct-gaze advantage for scrambled faces with intact eyes. These findings indicate that the direct-gaze advantage is influenced by the configuration of two eyes and the configuration of a single eye, but it is not dependent on facial contexts.

**Key Words**

Direct-gaze advantage, face configuration, eyes configuration, visual search task

## Introduction

Gaze perception plays an important role in our daily lives. The gaze of another reveals her/his desires and intentions (Boyer & Wang, 2018; Chacón-Candia et al., 2023; Hietanen et al., 2016; Langton et al., 2000; Nummenmaa & Calder, 2009). A recent meta-analysis by Chacón-Candia et al. (2022) further supports this view, showing that gaze and arrow cues often lead to similar attentional effects, highlighting the robustness of gaze as a social cue. People searched for direct eyes (directed to the observer) faster and more accurately than averted eyes (directed elsewhere), which is known as the stare-in-the-crowd effect or the direct-gaze advantage (Conty et al., 2016; Hu et al., 2013; von Grünau & Anston, 1995). Direct gaze can capture attention: in a visual search task, participants were easier to perceive the direct gaze of the observer than the averted gaze (Boyer & Wang, 2018; Hu et al., 2013); in ERP studies, direct gaze had early preferential processing as compared with averted gaze at the P1 and P3b (Burra et al., 2018), and N2pc, an attention indicator, was recorded in participants searching for direct gaze, but was drastically diminished in participants searching for averted gaze (Doi et al., 2009); in fMRI studies, the direct gaze is preferentially processed, direct gaze enhances the activation of components of the social brain network, including fusiform gyrus, anterior and posterior, medial prefrontal and orbitofrontal cortex, and amygdala (Senju & Johnson, 2009); oculomotor tasks revealed that direct-gaze faces (vs. averted) could capture attention more strongly (Dalmaso et al., 2017a; Dalmaso et al., 2017b)， for example, saccadic peak velocities were lower in the presence of faces with direct gaze rather than closed eyes, indicating that direct-gaze faces can capture attention more strongly. In addition, direct gaze only requires a little attention: unlike averted gaze, people can accurately discriminate direct gaze without a focus of attention (Yokoyama et al., 2014); for direct gaze, lower levels of neural activity are sufficient to give rise to awareness than for averted gaze (Madipakkam et al., 2015).

The direct-gaze advantage suggests that attention is more directed towards direct gaze targets than averted gaze targets, but the mechanism underlying the advantage remains unclear. From the perspective of visual perception processing, there are two possible explanations: “Physical Salience” and “Perceptual Template” (Ramamoorthy et al., 2021). The “Physical Salience” view suggests that direct gaze eyes are more physically salient than averted gaze eyes because the human eye's large exposed white sclera contrasts with its black iris to provide a physically salient stimulus directing attention without being coded by the observer (Conty et al., 2016; Kobayashi & Kohshima, 1997;

Lyyra et al., 2018). The "Perceptual Template" view suggests that the eyes, as a social stimulus, differ from other direction cues (such as arrows) and possess a special processing mechanism (Marotta et al., 2019). A perceptual template in human vision detects direct gaze eyes and guides attention toward them (Madipakkam et al., 2015). The configuration of eyes and faces can facilitate people's detection and recognition of eyes and faces (Maurer et al., 2002). The perceptual template, therefore, may include the configuration of eyes, faces, or both.

The direct-gaze advantage may rely on the configuration of a face. Faces can capture attention quickly (Langton et al., 2008). Detection of human faces among a variety of objects is close to independent of the size of the search array; in other words, the face "pops out" (Hershler & Hochstein, 2005). The specificity of the face may arise from its global face configuration, a whole perceptual "template" composed of the facial parts and their relative positions (Hershler & Hochstein, 2005; Tanaka & Farah, 1993; Young et al., 1987). When the eyes are averted, the global template will be destroyed (Vrancken et al., 2017), suggesting that the template based on face configuration may be the source of the direct-gaze advantage. There is some evidence to support this assumption. When eyes are displayed in a face, people can identify the direct eyes more quickly and accurately than when the eyes are presented alone, but there is no direct-gaze advantage when the face is inverted (its configuration is destroyed) (Riechelmann et al., 2021). Breil et al. (2022) employed an attention-capture paradigm to investigate the effect of direct eye gaze on attention capture across different contexts (photographic human faces; arrows; schematic isolated eye stimuli; photographic isolated eye stimuli; schematic face stimuli with or without head orientation). Findings revealed a direct-gaze advantage solely within the context of photographic human faces, whereas no direct-gaze advantage was observed when eyes were presented in isolation, indicating that the direct-gaze advantage is contingent upon the face configuration.

The direct-gaze advantage, however, appears to be independent of face configuration, according to a recent study. Burra and Kerzel (2021) found that the suddenly presented direct eyes can still catch attention more quickly, regardless of whether the eyes are presented alone or the face is presented inverted. This is interesting because when a face is presented inverted, it can disrupt the processing of the face's configuration (Tanaka & Farah, 1993; Young et al., 1987). However, the study shows that even if the processing of face configuration is disrupted, the direct-gaze advantage still exists. Another noteworthy point in this study is that the two eyes always appear as one whole. Inversion can interfere with the processing of the face's configuration, but it has no effect on the processing of the eye area. Namdar and his colleagues (2015) found that when the face is presented upside down, people lose awareness of the spatial relationship between different facial features, such as the eyes and the nose, but their ability to distinguish between the positions of the two eyes remains unaffected. In a study, the early ERP negative component, N170, which is an index of face holistic processing, was significantly larger when the eyes region was presented isolated compared with a whole face (Bentin et al., 1996). Consequently, the binocular structure could potentially serve as a template, with the direct-gaze advantage contingent upon this particular configuration of the two eyes.

The goal of the current study was to determine if the direct-gaze advantage in attracting attention depended on a particular configuration (either face configuration or two-eye configuration) using a visual search task (Dunn et al., 2018). There were two experiments in the study. In Experiment 1, we presented participants with three kinds of images: an intact face (preserving eyes and face configuration), a scrambled face with intact eyes (destroying face configuration but preserving two-eye configuration), and a fully scrambled face (only preserving single-eye configuration). Participants were asked to determine whether there was a target (direct gaze or averted gaze) in the four images presented simultaneously. By comparing the search performance (accuracy and correct reaction times in our study) across three conditions, we investigated the effects of face configuration and two-eye configuration on the direct-gaze advantage. The direct-gaze advantage refers to the higher accuracy (ACC) or shorter reaction times (RTs) when searching for a direct gaze compared to an averted gaze. In Experiment 2, we added a variable "orientation" and used the scrambled face with intact eyes and the fully scrambled face as experimental materials. Inversion has little effect on the processing of the eyes' configuration, but it will harm the processing of a range of stimuli (such as faces, Chinese characters, etc., Leder & Carbon,2006; Li et al., 2022). By comparing search performance in upright and inverted conditions, we explored the effects of the two-eye and single-eye configurations on the direct-gaze advantage. It should be pointed out that the previous experiments (Breil et al., 2022; Burra & Kerzel, 2021) used the whole face and the eyes as stimuli and found that the direct-gaze advantage for the whole face was stronger (Breil et al., 2022). However, this could be due to the fact that the whole face provides more information compared to the eyes alone, making it difficult to differentiate between the effects of facial configuration and the amount of information. In this study, we used scrambled faces in both experiments. This helped minimize interference from the amount of information provided by the stimuli, as the information amount was consistent for each type of stimulus.

According to our hypothesis, the results are predicted as follows. In Experiment 1, we expect: (1) If the direct-gaze advantage depends on the face configuration, there is a direct-gaze advantage in the intact face condition and this advantage is absent in the partially scrambled face with intact eyes condition and the completely scrambled face condition where face configuration is destroyed. (2) If the direct-gaze advantage depends on the configuration of two eyes, such as their relative position, there is a direct-gaze advantage in the intact face condition and the partially scrambled face with intact eyes condition, but not in the completely scrambled face condition. (3) If the direct-gaze advantage depends on single-eye configuration or information, the direct-gaze advantage will exist in all three conditions. Moving on to Experiment 2, we anticipate the following outcomes: (4) If the direct-gaze advantage is related to the physical information of the eyes(e.g., brightness, which is unaffected by scrambling or inversion), we predict a direct-gaze advantage in both upright and inverted conditions for faces with intact eyes or fully scrambled features. (5) If the direct-gaze advantage is related to the two-eye configuration (e.g., the relative position of the eyes, which is unaffected by inversion), there is a direct-gaze advantage for faces with intact eyes in both upright and inverted conditions. However, this advantage should not be observed for fully scrambled faces (which preserve only the single-eye configuration). (6) If the direct-gaze advantage depends on the single-eye configuration (e.g., the eye contour), a direct-gaze advantage should be observed in the upright condition for faces with intact eyes or fully scrambled features (both of which preserve the single-eye configuration). However, this advantage should disappear in the inverted condition.

## Experiment 1

### *Method*

*Participant.* We used G-Power 3.1 (Faul et al., 2009) to plan the sample size. For a 2 × 3 within-subject design experiment, a power analysis indicated that a sample size of 24 would be required to detect a medium effect size (0.25) at the 0.05 alpha level with a 0.95 power value. Thirty-three undergraduates took part in Experiment 1. Four participants were excluded due to their accuracy or response times being less or more than three standard deviations (SD) above the mean of all participants. Finally, we collected data from 29 participants (15 females, mean age=19.2±3.7). All participants reported normal or correct-to-normal vision, were right-handed, and gave informed consent before the experiment.

*Material.* We recruited 6 Asian undergraduates (3 females) to participate in the original face image collection. All of them had no makeup or jewelry. Two frontal photos were taken of each person: direct eyes and averted eyes.

Using Adobe Photoshop, we cut these 12 pictures into ellipses of the same size, removed external clues (hairstyle, ears, accessories, head shape), and finally got 12 standardized faces (240 × 320 pixels). Then, we cut the intact face horizontally into five parts: forehead, eyes, nose, mouth, and chin, and then randomly scrambled the middle three parts to get the scrambled face with intact eyes. Next, we cut the scrambled face with intact eyes vertically into 10 parts, kept the forehead and chin parts unchanged, disrupted the middle six parts completely, and controlled the two eyes on either side to get the fully scrambled face. Finally, we got six types of faces: 2 (gaze direction: direct or averted) × 3 (face type: intact face, scrambled face with intact eyes, fully scrambled face) (see Fig. 1).

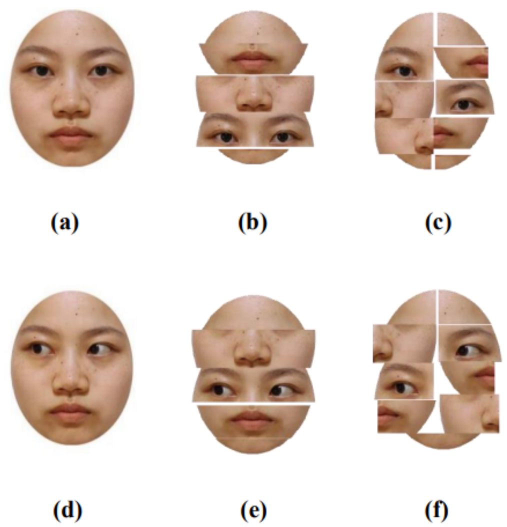


**Fig. 1** Six types of faces in Experiment 1. Direct gaze: in an intact face(**a**), in a scrambled face with intact eyes(**b**), and a fully scrambled face(**c**). Averted gaze: in an intact face(**d**), in a scrambled face with intact eyes(**e**), and a fully scrambled face(**f**).

An array of 4 faces was spaced on the corner of a square (See Fig. 2). When the search target (direct/averted gaze) existed (target-present condition), it was randomly presented in either of the four locations, and the other three images were all interfering stimuli in the other gaze direction. When the search target didn't exist (target-absent condition), all four images were interfering stimuli.

**Fig. 2** Examples of search array in target-present conditions.

*Procedure and Design.* Experiment 1 was conducted online. Participants used their own laptops to complete the experiment. Before the experiment began, participants were instructed to test the program. All participants' programs ran smoothly.

The participants were seated in front of the screen (resolution 1280 × 720 pixels) at a viewing distance of 60 cm. The experiment adopted the visual search paradigm, and the target was direct or averted eyes. Before the formal experiment, participants completed a 16-trial practice to familiarize themselves with the task.

Each trial started with a fixation cross displayed at the center of the screen(500ms), followed by a searching target (1000ms). Then, four pictures were presented on the screen (3000ms), and the participants were asked to make one of two keyboard responses as quickly as possible to indicate whether the target was among the four pictures (See Fig. 3).

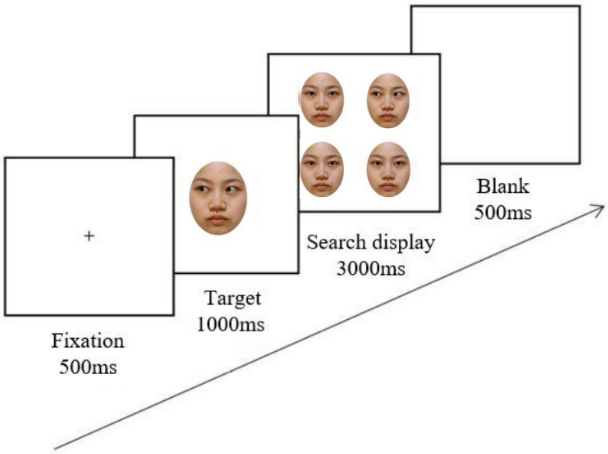


**Fig. 3** Schematic illustration of a trial.

We used a within-subject design. The stimuli of each trial varied based on the manipulation of two different dimensions: 1) gaze direction (direct gaze or averted gaze); and 2) face type (intact face, scrambled face with intact eyes, fully scrambled face). Collectively, each participant was presented with 288 trials in 3 blocks (face type: intact face, scrambled face with intact eyes, or fully scrambled face). Each block had 96 trials (48 trials in the target-present condition and 48 trials in the target-absent condition). In target-present conditions, each trial contained only one target stimulus. The order of presentation of the three blocks was counterbalanced across participants.

We measured accuracy (percentage of correct responses) and reaction time (RT) for correct trials as our primary dependent variables. The direct-gaze advantage was defined as significantly higher accuracy or faster RTs for direct gaze targets than averted gaze targets. For reporting effect sizes, we calculated partial eta squared ($\eta p^2$) for ANOVA analyses and Cohen's d for post-hoc pairwise comparisons, following the established guidelines in psychological research (Fritz et al., 2012; Lakens, 2013). Partial eta squared values of 0.01, 0.06, and 0.14 were interpreted as small, medium, and large effects, respectively, while Cohen's d values of 0.2, 0.5, and 0.8 were regarded as small, medium, and large effects.

*Result*

Accuracy (ACC) was calculated as the percentage of correct responses across all trials in the target-present condition, while reaction times (RTs) were analyzed only for correct trials in the target-present condition, following the procedure outlined by Hu et al. (2013). Detailed results can be found in Table 1.

**Table 1** ACC and RTs for three types of faces in Experiment 1 (N=29, Mean±SE).

| Face type | Gaze direction | ACC(%) | RTs(ms) |
|---|---|---|---|
| Intact face | Averted | 89.45±1.36 | 1255±36 |
| | Direct | 92.69±1.23 | 1290±34 |
| Scrambled face with intact eyes | Averted | 87.59±1.61 | 1328±30 |
| | Direct | 92.66±1.04 | 1324±33 |
| Fully scrambled face | Averted | 84.14±1.91 | 1441±50 |
| | Direct | 90.62±1.57 | 1463±51 |

*Accuracy.* A 3 (Face type: Intact face, Scrambled face with intact eyes or Fully scrambled face) × 2 (Gaze direction: Direct gaze or Averted gaze) repeated ANOVA was performed, with both independent variables as within-subjects factors. The main effect of face type was significant, $F(2,56)=4.08$, $p=0.022$, $\eta_p^2=0.13$, indicating differences in accuracy across face types. Post hoc tests (LSD) revealed that accuracy was higher for intact faces and scrambled faces with intact eyes than fully scrambled faces ($p=0.011$, $p=0.045$, respectively). However, there was no significant difference in accuracy between scrambled faces with intact eyes and intact faces ($p=0.493$). The main effect of gaze direction was also significant, $F(1,28)=17.38$, $p<0.001$, $\eta_p^2=0.38$, indicating that the search performance was better for direct gaze than for averted gaze. No significant interaction was found between face type and gaze direction, $F(2,56)=1.23$, $p=0.299$, $\eta_p^2=0.04$. (See Fig. 4)

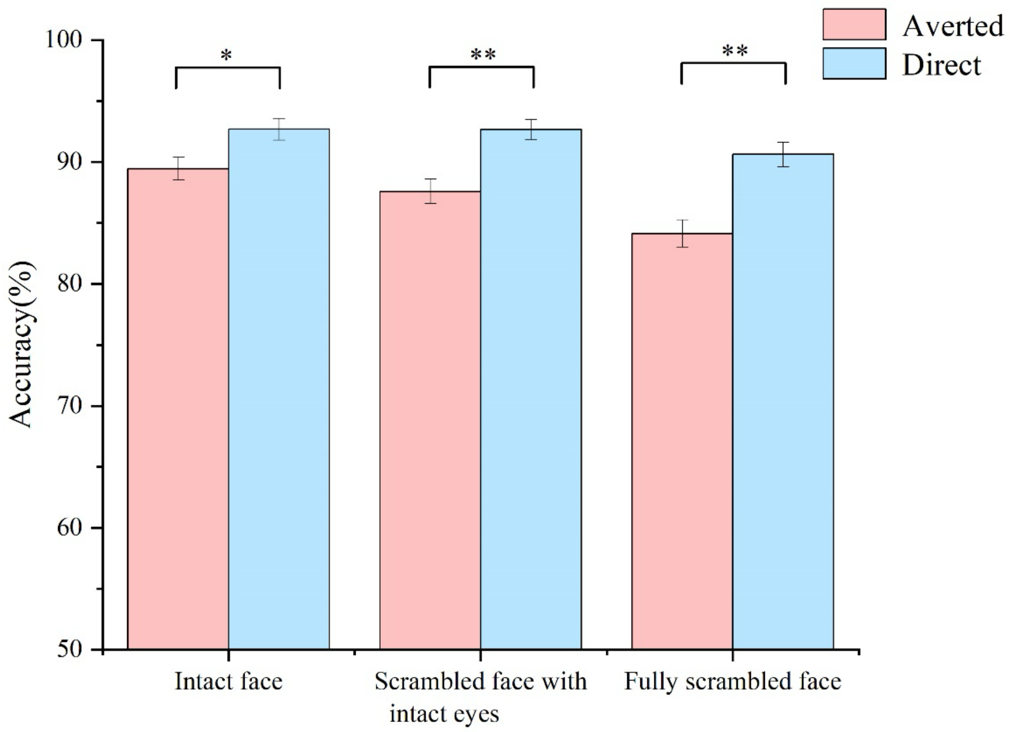


**Fig. 4** ACC for three types of faces in Experiment 1. Error bars indicate standard errors of the mean. * $p$<0.05, ** $p$<0.01.

*Response time.* A 3 (Face type: Intact face, Scrambled face with intact eyes or Fully scrambled face) × 2 (Gaze direction: Direct gaze or Averted gaze) repeated ANOVA was also performed for RTs, with both independent variables as within-subjects factors. The main effect of face type was significant, $F(2,56)=10.04$, $p<0.001$, $\eta_p^2=0.26$, indicating differences in reaction times across face types. Post hoc tests (LSD) revealed that participants responded faster to intact faces and scrambled faces with intact eyes than to fully scrambled faces ($p<0.001$, $p=0.007$). However, there was no significant difference in reaction times between scrambled faces with intact eyes and intact faces ($p=0.122$). The main effect of gaze direction was not significant, $F(1,28)=2.16$, $p=0.153$, $\eta_p^2=0.07$. Additionally, no significant interaction effect was found between face type and gaze direction, $F(2,56)=1.20$, $p=0.308$, $\eta_p^2=0.04$.

**Experiment 2**

In Experiment 2, we used only the scrambled face with intact eyes and the fully scrambled face.

This decision was based on the findings of Experiment 1, which demonstrated that even after the facial configuration was disrupted, both the scrambled face with intact eyes and the fully scrambled face still exhibited the direct-gaze advantage. We introduced a new variable, orientation (upright or inverted), to explore whether the direct-gaze advantage depends on the physical information of the eyes or their configuration. If the direct-gaze advantage depends on the physical information of eyes, such as brightness, we would expect to observe this advantage in both upright and inverted conditions. However, if the direct-gaze advantage depends on the two-eye configuration, such as the relative position of the eyes, there is a direct-gaze advantage only for the partially scrambled faces with intact eyes but not fully scrambled faces. Furthermore, if the direct-gaze advantage depends on the single-eye configuration, such as the eye contour, there is a direct-gaze advantage in the upright condition but not in the inverted condition for both partially scrambled faces with intact eyes and fully scrambled faces.

*Method*

*Participant.* Prior to data collection, we conducted an a priori power analysis using G*Power 3.1 (Faul et al., 2009) to determine the appropriate sample size. For our 2 × 2 × 2 within-subjects design, the analysis indicated that a minimum of 20 participants would be required to detect a medium effect size ($f = 0.25$) with an alpha level of 0.05 and a power of 0.90. Based on this calculation, we recruited 26 participants to account for potential attrition. Four participants were excluded due to their accuracy or response times being less or more than three standard deviations (SD) above the mean of all participants. Finally, we collected data from 22 participants (12 females, mean age=18.41±0.49). All participants reported normal or correct-to-normal vision, were right-handed, and gave informed consent before the experiment.

*Material.* There were 8 types of stimuli in this experiment in total: 2 (gaze direction: direct or averted) × 2 (face type: scrambled face with intact eyes or fully scrambled face) × 2 (orientation: upright or inverted) (see Fig. 5).

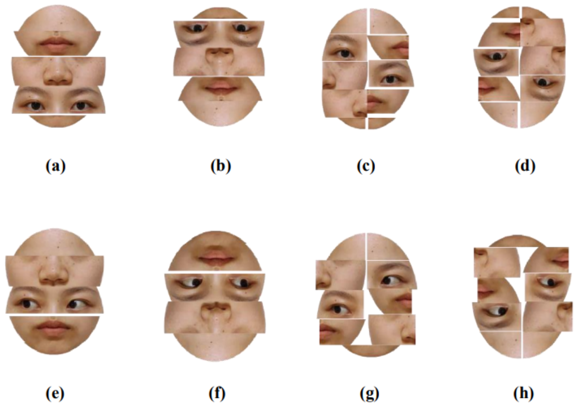


**Fig. 5** Eight types of stimuli in Experiment 2. Direct gaze: in an upright scrambled face with intact eyes(**a**), an inverted scrambled face with intact eyes(**b**), an upright fully scrambled face(**c**), and an inverted fully scrambled face(**d**). Averted gaze: in an upright scrambled face with intact eyes(**e**), an inverted scrambled face with intact eyes(**f**), an upright fully scrambled face(**g**), and an inverted fully scrambled face(**h**).

*Procedure and Design.* Experiment 2 was conducted in a quiet laboratory, and the participants sat 60cm from the monitor (resolution 1280 × 720 pixels). Stimuli were presented using E-Prime 2.0 software. The experiment also adopted the visual search paradigm, and the target was direct eyes or averted eyes. Similar to the task of Experiment 1, participants were asked to judge if there was a target gaze among the four pictures by pressing the keyboard.

We used a within-subject design. Stimuli of each trial varied based on the manipulation of three different dimensions: 1) gaze direction (direct gaze or averted gaze); 2) face type (scrambled face with intact eyes or fully scrambled face); and 3) orientation (upright or inverted).

Collectively, each participant was presented with 384 trials in 2 (face type: scrambled face with intact eyes or fully scrambled face) × 2 (orientation: upright or inverted) blocks. Each block had 96 trials (48 trials in the target-present condition and 48 trials in the target-absent condition). The order of presentation of the four blocks was counterbalanced across participants.

*Result*

We only analyzed the ACC and RTs in correct trials in target-present conditions, just like in Experiment 1 (see Table 2).

**Table 2** ACC and RTs for two types of faces in upright or inverted conditions in Experiment 2 (N=22, Mean±SE).

| Face type | Orientation | Gaze direction | ACC(%) | RTs(ms) |
|---|---|---|---|---|
| Scrambled face with intact eyes | Upright | Averted | 84.09±2.67 | 1420±58 |
| | | Direct | 88.63±1.76 | 1425±54 |
| | Inverted | Averted | 64.58±3.28 | 1423±57 |
| | | Direct | 78.99±2.83 | 1406±44 |
| Fully scrambled face | Upright | Averted | 82.38±2.99 | 1515±61 |
| | | Direct | 88.06±2.13 | 1523±55 |
| | Inverted | Averted | 83.34±3.46 | 1496±49 |
| | | Direct | 84.66±2.30 | 1454±48 |

*Accuracy.* A 2 (Face type: Scrambled face with intact eyes or Fully scrambled face) × 2 (Orientation: Upright or Inverted) × 2 (Gaze direction: Direct gaze or Averted gaze) repeated ANOVA was performed, with all independent variables as within-subjects factors. The main effect of face type was significant, $F(1,21)=15.48$, $p<0.001$, $\eta_p^2=0.42$, indicating that the search performance for scrambled faces with intact eyes was lower compared to fully scrambled faces. The main effect of orientation was also significant, $F(1,21)=33.52$, $p<0.001$, $\eta_p^2=0.62$, with higher accuracy for upright faces than inverted ones. The main effect of gaze direction was significant, $F(1,21)=22.26$, $p<0.001$, $\eta_p^2=0.52$, showing a direct-gaze advantage. We found significant interactions between face type and orientation, $F(1,21)=28.04$, $p<0.001$, $\eta_p^2=0.57$, and between face type and gaze direction, $F(1,21)=15.89$, $p<0.001$, $\eta_p^2=0.43$. However, there was no interaction between orientation and gaze direction, $F(1,21)=0.74$, $p=0.399$, $\eta_p^2=0.03$. Crucially, a significant three-way interaction was observed among face type, orientation, and gaze direction, $F(1,21)=12.82$, $p=0.002$, $\eta_p^2=0.38$. (See Fig. 6).

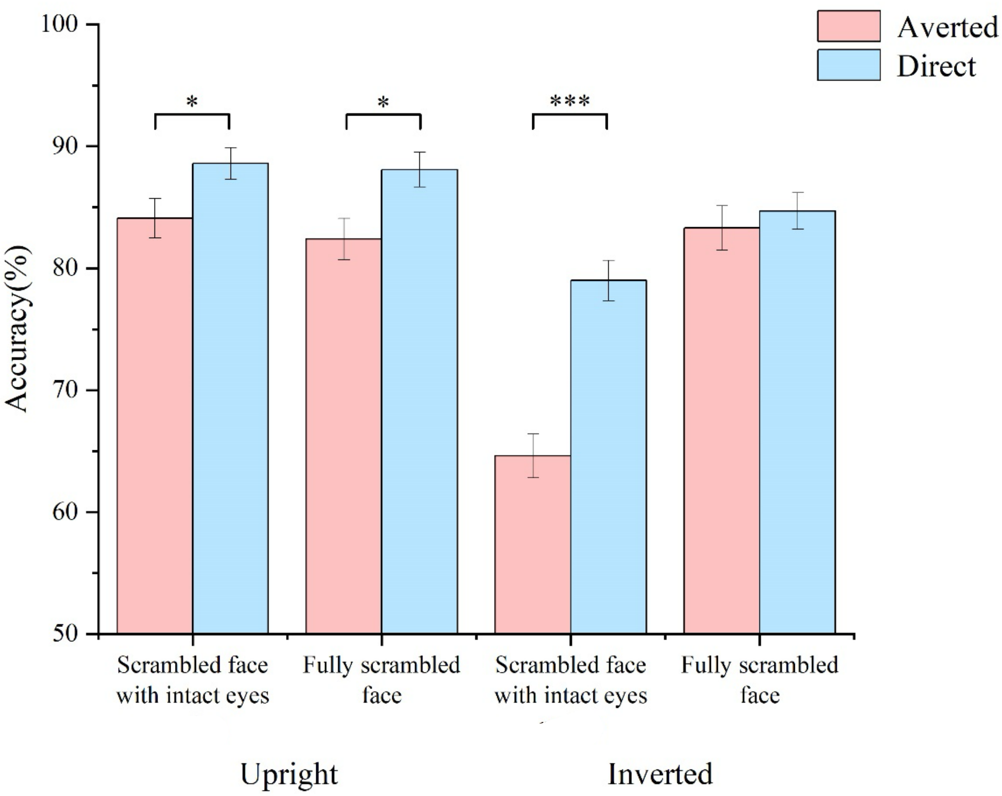


**Fig. 6** ACC for two types of faces in upright or inverted conditions in Experiment 2.

*Accuracy Comparison Between direct gaze and averted gaze.* To further analyze the significant three-way interaction among face type, orientation, and gaze direction, we conducted separate 2 (Face type: Scrambled face with intact eyes or Fully scrambled face) × 2 (Gaze direction: Direct gaze or Averted gaze) repeated-measures ANOVAs for the upright and inverted conditions.

In the upright condition, the effect of gaze direction was significant, $F(1,21)=6.50$, $p=0.019$, $\eta_p^2=0.24$, showing a direct-gaze advantage. However, there was no significant effect of face type, $F(1,21)=0.59$, $p=0.452$, $\eta_p^2=0.03$, nor a significant interaction, $F(1,21)=0.23$, $p=0.638$, $\eta_p^2=0.01$.

In the inverted condition, the effect of face type was significant, $F(1,21)=30.15$, $p<0.001$, $\eta_p^2=0.59$, with higher accuracy for fully scrambled faces than scrambled faces with intact eyes. The effect of gaze direction was also significant, $F(1,21)=12.63$, $p=0.002$, $\eta_p^2=0.38$, showing a direct-gaze advantage. Moreover, a significant interaction was found, $F(1,21)=25.52$, $p<0.001$, $\eta_p^2=0.55$. Post hoc tests(LSD) revealed a significant direct-gaze advantage for scrambled faces with intact eyes ($p<0.001$) but not for fully scrambled faces($p=0.624$).

To further explore the direct-gaze advantage, we conducted a series of paired-sample t-tests of direct gaze and averted gaze in different face types and orientations (see Table 3). The results showed that the direct-gaze advantage was a remarkably stable effect, persisting even when the two-eye region was displayed in an inverted orientation. However, the advantage disappeared when the two eyes were not on a horizontal line and were inverted.

**Table 3** paired-samples t-tests of direct gaze and averted gaze in different conditions.

| | Orientation | Face type | *t* | *p* |
|---|---|---|---|---|
| ACC | Upright | Scrambled face with intact eyes | -2.322 | 0.030 |
| | | Fully scrambled face | -2.140 | 0.044 |
| | Inverted | Scrambled face with intact eyes | -5.856 | <0.001 |
| | | Fully scrambled face | -0.498 | 0.624 |
| RTs(ms) | Upright | Scrambled face with intact eyes | -0.246 | 0.808 |
| | | Fully scrambled face | 0.257 | 0.800 |
| | Inverted | Scrambled face with intact eyes | 0.562 | 0.580 |
| | | Fully scrambled face | 1.420 | 0.170 |

*Reaction time.* A 2 (Face type: Scrambled face with intact eyes or Fully scrambled face) × 2 (Orientation: Upright or Inverted) × 2 (Gaze direction: Direct gaze or Averted gaze) repeated measures analysis of variance did not show any significant effect or interaction, *ps*>0.1.

**Discussion**

In the current study, we used a visual search task to investigate whether the configurations (facial configuration, eye configuration, or both) were vital for the direct-gaze effect. 1) All three types of faces (intact face, scrambled face with intact eyes, and fully scrambled face) showed a direct-gaze effect in the upright condition, and their effect sizes were comparable (Experiment 1 and Experiment 2). 2) In the inverted condition, a direct-gaze effect was observed only for scrambled faces with intact eyes but not for fully scrambled faces (Experiment 2). 3) The direct-gaze advantage for faces with intact eyes was significantly enlarged when faces were presented in an inverted position (Experiment 2). All these findings showed that direct-gaze advantage was dependent on the configuration of two eyes or a single eye, but it was independent of the facial configuration.

In Experiment 1, we observed a direct-gaze advantage for all three types of faces in the context of upright presentation, indicating that the configuration of the face did not affect the direct-gaze advantage. This finding aligns with several previous studies (von Grünau & Anston, 1995; Burra & Kerzel, 2021). von Grünau and Anston (1995) used schematic eyes in isolation as stimuli and also discovered a direct-gaze advantage, suggesting that direct eyes can capture attention regardless of face context. Similarly, in the study by Burra and Kerzel (2021), direct eyes attracted attention more quickly than averted eyes, whether presented in isolation or within a facial context. All these findings suggest that the direct-gaze advantage is independent of face configuration.

When faces were presented invertedly, the two-eye configuration proved to play a key role in the direct-gaze advantage. In the inverted condition, a direct-gaze effect was observed only for scrambled faces with intact eyes but not for fully scrambled faces (Experiment 2). It means that the direct-gaze effect disappeared when the spatial relations between the two eyes were disrupted (i.e., fully scrambled faces). It supports the view of the two-eye configuration that the two-eye region is processed as a whole (Namdar et al., 2015). The two-eye region operates as a separate 'gestalt' unit and is immune to inversion, which is a common manipulation to hamper configural processing (Tanaka & Farah, 1993; Young et al., 1987). Burra and Kerzel's (2021) study also showed that a direct gaze could capture attention even when the faces were presented invertedly. Consequently, the integrity of the two-eye region may be vital for the direct-gaze advantage, and our results supported the explanation of the "Perceptual Template" of eyes. It is noteworthy that direct gaze advantage was not observed in inverted, fully scrambled faces (Experiment 2), which disrupted facial and single-eye configuration while preserving feature information within a single eye. Therefore, the "Physical Salience" perspective discussed earlier does not fully explain the direct gaze advantage observed in upright, fully scrambled faces.

The third result is that the direct-gaze advantage for faces with intact eyes was significantly enlarged when faces were presented in an inverted position (Experiment 2). This is an interesting finding because the processing of the two-eye region will not be influenced by inversion (Namdar et al., 2015). Maybe two probabilities could account for it. One probability is that inversion strengthens people's processing of the gestalt of the two-eye region. Electrophysiological studies have found there are face- and eye-selective neurons that coexist in the superior temporal sulcus (STS) region, the upright face context depressed eye-selective neurons, while the inversion destroyed the facial configural information, and the eye-selective neurons still responded to the inverted eyes (Itier et al., 2006, 2007). Another probability is the ceiling effect. In Experiment 2, the performance in inverted faces with intact eyes significantly dropped. It is likely that the task in the upright condition may be so easy that it showed a ceiling effect that made the detected direct-gaze effect smaller, thus strengthening the effect of inversion on direct-gaze advantage.

According to the results of our study, we can infer that two kinds of eye configurations play different roles in the direct-gaze advantage. The first one is the single-eye configuration (i.e. morphological character of the eye), which consists of the spatial relationship between the black iris and white sclera, eye shape, the location of eyelids, eyelashes, and eyebrows, and so on (Itier & Batty, 2009; Kobayashi & Kohshima, 1997). When the single eye is inverted, the single-eye configuration will be destroyed. For example, a study by Rakover (2012) demonstrated that participants' detection performance of tilted eyes decreased significantly when the eyes were presented inverted as opposed to upright. This finding implies that the alteration in eye orientation affects the perception of the eye’s configuration, thereby leading to a decline in processing single-eye configuration under inversion. Similarly, Experiment 2 revealed that the processing of fully scrambled faces, consisting of the single-eye configuration, experienced disruption in the inverted condition, resulting in the disappearance of the direct-gaze advantage. It is important to note that while upright fully scrambled faces were able to demonstrate this effect. The second one is two-eye configuration, which mainly refers to the relative spatial relationship between the two eyes within a face in our study. In a normal face, the two eyes always appear in the same horizontal position, one on the left and one on the right, so the two-eye configuration is independent of the inversion. For instance, the perceived distance between the two eyes, a kind of two-eye configuration, was not affected by the inversion (Namdar et al., 2015). Because the scrambled faces with intact eyes contained both the single-eye configuration and two-eye configuration, and inversion only disrupted the former while preserved the latter, the direct-gaze advantage still existed for inverted scrambled faces with intact eyes. Therefore, we inferred that the direct-gaze effect depends on two configurations: two-eye and single-eye configurations.

In the current study, we observed a direct-gaze advantage in accuracy but did not find this effect in reaction time. This result is consistent with previous studies (Dunn et al., 2018; Palermo & Rhodes, 2003; Ramamoorthy et al., 2021; Ricciardelli et al., 2000). Reaction time and accuracy may reflect different cognitive processes. The enhancement in accuracy may indicate that direct gaze has an advantage in perception or recognition, while the lack of a significant difference in reaction time suggests that this advantage does not accelerate overall response speed. Conty et al. (2016) proposed in a review that the gaze effect may involve higher-level social cognitive processing rather than quick automatic responses, which could explain why differences in reaction time are not always apparent. However, the aforementioned studies, including ours, focused on recognizing gaze direction, such as detecting faces with different gaze directions or judging the gaze direction of faces. When gaze direction was used as a cue, studies showed that direct gaze significantly sped up reaction times under valid cue conditions (Hietanen & Leppänen, 2003). Another study investigated the effects of direct gaze on covert and overt social attention processes and found that direct gaze significantly sped up reaction times in covert attention but had a minor effect on overt attention (e.g., eye movements) (Boyer & Wang, 2018). Therefore, the impact on reaction time may depend on the specific task type. Future research could explore the cognitive mechanisms underlying the direct-gaze advantage by considering task types and the differences between reaction time and accuracy.

One limitation of the study is that we did not explore the effect of eyebrows in our experiments. We divided the upper part of a face into the forehead and eyes, which made some of the stimuli have their eyebrows accidentally destroyed. The removal of eyebrows seemed to interfere with the processing of the configural information in the upright condition but to facilitate processing in the inverted condition (Rakover, 2012). This may partly explain why inversion enlarged the direct-gaze advantage for faces with intact eye regions in Experiment 2. In future research, when we explore the effect of the configuration information of the eyes on the direct-gaze effect, we may consider not only the configuration information between the two eyes but also the configuration between the eyes and eyebrows. Another limitation of the study is that we only used averted gaze in one direction. We did this to make the difficulty of the task of searching for an averted gaze and searching for a direct gaze consistent. However, the left- and right-averted gaze seemed to be different. In a backward-masking gaze-discrimination task, the left-averted gaze was discriminated significantly better than the direct gaze and the right-averted gaze for upright faces, while they did not significantly differ for inverted faces (Riechelmann et al., 2021). It is still unclear whether there is a left-gaze advantage in a visual search paradigm involving attention capture. In the current study, we only used the left gaze as an averted gaze, but it is necessary to comprehensively consider both the left and right gaze in exploring the direct gaze effect in our future research.

In summary, this study aimed to investigate the underlying mechanisms of the direct-gaze advantage by examining whether it is influenced by face configuration or eye configuration. The results demonstrated that the advantage depends on the configuration of either two eyes or a single eye rather than the overall facial configuration. Furthermore, the study revealed a distinction between the two types of eye configurations: the direct-gaze advantage associated with a single eye is disrupted by inversion, while the direct-gaze advantage associated with the configuration of two eyes remains unaffected by inversion. Both configurations, however, contribute to the direct-gaze advantage.

## Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.


## Funding

This research was supported by Zhejiang Provincial Natural Science Foundation of China under Grant No. LY20C090010 and No. LY19C090006.


## Availability of data and materials:

The data and materials for all experiments are available at https://www.scidb.cn/s/u2iuAf.
None of the experiments was preregistered.

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