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Brief article

Eye contact facilitates awareness of faces during interocular suppression

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ABSTRACT

Eye contact captures attention and receives prioritized visual processing. Here we asked whether eye contact might be processed outside conscious awareness. Faces with direct and averted gaze were rendered invisible using interocular suppression. In two experiments we found that faces with direct gaze overcame such suppression more rapidly than faces with averted gaze. Control experiments ruled out the influence of low-level stimulus differences and differential response criteria. These results indicate an enhanced unconscious representation of direct gaze, enabling the automatic and rapid detection of other individuals making eye contact with the observer.

1. Introduction

Eye contact is a salient visual signal for a large number of species. In many vertebrates, the rapid perception of eye contact supports the effective detection of potential predators (Emery, 2000). By contrast, in human and non-human primates eye contact is a pivotal element in complex social behavior and therefore receives privileged visual processing and modulates cognitive processes. For example, humans orient to eye contact preferentially (e.g., Senju & Hasegawa, 2005; Senju, Hasegawa, & Tojo, 2005; von Grünau & Anston, 1995a), even in the first few days of their lives (Farroni, Csibra, Simion, & Johnson, 2002). This innate capability to detect eye contact lays the foundation for the later development of social cognition. Eye contact also improves performance in more complex face-related tasks, such as gender discrimination (Macrae, Hood, Milne, Rowe, & Mason, 2002) or recognition memory (Hood, Macrae, Cole-Davies, & Dias, 2003; Mason, Hood, & Macrae, 2004). The modulation of perceptual and cognitive processes by direct gaze has been referred to as the 'eye contact effect' and is thought to be mediated by a subcortical face detection pathway including the amygdala (Senju & Johnson, 2009). A rich body of literature has shown that emotional stimuli activate such subcortical structures, even when suppressed from visual awareness (e.g., Pasley, Mayes, & Schultz, 2004; Williams, Morris, McGlone, Abbott, & Mattingley, 2004). However, evidence for the unconscious processing of direct gaze has been lacking.

Given the special perceptual status of direct gaze as well as the proposed involvement of subcortical structures in mediating this eye contact effect, we asked whether the processing of eye contact might occur automatically, even outside of conscious awareness. We used continuous flash suppression (CFS; Tsuchiya & Koch, 2005) to render faces with direct or averted gaze invisible at the beginning of each trial. CFS is a recently developed variant of binocular rivalry in which a stimulus presented to one eye is suppressed from awareness by dynamic Mondrian-like

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masks flashed to the other eye. The potency of stimuli to overcome such interocular suppression and break into awareness is regarded as an index of unconscious processing (Costello, Jiang, Baartman, McGlennen, & He, 2009; Jiang, Costello, & He, 2007; Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009; Yang & Yeh, 2010; Yang, Zald, & Blake, 2007; Zhou, Jiang, He, & Chen, 2010). Accordingly, enhanced unconscious processing of direct gaze would be reflected in shorter suppression periods of faces with direct gaze compared to faces with averted gaze.

2. Method

2.1. Participants

Participants were students (age range 19–32 years) with normal or corrected-to-normal vision. All were naïve to the purpose of the study. There were fourteen participants in each of the experiments.

2.2. Apparatus and stimuli

Observers viewed a pair of dichoptic displays through a mirror stereoscope. The observer's head was stabilized by a chin-and-head rest at an effective viewing distance of 50 cm. Stimuli were presented against a uniform gray background. Two red frames ($10.6° \times 10.6°$) were displayed side by side on the screen, such that one frame was visible to each eye. To further support binocular alignment, fusion contours (width 0.8°) consisting of random noise pixels were presented within the red frames. In the center of each frame a red fixation dot ($0.7° \times 0.7°$) was displayed. Participants were asked to maintain stable fixation throughout the experiment.

Face stimuli were selected to rule out the potential confounding influence of greater eye symmetry present in faces with direct gaze and straight head direction. For Experiment 1, we adopted face photographs that were used in a series of previous studies investigating the detection of visible gaze directions (Senju & Hasegawa, 2005; Senju et al., 2005a). These stimuli were constructed from the same base image depicting a female model with a laterally averted head. Eye regions derived from other photographs of the same person were then superimposed onto the base image and carefully smoothed into the base image. The superimposed eyes were directed either maximally to the left or to the right. This yielded the impression of direct gaze when eye gaze and head were oriented in opposite directions and the impression of averted gaze when eye gaze and head were pointing in the same direction. Face stimuli were cropped to oval shapes ($3.3° \times 4.6°$), equalized for global contrast and luminance and the edges of the ovals were blurred into the background.

For Experiment 2, the same method used to generate the stimuli for Experiment 1 was applied to three facial identities (all female) that had also been used in previous studies investigating the detection of visible gaze directions (Senju, Tojo, Yagushi, & Hasegawa, 2005b; Senju, Yagushi, Tojo, & Hasegawa, 2003). For Experiment 2, we also created inverted versions of these faces by flipping them vertically.

To test if the faces employed in Experiment 2 truly induced the impression of direct gaze and averted gaze, an independent sample of 37 subjects judged these faces for the impression of direct gaze on a scale ranging from 1 ('not looking at me') to 5 ('directly looking at me') administered as a paper-and-pencil questionnaire. Wilcoxon signed-ranks tests revealed that both upright and inverted faces with direct gaze received significantly higher scores than their respective counterparts with averted gaze, $Z = 5.01$, $p < .001$, and $Z = 4.79$, $p < .001$, respectively.

2.3. Procedure

Each trial commenced with a 1-s presentation of the red frames, the fusion contours and the fixation dots only. Next, high-contrast colored Mondrian-like masks ($9.0° \times 9.0°$) flashing at 10 Hz were presented to one randomly selected eye while a face stimulus was gradually introduced to the other eye. The contrast of the face stimulus was ramped up linearly from 0% to 100% within a period of one second from the beginning of the trial and then remained constant until response or for a maximum of 10 s. Face stimuli were shown either to the left or to the right of the fixation dot (horizontal center-to-center distance 2.7°) at a random vertical position relative to the fixation dot (maximum vertical center-to-center distance 2.1°; Fig. 1). Participants were required to press the left or the right arrow key on the keyboard to indicate whether the face appeared left or right to fixation. They were in-

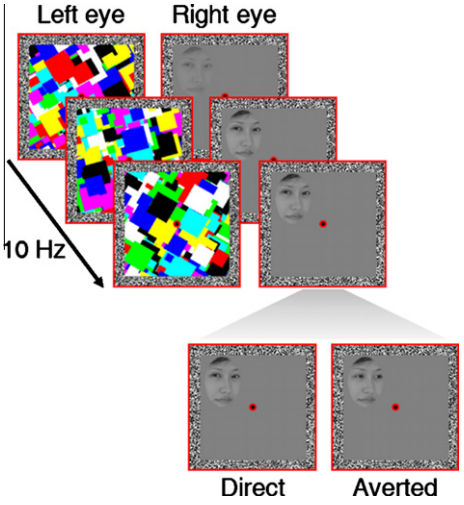

Fig. 1. Schematic of an example trial in Experiments 1 and 2. During each trial, participants were presented with Mondrian-like masks to one eye, while a face with direct or averted gaze was gradually faded into the other eye. Participants indicated on which side of fixation the face (or any part of the face) became visible. Please note that the perceived gaze direction of the face stimuli only depended on the particular combination of head orientation and eye gaze direction, thereby eliminating greater eye symmetry in faces with direct gaze as a potential confound (e.g., Senju et al., 2003).