Cognition 143 (2015) 108–114

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

# Making eye contact without awareness

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ARTICLE INFO

*Article history:*
Received 12 February 2015
Revised 23 June 2015
Accepted 24 June 2015

*Keywords:*
Social cognition
Unconscious processing
Eye movements
Face perception
Gaze direction

ABSTRACT

Direct gaze is a potent non-verbal signal that establishes a communicative connection between two individuals, setting the course for further interactions. Although consciously perceived faces with direct gaze have been shown to capture attention, it is unknown whether an attentional preference for these socially meaningful stimuli exists even in the absence of awareness. In two experiments, we recorded participants' eye movements while they were exposed to faces with direct and averted gaze rendered invisible by interocular suppression. Participants' inability to correctly guess the occurrence of the faces in a manual forced-choice task demonstrated complete unawareness of the faces. However, eye movements were preferentially directed towards faces with direct compared to averted gaze, indicating a specific sensitivity to others' gaze directions even without awareness. This oculomotor preference suggests that a rapid and automatic establishment of mutual eye contact constitutes a biological advantage, which could be mediated by fast subcortical pathways in the human brain.



## 1. Introduction

Most of us have experienced situations in which our eyes appear to be automatically turned towards another person whose gaze is directed at us, although only subsequently we seem to become aware that this person was looking at us (cf. Titchener, 1898). Indeed, we are highly sensitive to whether someone is staring at us, presumably because this information functions as a meaningful social signal (Kleinke, 1986). When others' faces are clearly visible, our attention is predominantly attracted by people who are looking at us (Senju & Hasegawa, 2005; Von Grünau & Anston, 1995). However, the frequently experienced phenomenon mentioned above further suggests that our sensitivity for direct gaze may extend even beyond our conscious perception.

A frequently adopted technique that has been used by previous studies to investigate face processing in the absence of awareness is continuous flash suppression (CFS; (Tsuchiya & Koch, 2005), in which face stimuli presented to one eye are suppressed from awareness by the concurrent presentation of mask stimuli to the other eye. Manual responses indicating the breakthrough of the face stimuli into participants' awareness were observed to be faster for direct compared to averted gaze (Chen & Yeh, 2012; Stein, Senju, Peelen, & Sterzer, 2011). While such findings indicate that faces with direct gaze enter awareness faster than faces with averted gaze, they cannot provide unequivocal evidence for a preferential processing of direct gaze during the phase in which the face stimuli are still suppressed (Stein & Sterzer, 2014). Instead, they could reflect differences arising from the transition period, that is, the phase during which the stimuli gradually reach awareness (Gayet, Van der Stigchel, & Paffen, 2014). Most critically, such findings cannot clarify whether an unconscious processing of gaze directions can guide the observer's eye movements towards direct gaze, which represents a critical step for establishing mutual eye contact.

In the current study, we therefore sought to test whether faces with direct eye gaze attract observers' eye movements to a greater extent than faces with averted gaze, even when presented outside awareness. Such a bias in eye movements would provide unequivocal evidence for a differential processing of direct and averted gaze during unawareness of the faces. To this aim, we recorded participants' eye movements while they were exposed to faces that were made invisible by CFS, based on the previous finding that the oculomotor system is susceptible to visual information that is presented outside conscious awareness (Rothkirch, Stein, Sekutowicz, & Sterzer, 2012).

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http://dx.doi.org/10.1016/j.cognition.2015.06.012
0010-0277/

## 2. Experiment 1

### 2.1. Materials and methods

#### 2.1.1. Participants

Thirty-four volunteers took part in experiment 1. Five participants from experiment 1 were excluded due to poor eyetracking quality. The data of another three participants were discarded, because they were able to indicate the appearance of the faces with above-chance accuracy and could thus not be considered unaware of the face stimuli (see Section 2.1.4). After applying our exclusion criteria, the final sample consisted of twenty-six participants (21 female; mean age: 24.65 (±0.76 SEM) years). All participants had normal or corrected-to-normal vision and written informed consent was obtained from each participant prior to the start of the experiment. The study was conducted in accordance with the 2008 World Medical Association Declaration of Helsinki and was approved by the local ethics committee.

#### 2.1.2. Stimuli

Face stimuli were photographs of three different female faces that have been used in a series of previous studies (e.g. Senju & Hasegawa, 2005; Stein et al., 2011). There were two versions of each exemplar differing in their eye gaze direction. To avoid low-level stimulus differences between gaze directions, all faces were rotated to the left or the right. The impression of eye gaze being either directed at or away from the observer was achieved by a shift of the pupil to the left or the right. For example, a head rotated to the right together with the pupil shifted to the left resulted in the impression of a face looking at the observer. All faces were cut into oval shapes comprising a size of $3.8^\circ \times 4.5^\circ$ and equalised for global contrast (root mean square (RMS) contrast of 0.05) and luminance. Both face stimuli together covered 18.6% of the whole search field.

#### 2.1.3. Procedure

Participants viewed the screen through a mirror stereoscope, which provided separate visual input to the two eyes. Participant's head was stabilised by a chin rest at a viewing distance of 50 cm. Stimuli were displayed on a 19-in. CRT monitor (resolution: $1024 \times 768$ Px; refresh rate: 60 Hz). Participants' eye movements were recorded with a high-speed video-based eyetracker (Cambridge Research Systems, UK; sampling rate: 250 Hz; spatial accuracy: 0.05°).

Prior to the main experiment, each participant's dominant eye was determined using the interocular suppression technique continuous flash suppression (Tsuchiya & Koch, 2005; Yang, Blake, & McDonald, 2010). Briefly, on each trial high-contrast greyscale dynamic mask stimuli (size: $5^\circ \times 5^\circ$) were flashed to one eye at a frequency of 10 Hz while simultaneously a face was presented in one quadrant of the greyscale stimulus to the other eye. Participants had to indicate the location of the face by button press as soon as the face overcame interocular suppression. The eyes viewing the masks and the face stimuli were randomised across trials. Each participant's dominant eye was identified as the eye corresponding to shorter reaction times while viewing the face stimuli.

In the main experiment, each trial started with the presentation of a white frame ($12^\circ \times 12^\circ$) and a central fixation cross ($0.6^\circ \times 0.6^\circ$) to both eyes. A representative trial is depicted in Fig. 1. The white frame and central cross were displayed for 1500 ms, unless participants did not fixate the central cross. In this case, the lines of the cross were thickened and presented until central fixation was established. Two intervals of 800 ms duration followed, during which high-contrast greyscale mask stimuli ($12^\circ \times 12^\circ$) were flashed to the participant's dominant eye at a frequency of 10 Hz to induce continuous flash suppression (Tsuchiya & Koch, 2005). During one of the two intervals, two low-contrast face stimuli (root mean square contrast of 0.03, luminance: 30.06 cd/m$^2$) were presented simultaneously to the non-dominant eye, one in the left half and one in the right half of the white square (eccentricity of 3.4°). The eye gaze of one face was directed towards the participant while the eye gaze of the other face was averted. Both faces were presented at the same vertical position, that is, either 3° above, below, or at the horizontal meridian. Participants were instructed that their main task was to detect the presence of the faces. They were encouraged to actively search for the faces by making eye movements. Upon the first eye movement that landed on one face, both faces were removed from the screen. The withdrawal of the faces served two purposes. Firstly, it has previously been reported that an attentional prioritisation of visible faces with direct gaze over faces with averted gaze decreases over time: While for short presentation durations spatial attention is specifically captured by faces with direct gaze, the allocation of attention to direct and averted gaze levels out for longer presentations (Senju & Hasegawa, 2005). This indicates that direct gaze primarily influences early, reflexive-like responses, which is why we only focused on initial saccades within trials. Secondly, instantaneous removal of the faces was intended to reduce the risk that the faces might break into participants' awareness. At the end of each interval, mask stimuli were presented to both eyes for 200 ms to prevent afterimages. Both intervals were separated by a fixation period of 750 ms duration. Again, the second interval only started when participants fixated the central cross. After the two intervals, participants performed a manual two-alternative forced-choice (2AFC) task, in which they had to indicate which of the two intervals contained the face stimuli. Finally, participants rated their confidence regarding their 2AFC response on a four-level confidence scale to provide an exhaustive measure for gradual changes in their subjective awareness (Windey, Vermeiren, Atas, & Cleeremans, 2014).

Participants performed five runs, each consisting of 54 trials. Prior to each run, a nine-point calibration of the eyetracker was conducted. Additionally, six 'dummy' trials were randomly interspersed per run, in which the face stimuli were presented to the dominant eye at full contrast. These trials were intended to maintain participants' motivation to search for the face stimuli and were not included in the analyses. The spatial location of the faces as well as their allocation to one of the two intervals was fully randomised and counterbalanced.

#### 2.1.4. Data analyses

Trials were included in the analyses, if they met the following criteria: (i) Participants indicated the lowest level of confidence; (ii) participants made a manual response on both the 2AFC task and the confidence rating; (iii) at least 95% of the eyetracking data collected during one trial were available and not lost due to blinks or other artefacts.

The 2AFC task on each trial was intended to assess participants' awareness of the faces according to objective criteria, since an assessment of awareness solely based on subjective reports is prone to response biases (Kunimoto, Miller, & Pashler, 2001; Sterzer, Stein, Ludwig, Rothkirch, & Hesselmann, 2014). In this context, observers' unawareness of a particular stimulus is demonstrated by their inability to detect or discriminate that stimulus with above-chance accuracy. The following analyses were conducted to probe whether participants' performance exceeded chance level. Firstly, individual 2AFC task performances were subjected to binomial tests, which yielded statistically significant differences from chance level in three participants in both experiments. The data of these participants were excluded from all further analyses. Secondly, we tested whether the group mean of the included participants was at chance level. Since a non-significant result of a one-sample *t*-test cannot provide conclusive evidence for the null hypothesis, we further conducted a