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Short Communication

Processing of invisible social cues ☆

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Successful interactions between people are dependent on rapid recognition of social cues. We investigated whether head direction – a powerful social signal – is processed in the absence of conscious awareness. We used continuous flash interocular suppression to render stimuli invisible and compared the reaction time for face detection when faces were turned towards the viewer and turned slightly away. We found that faces turned towards the viewer break through suppression faster than faces that are turned away, regardless of eye direction. Our results suggest that detection of a face with attention directed at the viewer occurs even in the absence of awareness of that face. While previous work has demonstrated that stimuli that signal threat are processed without awareness, our data suggest that the social relevance of a face, defined more broadly, is evaluated in the absence of awareness.

1. Introduction

Faces convey a wealth of signals that facilitate social interactions. Through faces we recognize identity and infer the emotional and mental states as well as the direction of attention of others.

Faces are detected even when they are rendered subjectively invisible (i.e. non-conscious) with masking or interocular suppression. Continuous flash interocular suppression is a method to render stimuli invisible using binocular rivalry with a high energy, rapidly changing stimulus presented to one eye (Tong, Meng, & Blake, 2006; Tsuchiya & Koch, 2005). If the stimuli to the two eyes are of equivalent salience, awareness of stimuli fluctuates spontaneously. With continuous flash interocular suppression it is possible to prevent one image to reach awareness for longer periods of time. Because a stimulus is subjectively invisible prior to breakthrough, any factor that facilitates faster breakthrough indicates processing that occurs without conscious awareness. Thus, this technique affords study of unconscious perception and how unconscious perception influences direction of attention to potentially relevant stimuli (Eastwood & Smilek, 2005; Lin & He, 2009). For example, upright faces break through interocular suppression about one-half second faster than do inverted faces, indicating that the upright facial configuration is processed even when the subject is unaware of the image (Jiang, Costello, & He, 2007; Yang, Zald, & Blake, 2007; Zhou, Zhang, Liu, Yang, & Qu, 2010). Facial expressions also appear to be processed when the subject is unaware of the face image, as evidenced by faster breakthrough of interocular suppression by faces with fearful expressions (Jiang & He, 2006; Yang et al., 2007), unconscious imitation of masked facial expressions (Dimberg, Thunberg, & Elmehed, 2000), and amygdala response to masked or suppressed faces (Morris,

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Ohman, & Dolan, 1998; Whalen et al., 1998; Williams, Morris, McGlone, Abbott, & Mattingley, 2004; and for review see Pessoa & Adolphs, 2010; Tamietto & De Gelder, 2010).

Appropriate social interactions depend on correctly interpreting to what others are attending. Head direction and gaze are features that indicate whether another person's attention is directed at oneself or elsewhere in the environment. Attention directed towards oneself can signal interest, the desire to catch one's attention, or the intention to engage in a social interaction (Kampe, Frith, & Frith, 2003). Neurons in the anterior temporal cortex of the monkey that are tuned to direction of others' social attention cues such as head orientation, eye gaze and body movements have been described (Perrett et al., 1985). In humans, fMRI has shown specific regions such as the posterior and anterior superior temporal sulcus, the fusiform gyrus, the medial prefrontal cortex, preferentially engaged by eye gaze and head turns highlighting how dedicated neuronal population are involved in processing relevant social cues (Carlin & Calder, 2012; Carlin, Rowe, Kriegeskorte, Thompson, & Calder, 2012; Engell & Haxby, 2007; Hoffman & Haxby, 2000; Pageler et al., 2003; Pelphrey, Singerman, Allison, & McCarthy, 2003; and for a review Senju & Johnson, 2009).

While the processing of gaze without awareness has been reported (Stein, Shenju, Peelen, & Sterzer, 2011), no specific evidence is yet available as to the processing of head direction, which also represents a powerful cue for directing social attention. We investigated whether head direction is processed in the absence of conscious awareness. Therefore, we rendered faces invisible using continuous flash interocular suppression (Kang & Blake, 2011; Tong et al., 2006; Tsuchiya & Koch, 2005). As mentioned above, because the observer is unaware of a suppressed stimulus prior to breakthrough, processes that facilitate breakthrough happen when it is still invisible.

Our results show that faces turned towards the viewer break through interocular suppression faster than do faces turned away from the viewer, confirming our hypothesis that this social signal is processed in the absence of awareness.

2. Methods

We used continuous flash interocular suppression to render faces invisible and test whether differences in head angle and gaze affected the time for these images to break through interocular suppression.

We conducted three experiments. The first experiment was a pilot study designed to validate our experimental setup. The main experiment tested our hypothesis that images of faces turned towards the viewer would break through interocular suppression faster than faces turned slightly away. The third experiment tested whether faster detection of full view faces in our interocular suppression paradigm could be attributed to faster detection after breakthrough, rather than faster detection prior to breakthrough.

2.1. Subjects

Twenty-six subjects (19 females, mean age = 24 ± 6 yr) participated in a pilot study to validate our experimental setup. 52 subjects (37 females; mean age = 21 ± 3) participated in the main experiment. 10 subjects (5 females, mean age = 24 ± 5) participated in a control experiment to test for an advantage of full-view face detection during conscious perception.

All subjects were healthy with normal or corrected to normal sight and gave written informed consent. The study was approved by the local ethical committee.

2.2. Stimuli

Face images were color pictures of 12 individuals. The 12 individuals (6 actors and 6 actresses) were paid models. To assure consistent image quality, all photographs were made in the same studio with identical equipment and lighting conditions. The head angle was either full view or turned away from the viewer by 23°. At this angle of profile, all facial features, including both eyes, are fully visible (see Fig. 1A and B for examples of stimuli). The eyes were directed either straight ahead or 23° to the side. For faces turned away from the viewer, averted gaze was directed towards the viewer. Face images were presented in an oval mask, subtending 1.6° of visual angle horizontally and 2° vertically. The mask was placed so that for the images with faces turned to the side, the ear towards the viewer was not visible. Thus, the visibility of facial features was equivalent for all face image conditions.

Suppressing stimuli were brightly colored, high contrast collages of different shapes (rectangular and curved figures), subtending 3° of visual angle horizontally and vertically, that changed every 100 ms (Fig. 1A). The dynamic suppressing and target stimuli were presented on different monitors with a mirror haploscope, mounted on a chin rest.

2.3. Procedure

Each trial was preceded by 1 s of a gray screen with a fixation cross. The trial began with 1–2 s of the dynamic suppressing stimuli presented to one eye and a phase-scrambled face image, with the same dimensions as the intact face images, presented to the other eye. Phase-scrambled face images matched the intact faces in terms of spatial frequencies and luminance. The target face was faded in over 1 s by gradually increasing its opacity from 0% to 100%. Beginning one second after the face