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Conscious awareness is required for holistic face processing

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ABSTRACT

Investigating the limits of unconscious processing is essential to understand the function of consciousness. Here, we explored whether holistic face processing, a mechanism believed to be important for face processing in general, can be accomplished unconsciously. Using a novel "eyes-face" stimulus we tested whether discrimination of pairs of eyes was influenced by the surrounding face context. While the eyes were fully visible, the faces that provided context could be rendered invisible through continuous flash suppression. Two experiments with three different sets of face stimuli and a subliminal learning procedure converged to show that invisible faces did not influence perception of visible eyes. In contrast, surrounding faces, when they were clearly visible, strongly influenced perception of the eyes. Thus, we conclude that conscious awareness might be a prerequisite for holistic face processing.

1. Introduction

Most people are good at recognizing faces, which is a capacity that is usually taken for granted. Yet, given that all faces are essentially very similar (e.g., all faces have a nose, eyes, and mouth; relative position of features is largely the same), the cognitive task of face recognition is far from straightforward. A key component of efficient facial processing is considered to be holistic processing (Farah, Wilson, Drain, & Tanaka, 1998; Richler, Cheung, & Gauthier, 2011) – the ability to perceive a face as a whole and not as a set of independent features. Probably the most spectacular demonstration of this phenomenon is the composite face effect (Young, Hellawell, & Hay, 1987) – that is, when a facial image is composed of the bottom and top halves of two different faces, where recognition of one half of a face (e.g., the top part) is modulated by that of the other half (e.g., the bottom part). Holistic face processing in general, and the composite face effect in particular, has been extensively explored in healthy populations using behavioral measures (for review: Rossion, 2013), functional MRI (e.g., Andrews, Davies-Thompson, Kingstone, & Young, 2010; Axelrod, 2010; Axelrod & Yovel, 2010, 2011; Schiltz, Dricot, Goebel, & Rossion, 2010; Schiltz & Rossion, 2006) and event-related potentials (e.g., Jacques & Rossion, 2009; Wiese, Kachel, & Schweinberger, 2013) as well as in participants with impaired face recognition (prosopagnosia) (Avidan, Tanzer, & Behrmann, 2011; Busigny & Rossion, 2011). However, whether conscious awareness is required for holistic face processing is not known.

Understanding the role of consciousness and conscious awareness is one of the fundamental challenges of the cognitive sciences (Baars, 1993; Dennett, 1993; Koch, 2004). Empirically, the level of conscious awareness is usually evaluated by an

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introspective, "subjective report" (whether a participant was aware of a stimulus) and "objective measure" (forced-choice discrimination, even for subjectively unaware stimulus) (Merikle & Daneman, 1998). While qualitative differences between conscious and unconscious perception have been debated for years (e.g., Cheesman & Merikle, 1986; Peremen & Lamy, 2014; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003), numerous behavioral (e.g., Marcel, 1983; Mudrik, Breska, Lamy, & Deouell, 2011; Sklar et al., 2012) and neuroimaging (e.g., Axelrod, Bar, Rees, & Yovel, 2014; Dehaene et al., 2001; Fahrenfort et al., 2012; Sterzer, Haynes, & Rees, 2008) studies demonstrate that information can be processed unconsciously. Unconscious face processing is one of the widely explored types of unconscious processing. A large body of evidence suggests that emotional aspects of face processing (for reviews: Pessoa & Adolphs, 2010; Tamietto & de Gelder, 2010), gaze (Chen & Yeh, 2012; Stein, Peelen, & Sterzer, 2012; Stein, Senju, Peelen, & Sterzer, 2011) and face familiarity (de Gardelle, Charles, & Kouider, 2011; Henson, Mouchlianitis, Matthews, & Kouider, 2008; Kouider, Eger, Dolan, & Henson, 2009) can be processed without conscious awareness; however, several studies have shown that facial identity (Moradi, Koch, & Shimojo, 2005; Stein & Sterzer, 2011; Stone & Valentine, 2005) and face gender/race (Amihai, Deouell, & Bentin, 2011) cannot be processed unconsciously. In the present study, we addressed the question of unconscious face processing from another angle, while asking whether holistic face processing can take place unconsciously. Based on the previous negative results of unconscious face identity/gender processing, and given that face recognition and holistic processing might share common underlying mechanisms (Richler, Cheung et al., 2011; Wang, Li, Fang, Tian, & Liu, 2012), one possibility is that holistic face processing cannot be accomplished without conscious awareness. Alternatively, it is also possible that holistic face processing is a more basic type of processing than face recognition, which implies that holistic processing might still occur unconsciously. In addition, given that holistic processing has been suggested to be an automatic process (Richler, Wong, & Gauthier, 2011), it therefore possibly could be executed unconsciously (Hasher & Zacks, 1979).

In the present study, we devised a novel "eyes-face" composite stimulus that was composed of a pair of eyes plus the remaining part of the face [c.f., top and bottom image face parts (Young et al., 1987)]. Participants had to discriminate between pairs of eyes in two consecutively presented composite images while the rest of the face was either the same or different (Fig. 1A and B). Critically, in the subliminal version of the paradigm, while the eyes were always visible, the rest of the face was rendered invisible using Continuous Flash Suppression (CFS; Fig. 1B) (Harris, Schwarzkopf, Song, Bahrami, & Rees, 2011; Tsuchiya & Koch, 2005). We asked whether invisible faces influenced discrimination of the visible eyes.

2. Experiment 1

In this experiment, we used three different sets of composite faces. The first set was comprised of five male composite faces (examples of faces: Fig. 1B left side). To increase the perceptual differences between images, a second set included three male and three female composite faces (examples of faces: Fig. 1C, top). The third set of images was comprised of three female faces, either with or without eyebrows (examples of faces: Fig. 1C, bottom). The motivation to include this third composite image set was that eyebrows are the closest facial feature to the eyes and, consequently, have a higher chance of being attended to when the task is eyes discrimination.

Participants were presented with two consecutive composite faces that contained visible eyes and faces. The face part of each image was rendered invisible by CFS (Fig. 1B). The pairs of eyes in the two images were always the same, and the invisible faces were either the same or different. The task was to report whether successive pairs of visible eyes were the same or different. Participants were told that this eyes discrimination task was very difficult, and were encouraged to look out for the smallest differences between the two stimuli. Notably, because the stimuli did not appear in the exact same screen position (a small amount of spatial jitter was added; see Methods) and the eyes were surrounded by a constantly changing CFS mask, it was not evident that sequential eye stimuli were actually identical. Effect size was defined in percent units as the percent of trials answered "eyes same" when the invisible faces of the two images were the same minus the percent of trials answered "eyes same" when the invisible faces of the two images were different. An effect size larger than zero was taken as evidence of a subliminal influence of the invisible faces on judgments of the visible eyes.

2.1. Methods: Experiment 1

2.1.1. Participants

Fifteen healthy volunteers (age 20–27 years, 10 females) participated in this experiment: all participants participated in the experiment with image set 1 (male faces), 14 of the same set of participants participated in the experiment with image set 2 (male and female faces), and 12 of the same set of participants took part in the experiment with image set 3 (faces with and without eyebrows). Two participants were excluded from the analysis of all three experiments because they reported that they could see the masked face. The experiment was approved by Tel-Aviv University ethics committee, and all participants gave informed consent to participate in the experiment.

2.1.2. Apparatus

For stimuli presentation, a CRT 17-in. color monitor was used. Screen resolution was 1024×768, and refresh rate was 85 Hz. Stimuli were presented using MATLAB 7.6 with Psychtoolbox (Brainard, 1997). Participants sat in a comfortable chair at a distance from the monitor of 30 cm. During the experiment, the room lights were turned off.