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Efficient visual information for unfamiliar face matching despite viewpoint variations: It's not in the eyes!

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ABSTRACT

Faces are encountered in highly diverse angles in real-world settings. Despite this considerable diversity, most individuals are able to easily recognize familiar faces. The vast majority of studies in the field of face recognition have nonetheless focused almost exclusively on frontal views of faces. Indeed, a number of authors have investigated the diagnostic facial features for the recognition of frontal views of faces previously encoded in this same view. However, the nature of the information useful for identity matching when the encoded face and test face differ in viewing angle remains mostly unexplored. The present study addresses this issue using individual differences and bubbles, a method that pinpoints the facial features effectively used in a visual categorization task. Our results indicate that the use of features located in the center of the face, the lower left portion of the nose area and the center of the mouth, are significantly associated with individual efficiency to generalize a face's identity across different viewpoints. However, as faces become more familiar, the reliance on this area decreases, while the diagnosticity of the eye region increases. This suggests that a certain distinction can be made between the visual mechanisms subtending viewpoint invariance and face recognition in the case of unfamiliar face identification. Our results further support the idea that the eye area may only come into play when the face stimulus is particularly familiar to the observer.

1. Introduction

The recognition of familiar faces is a rapid and effortless process for the majority of individuals (Jackson & Raymond, 2006, 2008; see however Barragan-Jason, Lachat, & Barbeau, 2012). Indeed, most can easily identify friends, colleagues and celebrities, regardless of considerable variations in visual conditions such as lighting, pose, age, health and facial expression (Burton & Jenkins, 2011). Our ability to identify faces affected by these changing visual conditions, however, is considerably hindered for unfamiliar or newly learned faces (Bruce et al., 1999; Murphy, Ipser, Gaigg, & Cook, 2015; White, Kemp, Jenkins, Matheson, & Burton, 2014). In an effort to clarify the reasons subtending this discrepancy between familiar and unfamiliar faces, many have investigated how changes in the visual conditions in which we encode new faces influence our accuracy in recognizing these stimuli. Despite a growing interest aimed towards this issue, the way we process faces varying in viewing angle or pose is still poorly understood. In fact, although faces are encountered in highly diverse angles in a real-world setting, the vast majority of studies in the field of face recognition have focused almost exclusively on frontal views of faces.

A number of authors have explored the question of viewpoint variations in face processing using different methodologies, such as behavioral performance measures (Bruce, 1982; Bruce, Valentine, & Baddeley, 1987; Hancock, Bruce, & Burton, 2000; Hill, Schyns, & Akamatsu, 1997; Liu & Chaudhuri, 2002; McKone, 2008; Moses, Ullman, & Edelman, 1996; Stephan & Caine, 2007; Troje & Bülthoff, 1996; Turati, Bulf, & Simion, 2008; Van der Linde & Watson, 2010), eye tracking (Bindemann, Scheepers, & Burton, 2009), event-related potentials (Caharel, Collet, & Rossion, 2015; Caharel, d'Arripe, Ramon, Jacques, & Rossion, 2009; Caharel, Jacques, d'Arripe, Ramon, & Rossion, 2011; see also Ewbank, Smith, Hancock, & Andrews, 2008), and functional imaging (Kowatari et al., 2004; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005a, 2005b). Generally, these studies show that

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face viewpoint variations are linked, in certain conditions, to changes in the visual, cognitive and neural processes involved in face recognition. Nonetheless, very little is known about the nature of the information useful for face matching when the encoded face and test face differ in viewing angle. Seeing a face in a certain angle highlights some facial cues and occludes others, thus most likely changing the diagnosticity of each facial feature (Stephan & Caine, 2007; see Bindemann et al., 2009 for the impact of face viewpoint variations on eye movements). In the context of frontal face recognition, we know that some features are more diagnostic than others (i.e. the eye area, and particularly the left eye; Schyns, Bonnar, & Gosselin, 2002; Sekuler, Gaspar, Gold, & Bennett, 2004; Vinette, Gosselin, & Schyns, 2004). Our current knowledge of the diagnostic value of each facial region was obtained, however, using tasks where there was no change in viewpoint between the study and test faces. More specifically, observers were asked to memorize a set of full-frontal view faces, and were subsequently tested using these identical stimuli (e.g. Caldara et al., 2005; Gosselin & Schyns, 2001; Schyns et al., 2002).

To our knowledge, only one study has explored the importance of each facial feature for the generalization of unfamiliar face identity across different viewpoints. Indeed, Stephan and Caine (2007) showed that, when a single feature is revealed (i.e. either the eyes, nose, or mouth), the generalization of a face's identity to a different viewpoint is more accurate in the eye condition compared to both the nose and mouth, which lead to similar levels of correct identity matches. Interestingly, results obtained using faces of celebrities, i.e. faces that have been viewed and encoded in highly diverse visual conditions, are consistent with those of Stephan and Caine (2007). With highly familiar faces, it appears that the eye area is even more diagnostic for accurate face recognition (Butler, Blais, Gosselin, Bub, & Fiset, 2010). However, based on the results from these studies, it is difficult to know if this bias favouring the eye area is a truly effective strategy for the generalization of a face's appearance across different viewpoints or is associated to face identification *per se*. In their paper, Stephan and Caine (2007) specifically asked their participants beforehand to learn the face identities used in the experiment. This allows the possibility that matching performance with two different viewpoints may have been mediated by perceptual strategies associated with face identification, instead of an attempt of the visual system to extract view invariant facial cues. Since the eye area is likely the most informative region for face identification, the fact that this region leads to viewpoint invariance was expected for previously learned faces. However, this strategy may be inefficient in the context of first encounters with faces, i.e. unfamiliar faces.

The main objective of our work was to pinpoint the diagnostic facial features for minimizing sensitivity to viewpoint variance in an unfamiliar face matching task. Although a relatively high number of identities (30) was selected and that our task did not explicitly ask the participants to memorize facial identity, it is likely that face identification strategies were eventually used by the observers in an effort to aid their performance. In order to isolate the process of viewpoint invariance as much as possible, we relied on an individual differences approach in which we verified which visual strategy was linked to a lower sensitivity to viewpoint variance. We hypothesized that the information useful for unfamiliar face matching differs from that of face identification. This point makes a clear prediction, as it suggests that in the context of a task where the same identities are repeated many times (as the one used here), the diagnosticity of facial features used in face identification and those associated with viewpoint invariance should follow a distinct pattern over time. More specifically, it predicts that the diagnosticity of the former will gain in importance, while the diagnosticity of the latter should instead decrease in importance.

In order to pinpoint, in an unbiased manner, the features associated with identification of faces encoded from different viewpoints, we used the *Bubbles* method (Gosselin & Schyns, 2001). The general idea behind *Bubbles* is that by randomly sampling specific visual information on a trial-by-trial basis, we will be able to precisely determine, after many trials, what information is significantly correlated with performance in any given visual categorization task (e.g. Robinson, Blais, Duncan, Forget, & Fiset, 2014; Royer et al., 2016; Smith, Cottrell, Gosselin, & Schyns, 2005; Thurman & Grossman, 2008; Willenbockel et al., 2010a). In our case, the method allowed us to reveal which facial cues are associated with the discrimination of frontal view faces previously seen in either the same or a different viewpoint.

2. Material and methods

2.1. Participants

Fifty Caucasian, right-handed participants aged between 18 and 35 provided informed consent to complete an ABX, match-to-sample Bubbles task for this study. The study was approved by the Université du Québec en Outaouais's Research Ethics Committee and was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). We chose this number of participants to ensure the presence of a wide range of individual differences in sensitivity to viewpoint variations in our sample (see Furl, Garrido, Dolan, Driver, & Duchaine, 2011; Richler, Cheung, & Gauthier, 2011 for similar sample sizes). This number also allowed us to include a sufficient amount of trials in each condition of our bubbles task (see Section 2.3). All participants had normal or corrected-to-normal visual acuity as confirmed by their score on the Snellen Chart and Pelli-Robson Contrast Sensitivity Chart (Pelli, Robson, & Wilkins, 1988). Data from the first two participants were not taken into account in the analyses as an error in the testing procedure forced us to exclude their results. Thus, analyses were conducted on data from forty-eight participants.

2.2. Apparatus

The experiments were conducted on MacPro QuadCore or Mac Mini computers. Stimuli were displayed on a 22-inch 120 Hz Samsung LCD monitor. The monitor's resolution was set to 1680×1050 pixels. Minimum and maximum luminance values were $0.4\ cd/m^2$ and $101.7\ cd/m^2$, respectively. The participants were seated in a dark room and viewing distance was maintained constant at 57 cm using a chinrest.

2.3. Bubbles task

The stimuli presented during this task consisted of 30 caucasian identities from the *Fundação Educacional Inaciana* (FEI) Face Database (15 females; Thomaz & Giraldi, 2010). All chosen identities exhibited a neutral facial expression. The grayscale stimuli were cropped with an elliptical aperture that masked their external facial features. Image resolution was 256×256 pixels, and the face width was 6 degrees of visual angle (Yang, Shafai, & Oruc, 2014). The spatial frequency spectrum was equalized using SHINE (Willenbockel et al., 2010b) and the stimuli from each condition (see below) were spatially aligned on the positions of the main internal facial features (eyes, mouth, and nose) using translation, rotation, and scaling.

To create a *bubblized* stimulus, a face (Fig. 1A) was first decomposed into five different spatial frequency (SF) bands (Fig. 1B; 106-53, 53-26, 26-13, 13-6, and 6-3 cycles per face, the