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Same critical features are used for identification of familiarized and unfamiliar faces

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A R T I C L E I N F O

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A B S T R A C T

Many studies have shown better recognition for faces we have greater experience with, relative to unfamiliar faces. However, it is still not clear if and how the representation of faces changes during the process of familiarization. In a previous study, we discovered a subset of facial features, for which we have high perceptual sensitivity (PS), that were critical for determining the identity of unfamiliar faces. This was done by assigning values to 20 different facial features based on perceptual rating, converting faces into feature-vectors, and measuring the correlations between face similarity ratings and distances between feature-vectors. In the current study, we examined the contribution of high and low-PS features to face identity after familiarization. To familiarize participants with unfamiliar faces, we used an individuation training protocol that was found to be effective in previous studies, in which different names are assigned to different faces and participants are asked to learn the face-name association. Our findings show that even after repeated exposure to the same image of each identity, which allows close examination of all facial features, only high-PS features contributed to face identity, while low-PS features did not. This subset of high-PS features includes both internal and external features and part and configuration features. We therefore conclude that identification of familiarized and unfamiliar faces may rely on the same subset of critical features. These findings further support a new categorization of facial features according to their perceptual sensitivity.

1. Introduction

One of the most fundamental question in the study of face identification, is which facial features are used to define the identity of a face. Previous studies have considered different types of features including configural vs. part-based features (for reviews see (Maurer, Grand, & Mondloch, 2002; McKone & Yovel, 2009), or external vs. internal facial features (Ellis, Shepherd, & Davies, 1979; O'Donnell & Bruce, 2001; Young, Hay, McWeeny, Flude, & Ellis, 1985) that may play different roles in face recognition. In a previous study, we proposed a new categorization of facial features, based on the perceptual-sensitivity (PS) to detect differences in these features across different faces. We found that facial features for which we have high perceptual sensitivity (high-PS) were critical for identification of unfamiliar faces more than facial features for which we have low perceptual sensitivity (low-PS). To discover these critical features, we used a novel "reverse-engineering" approach. The main premise of our approach was that critical features for face identity are those features that when changed, change the identity of a face. The complementary assumption is that feature changes that do not change the identity of the face, are not critical for face identity, and are therefore considered "allowable" changes in appearance (Abudarham & Yovel, 2016).

To reveal which features are critical for face identity we used the following procedure: First, we constructed a face-space, by perceptually assigning values to facial features, thereby representing faces as feature-vectors (Fig. 1A). This allowed us to calculate face-space distances between faces, i.e. mathematical distances between feature-vectors (Fig. 1B). We then computed the inter-rater agreement for each feature. This analysis revealed that features vary considerably in their level of inter-rater agreement, suggesting that participants have different perceptual sensitivity to detect feature differences across faces (Supp. Fig. 1). For example, we found higher perceptual sensitivity to detect eyebrow-thickness or lip-thickness differences across faces than for eye-distance or jaw-width. To test the hypothesis that features for which we have high perceptual sensitivity (PS) are critical for face identity, we changed facial features systematically, by either changing high-PS features or low-PS features, and measured identification. Our results showed that changing high-PS features changed the identity of a face, whereas changing low-PS features did not change the identity of the face. Accordingly, we concluded that high-PS features are critical for

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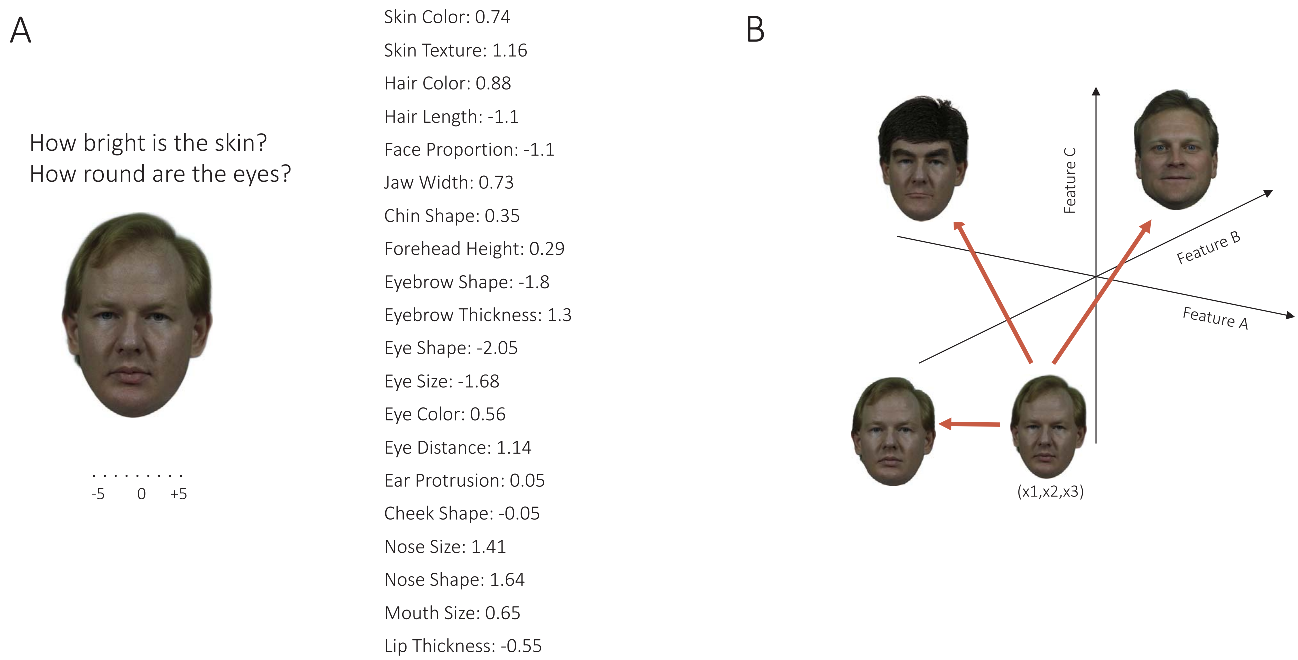

Fig. 1. A. Faces were converted to a feature representation by asking participants to perceptually rate each of 20 facial features. For example, how long is the hair, how wide is the face. B. Face space distances between faces were computed based on the mathematical distance between feature vectors.

face identity. Finally, we found that high-PS features tend to vary less under pose changes, compared with low-PS features. This suggests that high-PS features are more important for identification because they allow identification of the same person across different appearances.

The critical features that we revealed were based on matching of unfamiliar faces. However, it is possible that repeated exposure to the same face may allow participants to acquire information about face identity from additional facial features. Thus, our findings that high-PS features contribute more than low-PS features to face identity may be limited to faces that we have no prior exposure to, whereas all or additional features may become equally important once we get familiarized with a face. Alternatively, if following repeated exposure to the same face, participants still use the same subset of high-PS features, that would indicate that high-PS features dominates face identity even when low-PS features are available for repeated and close inspection.

To test this hypothesis we familiarized participants with unfamiliar faces, using an individuation training protocol (Tanaka & Pierce, 2009; Yovel et al., 2012), and then applied the same approach that we used to discover the critical features for unfamiliar faces, after familiarization. This familiarization protocol included repeated exposure to a single image of each familiarized face, allowing participants to study and memorize faces without variations. Although this protocol does not model how we naturally become familiar with faces in real life, a process which typically includes seeing the same face in varying appearances, it does enable us to test whether familiarization changes the weights of high-PS vs. low-PS features in a controlled manner. In addition, familiarization with multiple and variable images may encourage participants to encode those features that stay invariant across appearances (high-PS features), whereas using a single image is more likely to enable using also low-PS features.

To this end, we first familiarized participants with 30 different identities. We then changed facial features (Fig. 2), measured similarity between original and changed faces, and the feature vector distance (i.e., face space distance) between them. We then measured the correlation between perceptual similarity scores between faces, and the face-space distances, as a function of the type and number of features used to compute the face space distances. This allowed us to reveal which features are used to determine the identity of familiarized faces.

2. Method

2.1. Participants

Twenty-two Psychology students participated in the study in exchange for class credit. The study was approved by the ethics committee of Tel Aviv University.

The following methods of creating the stimuli, tagging faces, changing facial features and the face matching task are identical to those described in (Abudarham & Yovel, 2016), and are reproduced here for convenience.

2.2. Stimuli

A total of 100 Caucasian male faces, with no glasses or facial hair were taken from the Color FERET database. All faces had neutral expression. The pictures were frontal, and taken with adequate lighting. For each face, we took two different pictures that were physically different, i.e. taken at different times under similar lighting/pose/camera conditions (see Fig. 3 for an example of a Same pair). One of these pictures served as the “reference” picture used for comparison, and the other served as a “base” picture, and was later changed.

2.3. Face tagging: Converting faces into feature vectors, and measuring face-space distances

To assess face-space distances between faces we converted each of the 100 faces in our database into a vector representation, by assigning values to 20 features for each face (see Fig. 1A for an example of a feature vector of a face). These values were assigned by asking participants to rate each feature between -5 and $+5$ (for example: how bright is the skin? how large are the eyes?). (Fig. 1, see also (Abudarham & Yovel, 2016) This allowed us to measure face-space distances between faces, by calculating the L1-norm between feature-vectors, i.e. taking the sum of the absolute differences between the feature-vectors before and after change.