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Authors
Lorenzino, Martina
Gronchi, Giorgio
Caudek, Corrado

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Expressive faces are remembered with less pictorial fidelity than neutral faces

Martina Lorenzino (martina.lorenzino@unifi.it)
Department of Neurosciences, Psychology, Drug Research, and Child Health (NEUROFARBA), University of Florence
via di San Salvi 12, Complesso di San Salvi, Padiglione 26, 50135 Firenze (FI), Italy

Giorgio Gronchi (giorgio.gronchi@unifi.it)
Department of Neurosciences, Psychology, Drug Research, and Child Health (NEUROFARBA), University of Florence
via di San Salvi 12, Complesso di San Salvi, Padiglione 26, 50135 Firenze (FI), Italy

Corrado Caudek (corrado.caudek@unifi.it)
Department of Neurosciences, Psychology, Drug Research, and Child Health (NEUROFARBA), University of Florence
via di San Salvi 12, Complesso di San Salvi, Padiglione 26, 50135 Firenze (FI), Italy

Abstract

A repeated finding in the literature of face recognition is that expressive faces are remembered better than neutral faces. However, a better facial-identity recognition may come at a cost of a reduced precision with which the pictorial facial features, irrelevant for identity recognition, are represented in memory. By means of a continuous-report task, we tested this hypothesis by measuring the memory precision of expressive and neutral faces. Commensurable face-identity and facial-expressions variations were generated with the method of Fechnerian scaling. The results confirm our hypothesis, but only under conditions of high memory load. We interpret the present findings as due to the effects of the categorical processes required for facial-identity recognition.

Keywords: emotion; faces; continuous-report procedure; visual working memory

Introduction

It has been often shown that expressive faces are easier to remember than neutral faces (Jackson et al., 2008; Langeslag et al., 2009). Some studies have found an advantage for the memory of positive expressive faces compared to negative faces (D'Argembeau & Van der Linden, 2007; D'Argembeau et al., 2003; Shimamura, Ross, & Bennett, 2006). However, the greatest evidence for a memory advantage for expressive versus neutral faces comes from studies comparing memory for facial expressions with a negative valence and with neutral faces (Jackson et al., 2008; Jackson, Linden, & Raymond, 2014; Jackson et al., 2009; Sessa et al., 2011). This memory advantage has been attributed to a more accurate encoding and memory maintenance for expressive faces, compared to neutral faces (Jackson et al., 2014; Ridout et al., 2003; Sergerie, Lepage, & Armony, 2005; Sessa et al., 2011).

It is important to point out that the majority of studies in this area of research has employed an old-new face recognition task, in which participants are asked to decide whether a test face had been previously presented in an array of expressive faces, or not. In this respect, it should be noted that a better performance in a old-new recognition task does not necessarily imply a better pictorial resolution for the memory representation of expressive faces compared to neutral faces. In fact, the memory representation of a face endowed of a high pictorial fidelity contains all those transient facial features which are irrelevant for face-identity categorization. On the other hand, what characterizes face-identity recognition is exactly the ability to isolate the identity-defining properties of a face, while disregarding its transient features (*e.g.*, pose, lighting, transient muscles variations, and so on). Thus, in general, one might expect that a better ability to recognize a face comes to the cost of a worst pictorial fidelity with which that face is represented in memory.

The aim of the present study is to measure the pictorial fidelity of the Visual Working Memory (VWM) representations of expressive and neutral faces. In this regard, we can make a specific prediction which is motivated by the following considerations. All the rest being the same, we should expect that is more important to remember the identity of a stranger if, in a casual encounter, she/he displays an angry expression (or a happy expression, for that matter) rather than a neutral face (Jackson et al., 2009; Jackson et al., 2014). This seems obvious, considering the implications of this situation for future social interactions with that person. On the top of this, we should also consider the fact that, as remarked above, the creation of a facial-identity category requires the selection of the identity-defining features and the omission of the category-irrelevant features. Specifically, the transient pictorial features of a face (the image properties that vary as a function of illumination, pose, and so on) are certainly irrelevant for a facial-identity category. Therefore, we hypothesize that (1) these transient pictorial properties are represented with a lower pictorial fidelity in memory when a facial-identity category is created, and (2) this process is stronger for expressive compared to neutral faces, because it is more important to recognize facial identity in the former case than in the latter.

A face can be represented in memory with different degrees of pictorial fidelity. For example, we can remember the gist of a face and disregard its pictorial details (Leal, Tighe, & Yassa, 2014), or we keep in memory a very detailed photographic representation of a face. By adapting the procedure of Wilken and Ma (2004), in the present study we asked participants to select from a morphing continuum the image of a learned face (*e.g.*, Bays & Husain, 2008; Lorenc et al., 2014; Zhang & Luck, 2008). We expect to find (1) a lower pictorial fidelity of VWM for expressive compared to neutral faces, and (2) a decrease in VWM fidelity with the increase of the set size of to-be-remembered faces.

Experiment

The degree of pictorial fidelity with which a face is represented in memory can be measured with the continuous report task (Wilken & Ma, 2004). Although this task has been mostly employed with simple features (such as orientation or color, for example), it can also be used with faces. In the present study, participants were required to select a probe within a morphing continuum in order to match it to a learned face. This task was performed with face images belonging to two different kinds of morphing continua. A first continuum provided facial-identity variations with a neutral facial expression. A second continuum provided emotional expressions variations while keeping constant facial identity.

In general, it's not possible to directly compare distances along different morphing continua, because there is not a linear relation between the physical distance on such continua and the similarity space among the stimuli in the mental memory representations (Caudek, 2013; Danilova & Mollon, 2014). To deal with this problem, we generated the two morphing continua with the technique of Fechnerian scaling, which creates (for each participant) perceptually commensurable spaces for identity and expression variations. In this manner, the memory fidelity for the two classes of stimuli can be directly compared because, in both cases, the unit of measurement for each continuum corresponds to each subject's threshold of perceptual discrimination (Domini & Caudek, 2009; Dzhafarov & Colonius, 1999).

Method

Participants Eight subjects (n=8; 7 females; age range 26-30 years) with normal or corrected-to normal vision participated voluntarily to the Experiment. They were naïve to the purpose of the study and none of them had previously been exposed to the stimuli employed. The experiment was undertaken with the understanding and written consent of each participant. The experiment conformed with the institutional and national guidelines for experiments with human subjects and with the Declaration of Helsinki.

Stimuli Seven Caucasian faces (all males) were selected from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998): Five images showed five different facial identities with a neutral expression (A, B, C, D, E, Figure 1a) and two images represented one of the previous facial identities with an happy and an angry emotional expression (100hA, 100aA, Figure 1b-c). All images were converted to grayscale, an oval aperture was superimposed on each face, and the ovals were placed on a transparent background. Each face image measured 280 $\times$ 329 pixels and all stimuli were matched for luminance and contrast values. We generated three different morphing continua: (1) a continuum between two face identities (indicated with A and B), both having a neutral expression (Figure 1a, top row); (2) a continuum between a neutral face A to an "happy" face (50hA)[1] with the same identity (Figure 1b, top row); (3) a continuum between a neutral face A to an "angry" face (50aA)[2] with the same identity (Figure 1c, top row).

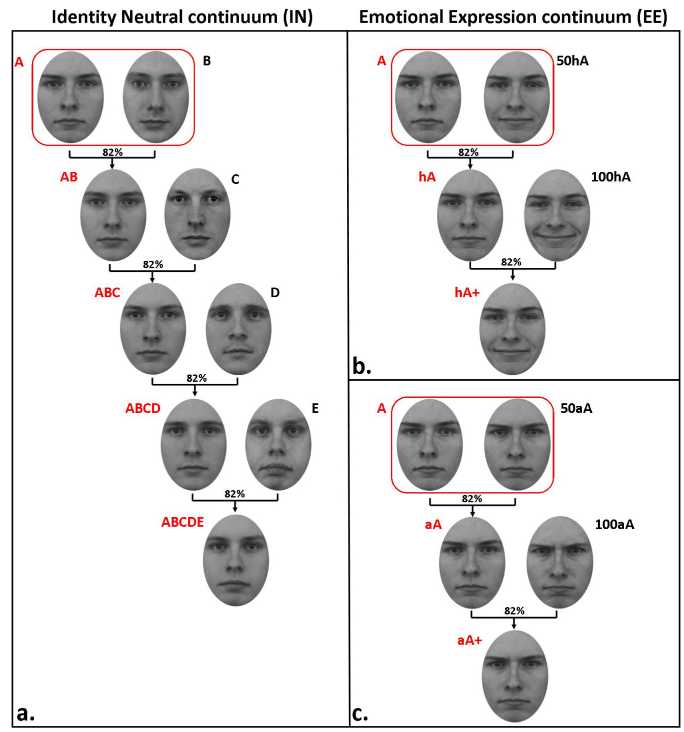

Figure 1: **(a)**. Creation of the Identity Neutral continuum. A 100-steps morphing was created between image A and image B. The image that produced an 82% rate of correct discrimination between A and B was employed as the new extreme (AB) for the creation of a new morphing continuum. This procedure has been repeated in order to obtain four thresholds of perceptual discrimination (AB, ABC, ABCD, ABCDE). **(b-c)**. Creation of Emotional Expression continuum. A 100-steps morphing was created between image A and image 50hA and between image A and 50aA. The images that produced an 82% rate of correct discrimination between A and 50hA and between A and 50aA were employed as the new extremes (hA and aA, respectively) for the creation of a new morphing continuum. This procedure has been repeated in order to obtain four thresholds of perceptual discrimination (hA, hA+, aA and aA+).

Procedure *Phase 1.* With the method of Fechnerian scaling, we generated the morphing continua that were then used in Phase 2. A 2AFC discrimination task was used for determining face discrimination thresholds between pairs of images belonging to each morphing continuum. For the fa-

[1]The 50hA image corresponded to the image numbered 50 of a morphing continuum between A and 100hA.

[2]The 50aA image corresponded to the image numbered 50 of a morphing continuum between A and 100aA.

cial identity variations, for example, we created a morphing continuum between two facial identities. We kept fixed one image (origin of the scale) and then, with psychometric methods, we selected a second face image which produced, for each participant, an 82% success rate in a perceptual-discrimination task. We then morphed this second image with a third face identity and repeated the procedure (Figure 1a). In this manner, we selected, for each participant, four face images (three pairs of images, each one characterized by one threshold of perceptual discrimination). We then linearly morphed each of the successive pairs of images, so as to generate the Fechnerian continuum for face-identity variations (Figure 2a). A similar procedure was used for generating the Fechnerian continuum for face-expressions variations (Figure 1b-c; 2b).

To determine each perceptual discrimination threshold, in each trial we presented the reference face (*i.e.*, the frame number 10 within the morphing continuum) and one of seven test faces corresponding to greater distances along the morphing continuum from the reference face. A 1.000 ms fixation cross indicates the start of each trial, followed by a 1.000 ms blank screen. A comparison face (frame 100 of the morphing continuum) was centrally presented for 1.000 ms. After a 1.000 ms blank screen, the reference and test faces were centrally presented side-by-side. Participants were asked to decide which of the two simultaneously presented faces was more similar to the comparison face presented before each trial. Stimuli were shown on the screen until the participant's response (Figure 3a).

A psychometric function was computed for each participant. The psychometric function was defined by the equation $P(x) = \gamma + (1 - \gamma - \lambda)p(x)$, where γ is the lower asymptote, λ is 1 - the upper asymptote, and $p(x)$ is the base psychometric function, varying between 0 and 1 (Wichmann & Hill, 2001)[3]. From this fitted psychometric curve we then derived the stimulus image corresponding to an 82% rate of correct discrimination.

Phase 2. Each trial started with a fixation point for 1.000 ms, then one or four faces were presented on the screen for 4.000 ms. After a 1.000 ms blank screen, participants were asked to select, from the Fechnerian continua generated in phase 1, the image that more closely matched the test stimulus. Participants could move along the Fechnerian continuum with a keypress, with only one image being shown on the screen at any time.

For set-size four, each trial started with a fixation point for 1.000 ms, then four faces were shown on the screen for 4.000 ms. After a 1.000 ms blank screen, four grey ovals were shown on the screen for 3.000 ms, in the same positions as the previously presented faces, with a red dot indicating the to-be-remembered face (Figure 3b).

Each session included 160 trials with 8 blocks of 20 trials each and lasted for about 1 hour. Each participant completed a total of 320 trials (160 × 2 set-sizes). The two set-sizes were tested in separate sessions, with the order of presentation of the two sessions being counterbalanced among participants.

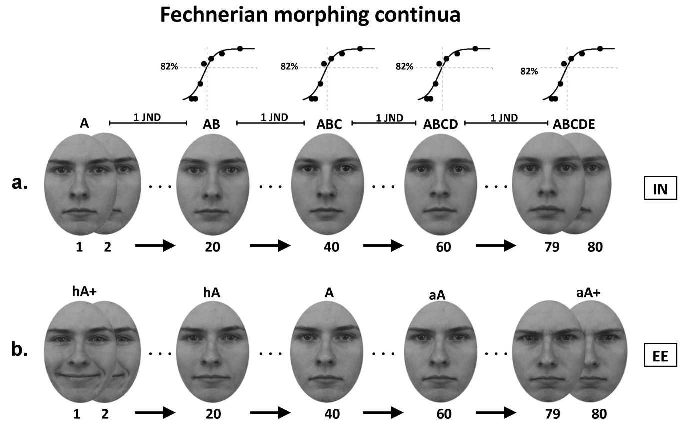

Figure 2: Each Fechnerian morphing continuum was created, for each participant, by morphing between the four images corresponding to the face discrimination thresholds measured in Phase 1 and consisted of 80 images. We generated two different types of Fechnerian continua: One Fechnerian morphing continuum of facial identity variations with a neutral expression (Identity Neutral [IN] continuum) and one Fechnerian morphing continuum of variations of emotional expression (Emotional Expression [EE] continuum). **(a)** IN continuum. The continuum was created by generating 20-steps morphing between faces corresponding to the discrimination thresholds obtained in the first phase (A/AB, AB/ABC, ABC/ABCD, ABCD/ABCDE). **(b)** EE continuum. The continuum was created by generating 20-steps morphing between faces corresponding to the discrimination thresholds obtained in the first phase (hA+/hA, hA/A, A/aA, aA/aA+).

Results

Figure 4 shows the average distance between the test face and participants' response, for each Fechnerian morphing continuum and for each set-size. The average response error was smaller than the average perceptual discrimination thresholds measured in Phase 1. The difference in memory fidelity between the IN and EE continua was not statistically significant, χ^2_1 = 0.44, p = .5075. The effect of Set-size was statistically significant, χ^2_1 = 3.85, p = .049. More importantly, the Continuum × Set-size interaction was statistically significant, χ^2_1 = 10.49, p = .0012. We also divided the EE continuum into two segments ("happy faces," from frame 1 to frame 40, and "angry faces," from frame 41 to frame 80). However, the effect of face valence (positive, negative) was not statistically significant, χ^2_1 = 1.60, p = .2057. The Face Valence × Set-size interaction was not statistically significant, χ^2_1 = 0.19, p = .6599.

[3]Psychometric functions were fitted by using `R` (R Core Team, 2013) and `psyphy` (Knoblauch, 2007)

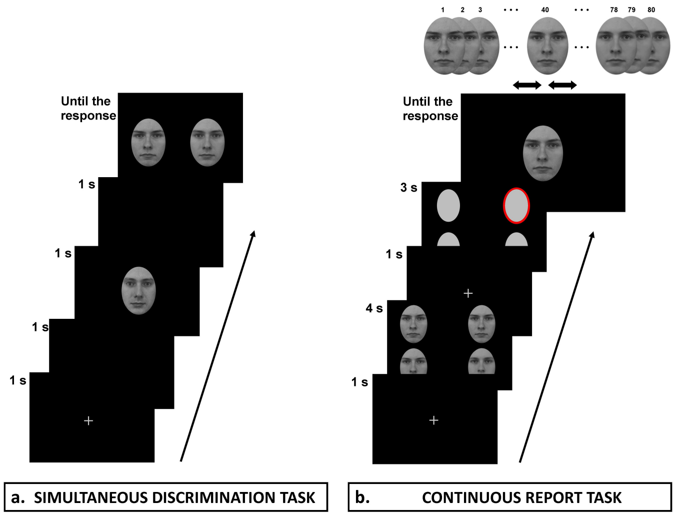

Figure 3: Experimental procedure. **(a)** In the simultaneous discrimination task (Phase 1) participants were forced to choose the face more similar to a comparison face previously shown. **(b)** In the continuous report task (Phase 2) a set (n = 1 or n = 4) of randomly chosen faces from a Fechnerian morphing continuum were shown (the figure reports the 4 items set-size condition). After 1 second interval, a cue indicated which image had to be remembered. In order to produce the response, participants manipulated a scalar probe that could vary along the morphing continuum.

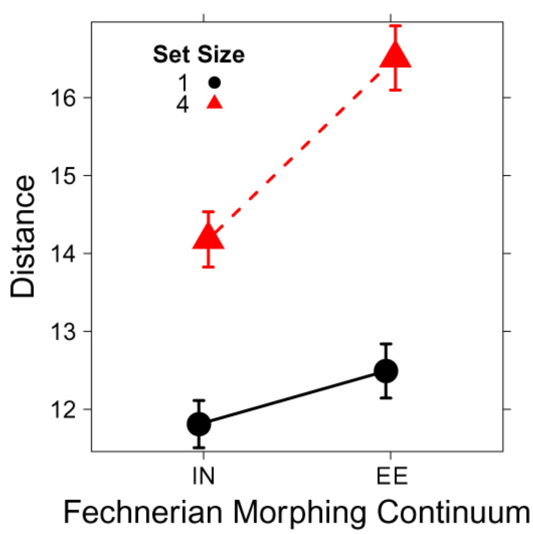

Figure 4: Average of the absolute value of the difference between the value of the Fechnerian morphed face reported by each participant and the value of the studied Fechnerian morphed face, for the IN and EE continua, as a function of the set-size.

Discussion

We asked whether the memory advantage for emotional compared to neutral faces, which has been found with the old-new recognition task, occurs at the expenses of the pictorial precision with which the expressive faces are represented in memory. The recognition of face identity is the consequence of an act of categorization. Each act of categorization weakens the representation of the category-irrelevant features (Caudek, 2013). We assumed that remembering face identity is more important for expressive than for neutral faces. As a consequence, we hypothesized that expressive faces should be represented in memory with a lower pictorial fidelity than neutral faces. Our results confirm this hypothesis, but only for set-size of four (not for set-size of one). We interpret this result as indicating that the negative impact of the categorization processes on the pictorial fidelity of the memory representation is stronger under a high memory load. With a low memory load, in fact, we found no difference in the precision of VWM for neutral and expressive faces, thus replicating the results of Bankó, Gál, & Vidnyánszky (2009).

Although it could be expected that face identity recognition is more important in the case of angry compared to happy faces (Jackson et al., 2009; Jackson et al., 2014), we did not find a difference between these two conditions. However, it should be noted that in the present study the level of emotional intensity was very low. Therefore, we could expect different effects on memory fidelity for angry compared to happy faces when emotional intensity is higher. Finally, in line with the previous literature, we found a decrease of VWM precision with an increase of set size (Alvarez & Cavanagh, 2004; Bays & Husain, 2008; Brady, Konkle, & Alvarez, 2011; Caudek, 2013).

A few limitations deserve mention. In particular, the present experimental design does not allow to determine if results are due to differences in memory for emotional versus neutral faces, or differences in memory for expression versus identity. To address this limit, in future experiments we plan to compare memory for emotional versus neutral faces by using the same type of response continuum, by producing stimulus variations, for example, by a change in the illuminant direction or in the orientation of the face, or by considering the subtle transformations of the morphological properties of the face during speech and language production. A second limit of the present study concerns the low statistical power due to small sample size. Finally, another issue to consider in future research has to do with the impact that face familiarity may have on VWM fidelity. We expect that familiar faces, by encouraging an act of individuation more strongly than unfamiliar faces, will show a lower VWM fidelity for transient facial features than unfamiliar faces. At the upper extreme of the familiarity spectrum, the self-face is the most important face (Kircher et al., 2001). Therefore, we speculate that VWM fidelity for irrelevant information should be lower for the self-face than for other personally-familiar faces.

Conclusions

The VWM advantage for expressive compared to neutral faces that had been found with the old-new recognition task comes with a cost: Expressive faces are represented in VWM with a lower pictorial fidelity than neutral faces. We interpret this result as due to the effects of the categorical processes required for facial identity recognition.

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