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The effect of familiarity on face adaptation

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Abstract. Face aftereffects can provide information on how faces are stored by the human visual system (eg Leopold et al, 2001 *Nature Neuroscience* **4** 89 – 94), but few studies have used robustly represented (highly familiar) faces. In this study we investigated the influence of facial familiarity on adaptation effects. Participants were adapted to a series of distorted faces (their own face, a famous face, or an unfamiliar face). In experiment 1, figural aftereffects were significantly smaller when participants were adapted to their own face than when they were adapted to the other faces (ie their own face appeared significantly less distorted than a famous or unfamiliar face). Experiment 2 showed that this 'own-face' effect did not occur when the same faces were used as adaptation stimuli for participants who were unfamiliar with them. Experiment 3 replicated experiment 1, but included a pre-adaptation baseline. The results highlight the importance of considering facial familiarity when conducting research on face aftereffects.

1 Introduction

Selective adaptation has been described as the "psychologist's microelectrode" (Frisby 1979), providing information about the mechanisms underlying visual perception. Aftereffects produced by adaptation can result not only from prolonged exposure to low-level properties like line orientation (eg He and MacLeod 2001), but can also occur for natural images such as faces. Face aftereffects can provide information about how faces are stored and encoded by the human visual system (see Clifford and Rhodes 2005, for a review).

Prolonged exposure to a face systematically affects its subsequent appearance. Webster and MacLin (1999) adapted participants to distorted images of faces in which internal features were either expanded or contracted. After prolonged exposure to a distorted face, a normal face appears to be distorted in the opposite direction. These 'figural aftereffects' have been found to transfer to the faces of individuals other than the adapting identity (Robbins et al 2007; Webster and MacLin 1999; Yamashita et al 2005). However, aftereffects can also be identity-specific: Leopold et al (2001) used a different adaptation methodology, based on Valentine's (1991) multidimensional face-space framework. This model suggests that each face has its own location in 'face space', depending on how much it deviates from a centrally located internal average of all faces, or 'norm'. Leopold et al (2001) produced face pairs which consisted of a target face and an 'anti-face'. These pairs were positioned at opposite locations in face space. Aftereffects were identity specific: prolonged exposure to an identity in face space selectively increased participants' sensitivity to that identity's anti-face, but not to other faces.

It has been suggested that the mechanism underlying adaptation aftereffects can be explained in terms of an 'opponent-process' model. The model proposes that there are pairs of pools of neurons that code opposite facial dimensions around a norm. Adaptation may result in a shift of the norm due to the selective fatigue of those neurons that are being stimulated by the adapting face (Robbins et al 2007). It has also been hypothesised that faces are coded in relation to a 'norm' or average face (eg Leopold et al 2001; Rhodes and Jeffery 2006). Rhodes et al (2005) suggest that this norm is constantly calibrated to reflect properties of the faces with which an individual has experience.

While there has been extensive research into face-adaptation effects during the past decade, very few studies have used highly familiar faces: most have used faces that were either wholly unfamiliar to the participants (eg Webster and MacLin 1999), or faces to which they were familiarised during the experiment itself (eg Leopold et al 2001). However, facial familiarity needs to be taken into account, given that it is now well-established that recognitions of familiar and unfamiliar faces differs considerably. Familiar-face recognition seems to be based on 'abstractive', viewpoint-independent facial representations, that are relatively unaffected by changes in viewpoint, lighting, and expression. In contrast, unfamiliar-face recognition is much more closely tied to the particular facial image that is being viewed, and as a result is more 'fragile' than familiar-face recognition (Hancock et al 2000; Megreya and Burton 2006). As one of our reviewers pointed out, if one is interested in using adaptation techniques to investigate the representations underlying face recognition, it is necessary to use familiar faces: representations of unfamiliar faces are likely to be transient and different in nature from the more stable representations underlying the recognition of familiar faces.

A few studies have already found effects of familiarity on face adaptation. For example, Carbon et al (2007) used an adaptation paradigm similar to Webster and MacLin's (1999), but with famous faces. They found that adaptation to a distorted famous face affected the subsequent perception of an undistorted image of that individual, be it the same or a different image. However, in contrast to Webster and MacLin's results with unfamiliar faces, Carbon et al found that the transfer of aftereffect was not equivalent when the adapting and test faces were from different famous individuals. This suggests that figural aftereffects for familiar faces are significantly influenced by the identity of the face. More recently, Carbon and Ditye (2010) have shown that, whereas figural aftereffects for unfamiliar faces are generally reported to be quite short-lived, comparable aftereffects for familiar (famous) faces are much more long-lasting, being detectable as long as a week after adaptation first took place.

The importance of distinguishing between familiar and unfamiliar faces when researching adaptation effects has also been highlighted by Ryu and Chaudhuri (2006). They compared Fang and He's (2005) viewpoint aftereffects for familiar and unfamiliar faces. After prolonged exposure to a face in one orientation, a frontal view appears to be facing in the opposite direction. When adapting and test faces were the same identity, similar viewpoint aftereffects were found for both familiar and unfamiliar faces. However, although viewpoint aftereffects transferred between two different unfamiliar faces, they did not transfer between two different familiar faces. Further to this, findings from Jiang et al (2007) suggest that the strength of adaptation effects can be increased by manipulating the familiarity of a face (by increasing the number of exposures to it). Taken together, these studies suggest that familiarity with a face is important, as even brief periods of familiarisation under experimental conditions can influence adaptation effects.

These studies have demonstrated the effects of one kind of familiarity, that produced by celebrity status (fame): however, there also seem to be important differences between the representations of different kinds of familiar face, namely famous faces and faces with which we are personally familiar, such as those of friends and family, and our own face. On the basis of experiments showing reduced search times for own-faces compared to other faces, Tong and Nakayama (1999) suggested that the representations for personally familiar faces are more 'robust' than those for other 'familiar' faces, such as those of celebrities or those for whom 'familiarity' has been created within an experiment. Because personally familiar faces are encountered on a large number of occasions and under a variety of conditions, they become highly over-learned. This is in contrast to celebrity faces, or faces that are encountered only during an experiment. 'Robust' faces appear to be processed differently; they demand fewer attentional resources and their representations contain both view-invariant and abstract information (Tong and Nakayama 1999).

Differences between the processing of famous and personally familiar faces were also demonstrated in a study by Carbon (2008). He investigated the effects on recognition of either making minor changes to a face or presenting it in an uncommonly encountered version. These manipulations impaired recognition of famous faces significantly more than they affected recognition of personally familiar faces (the participants' lecturers). Carbon concluded that, for famous faces, 'familiarity' was more with iconic images of the celebrities concerned than with the individuals themselves. Carbon's view is that an important difference between famous and personally familiar faces is that the representations of the latter are derived from experience with dynamic and socially relevant 3-D instances of them.

Neuroimaging studies also show that different brain regions are activated when making judgments about faces that are either novel, personally familiar, or one's own (eg Platek et al 2006; Sugiura et al 2010). A number of studies (eg Collin and Byrne 2010; Mohr et al 2002) suggest that, in contrast to unfamiliar faces, familiar-face recognition appears to be mediated bilaterally, perhaps by 'transcortical cell assemblies' (Pulvermüller and Mohr 1996).

Findings such as these highlight the need to properly distinguish between faces with different degrees of familiarity when investigating the properties of facial representations. Although some adaptation studies have considered how aftereffects are affected by facial familiarity (eg Carbon et al 2007; Ryu and Chaudhuri 2006), to our knowledge none has used personally familiar (and therefore truly robustly represented) faces.

In the present studies we sought to address these issues by using adapting stimuli that varied in familiarity for the perceivers. The first study aimed to extend previous research on figural aftereffects from distorted familiar (famous: eg Carbon et al 2007) and unfamiliar (non-famous: eg Webster and MacLin 1999) faces, by examining whether comparable aftereffects would be produced by the participant's own face. On the basis of Tong and Nakayama's (1999) findings, we might predict that after prolonged exposure to one's own face (which is presumably very robustly represented), the resultant aftereffect should be smaller, perhaps because a face of this nature requires fewer attentional resources (Tong and Nakayama 1999). Alternatively, Jiang et al (2007) suggest that increasing familiarity with a face may enhance the strength of adaptation. Therefore an alternative prediction is that the size of aftereffects would increase in line with facial familiarity: in other words the greatest adaptation effects would be to robust (own) faces, compared to famous and non-famous faces.

2 Experiment 1

2.1 *Method*

2.1.1 *Design.* There were two independent variables: the identity of the face in the adaptation phase and the identity of the face in the test phase. The identity of the adapting face was a repeated-measures variable: each participant was adapted twice to her own face, twice to a famous face, and twice to an unfamiliar face, making a total of six adaptation phases. The identity of the test face was also a repeated-measures variable. For each of the identities (self, famous, and non-famous), participants were tested on two different visual arrays: one consisted of faces of the same identity, and the other consisted of an array based on the average face.(1) In total, each participant experienced six pairs of adaptation and test phases.

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(1) The average face used was taken from Perrett et al (1994) and contained information from 60 faces. We describe this manipulation merely so that our procedure can be replicated in every aspect; the manipulations produced no results of any theoretical significance, and so they will not be discussed further in this paper.

The strength of the adaptation effect was measured by presenting participants with a 3 × 3 grid containing nine faces with various levels of figural distortion, and recording which face was perceived to be the most 'normal'.

2.1.2 *Participants.* The participants were students at the University of Sussex, who participated voluntarily. Overall forty participants were tested, but their data were only retained if they satisfied the following criteria: satisfactory recognition of their own face (as shown by familiarity ratings of $\geqslant$5 on a 7-point scale, where 1 was 'highly unfamiliar' and 7 was 'highly familiar'); satisfactory recognition of celebrity faces (by familiarity ratings of $\geqslant$4); non-recognition of unfamiliar faces (by familiarity ratings of $\leqslant$3); showing they understood the task by completing the practice trial appropriately (picking the most 'normal' face to be one without figural distortions); and provision of a complete data set. Data of thirty participants remained in the final analysis. Since all of the famous and unfamiliar stimuli were Caucasian female faces, all participants were Caucasian females aged between 18 and 35 years (mean age = 22.8 years, SD = 4.2 years). Only Caucasian female faces were used, since evidence suggests that there may be distinct norms and face spaces for different facial categories (eg for males and females, and for different races: Rhodes and Jeffery 2006).

2.1.3 *Stimuli*

(a) *Familiarity check*: As a check on facial familiarity, three undistorted images were presented to each participant: her own face, a famous face, and a non-famous face. To produce the own-face stimuli, an image of each participant's own face was taken on a digital camera (Samsung L100) and then uploaded onto the computer. So that the image corresponded to the view of the face that the participant was most familiar with,(2) it was then mirror-reversed. To produce the famous and non-famous face images, 20 famous and 20 non-famous (unfamiliar) Caucasian female faces were downloaded from the Internet. All images were frontal views with a neutral expression. Hairstyles were mostly off the face and all images were changed to grey-scale. Each image was cropped to display only the face and resized to a width of 40 mm. Each participant saw one of the famous faces from this set, and one of the non-famous faces. To assess familiarity, normal (ie undistorted) versions of the faces were presented in the centre of the screen.

(b) *Adaptation stimuli*: The stimuli used in the adaptation phase consisted of distorted versions of the same three images seen by a participant in the pre-test. Figural distortions were produced with Adobe Photoshop 7.0. The internal features of each face were selected with an oval marquee and then distorted (contracted in the middle and expanded towards the periphery) using the 'Pinch' function set to 60%. Figural aftereffects are known to occur after adaptation to both expanded and contracted faces (Webster and MacLin 1999). Therefore, to reduce the number of trials for each participant, only contracted faces were used in the adaptation phase. All distorted faces were presented on a white background and displayed 20 cm to the left of the centre of the screen. This was to reduce retinotopic adaptation, by ensuring that the adapting face did not overlap with the array of test faces shown subsequently.

(c) *Test stimuli*: The stimuli used in the test phase were 9 images of the face shown in the adapting phase, each varying in its amount of figural distortion, and presented in a 3 × 3 grid. For each participant there were six different visual arrays: an own-face array, a familiar-face array, an unfamiliar-face array and three different average-face arrays.

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(2) While it is impossible to know for certain how much experience an individual has had with seeing one's own face in a mirror as opposed to seeing it in photographs, it seems reasonable to assume that most people will have had more experience with their own faces, as a consequence of their daily grooming rituals.

The adapting images were cropped to show only the face and resized to a width of 4 cm. The brightness and contrast were manipulated in Photoshop in order to make the images similar to each other. Each of the 9 faces within an array varied in its amount of distortion (−60%, −45%, −30%, −15%, 0%, 15%, 30%, 45%, 60%, where positive values represent faces that were contracted towards the centre and expanded towards the periphery, and negative values represent faces that had a 'fisheye' appearance to varying extents). The faces were arranged randomly in every array.

Both the adaptation and test phases were administered to participants in a program written in Superlab 4.0 (Cedrus Corporation). The entire experiment took just under 10 min to complete, excluding the time taken to add each participant's own face into the presentation.

2.1.4 *Procedure.* Each participant was tested individually. A photo was taken of the participant's face on her arrival and she was then given reading material whilst the experimenter uploaded and manipulated her photograph. The participants were then seated at the computer, where they were told how to use the numeric keypad to record their responses. At this stage, what constituted a 'normal' face was clarified to them.

(a) *Familiarity check*: In the first task participants were required to rate how familiar 3 undistorted faces were (their own face, a famous face and a non-famous face) on a scale from 1 to 7 (1 = highly unfamiliar and 7 = highly familiar). This aspect of the procedure served a number of functions. First, it helped to eliminate any ambiguity about what constituted a 'normal' face for the purposes of the experiment. Second, it helped to control for the participant being primed to see her own face after having just been photographed. Third, it confirmed that the famous face was familiar to the participant and that the non-famous face was unfamiliar. Each face was preceded by the name of the individual for 3 s (a fake name was given to the non-famous face). It was explained to each participant that she would see 3 faces and that after each face she would be required to rate how familiar it was to her. Each face was presented for 3 s followed by instructions reminding participants how to rate familiarity.

Each of the 20 famous faces and each of the 20 non-famous faces was presented to two participants (eg two participants saw Angelina Jolie and unfamiliar face 1; a different two participants saw Britney Spears and unfamiliar face 2; and so on). This was to ensure that any differences in adaptation between conditions were due to the familiarity status of the faces and not due to the underlying structure of a particular face.

(b) *Practice trial*: Before performing the main experiment, participants were given the opportunity to ask questions. They then completed a practice trial, in order to familiarise themselves with the procedure used in the main experiment. This trial consisted of being adapted to a distorted face (the actress Hilary Duff) for 30 s. During this period, the participant was asked to look for a mirror-reversed version of this face and to press the space bar if she detected one. (The fifth face in the sequence was always mirror-reversed.) The practice trial ended with the presentation of an array of 9 versions of Hilary Duff's face that varied in their level of distortion. The participants selected the face that looked most 'normal' to them. After completing the practice trial, participants were asked to press the space bar when they were ready to start the experiment proper.

(c) *Adaptation phase*: In the experiment proper, on-screen instructions told participants that they would have two tasks. In one task they would see distorted versions of the faces they had rated for familiarity earlier: they would have to concentrate on each face for the duration of its display and indicate, using the space bar on the keyboard, if a mirror-reversed face appeared. They were told that one, many, or none of the faces might be mirror-reversed. (This was merely a ruse to ensure participants concentrated on the adapting face for the duration of its display. In fact none of these faces was mirror-reversed compared to how they had been displayed previously when familiarity was checked.) During this adapting phase, the same distorted face was shown 20 times, for 3 s at a time. Thus there was a total of 1 min exposure to each adapting face.

(d) *Test phase*: Participants were told that the second task required them to identify as quickly as possible which face looked the most 'normal', from an array of 9 faces that were distorted to varying degrees. Participants used the numeric keypad to indicate their decision. Each of the six adapting trials was followed by an array, which was presented in the centre of the screen and remained visible until a response was given. Each array consisted of faces which were either of the same identity as the adapting face or of an average face.

There were six trials in total, each consisting of an adaptation and a test phase. Each participant was adapted twice to her own face, twice to a celebrity face, and twice to a non-famous face. After being adapted to each identity once, the participants were tested on the same identity or on an average face (see figure 1). The order in which trials occurred was randomised for each participant. The entire experiment took about 10 min to complete.

Adapting phase (from left to right): own, famous, and familiar faces. 20 identical manipulated images, shown for 3 s each.

Test phase: visual arrays of 9 faces with various levels of distortion, shown until participant makes a normality decision.

Figure 1. Diagram of the adaptation and test phases for one participant.

2.2 *Results*

Each participant provided data on which face she thought looked the most 'normal' (ie the least experimentally distorted) out of an array of 9 faces that varied in their amount of figural distortion. Following adaptation, faces should appear distorted in the opposite direction to the original image: after prolonged exposure to a contracted face, faces appear more expanded than they actually are, and vice versa. Consequently, if adaptation occurred, we would expect 'normal' ratings to be shifted towards the adapting image, to correct for the perceived distortion (Webster and MacLin 1999). In terms of our mean ratings, the stronger the aftereffect, the higher the (positive) rating should be. Figure 2 shows the mean distortion level chosen by participants as a function of adapting face (own face, famous face, or non-famous face). When participants were tested

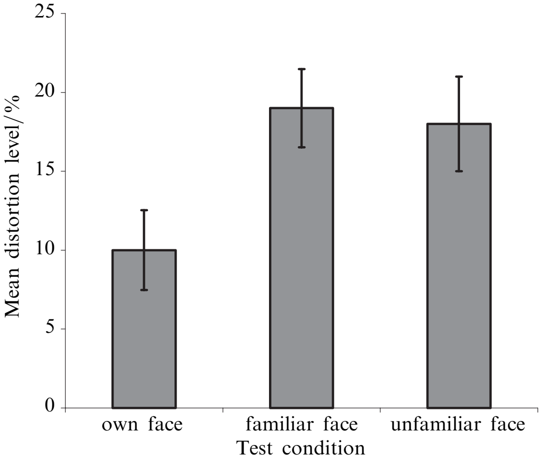

Figure 2. Experiment 1. The mean distortion level chosen by participants as a function of adapting face (own face, familiar face, or unfamiliar face) and test face (same identity as adapting face, or an average face). Error bars indicate ±1 SEM.

on the same identity as that to which they had been adapted, their own faces produced significantly less adaptation than did familiar or unfamiliar faces. This was confirmed with a one-way repeated-measures ANOVA, with three levels of adapting face (own face, familiar face, or unfamiliar face: $F_{2,58} = 3.39$, $p < 0.05$). Planned contrasts revealed that the mean amount of adaptation following exposure to the participant's own face ($M = 10.00$, $\mathrm{SD} = 13.83$), was significantly different from the amount of adaptation following exposure to both familiar and unfamiliar faces combined ($M = 18.50$, $\mathrm{SD} = 14.97$; $F_{1,29} = 4.66$, $p < 0.05$). Planned contrasts also revealed that familiar faces ($M = 19.00$, $\mathrm{SD} = 13.61$) and unfamiliar faces ($M = 18.00$, $\mathrm{SD} = 16.43$), did not differ in the amount of adaptation that they produced ($F_{1,29} = 1.44$, ns).

We also checked to ensure that participants in the three conditions did not differ in their decision times. Suppose that participants in the 'own face' condition took longer to make a decision than participants in the other two conditions. This could produce an apparent reduction in adaptation for own faces because the adaptation effect would be wearing off while participants were making their decision. In fact, a one-way repeated-measures analysis of decision times showed that there were no significant differences between the three conditions (mean own face = 7.05 s, SD = 0.58 s; mean familiar face = 6.96 s, SD = 0.47 s; mean unfamiliar face = 7.06 s, SD = 0.61 s: $F_{2,58} = 1.29$, ns).(3)

3 Experiment 2

Experiment 1 suggested that there was an 'own-face effect': aftereffects were smaller when participants were adapted to their own faces than when they were adapted to either familiar or unfamiliar faces. However, it is possible that this effect could have arisen from some peculiarity in the underlying structural properties of the participants' faces, rather than from their status as 'own faces' that possess robust representations. Experiment 2 was therefore performed to control for this possibility. The strength of adaptation effects was measured when the own-face stimuli of experiment 1 were shown to two groups: a subset of the participants who had previously taken part in

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(3) Even if we had found a difference, it should be noted that Carbon and Ditye (2010) found that adaptation effects with personally familiar faces can be extremely persistent, lasting over days or weeks. Therefore it is unlikely that differences in decision times could have affected our results to any serious extent.

experiment 1, and a separate group of participants who were unfamiliar with these faces. If the own-face effect of experiment 1 was due to properties of the faces themselves, then similar aftereffects should be experienced by both groups. On the other hand, if the effect in experiment 1 stemmed solely from the fact that the 'own-face' stimuli belonged to the participants, then the magnitude of the aftereffect should differ between the two groups.

3.1 *Method*

3.1.1 *Design.* The independent variable was whether or not the face used in the adaptation and test phase was the participant's own. This was a between-subjects variable: half of the participants were adapted to and tested on their own face (taken from experiment 1). The other half were adapted to and tested on the same face, but this face did not belong to them. Each participant was adapted to one face and tested on the same identity. The strength of the adaptation effect was measured in the same way as in experiment 1.

3.1.2 *Participants.* There were two groups of participants (overall mean age 22.5 years, SD = 4.0 years). The 'own-face' group consisted of twenty-five participants who had taken part in experiment 1. The criteria for inclusion in experiment 2 were that (i) they had been included in the final analysis of experiment 1, (ii) they consented to their names and faces being shown to one other person, (iii) they understood how to complete the task as indicated by picking the 'normal' face to be one without figural distortions in the practice trial. The 'other-face' group consisted of twenty-five participants who were similar in characteristics to the first group (white Caucasian female undergraduates at the University of Sussex, between the ages of 18 to 35 years), except that they were not familiar with the faces of the 'own-group' members. None of these participants had taken part in experiment 1.

3.1.3 *Stimuli.* The stimuli were images of those participants from experiment 1 who also took part in experiment 2. The images consisted of non-distorted faces (for the familiarity check), distorted adapting images, and 3×3 face arrays consisting of the same identity distorted to varying degrees.

Again, both the adaptation and test phases were administered to participants in a program written in Superlab 4.0 (Cedrus Corporation). The entire experiment took under 5 min to complete.

3.1.4 *Procedure.* The adaptation and test procedures were exactly the same as in experiment 1, except that the participants experienced only one familiarity check and only one trial. Participants in the 'own-face' condition provided data on which face in the test array looked most normal, after being adapted to their own faces. Participants in the 'other-face' condition completed exactly the same procedure, after being adapted to the same faces as the participants in the 'own-face' condition. Thus there was only one difference between the two conditions: all participants saw the same set of adapting stimuli, but for one group these constituted views of own faces while for the other group these represented the faces of different people.

3.2 *Results*

An independent-measures t-test revealed that there was a significant difference in the size of aftereffect, depending on whether the face was the participant's own (mean amount of adaptation, $M = 7.80$, $\mathrm{SD} = 13.77$) or not ($M = 18.60$, $\mathrm{SD} = 16.93$: $t_{48} = -2.47$, $p = 0.008$, one-tailed test). Aftereffects were significantly larger when the face that participants were adapted to and tested on was not their own. The 'own-face' group replicated their performance in the previous experiment, whereas for the 'other-face' group the size of the aftereffect was very similar to that obtained in experiment 1 for famous and unfamiliar faces.

As with experiment 1, we checked to ensure that participants in the two conditions did not differ in their decision times. An independent-measures *t*-test on decision times showed that there was no significant difference between the two conditions (mean own face = 7.04 s, SD = 0.61 s; mean other face = 6.82 s, SD = 0.19: $t_{28.61} = 1.66$, ns).

4 Experiment 3

Experiments 1 and 2 suggest that figural aftereffects are moderated by an 'own-face' effect: aftereffects were smaller when the adapting face belonged to the participant than when the same face was seen by a stranger. However, the previous studies only measured what is perceived as most normal *after* adaptation: we had no way of knowing for certain what distortion level would have been chosen as most 'normal' in the absence of adaptation. Experiment 3 was therefore conducted; it replicated experiment 1, but with the addition of a pre-adaptation baseline to ensure that participant's normality ratings for the three different face types were comparable before adaptation took place.

4.1 *Method*

4.1.1 *Design.* There were two independent variables: the identity of the face in the adaptation phase, and in the testing phase. The identity of the adapting face was a repeated-measures variable. Each participant was adapted to 3 different faces: their own face, a famous face, and an unfamiliar face. During each of these 3 adaptation phases, the relevant face was presented for 1 min.

Testing phase was also a repeated-measures variable. For each of the 3 faces, participants were tested twice: once before adapting to the face (to provide a pre-adaptation baseline) and once after adaptation had occurred. In each case, testing involved a visual array that consisted of the same face that had been used for adaptation.

The pre-adaptation baseline and the strength of the adaptation effect were both measured by presenting participants with a grid containing 9 faces (3 × 3) with various levels of figural distortion, and recording which face was perceived to be the most 'normal'. In contrast to the previous experiments, in which participants made their responses by using the numeric pad on the computer keyboard, experiment 3 used a simpler interface—a touch-screen computer monitor (a 17-inch Iilayama ProLite T17305)—and the participant touched the face in the array that she considered to be most 'normal'.

4.1.2 *Participants.* The participants were students at the University of Sussex, who received course credits for taking part. Overall twenty-two participants were tested, but their data were only retained if they satisfied the following criteria: satisfactory recognition of their own face (as shown by familiarity ratings of $\geqslant 4$ on a 6-point scale); satisfactory recognition of celebrity faces (by familiarity ratings of $\geqslant 4$); non-recognition of unfamiliar faces (by familiarity ratings of $\leqslant 3$); and provision of a complete data set. (Note that this scale was slightly different from the 7-point scale that was used in experiment 1. A 6-point scale was used to remove the mid-point from the scale, and hence help to clarify whether the participants regarded the faces as familiar or unfamiliar. Specifically, the points on the revised scale were: 1 = highly unfamiliar, 2 = unfamiliar, 3 = slightly unfamiliar, 4 = slightly familiar, 5 = familiar, and 6 = highly familiar.) There were nineteen participants included in the final analysis. As in experiment 1, all participants were 18–35-year-old Caucasian females (mean age = 22.5 years, SD = 4.9 years).

4.1.3 *Stimuli.* All aspects of stimulus preparation were identical to those in experiment 1.

4.1.4 *Procedure.* The procedure differed from that used in experiment 1 in the following ways. First, the familiarity check used a 6-point rather than 7-point scale. Second, responses were made via a touch-screen rather than the computer keyboard. Third, the pre-adaptation test phase was added. Fourth, the 'average face' manipulation was removed from the procedure. Finally, only 15 famous faces and 15 non-famous faces were used, rather than 20 as in the first experiment.

After the familiarity check, on-screen instructions told participants that they would have two tasks. It was explained that in one task they would see distorted versions of the faces they had just rated for familiarity. They were asked to concentrate on each distorted face for the duration of its display and click the left mouse button if a mirror-reversed version appeared. (As in experiment 1, this was merely a ruse to ensure participants concentrated on the adapting face for the duration of its display. In fact none of the faces was mirror-reversed.) During the adapting phase the same distorted face was shown 20 times, for 3 s at a time. Thus there was a total of 1 min's exposure to each adapting face.

Participants were told that the second task required them to identify, as quickly as possible, which face looked the most normal, from an array of 9 faces that were distorted to varying degrees. Participants used the touch-screen to indicate their decision. Each of the three adapting trials was followed by an array, which was presented in the centre of the screen and remained visible until a response was given. Each array consisted of faces which were the same identity as the adapting face.

Before completing a practice trial (again involving the face of the actress Hilary Duff), participants were given the opportunity to ask questions. The adapting phase in the practice trial lasted 30 s and the fifth face in the sequence was mirror-reversed. The practice trial, like all other trials, ended with the presentation of an array of 9 faces. After completing the practice trial, participants were asked to click the left mouse button when they were ready to start the experiment proper.

There were a total of three trials, each consisting of an adaptation and a test phase. Each participant was adapted once to their own face, once to a celebrity face, and once to a non-famous face. After being adapted to each identity once, they were subsequently tested on the same identity. The order in which trials occurred was randomised for each participant.

4.2 *Results*

A 2×3 repeated-measures ANOVA revealed a significant main effect of test phase ($F_{1,18} = 34.79$, $p < 0.0001$). Overall, participants perceived faces to be more contracted after adaptation ($M = 12.14$, $\mathrm{SD} = 13.51$) than before adaptation ($M = -0.36$, $\mathrm{SD} = 7.86$). There was a non-significant main effect of face identity ($F_{2,18} = 1.61$, ns), but there was a significant interaction between face identity and test phase ($F_{2,36} = 5.79$, $p < 0.01$). As can be seen from figure 3, these results reflect the fact that the strength of the figural aftereffect was affected by the familiarity of the face. Before adaptation took place, participants gave similar ratings of normality to all 3 faces (their own, the famous face, and the unfamiliar face). Adaptation had a much greater effect on the appearance of the famous and unfamiliar faces than it did on the appearance of the participant's own face. This interpretation was confirmed with follow-up tests. For each type of face, pre-adaptation and post-adaptation ratings of normality were compared. A significant adaptation effect was found with participants' own faces (mean difference = 6.32, $\mathrm{SD} = 10.39$: $t_{18} = 2.65$, $p < 0.02$). However, adaptation effects were much more pronounced for familiar faces (mean difference = 13.42, $\mathrm{SD} = 12.14$: $t_{18} = 4.82$, $p < 0.0001$) and unfamiliar faces (mean difference = 18.16, $\mathrm{SD} = 15.48$: $t_{18} = 5.12$, $p < 0.0001$). There was no significant difference in the strength of the adaptation effect for the latter two conditions ($t_{18} = 1.29$, ns).

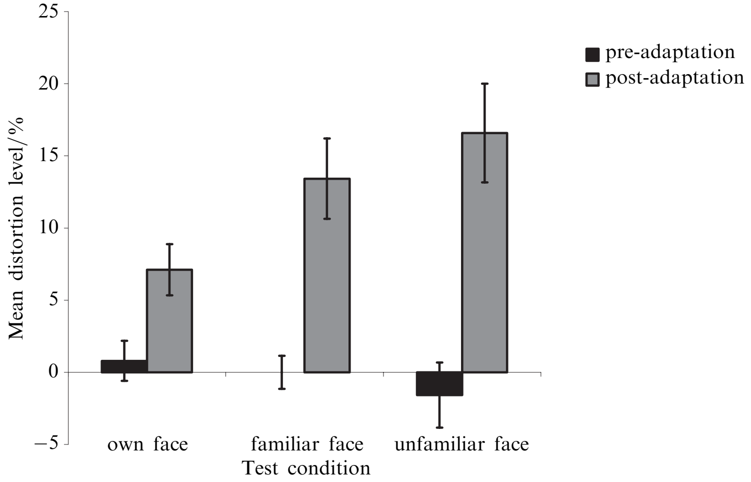

Figure 3. Experiment 3. The mean distortion level chosen by participants before and after adaptation to a distorted version of either their own face, a familiar face, or an unfamiliar face. Error bars indicate ±1 SEM.

Once again, we checked to ensure that participants in the three conditions did not differ in their decision times. A one-way repeated-measures ANOVA on decision times showed that there were no significant differences between the three conditions (mean own face = 6.96 s, SD = 0.31 s; mean familiar face = 6.93 s, SD = 0.28 s; mean unfamiliar face = 6.88 s, SD = 0.30 s: $F_{2,36} = 0.47$, ns).

5 Discussion

The aim of the current study was to investigate figural aftereffects in relation to facial familiarity (own face, famous, and non-famous). The results from experiments 1 and 3 indicate that when participants were adapted to their own face, they showed a significantly smaller aftereffect than when they were adapted to other faces (famous or non-famous). Experiment 2 showed that this reduction in the size of the aftereffect occurred only when the faces actually belonged to the participants.

What gives rise to this 'own-face' effect? Experiment 2 showed that it cannot be attributed to the structural properties of participants' faces. One possibility is that it is related to attentional factors. Tong and Nakayama (1999) suggest that robustly represented faces require less attentional resources. Therefore, when participants viewed their own face, they may have attended to it less. This in turn may have resulted in less fatigue of the neurons coding it. However, attentional differences seem an unlikely explanation in practice. First, the adapting image of each participant's face was grossly distorted and not an image that they would have had experience with before the experiment. Second, the 'mirror-reversal' task should have encouraged participants to pay close attention to all of the faces in the adaptation phase, regardless of familiarity.

Another possibility is that robustly represented faces might have a special status in face space. In one version of Valentine's (1991) Multidimensional Face Space model, individual faces are encoded as deviations from an average or 'norm' face. Rhodes et al (2005) have suggested that this norm may be constantly calibrated and fine-tuned by experience. If experience has an effect on face space and the internal norm, then faces with which each individual has had a huge amount of experience (their own face, and the faces of close relatives) might have a major influence on the development of this norm.

The own-face effect may be a result of one's own face having a moderating effect on the internal norm. Leopold et al (2001) found that adapting participants to an average face produced a minimal alteration in sensitivity compared to the effects with anti-faces. This finding is comparable to the own-face effect, if the own-face is considered to have a central location in face space. In other words, adaptation to one's own face might produce alterations in sensitivity which are not as great as the effects found for other faces. Indeed findings from Platek and Kemp (2009) support the hypothesis of a "cortical network for discrimination of kin based on self-referent phenotype matching" (page 855). They suggest that there are mechanisms for discriminating kin from non-kin faces by self-referent computational mechanisms. This could be a revision to the idea of norm-based coding; instead of the internal 'norm' simply representing a highly average face, it may be that the centre of each individual's personal face space is based on his/her own face. This idea could be supported by evolutionary theory highlighting the importance of discriminating kin from non-kin for the avoidance of inbreeding (DeBruine et al 2008). Having one's own face in the centre of face space may promote more efficient coding as each incoming face is coded in respect to it.

Future research should determine whether the 'own-face effect' found here is specific to one's own face, or whether it can be generalised to other personally familiar (robustly represented) faces such as those of kin. One's own face may have a special status, even amongst 'personally familiar' faces (Keenan et al 2000a, 2000b; Ma and Han 2010). However, humans cannot have evolved to become experts with their own faces, as it is only relatively recently in evolutionary history that we have had access to mirrors and photographs (DeBruine et al 2008). If future research shows equivalent findings with other personally familiar faces, it may indicate an evolved process of other-referential phenotype matching. In other words, information about one's own face might be gleaned from kin, in order to discriminate other faces as kin or non-kin. It could be that the 'norm' of face space is based on an average of the faces of one's closest kin (probably resulting in a face very much like one's own face).

An alternative possibility is that the 'own-face' effect might indeed be special to one's own face, if there were self-referent phenotype matching mechanisms that only exist today because people do have much more experience with their own face (DeBruine 2002). This increase in experience may augment processes which originally evolved to be reliant on information from other faces.

As others have suggested, one way to resolve this issue would be to use adopted individuals as participants (DeBruine et al 2008; Platek and Kemp 2009). Adopted children's faces should be less structurally similar to their adoptive parents than to their biological parents. Therefore the 'norm' of their personal face space might be based on their adoptive parents' faces, faces they have actual experience with, and not their own face. This would be the case if self-referent phenotype matching comes from an evolved process of extracting information about the self from one's closest kin.

Self-referent phenotype matching could be interpreted to suggest that faces are coded in relation to one's own face. However, this does not necessarily rule out that an average face may reside in the centre of face space as suggested by research from Leopold et al (2001). It would be interesting to find out if there is a potential interaction between the two in order to identify the potential computational mechanisms within a multidimensional face space. As one of our reviewers pointed out, extensive experience with kin and own faces might bias the norm simply because these faces are seen more often.

Although the present experiments may indicate that there is an own-face effect, there are some methodological issues that need to be considered. One relates to the method by which we measured adaptation (ie by presenting arrays of faces that remained visible until a decision was made). As one reviewer pointed out, uncontrolled adaptation effects may have resulted from mere inspection of the set. However, it was found that there was no significant difference in how long participants took to respond to the face arrays between all conditions, in all three experiments. Therefore any uncontrolled adaptation would have remained a constant across all conditions. In any case, despite any possible uncontrolled adaptation, own-face effects were still found.

A more important methodological limitation is that the adapting image and the test images were all based on the same picture of a particular face. Consequently, there may have been some low-level adaptation occurring, eg to the picture rather than the face itself. It would have been preferable to have used different images of the same individual in the adapting and test phases. Nevertheless, low-level adaptation effects cannot explain all of the results that were found, because there was still less adaptation to participants' own faces than to famous or unfamiliar faces. Incidentally, the fact that physically identical face images gave rise to different amounts of adaptation in experiment 2, depending on whether or not the face belonged to the participant, represents further strong evidence that face-adaptation effects involve more than just adaptation to low-level image properties (see also Carbon and Ditye 2010; Hills et al 2010; Hole 2011).

Overall, the current study provides a promising starting point for how adaptation effects can be used to understand about how robustly represented faces might be processed. The underlying causes of the own-face effect warrant further research. However, it is clear that it is necessary to take into account the degree of facial familiarity when conducting research into face aftereffects: not all faces are equal, as far as face adaptation is concerned.

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