The Effect of Familiarity on Face Adaptation

Sarah Laurence

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Declaration

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree. However, the thesis incorporates to the extent indicated below, material already submitted as part of required coursework for the degree of Psychology BSc which was awarded by the University of Sussex:

Reported in Chapter 5 (Experiments 1 and 2)[1].

Signature:

Portions of the thesis have also been published in the Psychology Journals listed below:

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Portions of this thesis were carried out in collaboration with others:

Reported in Chapter 3: Professor Peter Hancock's contribution to this paper was the provision of the transformed adapting stimuli used in experiments 1, 2, 3 and 4. He also provided the specifics of the theoretical framework that the author of this thesis used to interpret the results. The design, execution and reporting of all experiments was conducted by the author of this thesis and supervised by Dr Graham Hole.

[1] Experiment 3 was conducted while the author was registered for the degree of Doctor of Philosophy in Psychology.

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UNIVERSITY OF SUSSEX

Sarah Laurence

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Summary

Face adaptation techniques have been used extensively to investigate how faces are processed. It has even been suggested that face adaptation is functional in calibrating the visual system to the diet of faces to which an observer is exposed. Yet most adaptation studies to date have used unfamiliar faces: few have used faces with real world familiarity. Familiar faces have more abstractive representations than unfamiliar faces. The experiments in this thesis therefore examined face adaptation for familiar faces.

Chapters 2 and 3 explored the role of explicit recognition of familiar faces in producing face identity after-effects (FIAEs). Chapter 2 used composite faces (the top half of a celebrity's face paired with the bottom half of an unfamiliar face) as adaptors and showed that only recognised composites produced significant adaptation. In Chapter 3 the adaptors were cryptic faces (unfamiliar faces subtly transformed towards a celebrity's face) and faces of celebrity's siblings. Unrecognised cryptic and sibling faces produced FIAEs for their related celebrity, but only when adapting and testing on the same viewpoint. Adaptation only transferred across viewpoint when a face was explicitly recognised. Chapter 4 demonstrated that face adaptation could occur for ecologically valid, personally familiar stimuli, a necessary pre-requisite if adaptation is functional in calibrating face processing mechanisms. A video of a lecturer's face produced FIAEs equivalent to that produced by static images. Chapters 5 and 6 used a different type of after-effect, the face distortion after-effect (FDAE), to explore the stability of our representations for personally familiar faces, and showed that even representations of highly familiar faces can be affected by exposure to distorted faces. The work presented here shows that it is important to take facial familiarity into account when investigating face adaptation effects, as well as increasing our understanding of how familiarity affects the representations of faces.

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List of Abbreviations

FIAE – Face Identity After-Effect
FDAE – Face Distortion After-Effect
MDFS – Multidimensional Face-Space
OFA - Occipital Face Area
FFA- Fusiform Face Area
STS – Superior Temporal Sulcus
MTG – Medial Temporal Gyrus
CFE - Composite Face Effect
IAC – Interactive Activation and Competition model
FRU – Face Recognition Unit
PIN – Person Identity Nodes
NRU - Name Recognition Unit
SIU - Semantic Information Unit
VRU - Voice Recognition Unit
PCA – Principal Component Analysis
CCTV – Closed Circuit Television
ERP – Event Related Potential
IFA – Internal Feature Advantage
ANOVA – Analysis of Variance
SD - Standard Deviation
SEM - Standard Error of the Mean
SE - Standard Error
MSE – Mean Squared Error

CHAPTER 1:
THE EFFECT OF FAMILIARITY ON FACE ADAPTATION – OVERVIEW

1.1. Introductory Remarks

1.1.1. Why is it Important to Study the Processing of Identity?

All faces share the same basic structure: they all have two eyes above a nose, above a mouth (first-order configuration). Yet despite this similarity we can get a lot of information from faces, such as sex, age, attractiveness, emotion, race, identity etc. This thesis is concerned with the processing of identity. Being able to recognise an identity is an important part of our social interactions. Infants can recognise their mother rapidly after birth: infants prefer to look at their mother's face rather than the face of a stranger within hours of being born (Bushnell, 2001). Our memory for familiar faces can last for decades: we are able to recognise the faces of classmates up to 35 years later (Bahrick, Bahrick & Wittlinger, 1975). Yet a failure to recognise an identity can have important personal and social implications. An example comes from the face processing disorder prosopagnosia, in which an individual has a severe and apparently relatively selective deficit in recognising familiar faces (Damasio, 1985). This deficit has been found to have psychosocial consequences such as anxiety, avoidance of social situations and a loss in self-confidence (Yardley, McDermott, Pisarski, Duchaine & Nakayama, 2008). At a more applied level, false recognition (misidentification) of individuals has resulted in the imprisonment of innocent people. Calvin Willis was imprisoned for 22 years for a crime that he did not commit, because he was falsely recognised (see The Innocence Project, n.d.). These examples demonstrate that failure to be able to recognise a person can have a devastating effect on both the individual concerned, and on society.

A central issue in the processing (and recognition) of identity is the difference between familiar and unfamiliar faces. Humans are considered to be "experts" at processing faces (e.g. Carey, 1992). However, it is becoming clear that the processing of familiar and unfamiliar faces is qualitatively different (see Johnston & Edmonds, 2009; Natu & O'Toole, 2011; Jenkins & Burton, 2011 for reviews). A striking demonstration of this comes from matching tasks: participants are shown multiple images of a face and they need to decide whether these faces are of the same person, or of different people (see Figure 1.1). This seemingly simple task is very difficult when the images are of unfamiliar identities, but it is easy when they are familiar (Burton, Wilson, Cowan & Bruce, 1999; Bruce, Henderson, Newman & Burton, 2001; Megreya & Burton, 2006; Jenkins, White, Van Montford & Burton, 2011). Familiar faces have representations which are not dependent on things like lighting, pose and image quality (Burton, Jenkins & Schweinberger, 2011), whereas unfamiliar face processing is more dependent on such image properties (Hancock, Bruce & Burton, 2000).

Image removed for copyright reasons.

Figure 1.1. Images taken from the Glasgow Unfamiliar Faces Database. a) contains two images of the same person b) contains two images of different people. (Reproduced from Jenkins and Burton, 2011).

1.1.2. An Introduction to Adaptation.

Adaptation has been termed "a Psychologist's microelectrode" (Frisby, 1980). It is extremely useful for exploring the neural mechanisms that underpin our perception of the world. Adaptation occurs when our perceptual system alters in response to a given input: it can occur within seconds or minutes and it can result in after-effects (Clifford & Rhodes, 2005). A famous example is the waterfall illusion. This occurs after prolonged exposure to a constantly moving stimulus (e.g. a waterfall). When the movement stops, a static stimulus (e.g. a branch) appears to be moving in the opposite direction for a short time. This is known as a motion after-effect. Wade and Verstraten

(2005) suggest that there are three ways that adaptation can be defined: perception, procedure and process. Perception is the change in experience that occurs because of exposure. In the case of procedure, adaptation refers to the "adapting stimulus". This is the stimulus, and the amount of time it is shown for, that leads to a change in perception. The adaptation procedure is usually: pre-test, adaptation and post-test. For the definition of process, they suggest that adaptation is the inferred or measured physiological change that takes place. Wade and Verstraten state that in psychology the process is mostly inferred rather than measured.

There has been lots of research investigating adaptation in response to visual inputs such as contrast (e.g. Greenlee & Heitger, 1988) or motion (e.g. Mather, Pavan, Campana & Casco, 2008; also see Webster, 2011 for a review). These effects are not simply retinotopic: they can reflect cortical mechanisms too (see Ibbotson, 2005 for a review of contrast and motion adaptation). It has been suggested that some types of adaptation can be functional. For example adaptation to a constant speed can result in a decrease in perceived speed. However, as our perception of speed decreases, our ability to detect changes in speed increases proportionately (Clifford & Langley, 1996; Clifford & Wenderoth, 1999).

Adaptation has a long history of research, for example the motion after-effect was first reported scientifically early in the nineteenth century (see Wade & Vernstraten, 2005 for a brief history of the motion after-effect). It is only much more recently (in the last 15 years or so) that adaptation has been used to investigate how faces are processed. It has been used to investigate different aspects of face processing, such as relatively stable facial categories such as gender and race, or things that vary within an individual like expression (Webster, Kaping, Mizokami & Duhamel, 2004), viewpoint (Jeffery, Rhodes & Busey 2006; Jiang, Blanz & O’Toole, 2006, 2007; Fang, Ijichi & He, 2007;

Daar & Wilson, 2012) and eye gaze (Jenkins, Beaver & Calder, 2006; see Table 1.1). In the case of gender, prolonged exposure to a female face can make an ambiguous face appear to look more male, and vice versa (Webster et al, 2004; Little, De Bruine & Jones, 2005; Afraz & Cavanagh, 2009; Zhao, Series, Bednar & Hancock, 2011; Storrs & Arnold, 2012). Gender adaptation can also occur as a result of exposure to male or female voices (Schweinberger et al, 2008), headless bodies (Ghuman, McDaniel & Martin, 2010) and even biological motion (Jordan, Fallah & Stoner, 2006; Troje, Sadr, Geyer & Nakayama, 2006). These effects might tell us about how the diet of faces which we encounter in everyday life update how faces are perceived and represented. This thesis will consider two types of adaptation after-effect: the face distortion after-effect (FDAE) and the face identity after-effect (FIAE). Table 1.1 provides a brief overview of the facial dimensions that have been investigated in adaptation experiments. The FIAE and FDAE will be explained in detail in subsequent sections of this overview.

Table 1.1

Classifications of Adaptation

Name	Techniques
FIAE*	1. Morph Continuum: exposure to an identity results in ambiguous morphs resembling a different, unadapted identity. ** 2. Anti-Faces (faces that are computationally opposite to a target face within a face space framework): exposure to an anti-face results in an average face resembling the target.
FDAE	1. Pinched Distortion (faces where the internal features are expanded or contracted): exposure to a pinched face results in a normal face looking expanded. ** 2. Configural Distortion: exposure to a face with increased eye height can make a normal face appear to have lower eyes.
Race/Gender/Age/ Emotion	Exposure to a female face results in gender-ambiguous faces appearing to look more masculine (similarly for happy/sad, Asian/Caucasian etc.)
Viewpoint/ Eye Gaze	Exposure to eye gaze/viewpoint oriented in one direction (e.g. to the left) can result in eye gaze/viewpoint oriented in that direction (to a lesser extent than the adaptor) appear to be directed towards the viewer.

* The FIAE is measured in a similar way to race/gender/age/emotion, however, the FIAE is mentioned separately in this table as the focus of this thesis is on identity processing.
* *This method of adaptation was used experimentally in this thesis.

Note. Classifications of the types of after-effects used in face adaptation experiments and how they are referred to in this thesis. This list is not exhaustive of all the perceptual effects of face adaptation (e.g. exposure to distortions can also affect attractiveness judgements). Its purpose is to provide a general introduction to aid the reader’s understanding of this overview.

At the time of starting this thesis, most work on face adaptation had been concerned with faces that were unfamiliar or familiarised to participants within the course of the experiment. Only a few studies had used adaptation to investigate familiar face processing. This seemed surprising, considering the differences between familiar and unfamiliar face processing. The central aim of this thesis was, therefore, to investigate our underlying representations for familiar faces using FDAEs and FIAEs as a tool. Papers 1 and 2 examined the role of explicit recognition of familiar faces with FIAEs. This was in order to find out whether recognition is required for adaptation to occur and to give us an insight into the neural mechanisms that might underlie familiar face processing. Paper 3 looked at what type of stimuli are sufficient to access representations for familiar individuals. In particular, it investigated whether moving faces produce after-effects equivalent to those produce by static images. This was to find out whether adaptation could occur with more ecologically valid stimuli. Most studies have used static images as adaptors, but when we see faces in the real world they are moving. Finally papers 4 and 5 used FDAEs in order to investigate how flexible our representations are for personally familiar faces. This was done by using distorted images of highly familiar faces (e.g. one's own face) as adaptors.

This overview will outline the adaptation literature to date that investigates the processing of identity, including how models of face processing have been used to explain findings from adaptation studies. It will also review what we know about familiar face processing, as indicated by other experimental paradigms.

1.2. Face adaptation

1.2.1. An Introduction to the Adaptation Techniques used in this Thesis

1.2.1.1. The face distortion after-effect (FDAE)

One of the first demonstrations of adaptation to faces was by Webster and MacLin (1999). They were able to induce face distortion after-effects (FDAEs) for faces (also referred to as figural after-effects). They did this by exposing participants to faces that were either expanded or contracted, relative to a midpoint on the nose (see Figure 1.2). These faces were distorted in terms of both their features (eyes, nose and mouth) and configuration (the distance between the facial features). The result of prolonged exposure to them was that undistorted faces appeared distorted in the opposite direction. For example, a face that had initially been rated as being normal prior to adaptation, looked contracted after prolonged exposure to an expanded face. FDAEs have also been demonstrated where the distortion applied to the adapting face just has a configural, but no featural, component. Robbins, McKone and Edwards (2007) demonstrated that adaptation could occur for faces with increased eye height. Looking at a face with the eyes moved up by 20 pixels made a normal face appear to have eyes lower than what was considered normal pre-adaptation. These findings suggest that exposure to certain types of facial characteristics can influence our perception of faces.

Image removed for copyright reasons.

Figure 1.2. An example of the stimuli used by Webster and MacLin (1999) – taken from Webster and MacLeod (2011).

1.2.1.2. The face identity after-effect (FIAE)

Leopold, O'Toole, Vetter and Blanz (2001) found that adaptation to a particular identity could bias perception of subsequently viewed faces. They used computer-generated face pairs, each of which consisted of an individual face and its corresponding "anti-face" (see Figure 1.3). The anti-face was computationally opposite to the original face in its appearance. For example if Henry had wide lips, then anti-Henry would have narrow lips. The anti-face was generated by mapping three dimensional and reflectance information between the target and an average face (consisting of 200 faces). Prolonged exposure to anti-Henry would result in the average face resembling Henry, but not other identities (Jim or Adam would not look more like Henry, after adaptation to anti-Henry). These findings have been interpreted as evidence for faces being processed within a multidimensional face-space (MDFS). It is suggested that within this MDFS all faces are stored around an internal "norm" (or average/prototype). Adaptation to an identity biases the norm away from that identity along the trajectory specific to that face, i.e. towards the anti-face (there will be more description of MDFS in section 1.2.3.).

Image removed for copyright reasons.

Figure 1.3. an example of the stimuli used by Leopold et al (2001) – taken from Webster and MacLeod (2011).

An alternative way that FIAEs have been measured is by using a morph continuum between two identities (e.g. Benton, Jennings & Chatting, 2006; see Figure 1.4). Exposure to one of the identities results in the morphs being more likely to be judged to resemble the second identity. Benton et al (2006) labelled their unfamiliar identities Barbara and Isabelle. Adaptation to Barbara resulted in more of the morphs being judged to look like Isabelle and vice versa.

Image removed for copyright reasons.

Figure 1.4. the morph continuum between two identities used by Benton et al (2006).

In the literature both methods have been referred to as identity adaptation. However, the Leopold et al (2001) stimuli are located directly opposite each other in regards to the norm face, whereas the faces used by Benton et al (2006) do not necessarily need to have these locations. Hills, Elward and Lewis (2008) suggest that it is possible that the latter type of FIAE may be operating via a different mechanism (this will be described along with MDFS in section 1.2.3.). The FIAE paradigm that was used in this thesis was similar to the Benton et al (2006) method. This method of adaptation suggests that exposure to a face can alter how we discriminate that face from others.

1.2.1.3. Do the FDAE and the FIAE tap into the same face processing mechanisms?

Webster and MacLeod (2011) argue that the mechanisms that underlie the FDAE and FIAE are probably the same. This is because what participants are adapting to is a configural deviation from either the average face (in the FIAE) or an undistorted face (FDAE). In both the FDAE and the FIAE, prolonged exposure to the average face (or an undistorted face) does not produce after-effects (Webster & MacLin, 1999; Leopold et al, 2001). Also, both the FIAE and the FDAE show a similar pattern of build-up and decay of adaptation for unfamiliar faces (Rhodes, Jeffery, Clifford & Leopold, 2007).

Other evidence suggests that FIAEs and FDAEs may be tapping into different processes. People with Prosopagnosia can have normal FDAEs but abnormal FIAEs, indicating a dissociation between the two (Palermo, Rivolta, Wilson & Jeffery, 2011). Storrs and Arnold (2012) have found that adaptation to gender and FDAEs differ qualitatively as they showed different patterns of response shifts. In the FDAE the appearance of the adaptor changed after adaptation: the distorted adapting face was judged to look more neutral (as opposed to looking pinched or expanded). This was not the case after adaptation to facial gender, e.g. a female adapting face was not judged to look more gender neutral after adaptation. This suggests that adaptation to different facial dimensions may operate via different mechanisms. Yet at present no such comparison has been made for FDAEs and FIAEs.

There also seem to be differences in transfer effects for the FIAE and FDAE (by transfer effects we mean adaptation transferring to another identity, i.e. someone other than the adaptor). The FIAE is identity specific: exposure to a particular familiar identity selectively adapts that identity, but not another, unadapted, familiar identity[2] (Hole, 2011). Yet, significant FDAEs have been observed when adapting and test faces are of different familiar identities (e.g. Carbon et al, 2007). It has, however, been suggested that some of the FDAE has identity specific elements too (Carbon & Ditye, 2010). Carbon et al (2007) found that they could produce FDAEs that were contingent on a particular identity which supports the idea of FDAEs selectively updating the representation of a specific individual. They were able to simultaneously adapt participants to an expanded distortion applied to one identity at the same time as a contracted distortion in another identity. If the after-effects were not selective for each identity then they should cancel each other out (also see Yamashita, Hardy, DeValois & Webster, 2005).

One reason why FDAEs may show transfer across identities is because the FDAE can arise from shape generic mechanisms, which are not face specific. They can transfer from a human face, to a clock face (Dennett, Edwards & McKone, 2012). They can also arise from second order configurations (distances between features) which do not belong to faces: for example, they can be induced by a T shaped adaptor (Suslio, McKone & Edwards, 2010) or by just three dots arranged in the position of the eyes and a mouth (Vakli, Nemeth, Zimmer, Schweinberger & Kovacs, 2012). This suggests that the overall observed FDAE is mediated by both shape and configural processing. Tillman and Webster (2012) suggest that the FDAE is more dependent on facial configurations than the FIAE. They found that FDAEs are the same size when adapting and testing on either the same identity, or a test face of a different gender. However, when the test face had a different expression to the adaptor, the after-effect was smaller.

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[2] However, it should be noted that FIAEs have been found to transfer to other *related* identities (e.g. Hills Elward & Lewis, 2010). For example adapting to Eric Morecambe produces after effects when testing on Ernie Wise.

In contrast, FIAEs are equivalent when the adapting and test face have the same or different expression (Fox, Oruc & Barton, 2008). Fox et al. also used contrast thresholds for discriminating faces to find out whether pairs of faces of the different identities were easier to discriminate than pictures of a single identity with different expressions. This revealed that the expression-independent FIAE was not due to perceptual similarity: two different people with the same expression were just as easy to discriminate as two pictures of the same person with different expressions. Taken together, the findings from Tillman and Webster and Fox et al. seem to suggest some dissociation between the processes involved in the FDAE and the FIAE: the FDAE might be more dependent on facial configurations than the FIAE.

1.2.2. Face or Low Level Adaptation?

Faces are processed by a distributed network (Haxby, Hoffman & Gobbini, 2000) and face adaptation may be occurring at multiple sites and at different levels of processing. Something which has been extensively researched is whether adaptation is occurring at the level of face processing mechanisms or whether it is the result of low level picture adaptation. There is evidence to suggest that face adaptation is not a purely higher-level, face specific phenomenon. Dickinson, Mighall, Almeida, Bell and Badcock (2012) showed that rapidly acquired face adaptation can be retinotopic and can occur as a result of tilt after-effects. They found that after-effects only occurred when the adaptor and test face were retinotopically aligned and that gratings can influence the perception of facial emotion (also see Dickinson, Almeida, Bell & Badcock, 2010). Also, colour and shape can contribute to FIAEs. Song, Shinomori and Zhang (2010) produced two morph series between faces that either varied in terms of colour or shape (facial contour) alone. Adapting to a colour chip or to a silhouette both produced significant after-effects. However, it is important to note that the FIAE was significantly smaller than when the adaptor was a face. This suggests that lower level properties like colour or facial contour cannot explain all of the FIAE.

Other research has shown that face adaptation is not the result of purely low-level picture adaptation. FIAEs have been found to transfer between faces with different orientations and sizes (e.g. Leopold et al, 2001). After-effects are present when orientation is incongruent, for example when adapting to an inverted face and testing on an upright face (e.g. Webster & MacLin, 1999; Robbins et al, 2007; Hills & Lewis, 2012; but also see Guo, Oruç & Barton, 2009). Rhodes, Jeffery, Watson Clifford and Nakayama (2003) found significant FDAEs when adapting and testing on faces at different orientations (-45° vs. +45°), suggesting that these effects are not retinotopic. Watson and Clifford (2003) used a similar orientation technique (-45° vs. +45°) except the distortion was either based on image properties or facial properties. In one condition their adapting face had a distortion along a horizontal axis, and was presented at -45°,and their test stimuli either had a distortion along a horizontal (same as the adaptor) or vertical (opposite to the adaptor) axis which was presented at 45°. If the FDAE was due to image properties then the after-effect would be observed for a test face with the vertical distortion, as it would be along the same axis as the adapting distortion (i.e. the axis of distortion would be the same). If, on the other hand, the FDAE was selective for facial properties then the after-effect would change orientation with the test face (i.e. the test face with the distortion along the horizontal axis would be affected). In practice they found that the latter was true: the FDAE changed orientation with the test face, suggesting face-specific adaptation. This was an extremely compelling demonstration of

FDAEs altering our perception of facial structure, rather than it affecting image based properties.

FDAEs and FIAEs have also been found to transfer between adapting and test images of different sizes (Zhao & Chubb, 2001; Anderson & Wilson, 2005; Leopold et al, 2001). Zhao and Chubb (2001) tested participants on faces that were either much smaller, or much bigger than the adapting face (e.g. either half or quarter of the size of the adapting face). The FDAE was biggest when the adapting and test faces were the same size, which may implicate the involvement of some lower-level mechanisms. However, there were still significant FDAEs even when the adapting and test face differed in size the most. This suggests that not all of the FDAE can be explained by retinotopic adaptation.

Leopold et al (2001) found that the FIAE was position invariant, as it transferred between adaptors and test stimuli separated by 6° of visual angle. However, their adapting and test stimuli did overlap spatially due to the size of the test stimuli, something which has been taken into account by subsequent investigations. Some of the FIAE is retinotopic, as the FIAE decreases when the adapting and test stimuli are not in the same location (Afraz & Cavangah, 2009). Kovacs, Zimmer, Harza, Antal and Vidyanszky (2005) found that adaptation to facial gender has both position specific and position invariant components. The size of the effect was bigger when the adaptor and test were presented in the same hemifield than in opposite hemifields, yet significant adaptation still occurred for the latter condition (also see Kovacs, Zimmer, Harza & Vidyanszky, 2007; Kovacs et al, 2006). The magnitude of the FIAE depends on the physical distance between the adapting and test stimuli, rather than which hemisphere they are presented to (Afraz & Cavanagh, 2009). Zimmer and Kovacs (2011) suggest that these findings point to higher level adaptation of neurones with large receptive fields.

It has been suggested that the neuroanatomical basis for position-specific adaptation is the occipital face area (OFA), whereas position-invariant adaptation has been found in the fusiform face area (FFA) (Kovács, Cziraki, Vidnyánszky, Schweinberger, Greenlee, 2008). Kovács et al. only found gender adaptation (indicated by a reduction in fMRI signal) in the OFA when the adapting and test stimuli were presented in the same hemifield. However, the FFA showed adaptation effects when the adapting and test stimuli were presented in the same or different hemifields. The OFA and FFA are both known to be involved in the processing of faces (Haxby et al, 2000). Using a FIAE paradigm, Furl, van Rijsbergen, Treves and Dolan (2007) also found that activity was reduced in these areas (see also Rotshtein, Henson, Treves, Driver & Dolan, 2005). However, the change in categorical perception (the identity boundary) which arose as a result of the FIAE, related to a heightened response in anterior medial temporal structures, including perirhinal cortex and anterior hippocampus. Other research suggesting that late visual areas are involved in high-level FIAEs used binocular rivalry to suppress the adapting face from awareness. Moradi, Koch and Shimojo (2005) found that FIAEs were diminished by binocular rivalry, but this was not the case for lower level orientation adaptation produced by drifting sinusoidal gratings. They suggest that the FIAE depends on late visual processing.

Our knowledge of faces seems to play some part in face adaptation. MacLin and Webster (2001) have shown that after-effects arise when a distortion is applied to a face, but not when it is applied to natural scenes. Also adaptation effects are bigger when the adapting distortion is a natural facial dimension compared to one that is anatomically impossible (Robbins et al, 2007). FDAEs have been found to be more selective for contrast polarity and spatial frequency, than for colour, size or contrast (Yamashita et al, 2005). Yamashita et al. argue that contrast polarity and spatial frequency have greater effects on the perceived identity of a face and the pattern of their findings suggests that FDAEs depend on the stimuli being viewed as faces.

Other research, not using adaptation techniques, has shown that inverted faces are processed differently from upright faces (e.g. Yin, 1969; Maurer, Le Grand & Mondloch, 2002). Yet Webster and MacLin (1999) and Robbins et al (2007) found that FDAEs were of a similar size for upright and inverted faces. Equivalent FIAEs can also be induced for upright and inverted faces (Leopold et al, 2001; Pichler, Dosani, Oruç & Barton, 2011). This seems surprising, given what we know about inverted face processing. Yet despite this, FDAEs can occur simultaneously for upright and inverted faces (Rhodes et al, 2004), which suggests they are occurring via different mechanisms (also see Guo et al, 2009; Susilo et al, 2010; Valki et al, 2012; Dennett et al, 2012). After-effects for inverted faces may stem from shape generic mechanisms, whereas after-effects for upright faces arise from both shape generic and face-space mechanisms. Susilo et al. found that using a T shape as the adaptor instead of a face could account for almost all of the FDAE in inverted faces, but only part of the effect for upright faces. This is an important finding, as it suggests that FDAEs do affect face processing mechanisms, rather than just more generic object processing mechanisms.

Very convincing evidence for face adaptation not being the result of low level picture adaptation comes from studies in which there is minimal physical overlap between the adapting and test stimuli (e.g. Hole, 2011). For example FIAEs can occur when the adapting and test stimuli have different expressions (Fox et al, 2008; Mian &

Mondloch, 2012). Studies have also shown that conceptual adapting stimuli (where no face is present) can produce face adaptation. Headless human bodies can produce FIAEs (Ghuman et al, 2010) and so can just seeing the name or hearing the voice of a person (Hills, Elward & Lewis, 2010). This rules out all of the effect being based on incoming visual information, and suggests that it does reflect person adaptation.

Overall, the evidence seems to suggest that both low-level picture adaptation and higher level face adaptation contribute to face adaptation. Most studies have shown the biggest effect when the adapting and test stimuli are the same. Hills and Lewis (2012) speculate that approximately half of the total FIAE effect can be explained by lower level adaptation. However, significant face adaptation can still be observed when physical overlap between the adapting and test stimuli is reduced. Even when the contributions of low-level attributes are eliminated or reduced, FDAEs and FIAEs still persist.

1.2.3. Theoretical Models Used to Explain Face Adaptation

The previous subsection provides evidence for adaptation affecting face-processing mechanisms. But an important question is what processes underlie adaptation to faces? This subsection will outline how models of face processing have been used to explain the findings from investigations of face adaptation.

Valentine's (1991) model for how faces are encoded postulates the existence of a MDFS. Within this face-space, each incoming face is encoded as a single point or vector based on dimensions used to discriminate faces. Valentine suggests that face-space is normally distributed. More typical faces are stored nearer to the centre of face-space and less typical (and more distinctive) faces are represented further away. The nature of an individual's face-space is largely dependent on their own experiences: the dimensions of face-space change, based on experience. Therefore typical faces, nearer to the centre of face-space, will be those seen more often, whereas distinctive faces are less common and are further away from the centre. As a consequence, a distinctive face is better remembered because there are fewer faces coded around it with which to confuse it. Valentine (1991) suggests that there are two explanations for how faces are coded within face-space. The first is a norm-based coding model, where incoming faces are encoded with reference to a norm or prototype (which is the central tendency of face-space). The second is an exemplar-based model which suggests that no norm is extracted and that only specific instances of faces are stored. Norm-based coding has been suggested to operate via opponent coding and exemplar-based coding has been linked with multichannel coding (Rhodes & Leopold, 2011). In opponent coding, two complementary pools of neurones code a given facial dimension (see Figure 1.5). One pool is optimally tuned to values above average, and the other for values below average. When viewing an average (mid-point) stimulus, both pools are equally activated. If one pool is activated for a prolonged amount of time, activity is eventually suppressed in that pool. This results in the relative contribution of the two pools being altered temporarily: perception will now be biased towards the opposite set of values. The mid-point (between the two pools) shifts due to greater activity in one pool compared to the other. The results of several face adaptation studies, using FIAEs and FDAEs, have been explained using this model (e.g. Leopold et al., 2001; Rhodes & Jeffery, 2006; Tsao & Freiwald, 2006; Robbins et al 2007; Susilo et al, 2010; Jeffery, Rhodes, McKone, Pellicano, Crookes & Taylor, 2011 ; Rhodes & Leopold, 2011; Short, Hatry & Mondloch, 2011).

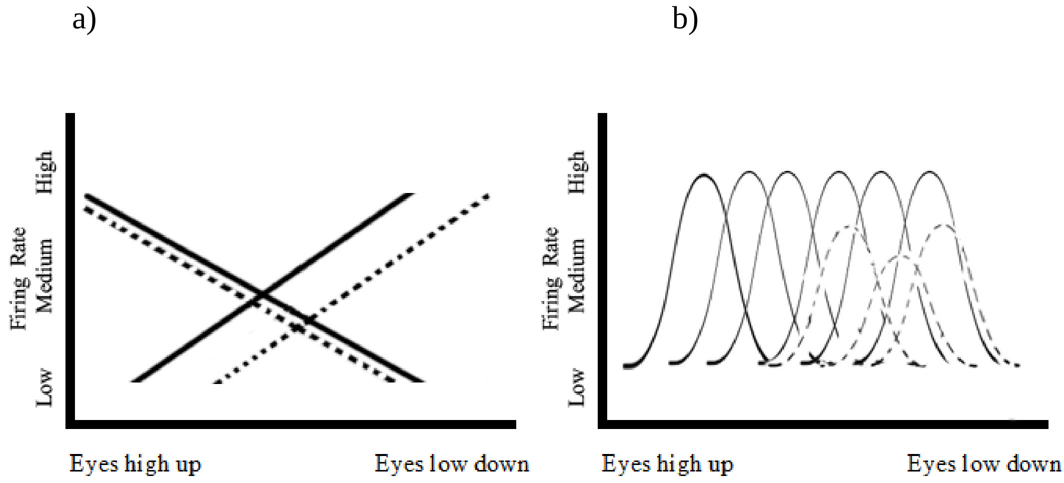

Figure 1.5. an example of the response shifts after adapting to a face with eyes low down for a) an opponent coding model and b) a multichannel model. The solid lines represent the pattern of activation before adaptation and the dashed lines represent the pattern of activation after adaptation. a) Exposure to a face with eyes low down results in a temporary reduction of the firing rate of the pool of neurones optimally tuned to low down eyes. The mid-point (or norm) where the two lines crossed has shifted towards the adapted facial dimension. b) Only the active channels have any reduction in their responsiveness. The channels with the biggest reduction are those that were the most responsive to a given stimulus in the first place.

In multichannel coding there are separate channels, each tuned to a specific stimulus value along a facial dimension. Perception is determined by averaging the responses of all the active channels. Adaptation to a given stimulus reduces the responsivity in the channels that code it: channels that are most responsive to the stimulus have the biggest reduction. The reduction in a channel’s responsiveness after adaptation, decreases in line with how responsive that channel was to the stimulus in the first place. Adaptation studies looking at eye gaze and head direction provide support for multichannel coding (Calder, Jenkins, Cassel & Clifford, 2008; Lawson, Clifford & Calder, 2011). An assumption of opponent coding is that adaptation to a neutral stimulus activates both pools of neurones equally, which results in no perceptual after-effect. In a multichannel system, exposure to a neutral stimulus will alter perception of that neutral stimulus and, albeit to a lesser extent, channels around the neutral point. Calder et al (2008) found that as a result of exposure to a face with direct eye-gaze (towards the viewer) eye-gaze that was actually directed a small degree to the left or right subsequently appeared averted to a greater extent. For example after adaptation, eye gaze which is averted slightly to the right will appear to be even more averted to the right. The authors interpret this finding as providing support for one of the assumptions of multichannel coding.

Rhodes and Leopold (2011) suggest that the results from face adaptation experiments using the FIAE and FDAE provide support for norm-based coding models of face-space, rather than exemplar-based models. They propose that FIAEs provide evidence for the norm playing a special role in the coding of identity. Target/anti-face pairs located opposite each other produce larger after-effects than non-opposite ones (Leopold et al, 2001). This effect persists when the opposite/non-opposite pairs are matched for their perceptual dissimilarity, suggesting that a trajectory through the average is critical in driving the effect (Rhodes & Jeffery, 2006).

Neurological evidence for norm-based coding of the faces used in some FIAE paradigms comes from Leopold, Bondar and Giese (2006). They found that neurones in Rhesus Monkey's anterior inferotemporal cortex (which has been found to respond selectively to faces e.g. Perrett, Rolls & Caan , 1982) seemed to respond in a way which suggested that incoming faces were being referred to an internal norm (average) face. The responses of a number of neurones increased as facial stimuli increased in identity strength[3] (i.e. were further along their identity trajectory from the average face). A similar pattern has also been shown in human imaging studies using synthetic faces (computer generated images based on geometric information from real faces; Loffler, Yourganov, Wilkinson & Wilson, 2005). ERP data have also shown that the N250 component (which is apparently influenced by facial identity) increases as an unfamiliar face increases in identity strength from an average face (Zheng, Mondloch, Nishimura, Vida & Segalowitz, 2011). Other evidence for norm-based coding is that the size of after-effects increases in a linear fashion as the amount of distortion applied to the adapting face increases. As the distance between the adaptor and the average face increases, so too does the size of the after-effect for both FDAE paradigms (Susilo et al, 2010; also see Robbins et al, 2007) and FIAE paradigms (Jeffery et al, 2011). The opposite pattern is predicted by an exemplar-based model, which suggests that there will be smaller after-effects for faces further from the average than for faces nearer to the average (Jeffery et al, 2011). This is because exemplar-based models predict that only channels around the adaptor will be affected. Faces that are more distinctive, and are less common, fall further away from the centre of face-space, and hence have fewer neighbours in face-space. Faces that fall closer to the centre of face-space are more common and have lots of neighbours close by. If adaptation is dependent on the amount of overlap between active channels, then faces further from centre will overlap with fewer faces (e.g. there are fewer active channels to adapt).

FDAEs transfer to test faces of a different identity to the adapting face (e.g. Webster & MacLin, 1999; Rhodes et al, 2003). Rhodes and Leopold (2011) suggest that

[3] In their model, each identity is considered to be positioned around an average face within a MDFS (the average might be considered to have 0% identity strength, an individual face has 100% identity strength). The trajectory between the average face and an individual face is what Leopold et al (2006) manipulated. As a face stimulus moves away from the average towards a given identity it increases in identity strength (from 0% to 100%). They used facial stimuli with different values along this continuum.

this is because the norm has been updated to reflect the diet of faces that an individual is exposed to. Transfer of FDAEs to other identities suggests that the norm has been biased. Not only that, but a grossly distorted adapting face appears more normal at test. Webster and MacLeod (2011) suggest that this provides evidence for renormalization within a norm-based coding model. The adapting face appears less distinctive (i.e. more normal) because it has shifted its position towards the norm. In effect, face-space has been recalibrated in response to the adapting face. As Webster and MacLeod (2011) point out, these findings do not fit in with exemplar-based models. Multichannel coding predicts that only the active channels are affected, therefore there should only be less sensitivity to the adaptor and other similar faces. Also, this would not change the appearance of the adaptor, only the faces surrounding it.

Rhodes and Leopold (2011) suggest that we might have multiple different norms for different categories of faces. This is because opposite after-effects can simultaneously be induced in faces from different social categories such as sex (Little et al, 2005; Bestelmeyer et al 2008) or race (Jaquet, Rhodes & Hayward, 2007; Short et al, 2011). Little, DeBruine & Jones (2011) even found that opposing after-effects could be induced after giving meaningful labels to faces displayed in different colours (e.g. blue faces labelled as builders and red faces labelled as soldiers). However, Short and Mondloch (2010) did not find the same pattern when the faces were the same colour, but were presented on coloured backgrounds. These contradictory findings require further investigation.

Yet it has also been shown that encoding of race can be modulated by its perceived race, regardless of its physical structure. Humans are worse at encoding other-race faces compared to own-race faces: this is known as the “other-race effect” (see Meissner & Brigham, 2001 for a review). Michel, Corneille and Rossion (2010) asked participants to complete a composite face task with racially ambiguous faces. A composite face is one where the top half from one face is paired with the bottom half of another face. The composite face effect (CFE) paradigm involves participants being presented with two composite faces and having to decide whether the top halves are the same identity or two different identities. Participants find this more difficult when the composites are aligned compared to when they are misaligned (the bottom halves are shifted relative to the tops). This finding suggests that faces are processed holistically, where misalignment disrupts holistic processing (e.g. Young, Hellawell & Hay, 1987). Michel et al. adapted participants to other-race or own-race faces, and then asked participants to complete a composite face task. After adaptation to a face from another race, subsequently-viewed racially ambiguous faces appeared to look like one's own race, and vice versa (e.g. Webster et al, 2004). Michel at al found that after adaptation there was a bigger CFE when the test faces were perceived as being the same race as participants, compared to when the faces were perceived to be from another race. The very same physical stimuli were processed more holistically after adaptation biased perception (e.g. towards one's own race). These findings suggest that how a face is categorised can affect how it is encoded.

Rhodes and Leopold (2011) propose that there are multiple view-specific norms for distinct viewpoints. They suggest that this is supported by two findings that: Firstly, FIAEs and FDAEs are smaller when the adapting and test faces differ in viewpoint, compared to when they have the same viewpoint (Benton et al, 2006; Jeffery et al, 2006; Jiang, Blanz & O'Toole, 2006, 2007). Secondly, different FDAEs can be induced simultaneously in different viewpoints (Jeffery et al, 2007; Welling et al, 2009). Rhodes and Leopold acknowledge that familiar faces may have more broadly tuned representations, and that they are easier to match and recognise across viewpoint.

However, they also suggest that a change in viewpoint between “familiar” adapting and test faces reduces the FIAE. The studies that Rhodes and Leopold cite used “familiar” faces that were familiarised within the experiment. A decrease in the size of the FIAE for changes in viewpoint was not found by Hole (2011), who used familiar faces with real world familiarity (famous faces). Equivalent after-effects were observed when the adaptors and test faces were in the same viewpoint, or different viewpoints. View-invariance is a hallmark of many models of familiar face processing (e.g. Bruce & Young, 1986). Jenkins et al (2011) provide an interesting critique of the computer models of face-space (on which Leopold et al, 2001 and subsequent face/anti-face studies are based). They suggest that an assumption of face-space is that different locations in face-space represent an individual identity; therefore any move within face-space changes the perceived identity of a face. Jenkins et al. found that two different photographs of the same person can look very different - so much so, that when the person is unfamiliar the pictures are more likely to be identified as being two different people. Yet accuracy in matching is almost perfect when the pictures are of a familiar person. This within-person variability is not taken into account by some models of face-space (namely the one on which target/anti face computations are based). Jenkins et al. suggest that models should be adapted to incorporate how we decide that different images show the same person, as well as how we tell people apart. It is therefore surprising that very few studies of face adaptation have taken familiarity into account. If experience shapes face-space, then it makes sense to investigate face-space with faces that people have actual experience with, i.e. familiar faces.

Lewis and Johnston (1999) suggest a modified version of Valentine’s (1991) exemplar-based model, where faces are encoded within a multidimensional Voronoi diagram (similar to Tanaka, Giles, Kremmen & Simon’s (1998) attractor fields model).

In this model, face-space is divided up into identity regions. At the centre of each region is the optimal version of that identity for recognition purposes. Lewis and Johnston argue that a model like this is advantageous because, rather than an individual identity being an exact point or vector in face-space (implying there is only one recognisable version), an identity region (or “site”) allows different views of an identity to be recognised, as long as the view is not more similar to another known identity. The model suggests that novel faces are encoded relative to the closest known exemplar. Yet this is a problem as it suggests that all novel faces will be misidentified, rather than classed as “unknown”. The proposed solution for this is that in order for a face to be recognised, there is a threshold of activation that has to be met. A novel face will not be recognised if it falls at the border of an identity region and does not meet the required threshold for recognition. Hills et al (2008) propose that within a Voronoi space, prolonged exposure to an identity (FIAE) may result in its identity region being temporarily smaller. Subsequently, in order to activate that region, greater identity strength will be required. Hills et al. used familiar face adaptation and it is the only study, to my knowledge, to have used a Voronoi framework to interpret face adaptation.

Both Hole (2011) and Hills et al (2010) have used the Interactive Activation and Competition model of familiar face processing (Burton, Bruce & Hancock, 1999) to interpret their findings from investigations of familiar face adaptation. In the IAC model there are pools of processing units for different modalities. A Face Recognition Unit (FRU) is activated in response to any recognisable view of a particular face; it is connected to a Person Identity Node (PIN) which allows access to semantic information about that individual. The PIN is connected to a Name Recognition Unit (NRU) which contains information about the person's name (e.g. Prince Charles) and a Semantic Information Unit (SIU) which contains information about them (e.g. that they are

British). Excitatory links connect associated units across pools (e.g. multimodal information associated with a particular individual) and there are inhibitory links between units within pools (e.g. between the FRUs for two different unrelated individuals). Burton et al. suggest that FRU activation may occur via a principal component analysis (PCA) for faces. PCA is similar to a factor analysis, where greyscale information from every pixel in an image is calculated. The factors that emerge from the PCA are known as “eigenfaces” and each face can be determined by a weighted sum from all the eigenfaces. Burton, Jenkins, Hancock and White (2005) suggest that a limitation of PCA is that low-level image attributes (e.g. illumination) can affect the output. They suggest that eigenfaces might be derived from image averages rather than being instance based. In other words, they found that PCA was more effective if different images of an individual were averaged together, prior to PCA.

One idea is that adaptation increases the threshold required for a unit (or units) to become activated (Hills et al, 2010). Prolonged activation of a FRU may mean that it is less responsive subsequently. As a result, a greater identity strength is now required in order to activate that FRU. Not only that, but because excitatory links connect the FRU to the PIN which is also connected to NRU and SIUs, adaptation can spread to different modalities. For example, prolonged exposure to someone’s name can also result in FRU adaptation, via the PIN. Hole (2011) suggests that familiar face adaptation could in principle occur at any level of visual processing, from low-level to face specific adaptation, whereas unfamiliar face adaptation is more likely to occur only as a direct result of visual processing (because no FRUs or PINS exist for unfamiliar faces). In contrast familiar face adaptation might occur indirectly at a more conceptual level (e.g. from reading someone’s name (NRU) or hearing their voice (VRU)).

There are various models that have been used to explain the mechanisms underlying face adaptation. Most of the researchers using unfamiliar faces (and some using familiar faces) have interpreted their findings using a norm-based coding model. Yet a problem with this model is that it does not seem to account for how we decide that different images are of the same person. The findings from a small minority of adaptation studies have been explained using models that take into account the differences between familiar and unfamiliar face processing (e.g. Voronoi and IAC models of face processing). In the next section, findings from studies using familiar faces will be outlined and how the authors have interpreted their findings will be discussed in more detail.

1.3. Adaptation Effects for Familiar Faces

Most studies on face adaptation have used unfamiliar faces. Relatively few have used familiar faces. The remainder of this chapter will summarise the findings (from adaptation and some non-adaptation studies) using familiar faces. Subsection 1.3.1 will consider famous faces and a summary of paper 1 (subsection 1.3.1.4.) and 2 (subsection 1.4.1.) will be provided. Subsections 1.5. and 1.6. will outline research on personally familiar faces: Section 1.5. will be concerned with lecturers' faces and paper 3 will be summarised; Section 1.6. will be concerned with faces with which we have extensive experience (e.g. our own face) and a summary of papers 4 and 5 will be provided.

1.3.1. Famous Faces

1.3.1.1. Why look at familiar face adaptation?

Most FIAE investigations using target/anti-faces have used unfamiliar (or experimentally familiarised) faces – see previous sections. There is one study that has used the FIAE paradigm with faces that have pre-existing representations. Little, Hancock, DeBruine and Jones (2012) produced anti-faces for a number of different celebrities. This is advantageous as in other paradigms (e.g. Leopold et al, 2001) participants are trained on the stimuli during the course of the experiment - which Little et al. suggest may result in cues or learning about the identity of the target which might affect performance. They found that exposure to an anti-face made an average face appear to look more like the target celebrity than another unrelated celebrity. This effect was more dependent on shape than it was on colour information: they produced anti-faces either based on shape or colour information alone, and only the former produced adaptation. They also produced male anti-faces for a female target celebrity. Adaptation only occurred when the anti-face was female and not when it was male. The authors suggest the findings provide evidence for norm-based coding and distinct norms for male and female faces. However, they do also suggest that the norm doesn’t necessarily need to play a special role in the encoding of identity. Norm-based coding is said to operate via an opponent coding system and the norm is signalled by the average activation of the two pools. The norm may be coded implicitly, as a consequence of equal activation of the pools above and below the mean, rather than explicitly playing a role in processing faces (also see Rhodes & Jeffery, 2006).

So far it seems as if both familiar and unfamiliar faces produce adaptation, but an important question is whether familiarity is an important variable to consider in face adaptation studies. An interesting difference between familiar and unfamiliar faces is in the time course of face adaptation. Morikawa (2005) found that for unfamiliar faces, an FDAE was still observable 30 minutes after adaptation. In a different study, McKone, Edwards, Robbins and Anderson (2005) found that the longest period between adaptation and test, where FDAEs for unfamiliar faces were still observed was 15 minutes; the FDAE for unfamiliar faces was no longer observed 24 hours after adaptation. However, this was after adaptation for a period of 160 seconds. When participants were adapted for 5 seconds, the FDAE was still observed after 10 seconds, but was no longer present after 20 seconds. (McKone et al, 2005). Overall this seems to suggest that FDAEs for unfamiliar faces are quite short lived - especially when one considers the time course of the FDAE for famous faces. Carbon and his colleagues (Carbon & Leder, 2005; Carbon et al, 2007; Strobach, Ditye & Carbon, 2010; Carbon & Ditye, 2012) have investigated the FDAE for famous faces and found a different pattern of results. In their procedure they adapted participants to celebrities with expanded or compressed distortions and tested them on the same image (picture adaptation), a different image of that celebrity (person adaptation), or a different celebrity (novel adaptation). They found significant adaptation for all conditions. The after-effects for picture and person were equivalent in size, and the after-effect for novel faces was smaller. Carbon et al. suggest that the FDAE consists of both an identity specific component (reflected in the fact that there was more adaptation for picture and person) as well as an updating of more general face processing mechanisms (reflected by the existence of adaptation in the novel condition). After-effects were present when testing 5 minutes, 24 hours (Carbon et al, 2007) and 1 week after adaptation (Carbon & Ditye, 2010, 2012). These findings suggest that for familiar faces, adaptation is more long lasting. Carbon et al (2007) suggest that FDAEs are not merely perceptual effects and do affect our representations for faces. Representations of familiar faces are flexible and they can be readjusted in response to new information about that face. Even iconic images are susceptible to this type of adaptation, e.g. the Mona Lisa (Carbon & Leder, 2006).

The findings outlined above provide a promising indication of how the mechanisms underlying familiar and unfamiliar face adaptation might differ. Perhaps unfamiliar face adaptation only temporarily biases face processing mechanisms common to all faces. In contrast, familiar face adaptation might have a more enduring effect on both identity specific and generic face processing mechanisms. This does need to be investigated systematically in order to rule out whether methodological differences are playing a role in the time course of face adaptation. For example Rhodes et al (2007) have shown that the size of after-effects varies as a function of how long the adapting and test stimuli are presented for: for unfamiliar faces, the biggest FDAEs and FIAEs occur after long adaptors (16 seconds) and short test periods (200 ms) (also see Leopold, Rhodes, Muller & Jeffery, 2005). Strobach et al (2011) have shown that adaptation duration can also modulate FDAEs for familiar faces when testing occurs 5 minutes and 24 hours after adaptation. Again, longer adaptation periods produce bigger after-effects. It is possible that factors such as this may influence the size of the after-effect, and how long the effects last. A systematic investigation of the effects of timings on face adaptation was, however, beyond the scope of this thesis.

The effect of familiarity on the FIAE has been investigated within a single experiment. Jiang et al (2007) found that the size of FIAEs increased as familiarity with a face increased. These familiarised faces were wholly unfamiliar to the participant prior to the experiment. They also found that the FIAEs transferred more across viewpoints as familiarity with a face increased, though the effect was still bigger when adapting and testing on the same view (also see Jiang et al, 2009). The faces used in this experiment were target/anti-face stimuli that were familiarised within the experiment. Before adaptation, participants were either familiarised with only one view of the target, or multiple views of it. Interestingly, in terms of the size of the FIAE, familiarisation with multiple views of the target provided no advantage over familiarisation with one view. Familiarisation with just a frontal view of a face produced equivalent FIAEs that transferred across viewpoint just as much as when participants were familiarised with multiple viewpoints (Jiang et al, 2007, 2009). Yet familiarisation with multiple views of a face did provide an advantage when testing on a novel viewpoint of that face. However, this was true only when the illumination of the adapting and test faces was inconsistent (e.g. adapting faces illuminated from the top right, and test faces illuminated from the top left). The authors suggest that this may be because experience with a face is needed in order to interpolate the representation of a novel viewpoint (Jiang et al, 2009). These findings highlight the importance of considering facial familiarity when investigating face adaptation. The increase in adaptation as a face increases in familiarity suggests that one cannot necessarily explain how familiar faces are processed by generalising from the findings of studies using unfamiliar faces. Findings from Jiang et al (2007, 2009) suggest that as we build up a representation of a face, its representation becomes more malleable (e.g. adaptable).

Benton et al (2006) found viewpoint dependence in their FIAE investigation (using a set of morphs as test stimuli). They used unfamiliar faces and found that the size of the FIAE decreased as the angle between the viewpoint of the adapting and test face increased. Similar to findings from Benton et al, Jiang et al (2007, 2009) found that the size of the FIAE was bigger when adapting and testing on the same viewpoint compared to two different viewpoints. This was the case for the faces in their study which had been familiarised the most. As mentioned in section 1.2.3., Hole (2011) found equivalent FIAEs when adapting to the same or different viewpoint (in relation to the test face). A difference between Hole and Jiang et al's studies is that Hole used famous faces with real world familiarity, whereas Jiang used newly learned faces. We have extensive experience with faces of celebrities through the mass media (e.g. television/films) and lots of studies investigating the processing of familiar faces have used famous faces. These findings relate to other behavioural literature which seems to suggest that we have abstractive representations of familiar faces and more view-dependent processing of unfamiliar faces (which depends more on picture matching) (see Burton, Jenkins & Schweinberger, 2011 for a review). There may be some differences in how famous and personally familiar faces are processed, however, this will be considered in more detail in subsequent sections of the overview.

Whether pre-experimentally unfamiliar faces are still unfamiliar after adaptation is another issue. The prolonged exposure to an unfamiliar face during adaptation may familiarise a participant with that face to some extent. Indeed, in order to complete a morph task, which can be used to test FIAEs, there needs to be some familiarity with a face. For example, when viewing a morph between two unfamiliar faces (e.g. Joe and John), in order to decide that a morph looks like Joe there needs to be some representation (perhaps an FRU) for Joe. Quiroga, Reddy, Kreiman, Koch and Fried (2005) found single neurones in the medial temporal lobes of the human brain responded to the faces of individuals that the patient had only seen very briefly before starting the experiment (e.g. the experimenter's face). It is, therefore, possible that FRUs can be formed very rapidly after very brief exposure. What the different findings from Jiang et al (2007) and Hole (2011) highlight is that faces with real-world familiarity can have FRUs that respond more robustly to a wider range of input. This relates to Burton et al's (2005) idea of faces being represented as averages. They suggest that familiar face recognition might operate via a PCA. The more views of a face we have experience with, the easier it is to recognise. Averages based on more individual instances of a face are less affected by image-specific "noise": identity specific information is preserved and non-diagnostic information is averaged out.

1.3.1.2. Evidence for abstractive representations of familiar faces from non-face adaptation literature

In their review, Burton et al (2011) mention that performance on tasks that involve matching two different photographs of an unfamiliar person is poor. Unfamiliar face processing relies more on pictorial codes, whereas familiar face processing relies on more structural codes. When participants are asked to match two different images of an unfamiliar person, performance is disrupted by photographic 'noise' (e.g. differences in lighting or viewpoint). This disruption is not as problematic when the faces are familiar: familiar face matching is not as susceptible to the effects of photographic noise. For example Bruce (1982) found that recognition of personally familiar faces was just as accurate when different versions of those faces (in terms of viewpoint or expression) were seen at presentation and test. A change of expression or viewpoint did reduce the accuracy of unfamiliar face recognition. A change of context can also disrupt the recognition of unfamiliar faces, but this is not the case for familiar faces (Davies & Milne, 1982). Davies and Milne (1982) found that when a celebrity's face was explicitly recognised, a change of pose or expression did not affect later recognition. Familiar faces can even easily be recognised from grainy CCTV footage, whereas performance is poor for unfamiliar faces (Burton et al, 1999).

Even vertical and horizontal stretching does not significantly impair recognition of familiar faces. Hole, George, Eaves and Rasek (2002) found that stretching a face, to twice its normal height or width, did not affect how long it took participants to recognise whether a face was famous or not. Bindemann, Burton, Leuthold & Schweinberger (2008) replicated this using a repetition priming paradigm, where flashing up a face very briefly (e.g. 500ms) increases how fast that face is recognised when it is presented for a second time. Participants were primed with either: the same image that they were tested on later, the same image horizontally stretched, the same image vertically stretched, a different image of the same celebrity, or an image of someone else. Participants completed this task whilst ERPs were measured, specifically the N250 component which is related to facial familiarity. Priming occurred in all conditions, except for when a different identity was used as a prime. There was equivalent priming for all conditions where the same image was the prime (even when that image was stretched). This was also reflected in the ERP data, with similar ERPs for all three conditions. They did find a N250 for different images of the same person, however, it was smaller than for when the image was the same. Overall these findings suggest that there is some image specificity, but familiar faces can still be accurately recognised despite disrupting image properties by stretching a face. The findings highlight how abstractive familiar face processing can be.

It has also been found that internal features (eyes, nose, mouth) are more salient for familiar faces than unfamiliar faces (e.g. Ellis Shepherd & Davis, 1979). Young, Hay, McWeeny, Flude and Ellis' (1985) participants completed a series of tasks in which they viewed just the internal (or external) features of a face alongside an image of a complete face. The participants had to decide whether the images were of the same person or of two different people. There was an internal feature advantage (IFA) for familiar faces. Participants were faster for faces that were familiar, compared to when they were unfamiliar. This familiarity advantage was even observed when the two test images were of different viewpoints. However, there was no familiarity advantage when the two test images were from the same picture. This relates to the idea of unfamiliar face processing being more dependent on picture matching (where no familiarity advantage was shown). The IFA has been found to be a good index of familiarity (e.g. Clutterbuck & Johnston, 2005; Osborne & Stevenage, 2008).

Megreya and Burton (2006) have even gone so far as to say that "unfamiliar faces are not faces". They found that when measuring performance on a matching task, unfamiliar upright face processing was related to inverted unfamiliar face processing. In contrast, upright familiar faces were not processed in a similar way to inverted familiar faces. As mentioned earlier, inversion disrupts configural coding, which is said to be a component of the normal processing of upright faces (e.g. Freire, Lee, & Symons, 2000). The authors suggest that similar mechanisms may underlie the processing of upright and inverted unfamiliar faces, and that these findings may mean that unfamiliar faces are not processed configurally (unlike familiar faces). The CFE is another demonstration of how configural processing can be disrupted. Young et al (1987) produced composites that were made up of two famous faces (see Figure 1.6). Naming was significantly slower if the top halves were aligned, compared to if they were misaligned or inverted. Also when participants are presented with two composite faces simultaneously, or sequentially, it is difficult to tell whether the top halves belong to the same person when the bottoms differ. Pairing the top half of a face with the bottom half of another face effectively results in a composite with the configuration of a new face. Again, misalignment or inversion make the task of identification much easier. The CFE has also been observed with unfamiliar faces (Hole, 1994) but the traditional CFE paradigm has been criticised for being a decisional rather than perceptual effect (see Richler, Gauthier, Wenger & Palmeri, 2008; Rossion, 2013). Chapter 2 of this thesis used composite faces within a FIAE paradigm. This will be considered in more detail in the next section.

Image removed for copyright reasons.

Figure 1.6. an example of a composite face composed of the top half of David Cameron's face and the bottom half of Ed Miliband's face. Identification is easier when the halves are misaligned (right) compared to when they are aligned (left).

1.3.1.3. The FIAE for familiar faces

The non-adaptation literature mentioned above suggests that familiar face recognition is not heavily dependent on factors such as expression, view-point or context. Research on the FIAE for familiar faces also supports the idea of abstractive representations (this will be outlined in more detail below). The findings seem to echo what has been found using other behavioural paradigms. An advantage of using adaptation is that what we are actually measuring is somewhat distanced from the stimulus that is producing the effect. Rather than measuring speed and accuracy on a matching task, what we are actually measuring is perception of something dissociated from the stimuli driving the effect (e.g. a morph presented after exposure to a face). This reduces the contribution of decisional factors related to the adapting stimuli, as we are measuring perception of something else.

As mentioned earlier, Hole (2011) found that the size of the FIAE for famous faces was the same when adapting and testing on different viewpoints as it was when adapting and testing on the same viewpoint. Hole also found that stretched test and inverted test faces can produce equivalent FIAEs to upright faces. This relates to the idea that our representations for familiar faces are view-independent: a FRU can be activated by any view of a face (Burton et al, 1999). Ryu and Chaudhuri (2006) looked at viewpoint after-effects – where, for example, looking at a face oriented to the right, makes a frontal view face appear to be oriented to the left. When the adapting face was unfamiliar, viewpoint after-effects transferred to an unfamiliar identity. However, when the adapting face was one that participants were familiarised with, the after-effect did not transfer to different test faces. The findings from Hole and Ryu and Chaudhuri suggest that looking at the transfer of adaptation across viewpoint is a good test of whether FIAEs are tapping into a specific familiar identity's abstractive representation, or a more general mechanism common to all faces.

Hills and Lewis (2012) directly compared FIAEs for famous and unfamiliar faces across various image manipulations (photographic negation vs. photographic positives; inverted vs. upright faces; high pass filtered vs. low pass filtered vs. unaltered). Overall there were bigger after-effects for famous faces than unfamiliar faces. However, FIAEs are not bigger for famous faces than for unfamiliar faces when the difference between adapting and test stimuli is more subtle. There is no effect of facial expression on FIAEs for familiar and unfamiliar faces when the facial expressions varied between the adapting and test faces. Identity, regardless of familiarity, seems to be represented in an expression independent manner (Fox et al, 2008). Again, this relates to other theoretical models of face processing. Bruce and Young (1986) suggest that during structural encoding of a face, there are expression-independent descriptions which activate FRUs.

Hills et al (2010) provide further evidence for familiar face adaptation occurring via an IAC model of face processing. They found FIAEs for famous faces after exposure to the same image as the adaptor, a different image of the same identity, a name or a voice. The two image conditions produced the greatest FIAEs, and the FIAEs produced by a name or voice were equivalent. FIAEs were also observed after semantic information was presented, but only when the information was very specific: names (e.g. Tony Blair) and specific role information (e.g. Prime Minister) produced FIAEs but not occupations (e.g. Politician) or nationalities (e.g. British). Further, FIAEs could be induced by a related person (e.g. adapting to Eric Morecambe produced after effects when testing on a morph continua between Ernie Wise and another familiar identity). In the final experiment in the series, FIAEs were observed after imagining a familiar face, although the resultant FIAE was smaller than after adaptation to a veridical image. Also caricatures produced bigger FIAEs than veridical images. Hills et al. interpret their findings as follows. Within-modality adaptation was greater than between-modality adaptation. In other words, the largest FIAE was produced when adapting and testing on an image (via FRU adaptation only). When adapting to a name (NRU), a voice (VRU) or specific related semantic information (SRU) and testing on an image (FRU) the effect was smaller as adaptation transfers/spreads across modality via the PIN. When adapted to an imagined face (PIN) and tested on an image of a face (FRU) the effect was smaller than after adapting and testing on an image (FRU in both cases) (but also see Hills et al 2008; DeBruine, Welling, Jones & Little, 2010). Hills et al. suggest that because caricatures produce bigger after-effects than veridical images, it may be that memory adaptation produces bigger after-effects than after-effects produced by visual characteristics. Perhaps FRU activation *and* perceptual adaptation together, produce greater adaptation than perceptual adaptation alone.

Hills et al (2010) also suggest that their findings mirror some of the results from repetition priming studies. For example if an image of a face is shown briefly, then that face is easier to recognise subsequently. Priming is most effective (i.e. speeds up subsequent recognition) if the same image is the prime. However different images of a particular identity can also act as primes (Ellis, Young, Flude & Hay, 1987; Bruce & Valentine, 1985). Also associative ("semantic") priming has been found. This is when an image of an associated person can act as a prime, e.g. brief exposure to Eric Morecambe facilitating subsequent recognition of Ernie Wise (e.g. Bruce & Valentine, 1986). Hills et al. suggest that adaptation and priming may be at two ends of a continuum of stimulation within the IAC model. Priming lowers the threshold for units to become subsequently activated and adaptation raises the threshold for subsequent activation.

Walther, Schwienberger, Kasier and Kovacs (2012) found that priming and FIAEs for familiar faces could be induced within the same paradigm and suggest that the claims made by Hills et al (2010) are difficult to test. Walther et al. tested FIAEs on a morph continuum with test faces ranging from 100% of one identity to 100% of another identity. The 100% end points were classed as unambiguous test faces and ambiguous test faces were those from the middle of the continuum (e.g. an image containing 50% of each identity). The unambiguous faces were identified faster after adaptation to that face (priming). However, after adaptation, the unambiguous faces were also perceived to look more like an unadapted identity (adaptation). Walther et al. suggest that priming and adaptation arise from different mechanisms as they can both be induced simultaneously. Walther et al. also used EEG recordings during their experiment. Interestingly, they found that adaptation modulated both the N170 (supposedly involved in structural encoding of faces) and the N250 (which reflects identity processing).

In this section the results from familiar face adaptation (and some non-adaptation) studies have been outlined. The adaptation and non-adaptation literature using familiar faces seem to produce complementary findings. The overall conclusion from what has been reported so far is that familiar faces seem to have abstractive representations whereas unfamiliar face recognition is more "pictorial" in nature (the influence of superficial image properties is greater). Section 1.2.2. of this overview summarised the lengths that researchers interested in face adaptation have gone to in order to show that face adaptation is not low-level (or pictorial). Familiar faces can be recognised over a wide range of images, so using familiar faces in adaptation studies is a good way of reducing the contribution of low-level adaptation. Also, as Burton and Jenkins (2011) point out, within-person variability is an important issue that we need to understand if we want to find out how humans recognise faces.

1.3.1.4. Summary of paper 1

As mentioned in the last section, the CFE paradigm indicates that faces are processed holistically. However, it has also been suggested that the traditional CFE is subject to decisional factors (Richler et al, 2008). Richler et al. suggest that in some experimental paradigms, it is unclear whether the CFE arises because a) the perception of the top half of a composite is affected by the bottom half or b) the decision boundary for the top half of the composite is affected by the bottom half. The initial aim of the experiment presented in paper 1 was to investigate holistic processing whilst reducing the contribution of decisional factors, by using the FIAE. As mentioned in the last section, an advantage of using FIAEs is that what we are measuring is physically and temporally different to what is producing the effects. The morphs are physically different to the adaptor and they are presented at a different time during the experiment (e.g. morphs presented after a composite face). This is a way of getting around the potential issues highlighted by Richler et al. Our dependent variable was not a measure of participants' decisions about the top half of the face (same/different judgements). Another reason for performing this study was to further investigate the parallels between priming and adaptation proposed by Hills et al (2010) - when we started this study, Walther et al (2012) had not yet published their findings. Steede and Hole (2006) used composite faces within a repetition priming paradigm and compared priming with the composites to priming with just the top half of a face (like the composite, except without the irrelevant bottom half). They found that when both types of stimuli (the composite and the top halves) were recognised, significant and equivalent repetition priming was found. When the stimuli were unrecognised, no repetition priming occurred.

There were three adapting conditions in our study: participants were either adapted to complete faces, aligned composite faces or misaligned composite faces. To construct the composite faces, the top half of Brad Pitt's face was paired with the bottom half of an unfamiliar face. For each adapting condition there were five adapting faces which were in different viewpoints - this was to reduce the physical overlap between the adapting and test stimuli. There was also a further control condition in which participants did not experience any adaptation. Participants were adapted for a total of 2 minutes before being presented with morphs between Brad Pitt and Jude Law to varying extents. Participants had to decide whether each morph looked more like Brad Pitt or

Jude Law. Participants in the "no adaptation" condition completed only the test phase. We also asked participants if they were familiar with the adapting face, both before and after the adapting and test phases. Recognised complete faces, and the recognised aligned and misaligned composites, produced significant and equivalent FIAEs. The unrecognised aligned composites produced no measurable adaptation.

The paper extends the literature as it shows that the CFE is not purely a decisional effect - during adaptation participants were not required to make any decisions about the top halves of the face. But the most interesting result from this experiment was that what we found for the aligned composite faces depended on whether it was recognised or not. We initially thought that perhaps the unrecognised faces might produce some adaptation because the featural information present in the face would partially activate Brad Pitt's representation. However, the percept of a configurally new face seemed to override the featural information. The findings suggest that facial configurations are important during the structural encoding of faces. The findings also suggest that there may be parallels between adaptation and priming in terms of how they are explained via an IAC model of face processing, as proposed by Hills et al (2010): they complement those of Steede and Hole (2006) in showing that explicit recognition of composite faces is important for both repetition priming and adaptation to occur. Importantly, the findings also cannot be explained by purely low-level adaptation: exactly the same adapting stimuli produced a different pattern of responses, depending on whether or not they were recognised.

1.4. The Role of Explicit Recognition in FRU Activation

What we found in the composite study (paper 1) was that explicit recognition played a role in the FIAE: without it, an FIAE was not observed. Other research has found that the FIAE depends on conscious awareness of the adapting face. Moradi et al (2005) found that binocular rivalry eliminated FIAEs, but they did find that an orientation after-effects persisted. Moradi et al. suppressed the face from conscious awareness. Our participants were attending to the adapting stimuli and were aware of its presence, yet were not aware of its identity. Stein and Sterzer (2011) found that FDAEs could occur outside of awareness under continuous flash suppression. However, this was only when low-level adaptation was not controlled for. The FDAE only occurred for partially visible adaptors when low-level adaptation was reduced, by presenting the adapting and test faces to different eyes or at different sizes. Other research has found that expression after-effects can persist when adapting faces are suppressed from awareness (Adams, Gray, Garner & Graf, 2010). However, another investigation using continuous flash suppression[4] (using an alternative method which the authors argue is more effective at suppressing awareness than the method used by Adams et al) found that expression after-effects were eliminated (Yang, Hong & Blake, 2010). Yang et al. did find that after-effects were observed when participants were attending to the suppressed adaptor. However, identity and emotion may be processed somewhat independently from each other (e.g. Bruce & Young, 1986; Haxby & Gobbini, 2011) and other non-adaptation research has shown that emotional faces can be processed without awareness (Williams, Morris, McGlone, Abbott, & Mattingley, 2004; Kiss & Eimer, 2008). The findings from Steede and Hole (2006) suggest that explicit

[4] Continuous flash suppression is a technique where constantly changing high contrast images presented to the dominant eye suppresses a static stimulus presented to the other eye from awareness.

recognition is needed for repetition priming to occur for identity. However, as with paper 1 of this thesis, Steede and Hole (2006) used configurally and featurally altered faces.

There is evidence that brain regions such as the FFA respond to faces that are suppressed from awareness, and even when the faces are attended to. Kouider, Eger, Dolan and Henson (2009) used familiar and unfamiliar faces in a masked priming study whilst measuring brain activity. Participants were either primed with the same view or a different view of a face. The behavioural data indicated more priming for the familiar faces than the unfamiliar faces. Kouider et al. also found significant priming for different and same view primes when the faces were familiar. Same and different view priming was only at trend level for the unfamiliar faces (*p*-values greater than .05 for both). The findings reported so far are for when the prime faces were not consciously perceived (also see Harry, Davis & Kim, 2012). However, even when the primes were consciously seen, the same pattern of results was found. The brain imaging data for the subliminal priming did not show a reliable familiarity difference, which *was* shown by the behavioural data (see Burton & Jenkins, 2011 for a discussion of the dissociation of findings between behavioural and brain imaging data). Repetition suppression was found in the FFA, medial temporal gyrus (MTG) and superior temporal gyrus (STS). For the long-lag priming, where explicit recognition did occur, there was an effect of familiarity. There was no repetition suppression for the unfamiliar faces. There was both repetition suppression for the familiar faces in the same regions as in the subliminal conditions, and also in the ventral frontal cortex. For both the familiar and unfamiliar faces there was repetition enhancement in a number or regions such as the bilateral frontopolar, dorsolateral prefrontal, and medial and bilateral inferior parietal cortices. The findings from this study suggest that facial identity can be processed outside of awareness. The behavioural data suggest that there is a familiarity advantage for priming different views of a face even when that face is not explicitly recognised (the participant was unaware of its presence).

Further research using masked priming has also shown a dissociation between physical and categorical processing of faces, depending on awareness of an identity. Gardelle, Charles and Kouider (2011) primed their participants with a morph continuum between two faces. These morphs were used as primes for target faces (targets were 100% of the identity of one of the faces in the morph continuum) and were either presented subliminally or supraliminally. Gardelle et al. found no priming for unfamiliar faces and significant priming for famous faces (like Kouider et al, 2009). However, there was an interesting pattern of priming effects, which depended on whether the prime was subliminal or supraliminal. The subliminal primes produced a linear pattern of priming: as the amount of the target face in the morph decreased, so too did the amount of priming (e.g. RTs increased). In contrast, when the morphs were presented supraliminally, the pattern of responses was not linear. The authors suggest that the pattern of priming seemed to suggest categorical processing for the identity of the prime. When there was a high level of the target identity in the morph, priming was highly significant and priming decreased steeply as the distance between the target and the prime increased (after the amount of the target identity contained in the morph fell to roughly 60%).

Overall the results from Kouider et al (2009) and Gardelle et al (2011) suggest that physical information in a face can act as a prime, outside of awareness. They also suggest that subliminal faces are processed by areas of the brain that are known to be involved in face processing. Yet the findings do suggest that awareness of an identity is needed in order for the face to be processed categorically and for brain areas beyond the

FFA, MTG and STS to become activated. However, these studies did consider awareness in terms of whether a face is physically seen, as did Moradi et al (2005). Also a potential confounding factor was that their subliminal stimuli (43ms) were presented for much less time than their supraliminal stimuli (300ms). Therefore it would be interesting to find out if the same findings are replicable when the subliminal and supraliminal stimuli were presented for the same amount of time (such as by using continuous flash suppression).

The finding of a dissociation between physical information and categorical identity decisions has also been found in a brain imaging study. Rotshtein et al (2005) presented their participants with a morph continuum between two faces. Three faces along a morph continuum between Margaret Thatcher and Marilyn Monroe could all be physically the same distance apart (e.g. containing 20%, 40% and 60% of Margaret Thatcher) yet the 20% and 40% faces might look more similar as they both resemble Margaret Thatcher. The 40% and 60% morphs might look more different as they cross the identity boundary, resembling Margaret and Marilyn respectively. Rotshtein et al. found that the FFA seemed to respond to identity changes in an image. If participants were shown two morphs that both looked like Margaret, the FFA did not respond. However, if the second morph looked more like Marilyn, then the FFA response was greater. The OFA responded to any physical change in the image, and did not respond to identity per se.

Unlike the work by Kouider and colleagues, in our work participants were attending to the face and were aware of its presence, yet they were not explicitly aware of its identity (e.g. they were unaware that they were looking at Brad Pitt). Also, the amount of time that participants viewed the adapting face was the same for all conditions. There is some evidence that faces can be processed covertly when the viewer is unaware that they are looking at a face. For example it seems that even though people with prosopagnosia cannot explicitly recognise faces, some display physiological and behavioural results that indicate covert recognition (Bruyer, 1991).

Other evidence that faces can be processed covertly comes from Tanner and Maeng (2012). They found that unfamiliar faces morphed with a celebrity's face were seen as more trustworthy than when the unfamiliar faces were morphed with another unfamiliar face that looked similar to the celebrity. Participants were not explicitly aware that the face resembled the donor celebrity. Interestingly, in one of their experiments they showed participants an unfamiliar "salesman's" face which was morphed with the golfer Tiger Woods and asked participants whether they would buy from this man. A second salesman was morphed with an unfamiliar face which looked similar to Tiger Woods. Incidentally, participants were tested before and after a scandal involving Tiger Woods. Before the scandal, participants were much more likely to buy from the salesman morphed with Tiger Woods. The opposite pattern was observed after the scandal. The results of this study are interesting. However, the amygdala seems to play a role in processing trustworthiness (e.g. Adolphs, Tranel & Damasio, 1998), and in their review Gobbini and Haxby (2007) suggest that the amygdala is less responsive to the faces of familiar people and may be more finely tuned to the processing of the faces of strangers. It is possible that judgements of trustworthiness (as in Tanner and Maeng's study) are subserved by a different (but not necessarily distinct) mechanism from that involved in recognising faces.

In the studies outlined above there seems to be some processing of a facial identity, even when FRU activation (i.e. explicit recognition) has not occurred. What the results from paper 1 show is that FIAEs cannot be induced when a face is physically present but the adapting identity is not explicitly recognised. However, the faces in the experiment had their configuration altered and some of their features altered. Michel et al (2010) found that categorisation of an adapting face (e.g. in terms of race) can affect holistic processing. It is possible that recognition of the composite resulted in the adapting faces being processed differently from the unrecognised faces. Collishaw and Hole (2000) found that featural and configural distortions affect familiar and unfamiliar face processing in a similar way and to the same extent (also see Schwaninger, Lobmaier & Collishaw, 2002). However, it is possible that the composite face had been altered so much, in terms of its configuration and features, that it was not possible to observe adaptation. The composites might have been coded as a wholly new face which did not overlap with Brad Pitt's representation. Perhaps FIAEs can occur outside of awareness, but the method used in paper 1 was not sensitive enough to observe it. We adapted participants to multiple views of a face and tested them on frontal view morphs. If unfamiliar face processing is more view-dependent than familiar face processing then perhaps we would observe adaptation when adapting and testing on the same viewpoint.

1.4.1. Summary of Paper 2

Paper 2 contains the findings from a series of six experiments which we conducted to investigate the role of explicit recognition in the FIAE. The first four experiments reported in paper 2 used cryptic faces (whose method of production is explained in the subsequent paragraph) as adapting stimuli and the last two experiments used celebrity's sibling's faces as adapting stimuli.

We presented the experiment reported in Paper 1 at the BPS Cognitive Section conference (2011, September). This resulted in collaborative work with Professor Peter Hancock (University of Stirling) using a different set of composite faces. The composite faces provided by Peter Hancock were frontal views of unfamiliar faces which had been transformed to contain 30% of the vector difference between an average male face and the face of a particular celebrity. This procedure produced unfamiliar faces which looked very subtly like a celebrity, but not enough for the viewer to be aware of the resemblance. Each of 20 unfamiliar faces was subjected to this procedure twice: once to transform them towards the footballer David Beckham and again to transform them towards the actor Jude Law. We therefore ended up with two face sets, henceforth referred to as 'David Beckham plus' faces and 'Jude Law plus' faces. These face sets were our adapting stimuli. In the first experiment in paper 2, there were four groups of participants: one group was adapted to 20 different frontal images of David Beckham, the second group was adapted to the 20 unfamiliar David Beckham plus faces, the third was adapted to the 20 unfamiliar Jude Law plus faces and the final group was adapted to 20 different frontal images of Jude Law. We tested participants on frontal view morphs between David Beckham and Jude Law.

In terms of the number of 'David Beckham' responses made following adaptation, there was a significant difference between the recognisable David Beckham and Jude Law adapting conditions. Participants who saw the recognisable David Beckham images made significantly fewer David Beckham responses than participants who saw recognisable images of Jude Law. This pattern of findings suggested a FIAE had occurred for each celebrity. If a FIAE had not occurred (i.e. chance alone dictated who the morphs resembled) then we would not expect there to be any difference between these groups for the number of David Beckham responses. We found the same pattern of findings for the David Beckham plus and Jude Law plus faces: fewer morphs were judged to resemble David Beckham after exposure to the David Beckham plus faces compared to participants who were exposed to the Jude Law plus faces, and vice versa. This suggests that FIAEs can occur outside of awareness: even though participants were not aware they were being exposed to David Beckham or Jude Law (i.e. their FRUs had not been activated) they behaved in a way to suggest a FIAE had occurred. These findings seem to contradict what we found in paper 1.

In the second experiment in this paper the method was exactly the same, except the morphs that we used were 3/4 views of David Beckham and Jude Law. So in this experiment participants were adapted to frontal view images and tested on 3/4 view images. We found the same pattern of findings for the recognisable versions of both celebrities: participants who had prolonged exposure to images of David Beckham made significantly fewer David Beckham responses than those who saw images of Jude Law. We did not replicate the pattern of findings for the plus faces. There was no significant difference in the number of David Beckham responses for the 3/4 morphs between participants who viewed the David Beckham plus and Jude Law plus faces. The results of experiment 2 suggest a significant FIAE for the recognised faces and no FIAE for the plus faces. The third experiment used the same frontal view test faces as in experiment one, except that they were stretched to twice the height. We only had two adapting conditions which were the two 'plus' face sets. As in experiment two, we found no significant difference in the number of David Beckham responses between those participants who were exposed to the 'David Beckham plus' faces and those exposed to the 'Jude Law plus' faces, suggesting no FIAE had occurred. Taken together, the findings from all three experiments suggest that the cryptic faces only produced adaptation when adapting and testing occurred on the same viewpoint. A change of viewpoint or stretching the test faces seemed to abolish the FIAE. This led us to believe that the FIAE we found in experiment one was the result of low-level adaptation (i.e.

because of the pictorial overlap between the adapting and test images). However, before we came to this conclusion we conducted a fourth experiment.

The fourth experiment differed from the previous three experiments in the following ways: Firstly we used a different set of transformed faces. Instead of the 20 unfamiliar 'plus' faces, we used the faces of 20 celebrities transformed towards David Beckham and Jude Law. Secondly, there were only two adapting conditions, which were the ' David Beckham plus' famous faces and the ' Jude Law plus' famous faces. The morphs that participants saw were the same frontal view images which we used in experiment one. We found no evidence of a FIAE: there was no difference in the number of David Beckham responses between participants who saw the 'David Beckham plus' famous faces or the 'Jude Law plus' famous faces. If the results of experiment one were purely due to low-level picture adaptation then we should have observed the same findings in experiment four. This suggests that what we were measuring for the 'plus' faces in experiment one was face adaptation. However, we do not think it was identity adaptation (i.e. no FRU was activated). The evidence presented in the overview so far suggests that FRUs for familiar faces respond to a wide range of input. Indeed, when the images of Jude Law and David Beckham were recognised, we found equivalent adaptation when adapting and testing within and between viewpoint (effect sizes revealed that the FIAE was the same size for both). The unfamiliar 'plus' faces only produced adaptation when the morphs were sufficiently similar (e.g. in terms of their shape and viewpoint) to the test faces. In the next section of the overview we will attempt to explain how the findings from these four experiments could be accounted for by models of face-space.

The aim of the last two experiments in paper two was to replicate the findings of the last four experiments but with the faces of celebritys' siblings. Siblings share genetic and environmental influences, making them what could be considered to be naturally occurring cryptic faces. We wondered whether looking at Brad Pitt's brother (Doug Pitt) would produce an FIAE for Brad Pitt (even when participants were not aware of any resemblance between the two). Before we conducted experiment five we first piloted an experiment on nine participants. We adapted participants to images of Doug Pitt and tested them on morphs between Brad Pitt and Jude Law, before and after adaptation. After debriefing our participants, upon completion, eight of them had absolutely no idea who Doug Pitt was and they did not report that he resembled Brad Pitt during the experiment. We found that these eight participants made significantly fewer Brad Pitt decisions after looking at Doug Pitt compared to the number of decisions made before looking at him (i.e. looking at Doug Pitt produced an FIAE for his brother).

We then went on to complete the main experiment, but this time we had different adapting conditions and participants were tested on frontal view morphs. Participants were either adapted to Doug Pitt (and tested on morphs between his brother Brad Pitt and Jude Law), Nicolas Cowell (test morphs between his brother Simon Cowell and David Beckham), James Haven (morphs between his sister Angelina Jolie and Scarlett Johansson) and Amy Stiller (morphs between her brother Ben Stiller and Johnny Depp). We found equally sized FIAEs for all adapting conditions, regardless of whether or not the adapting face was recognised. This replicates the findings from the first experiment: when adapting and testing on the same viewpoint, FIAEs can occur for a celebrity after looking at pictures of someone who resembles them (in this case, their sibling).

The final study from paper two replicated experiment five, except it aimed to find out whether the FIAE transferred across viewpoint for the unrecognised sibling faces. We just used the Doug Pitt adapting stimuli, with Brad Pitt/ Jude Law test morphs.

The adapting stimuli were all frontal views and the morphs were 3/4 views. When participants did not recognise Doug Pitt, there was no FIAE. Similarly, when they misidentified Doug Pitt as looking like another celebrity (e.g. John Travolta) there was no FIAE. Only a few participants in this experiment did recognise Doug Pitt as resembling Brad Pitt, and these participants' responses were consistent with what we found in experiment five: these participants made fewer Brad Pitt responses after looking at Doug Pitt. In other words they experienced an FIAE. The failure to find any transfer across viewpoint for the unrecognised faces replicated the findings from experiment two. Also, the failure to find any FIAE for the misidentified faces replicated the findings from experiment four.

1.4.2. Implications of Paper 2: Models of Face Processing

In this section we will try to interpret the findings in terms of models of face processing. The findings suggest that the recognised and unrecognised faces might be exerting their effects in different ways. The specifics of the first model were proposed by Peter Hancock.

The Bruce and Young (1986) model suggests that early visual processing performs view-dependent structural analysis of faces. This could be done using predictive coding (e.g. Friston, 2005) which leads to some structural representation of a face (possibly within a face-space). This structural encoding mechanism could operate via a norm-based coding model with an explicit norm, an exemplar model (e.g. multichannel coding), or the average of responses between two pools of neurones in an opponent-process model with no explicit norm. Friston suggests that predictive coding rests on hierarchical Bayesian inference. Levels of processing have both upwards and downwards connections between them. It is suggested that upwards connections transmit the information forwards and result in cells in upper levels responding in a pre-specified way (if there is an appropriate pattern of inputs). Downwards connections can modulate the responses of lower levels. The higher levels deal with more abstract information and the lower areas deal with more concrete information. What a higher area attempts to do is to abstract meaning from the data it receives from the lower areas. It does this by sending back a reconstruction of what it believes best fits the lower-level input. By predicting what the lower level input might be, the higher level is able to provide the lower level with contextual guidance. In turn the lower-level sends back an error signal if the prediction is not accurate in predicting its input. The error is the difference between what the lower level 'knows' (its input) and the abstraction (the reconstruction) sent down from the higher level. This whole process is completed simultaneously (Mumford, 1992).

Friston (2005) suggests that there are two subpopulations of units that encode a response to a stimulus. The first type of unit is where the meaning from the lower level is abstracted, based on the higher level's expectations. The second type of unit codes the error. At a given level of processing there are two units: one abstracts meaning from its downward connection and the second calculates error from its upward connection. As the activity of units moves upwards to higher levels of processing (which are more abstractive) the error signal in lower areas is suppressed. This is to minimize the amount of energy needed by reducing the amount of prediction error[5]. In Friston's (2005) own words " the activity of error units at any one level reflects states that have yet to be

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[5] It is suggested that biological agents must avoid surprise in order to maintain equilibrium with the environment (e.g. Friston, 2010). If an agent minimises free energy, then they implicitly minimise surprise. According to Friston (2005, 2010) minimising free energy is equivalent to minimising prediction error. In other words, successful perception and cognition are when prediction error is suppressed i.e. top-down predictions are able to explain away prediction error (Seth, Susuki, Critchley, 2012).

explained by higher-level representations and will wax and wane as higher-level causes are selected and refined" (p 827). If a high level decision is to be made (e.g. recognition of an identity) this will emerge after an initial visual response due to top-down influences, possibly by explaining away the prediction error at lower levels (e.g. an FRU being activated). FRUs might operate by predicting the pattern of activation produced by a structural representation within face-space (structural representation – see Figure 1.7). Note that FRUs are not necessarily single units (e.g. Burton et al (2011) suggest that rather than storing a canonical image of a person, our representation is based on all the experience that we have with a face).

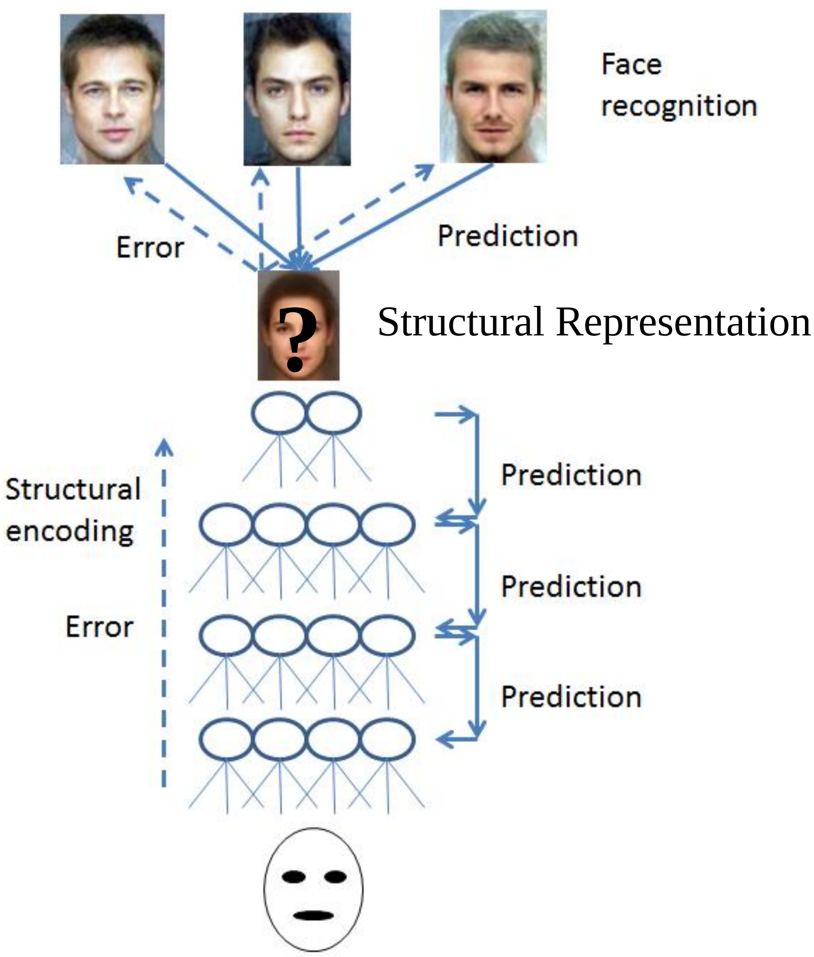

Figure 1.7. Model of face recognition using predictive coding. As activation moves to higher levels it becomes more abstractive.

This interpretation fits in well with He, Kersten and Fang's results (2012). They adapted participants to diamond and non-diamond shapes: in both cases, the outline of the shapes was formed from four tilted lines. He et al. found significant shape after-effects for the diamond shape, but not the non-diamond shape. They observed tilt after-effects for the shape outlines (the tilted lines) but these were smaller for the diamond stimulus than the non-diamond stimulus. He et al. suggest that perceptual grouping enhanced a higher level representation of shape and attenuated the lower level representation of bar orientation. They propose that higher level areas attempt to explain activity in lower areas. When higher level predictions match incoming sensory information, feedback might reduce activity in lower areas[6]. When the tilted lines interpreted as a diamond (due to perceptual grouping), this feeds back to lower areas and reduces their activity (reducing the tilt after-effect). When the higher area does not have any predictions about the information (non-diamond stimulus) there is no feedback to lower levels, so there is more activity there (increasing the tilt after effect).

In a predictive coding model of face processing, a standard FIAE (e.g. for David Beckham) happens at the level of FRUs. However, this will only occur when sensory information presented to the visual system is well accounted for by an FRU. Within a hierarchical model, the FRU is able to predict the pattern of activation at the level of structural encoding (by predicting patterns of activation in face-space). If this results in the recognition of an identity, then the error at lower levels is explained (i.e. the information is well accounted for by higher levels of processing). Adaptation of particular FRUs results in those units becoming less likely to fire. Following prolonged exposure to David Beckham, when an ambiguous morph between David Beckham and

[6] In a separate study using fMRI, Fang, Kersten and Murray (2008) found that when lines were perceived to form a coherent shape, activity in higher more abstractive levels of processing (lateral occipital complex) increased and activity in lower levels (primary visual cortex) decreased simultaneously.

Jude Law is presented, Jude Law's FRU is now better able to respond (see Figure 1.8, a & b).

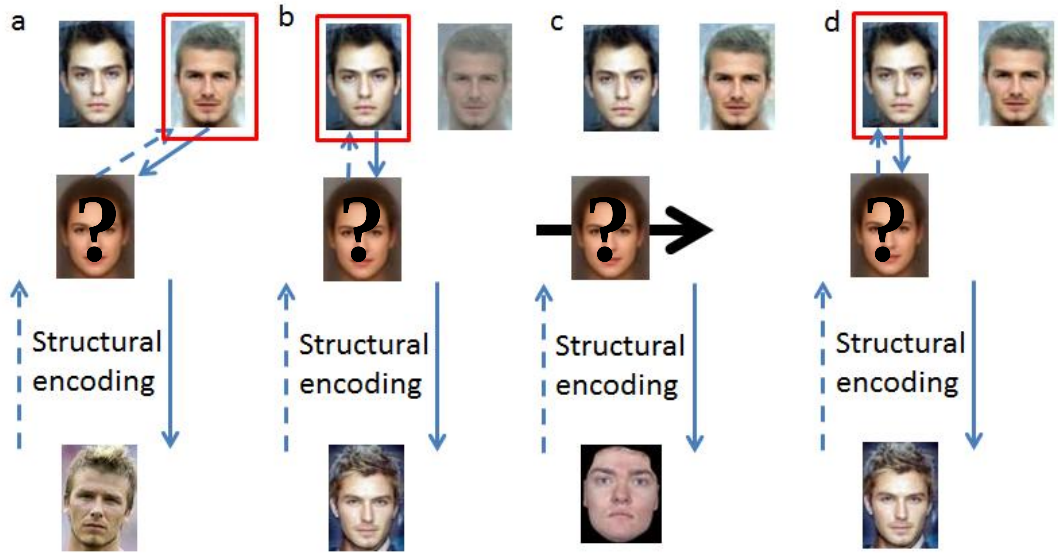

Figure 1.8. (a) and (b) depict the standard FIAE for David Beckham. (c) and (d) depict the after-effect for the faces transformed towards David Beckham. (a) The FRU for David Beckham is able to account well for the information in the adapting stimulus. (b) an ambiguous morph is presented to the visual system and Jude Law’s FRU is now better to respond. (c) no FRU can account for the information so the pattern of activation within face-space overlaps slightly with David Beckham’s. (d) an ambiguous morph is presented to the visual system and the Jude Law FRU is better able to respond.

If an unknown face is presented, which is transformed towards David Beckham, then there is no relevant FRU to account for this face's structural representation. In a norm-based model the average face shifts towards David Beckham; in an opponent-process model (without an explicit norm) the relative activation of two pools will shift towards David Beckham; in an exemplar model, all exemplars that share something in common with David Beckham will be active. When an ambiguous morph is presented, the Jude Law FRU will be better able to respond, because some representation of David Beckham has been adapted (see Figure 1.8, c & d) . If the morphs have been manipulated in terms of their shape or viewpoint, they become too different from the adapted structural representation for any effect of adaptation to be observed (structural analysis is viewpoint dependent). When the transformed faces are familiar, (e.g. Brad Pitt transformed towards Beckham), the FRU for that familiar face is activated and accounts well for the input. This would result in no detectable adaptation in face-space and would not affect decisions about the ambiguous morphs between David Beckham and Jude Law (see Figure 1.9, e).

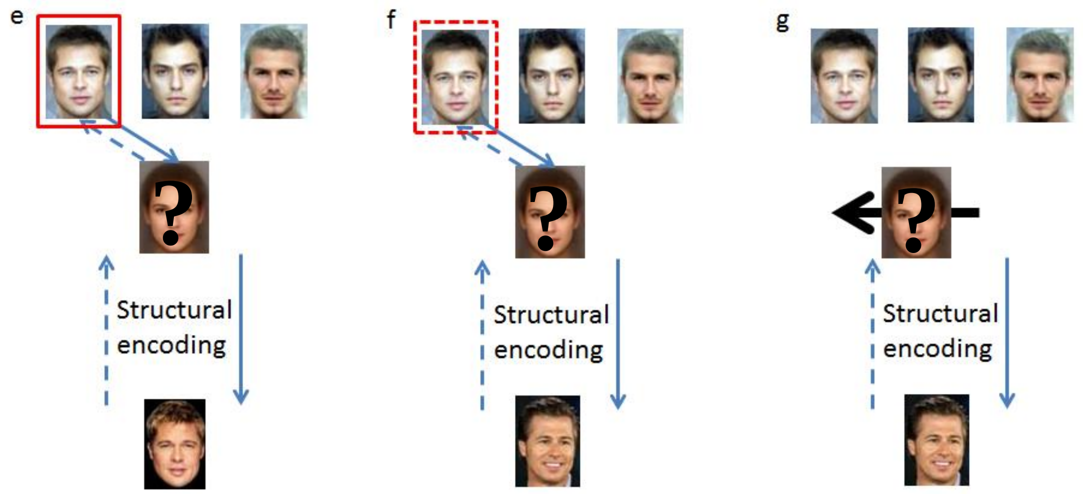

Figure 1.9. (e) depicts how the model accounts for the transformed famous faces (in this example Brad Pitt has been transformed towards David Beckham). Brad Pitt's FRU accounts well for the information so there is no adaptation in face-space. There is no detectable after-effect when testing on morphs between David Beckham and Jude Law. (f) exposure to recognised images of Doug Pitt activates Brad Pitt's FRU resulting in a FIAE for Brad Pitt (when testing on morphs between Brad Pitt and Jude Law). (g) with no FRU to respond, exposure to unrecognised images of Doug Pitt overlap slightly with Brad Pitts representation in face-space, as the brothers share structural similarities. When testing on ambiguous morphs between Brad Pitt and Jude Law, Jude Law's FRU is better able to respond.

If participants recognise a picture of Doug Pitt, Brad Pitt's FRU becomes somewhat active (at least active enough to account for the input and minimise prediction error). After prolonged exposure to Doug Pitt, Brad Pitt's FRU becomes less likely to fire when the visual system is presented with ambiguous morphs - a standard FIAE (see Figure 1.9, f). However, when participants fail to recognise Doug Pitt, no

FRU becomes active enough to account for the error signal. There is then some adaptation within face-space for a face that overlaps a bit with Brad Pitt's representation - presumably because the brothers share structural similarities. When an ambiguous morph is presented (between Brad Pitt and Jude Law), Jude Law's FRU will be activated more relative to Brad Pitt's FRU (see Figure 1.9, g). If the morph contains a different viewpoint, then the output of the structural encoding system (which is viewpoint dependent) is too far removed from the recognition stimulus to have an effect.

We are not the first to suggest that face adaptation can be explained by predictive coding. Furl et al (2007) and Furl, van Rijsbergen, Treves, Friston and Dolan (2007) have also proposed that face adaptation might operate via predictive coding rather than being a result of firing rate fatigue. They point out that an assumption of norm-based coding is that the mechanism that underlies adaptation is firing rate fatigue of neurones (via adjustments of the contributions of the two pools of neurons). They suggest that another possible explanation could be that adaptation reduces the amount of prediction error for that stimulus. The behavioural responses made during adaptation could be framed as a bias for the perception of novelty (i.e. being more likely to perceive the unadapted identity in the morphs). Top-down predictions are influenced by prior expectations which are based on recent experience. After adaptation, prediction error for the adapting stimulus is reduced and subsequent incoming information is signalled by deviations from expectations (i.e. prediction error). An ambiguous morph will now appear to be novel, compared to the adaptor, as there will be relatively more prediction error than there was before adaptation.

Whether the FIAE is a result of neuronal fatigue or a bias towards the perception of novelty is beyond the scope of this thesis. However, what the present findings do suggest is that whatever is adapted in the FIAE might depend on whether or not a familiar face is recognised. The model proposed here attempts to explain the empirical findings of this thesis in terms of a framework in which our expectations (top down predictions) could influence our perception and possibly the site at which adaptation occurs. Hancock's predictive coding model is still in development. However, it accounts nicely for the findings presented here, and provides a promising starting point for understanding how recognition can influence our perception of a face.

Another possible way to explain the findings in paper 2 could be by means of a Voronoi model (Lewis & Johnston, 1999). In this model there are identity regions in face-space which need to reach a threshold of activation for recognition to occur (see section 1.2.3.). Adaptation to all of the recognised stimuli in papers 1 and 2 might result in the corresponding identity regions being less responsive and therefore might cause a reduction in the size of those regions (as proposed by Hills et al, 2008). This reduction in size could explain why morphs are less likely to be judged to resemble the adapted identity. The model predicts that unfamiliar faces fall at the border of an identity region and they are not recognised if they do not meet the threshold required for recognition. The "unfamiliar" faces in our experiments (e.g. unfamiliar transformed faces and unrecognised sibling faces) produced adaptation for their related celebrity, so perhaps they fell at the border of that celebrity's region. Prolonged activation at the border of the region could result in a reduction in responsivity at the region's border. The internal region remains unchanged, but some of the border is now less responsive. In effect, the size of the region which is responsive is now smaller. This could explain why fewer of the morphs appeared to resemble the related celebrity. However, a limitation of the Voronoi model is that it does not explain why adaptation only occurred when the test images matched the adaptor in terms of its shape and viewpoint.

An advantage of the Voronoi model is that it does explain why exposure to the famous transformed faces, and the misidentified faces, failed to produce any after-effects. The model suggests that a face will be recognised (and will fall within a particular region) as long as a view is not more similar to another known identity. Perhaps the famous and misidentified faces fell within a different region to the one whose responsivity we were measuring. For example the recognised transformed famous faces (who were recognised as individual celebrities rather than being recognised as containing David Beckham or Jude Law) all fell within different regions and so would not produce adaptation in the same way as the unfamiliar faces (e.g. they would not fall at the border of one region). The misidentified faces looked more similar to another unrelated identity. For example, a few participants misidentified Doug Pitt as resembling John Travolta. This would presumably result in Doug's face falling within John Travolta's region and would therefore not have any effect on the size of Brad Pitt's region. If the unrecognised composites (in paper 1) were seen as a wholly new face, perhaps there was no adaptation to Brad Pitt because this "new" face fell within a different identity region. However, in view of the findings from paper 2, it could be that in paper 1 our paradigm was not sensitive enough to pick up any adaptation. It is possible that had we adapted participants to just a frontal view of the composite face, and also tested on a frontal view, we may have observed some adaptation.

A possible confounding factor could be that we used different stimuli in experiment 1 and 4 (paper 2). The famous transformed faces were more attractive than the unfamiliar transformed faces. If attractive faces are more average than unattractive ones (e.g. Langlois & Roggman, 1990) then famous faces might fall nearer to the centre of face-space whereas the unfamiliar faces might fall further away from the centre. Rhodes et al (2003) have shown that attractiveness decisions match normality decisions, and suggest that less attractive faces are those that are less prototypical. In a norm-based coding model, more distinctive faces produce bigger after-effects than less distinctive faces. For example it has been found that as an adapting face increases in identity strength (increasing its distance from the norm) the size of the FIAE increases too (Jeffery et al, 2011). This could be why we observed more adaptation for the unfamiliar faces: because they were less attractive, they were less prototypical and hence more adaptable. However, we believe that this explanation is unlikely in practice. DeBruine, Jones, Unger, Little and Feinberg (2007) have shown that there are non-average facial characteristics which are considered to be very attractive. We conducted a pilot study on 36 participants (18 males, 18 females) where we adapted them to an unfamiliar female's face and a famous female's face. We found a significant FIAE for both faces, and there was no significant difference in the size of the effect between the famous and unfamiliar faces. If famous faces are less adaptable because they are more attractive then we should not have found this pattern of results. Instead we would have found that the famous face was less adaptable than the unfamiliar face. Also, exactly the same stimuli were used in experiments 5 and 6 and produced a similar pattern of results to those observed in experiments 1 and 4.

Overall, the findings suggest that recognition of a familiar face can have implications for how that face is processed. If a face is recognised, then during adaptation there is a loss in sensitivity to that person which is probably occurring via selective fatigue of their FRU. This loss in sensitivity is not dependent on the format in which the test images are presented (relating to the idea of abstractive face representations for familiar faces). If researchers are interested in *person* adaptation, then care should be taken to eliminate adaptation occurring at a lower level; by lower-level we do not mean picture adaptation, but at a lower level of face processing than

FRUs. If a face is not recognised then there is a loss in sensitivity to that identity, but it is more dependent on image properties. This relates to the findings from Gardelle et al (2011); if the viewer is not explicitly aware of an identity then they are able to respond to its physical properties. Taking all of the above into consideration, the best fit for our findings is the first model. If there is sufficient information to activate an FRU, then in order to reduce prediction error, an FRU is what is adapted. If a face is unrecognised, not accounted for by an FRU, then some representation within face-space might be what is adapted. This representation within face-space is not abstractive: it is dependent on viewpoint and shape. Carbon and Ditye (2010) propose that face adaptation can be representational and perceptual. Our findings suggest that when a FRU is activated, adaptation is representational e.g. it is specific to that identity. If an FRU is not activated then adaptation might be more perceptual rather than updating the memory of a particular face.

1.5. Personally Familiar Faces

1.5.1. Lecturers' Faces

In the last section of the overview we outlined research about how familiar face processing is more abstractive than unfamiliar face processing. Papers 1 and 2 of this thesis used famous faces, however, there is some evidence to suggest that our processing of personally familiar faces might be even more abstractive. Famous faces can be highly familiar to the viewer, but experience is usually limited to media exposure (e.g. films or magazines). Personally familiar faces are faces for which we have real world experience and are used to seeing under more natural viewing conditions. Paper 3 of this thesis used lecturers' faces which were personally familiar to our undergraduate participants.

Bruce (1982) speculated that famous faces might be more recognisable than the faces of personally familiar lecturers: it might be easier to become famous if your face is distinctive. However, Carbon (2008) found that memory for famous faces was based on a more iconic representation than the faces of lecturers. When participants were shown pictures of famous faces and their lecturer’s faces in an uncommon view (e.g. before they were familiar) or modified in some way (e.g. by adding/removing facial hair), performance was poorer for the famous faces than it was for the lecturers’ faces. Herzmann, Schweinberger, Sommer and Jentzsch (2004) looked at ERP correlates and found that the N250r (associated with activation of a stored identity’s representation) was larger for personally familiar (lecturer) faces than for famous faces (it was also bigger for famous faces than for unfamiliar faces). Also changes in skin conductance responses were associated only with personally familiar faces, suggesting they have emotional relevance (Herzmann et al, 2004). Overall, some of the findings outlined above indicate that the representations of lecturers' faces might be more abstractive than for famous faces. There is one study that has used personally familiar, famous and unfamiliar faces within an FIAE paradigm (Fox et al, 2008). Fox et al compared the size of the FIAE when adapting and testing on faces of either the same expression, or different expressions. They found that the FIAE was the same size, regardless of whether the expressions were the same or different. However, there was no significant effect of familiarity in this experiment.

1.5.1.1. Is adaptation functional?

In section 1.2.3. it was considered how adaptation might calibrate face-space in the short term. Whether adaptation plays any functional benefits in aiding our perception of faces is a question which there has been some attempt to address. Some authors have suggested that adaptation is not functional as it does not improve ability on search or discrimination tasks (Ng, Boynton & Fine, 2008). Ng et al concluded that adaptation does not play any role in everyday face processing tasks. Other research suggests adaptation might provide some advantage. Michel et al (2010) have shown that adaptation to a face from a different race improves holistic processing of racially-ambiguous stimuli. After adaptation to an other-race face the ambiguous composites resembled one’s own race and performance on a CFE paradigm was impaired. However, this advantage seems to stem from the ambiguous stimuli resembling one's own race, rather than improving a more general ability for faces of another race. Rhodes, Watson, Jeffery and Clifford (2010) have shown that five minutes of exposure to the face of another race can make it easier to identify individuals from that race. Before adaptation, Caucasian participants were trained to identify four faces from another race and four from their own race. They also saw different versions of each face that varied in their identity strength: each face was morphed with a same race average to different extents. After adaptation to an Asian face, much less identity strength was required to identify the Asian faces, compared to before adaptation - however, adaptation to an Asian face did not facilitate identification of Caucasian faces. After adaptation to a Caucasian face, there was less identity strength required to identify both Caucasian and Asian faces. The authors suggest adaptation enhances identification ability, however, they do acknowledge a general practice effect could account for some of their findings.

One proposal is that face adaptation might enhance our discrimination of faces around an average/norm (e.g. Webster & MacLeod, 2011; Rhodes & Leopold, 2011). Rhodes Maloney, Turner, and Ewing (2007) conducted a series of experiments to find out whether adaptation could enhance discrimination around an average face. Their rationale was that adaptation might highlight differences between faces that we encounter the most. This was not what they found in practice: participants' ability to discriminate between faces that had an average appearance was not better after adaptation to an average face. Suslio et al (2010) have also shown that the ability to discriminate mouth and eye position is just as good for faces with eyes high-up/low-down as for normal faces. This suggests that our ability to discriminate faces near to average is not any better than for faces further from average. Rhodes et al do argue that their findings are not necessarily inconsistent with norm-based coding models of face processing, citing work by Leopold et al (2006) and Loffer et al (2005) which found that our face sensitive cortex increases in activity as a face becomes more distinctive (see section 1.2.3.) Rhodes et al propose that perhaps neural activity is minimised for faces that we have the most experience with. However, Kahn and Aguirre (2012) argue that there are confounding factors with the experimental designs of these studies. They suggest that because faces nearer to the mean are less physically distinct, blocks of prototypical faces presented together might be subject to more neural adaptation. Therefore the reduced responsiveness for the near average faces could be the result of neural adaptation, rather than due to an increase in responsiveness as a face increases in identity strength. This potential confound will need to be considered in future research.

There is some evidence that adaptation improves our ability to discriminate between faces around the adapting face (Rhodes & Leopold, 2011). This has been found for identity (Oruç & Barton, 2011), gender (Yang, Shen, Chen & Fang, 2011) and viewpoint (Chen, Yang, Wang & Fang, 2010). Webster and MacLeod (2011) draw on the colour literature which suggests that adaptation plays a role in colour constancy. Perhaps in the same way that colour constancy removes responses to irrelevant information (such as variations in illumination) from our perception of a stimulus, adaptation might remove uninformative information from our perception of faces. At the same time it might fine-tune our perception to diagnostic cues for our perception of faces (e.g. for an identity). This receives partial support from the literature. Carbon et al (2007) pointed out that while our perception of familiar faces can be affected by exposure to distortions, the identities of those faces are still recognisable. Also Walther et al (2012) have shown that priming effects can be observed when testing on unambiguous morph faces within the same experimental paradigm in which adaptation was found (adaptation was only observed for the ambiguous morph faces). Rather than the FIAE for familiar faces simply reflecting a loss in sensitivity to that face via neuronal fatigue, perhaps it actually makes us better at picking out veridical versions of that face. An ambiguous morph contains identity irrelevant information and adaptation might improve our ability to reject that identity-irrelevant information (rather than simply reflecting fatigue). This hypothesis requires more investigation. Walther et al tested their participants by presenting a morph between two identities for 300 ms and then images of the two identities. It would be interesting to find out whether the same pattern of effects is observed when participants are asked to judge who the face resembles from memory, rather than picture matching. Also the adapting and test images were the same (albeit different sizes) so would the effect persist when different images were used (reducing the contribution of low-level picture adaptation)? If adaptation does help us to fine-tune our perceptual system, by making our representations more abstractive, an interesting question is whether the same advantage will be found for unfamiliar faces. After all, the research outlined earlier suggests that unfamiliar face recognition is more disrupted by non-diagnostic image properties.

Daelli (2011) used Greebles within an identity after-effect paradigm (an ambiguous morph between two Greebles was the test stimulus). Greebles are a computer generated stimulus set that were created to be a control condition to be used in face processing experiments. Like faces, they have a similar number of parts in a similar configuration (Gauthier & Tarr, 1997). Daelli found that as participants were familiarised with Greebles, they were more likely to have an after-effect. This familiarisation advantage was found when the adapting and test images were of the same or different sizes (to control for low-level adaptation). When low-level adaptation was controlled for, Greebles that had not been familiarised were less likely to produce after-effects. Daelli suggests that a pre-existing representation is needed in order for after-effects to occur for novel objects. It might be that adaptation does fine-tune our perceptual system, by enabling us to reject ambiguous stimuli as resembling an identity, but only to the extent that we have a pre-existing representation. That might explain why adaptation is more viewpoint-dependent for unfamiliar faces (e.g. Benton et al, 2006).

1.5.1.2. Does adaptation happen in the real world?

Rhodes and Leopold (2011) propose that adaptation may calibrate face-space in the long term. Through adaptation, the diet of faces to which we have exposure may influence how we perceive faces. The research outlined above indicates that adaptation might be functional. Whether it actually is, and what its function is, lies beyond the scope of this thesis. However if adaptation is functional, then as a pre-requisite, adaptation should occur for ecologically valid stimuli.

There is some evidence to suggest that adaptation might happen in the real world from adaptation research looking at race and gender (see Webster and MacLeod, 2011 for a review). Webster et al (2004) tested Japanese and Caucasian participants on a morph continuum between an average Caucasian and an average Japanese face. They found that the perceptual boundary between these two faces changed depending on experience. Japanese participants who lived in the US for longer periods had a perceptual boundary more similar to that of Caucasian participants than to that of Japanese participants who had just arrived in the US. Attractiveness decisions also differ depending on experience. Tovee, Swami, Furnham and Mangalparsad (2006) have demonstrated that what is considered attractive can vary between cultures. They also found that moving from one culture to another shifts attractiveness decisions. In the case of gender, there is evidence that children at single-sex schools prefer faces more similar (masculinised or feminised stimuli) to their own gender than children at mixed sex schools (Saxton, Little, DeBruine, Jones & Roberts, 2009). Carbon and Ditye (2012) found that FDAEs could occur when adapting and testing took place in different places outside of their experimental laboratory. For example, in one condition they adapted their participants in the laboratory and tested them seven days later in "an informal leisure room setting". Carbon and Ditye suggest that adaptation effects are not the result of episodic memory but reflect how our representations for faces can be updated depending on our experience. It seems that there is some evidence to suggest that adaptation might change how we see faces in the real world.

The above subsections have discussed how adaptation might be functional and whether it happens in the real world. If both of these assertions are true then it could be argued that adaptation should be observed after exposure to more realistic stimuli. In other words, it should be observable after exposure to adapting stimuli that are more similar to what we see in our everyday lives. When we see faces in the real world they are moving. However, not many studies have looked at whether adaptation can occur for faces that we see in the real world that are moving.

To our knowledge, the only studies using moving faces as adaptors have not been within a FIAE paradigm. de la Rosa, Giese, Bulthoff and Curio (2013) used moving adaptors when investigating expression perception. They found that static adaptors produced bigger effects than dynamic adaptors. Chen, Russell, Nakayama and Livingstone (2010) got participants to either watch a cartoon (where the characters have big eyes) or footage of a TV program where the actors had normal eyes. After watching the cartoon, participants indicated that unfamiliar faces with big eyes were more attractive, suggesting that a face distortion after-effect had occurred to moving images. However, Chen et al did not compare the size of the effect between moving and static adaptors.

1.5.2. Summary of Paper 3

The aim of paper 3 was to find out whether FIAEs would occur for ecologically valid, moving stimuli. Most studies have used static stimuli as adaptors and, at the time of writing paper 3, to our knowledge none had used moving faces to test identity after-effects. If adaptation is indeed functional in fine-tuning face-space (e.g. Rhodes & Leopold, 2011) then as a prerequisite it should occur for moving faces as well as static faces. Not only that, but FIAEs should also occur for personally familiar faces such as the faces of lecturers. In order to test these hypotheses we conducted a study with three adapting conditions: participants were either exposed to a video, 24 static images or a single image of a familiar lecturer. We found significant and equivalent adaptation for each of these conditions. Had we found a difference between our conditions (e.g. a smaller after-effect for the moving images) then this would have suggested that the FIAE was epiphenomenal. The finding of equal after-effects for moving and static images is a necessary pre-condition for FIAEs to be functional. However, this it is not evidence, in itself, that the FIAE is functional. What we have found also suggests that the FIAE is not purely due to low-level picture adaptation. If it was then we would expect the biggest after-effects to have occurred in the single image condition. These results complement findings from Hole (2011) who found equally sized FIAEs after adapting to upright, inverted, stretched faces or faces of a different viewpoint to frontal view test faces. Taken together these findings support the idea that familiar face processing is abstractive in nature. If FRUs for familiar faces are the site of adaptation effects, then these FRUs are affected to the same extent, regardless of the format that a familiar face is presented in, as long as that familiar face is recognisable. Haxby et al's (2000) neurological model of face processing suggests that there are two routes which interact with each other. One route deals with changeable aspects of face processing such as expression or lip-reading. The other deals with invariant aspects of face processing such as identity. The FIAE seems to be affecting our invariant representation of a familiar face and is not selective for variable facial properties that arise from rigid and non-rigid head movement.

1.6. Robustly Represented Faces

Tong and Nakayama (1999) suggest that we have "robust representations" for highly over-learned faces. They conducted a series of experiments comparing performance for one's own face compared to unfamiliar faces on a variety of tasks. Even after extensive experience with the unfamiliar faces, Tong and Nakayama found an own-face advantage. They suggest that robust faces: are processed rapidly and asymptotically[7]; develop after lots of visual experience; have representations that contain abstractive view-invariant information; facilitate decisional processes; and they require fewer attentional resources.

Paper 3 demonstrated that FIAEs can occur for personally familiar faces. Paper 4 and paper 5 also examined adaptation for personally familiar faces, except that the faces were extremely familiar to participants. The last two studies used a different method of adaptation, the FDAE. As mentioned in section 1.2.1.1., the FDAE occurs when exposure to a distorted face (e.g. a face with contracted internal features) changes normality judgements for subsequently presented faces. A face that is judged to look normal prior to exposure, will appear expanded after exposure. Even exposure to gross figural distortions can affect normality decisions for faces.

At the time of starting this thesis most investigations of FDAEs had used unfamiliar faces and none had systematically compared the size of the FDAE for faces varying in their familiarity. Jiang et al (2007) found that as a face increases in its familiarity the size of the FIAE increases. Therefore we wanted to find out whether FDAEs would be bigger for highly familiar faces compared to unfamiliar faces. Carbon and Ditye (2010, 2012) have found FDAEs for highly familiar faces that have been observed to last for up to a week after adaptation. They suggest that our representations for familiar faces are flexible in order to accommodate new information and keep an up-to-date version of that face in memory (Carbon et al, 2007).

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[7] When performance (e.g. reaction times) at recognising a faces can no longer be improved it is said to be asymptotic. There are no measurable improvements in how fast a robustly-represented face can be recognised. The same can be true of less familiar faces where performance can appear to be asymptotic, however it is not the true asymptote which is observed for robustly-represented faces.

1.6.1. Summary of Papers 4 and 5

The aim of papers 4 and 5 of this thesis was to investigate FDAEs for highly familiar faces. We wanted to find out whether our representations of robustly represented faces are just as adaptable as those for famous and unfamiliar faces.

Paper 4 is a three experiment paper, however the first two studies were completed prior to starting work on this thesis (as part of an undergraduate project). In experiment one we exposed participants to distorted versions of their own face, a famous face and an unfamiliar face. After adaptation to each of these identities, participants were tested using a visual array containing different images of the same identity. The arrays contained nine images of the face that varied in their level of distortion. We asked participants to select which face looked the most normal. When the arrays contained different versions of their own face, participants were more likely to choose a normal version than when the arrays contained famous or unfamiliar faces. For the famous and unfamiliar faces participants were more likely to pick a distorted version of the face as looking normal. This pattern of findings suggested that one's own face is less adaptable (i.e. there was a smaller FDAE) than famous or unfamiliar faces: we called this an "own-face effect". In order to rule out the "own face effect" as being a result of stimulus properties, and to find out if it was the familiarity status of the face driving the effect, we conducted a second experiment. In the second experiment a group of participants who were unfamiliar with the participants from experiment one, completed the own face condition from experiment one. We found that these participants were more likely to pick a distorted version of the face as looking normal after adaptation than the participants from experiment one. This suggested to us that the "own-face effect" was due to the familiarity of the face (i.e. that the face was the participant's own) rather than something to do with the images per se.

The third experiment from paper 4 was conducted to replicate the findings from experiment one. A problem with experiment one was that there was no baseline measure of what was considered normal prior to adaptation. We therefore could not be sure if a FDAE had even occurred, as we were not measuring a shift in what was considered normal. Experiment three was exactly the same as experiment one, except participants saw the visual arrays before and after adaptation. The findings showed the same pattern as in experiment one. There was a significant shift in what was considered to be normal for all of our conditions: after exposure to a contracted face, a slightly contracted version was considered to look the most normal. However, the shift was smaller for one's own face than for the famous or unfamiliar faces. This pattern of findings supports the idea of an "own-face effect" that we found in experiment one.

Since the completion of Paper 4 there have been two other studies looking at FDAEs for robustly represented faces, by Walton and Hills (2012) and Rooney, Keyes and Brady (2012). They used two different methods of testing adaptation. The first way is to test participants on the same face that they were adapted to (within person adaptation). The second way is to test participants on a different identity to the one they are adapted to (across person adaptation - similar to the transfer condition used by Carbon (2007)). Rooney et al used between person adaptation: they adapted their participants to a distorted unfamiliar face and tested normality judgements for the participant's own face or the face of a friend. Walton and Hills used between-person and within-person adaptation: they adapted participants to distorted versions of their parent's face, a famous face and an unfamiliar face. After adaptation to each of these identities, participants were tested on all three identities.

Rooney et al (2012) found equally-sized FDAEs for a participant's own face and the face of a friend, after adapting to a distorted unfamiliar face. Walton and Hills (2012) found smaller within-person adaptation for the face of a parent, than for the famous or unfamiliar faces. This is similar to the "own-face effect" that we found in paper 4. However, they also found that after-effects transferred more from unfamiliar faces to personally familiar faces, than vice versa. The aim of paper 5 of this thesis was to systematically compare the size of the FDAE for three robustly represented faces: one's own face, a family member's face and the face of a friend. Rooney et al compared self and friend adaptation, but they adapted participants to an unfamiliar face. We wanted to find out whether the "own-face effect" was specific to the self-face or whether other robustly-represented faces were equally as adaptable. No study has systematically looked at within-person adaptation for these different types of highly familiar face.

In paper 5 we compared FDAEs for each participant's own face, their sister's face and the face of a friend. We used within-person adaptation: participants were adapted and tested on the same face, before and after adaptation to a contracted version of that face. In paper 4 we used visual arrays, but in paper 5 we used a more traditional method of testing FDAEs. Each test face was presented in isolation and participants had to decide whether it looked normal or odd. We found equivalent FDAEs for each condition. This suggests that our own face is no less adaptable than other highly familiar faces. However, the shift was a lot bigger for the own face condition than what we originally found in paper 4. One possibility is that the "own-face effect" may have been partly a decisional effect rather than a purely perceptual effect. Tong and Nakayama (1999) have shown that we are much better at making decisions about our own face than we are at making decisions about unfamiliar faces. They suggest that there may be a distractor rejection advantage (it is easier to reject distractors of your own face [8]). It is

[8] In one of their experiments, participants had to search for an image of their own face amongst images of a stranger (the distractor), or search for an image of a stranger

conceivable that when participants were choosing a "veridical" version of their own face from the arrays in paper 4, they may have been using a different strategy compared to when the face was less familiar. Alternatively, perhaps participants were using the same strategy for all of the arrays, but they were better when the faces were their own (the after-effect might have interfered more when making decisions about the less familiar faces). In light of paper 5, it is difficult to be sure whether the own-face effect that we observed in paper 4 was a perceptual effect (e.g. participants were picking the face that they perceived to look the most normal) or whether it was a decisional effect (e.g. participants used more efficient strategies to decide which face was not distorted). An alternative possibility is that we observed a bigger after-effect in this experiment because the test faces were presented for a much shorter duration (200ms) than in paper 4 (roughly 7 seconds). Rhodes et al (2007) have shown that as test duration increases, so too does the size of the after-effect.

A limitation of paper 5 is that there was no unfamiliar face condition, in which participants were adapted and tested on an unfamiliar face. When we started this experiment we had initially intended to complete a second experiment. We wanted to recruit participants who were wholly unfamiliar with the participants in paper 5 to complete the same experiment (similar to experiment 2 in paper 4). The reason we were unable to do this is because at baseline (paper 5), participants made significantly more "normal" decisions to the contracted faces than they did to the expanded faces, i.e. a face that was slightly contracted was perceived to be "normal". We think that this could be due to the stimuli we used. We asked participants to provide us with images of faces (self, sister, friend) which may have been taken on smart phones and webcams. This is a problem because these types of devices have comparatively wide-angle lenses which

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amongst images of their own face (the distractor). Reaction times were faster when one’s own face was the distractor compared to when the stranger was the distractor.

may have distorted the images. The photos that our participants provided us with may have been slightly expanded, compared to what participants are used to seeing in real life. If participants viewed an unfamiliar face, and were then asked to make normality decisions about that face, then they would have nothing to refer it to – the original veridical (undistorted) image that they see would be normal to them. The distortion we applied to the image would therefore not be equivalent for the familiar and unfamiliar conditions. Participants might have provided us with slightly expanded images of their face (due to the camera) so the contracted distortion we applied was not as big as if the image they provided us with was a undistorted image of their face. An undistorted image of an unfamiliar face might be truly undistorted (they have never seen this face before so there is no reason to think the image is odd) so the distortion we applied to the face would be bigger than when the face was familiar. We know that as the distortion increases, so too does the size of the FDAE (e.g. Robbins et al, 2007). Therefore if we observed a difference between our conditions it might be due to the size of the perceived adapting distortion and not due to the familiarity of the face. The only way that this problem could be resolved would be to redo the experiment with everyone photographed under the same conditions. In a purely practical sense this would be unfeasible as people's sisters (and possibly friends) were not necessarily local.

Taken together the findings seem to suggest that highly familiar faces are just as adaptable as each other, although this is a rather tentative conclusion based on the limitations outlined above. More empirical testing is required to find out whether the FDAEs observed for these faces are smaller than for other less familiar faces however, the findings from Walton and Hills (2012) suggest that this might be the case. Future research should eliminate decisional factors by presenting test faces independently, rather than in visual arrays. It is also important to control for test duration in FDAE experiments. However, whether FDAEs are the best method for investigating identity-specific representations is questionable. Tillman and Webster (2012) have shown that FDAEs are more selective for a change in expression (affecting the configuration of a face) than a change in gender (affecting the identity of a face). Suslio et al (2010) and Vakli et al (2012) have shown that configurations in non-face stimuli can induce FDAEs. Therefore it is difficult to tease apart how much of the FDAE is shape-generic and how much is face-specific. Faces are all similar in terms of their first-order configuration. The results from paper 2 show that the best way to find out whether an abstractive representation for a familiar face is being selectively adapted is to test on a different viewpoint. Also paper 3 suggests that the FIAE for familiar faces cannot solely be the result of low-level properties. Therefore perhaps the FIAE (or the FDAE), when adapting and testing on different viewpoints, is the best method to investigate face processing using adaptation.

1.7. Conclusion

The aim of thesis was to investigate how familiar faces are processed using adaptation after-effects, in particular using the FIAE and FDAE. Adaptation has been used as a tool to investigate face processing and it has been influential in providing support for various models of face processing. However, only relatively few face adaptation studies have used familiar faces. As argued in the introduction, this is an oversight, due to familiar face processing being more abstractive than unfamiliar face processing. In particular, research suggests that the processing of unfamiliar faces is much more viewpoint-specific than that of familiar faces.

The first two papers in this thesis looked at the role of explicit recognition during adaptation. Research suggests that one needs to be aware of the presence of an identity in order to adapt to it (e.g. Moradi et al, 2005). However, Moradi et al used faces that were suppressed from awareness. The first paper used different views of a composite face (top half of Brad Pitt's face paired with the bottom half from an unfamiliar face) and the adaptor and test faces were morphs between Brad Pitt and Jude Law. In our study, participants were aware of the adaptor, but were not necessarily aware of the identity of the adaptor. We found that FIAEs for Brad Pitt only occurred when the composites were explicitly recognised as resembling him. The unrecognised composite faces produced no measurable FIAE. These findings suggest that the FIAE is a high-level effect that does not depend on the physical properties of the adapting face. It also suggests that the internal state of the viewer can affect how a face is processed: paper 2 built on this idea except the viewpoint of the stimuli was manipulated more carefully.

Experiments one to three of paper 2 used unfamiliar faces as adaptors, transformed to look subtly like David Beckham or Jude Law. These unrecognised stimuli did produce after-effects, but only when testing occurred using the same viewpoint (e.g. frontal view faces). This suggests that unrecognised faces can produce FIAEs, but only when the viewpoints of the adapting and test faces are congruent. This was not what we found when the transformed faces were famous faces, transformed to look like David Beckham or Jude Law. The very same manipulation did not produce FIAEs when the transformed adapting stimuli were familiar. We found a similar pattern of findings when we used celebrity's siblings as adapting faces. We observed FIAEs for a celebrity after adaptation to their sibling. This was when the adapting and test viewpoint was congruent, regardless of whether the sibling was recognised. However, if the adapting and test viewpoint was incongruent there was only a FIAE for the recognised siblings. Similarly, if the sibling was misidentified (e.g. Brad Pitt's brother was misidentified as looking like John Travolta) there was no observable FIAE for Brad Pitt. These findings have implications for models of face processing. The findings suggest that familiar faces are processed independently of each other. If a familiar face is recognised (and an FRU is activated) then this accounts for the incoming information from the visual system. This can be explained by predictive coding, where there are both forwards and backwards connections between levels of processing and FRUs are at a higher level of processing than structural encoding. Activation of FRUs attenuates the responses of low level structural encoding. Whatever was adapted by the unrecognised composite faces (paper 1) was too far removed from the test stimulus (in terms of its configuration and/or viewpoint) to observed any effect.

Paper 3 shows that equivalent FIAEs for familiar faces can arise after exposure to videos or static images. This is important because it tells us that the FIAE is not due solely to stimulus properties (such as those found in static images) but can occur for more realistic stimuli. If face adaptation is functional in fine-tuning our visual system, then this is a necessary prerequisite. It suggests that the FIAE is selective for invariant aspects of facial identity, rather than variable aspects such as expression or lip-movement. The findings replicate and extend the findings of Hole (2011) which suggest we have abstractive representations for familiar faces. FIAEs are equivalent regardless of whether the adaptor is moving or static, or of a different viewpoint to the test face. However, this depends on the adapting face being explicitly recognised by the viewer, therefore activating its FRU.

The last two papers (4 and 5) used the FDAE to find out whether our representations for faces that differ in their familiarity are just as stable as each other. It has been shown that the FDAE can occur for highly familiar celebrity faces (e.g. Carbon et al, 2007). However, when work begun on this thesis, no study had directly compared the size of the FDAE for faces with different levels of familiarity to the participant. We found that participants were better able to pick a normal version of their own face, after adaptation to a distorted image of their face, compared to after adapting and testing on a famous or unfamiliar face. However, this was when participants were presented with visual arrays and had to pick out a veridical version of a face. In another study we found equivalent FDAEs for three highly familiar faces: the participant's own, their sister's or their friend's. Test faces were presented in isolation and there were big after-effects in all conditions. In this study, the after-effects were much bigger in the own-face condition than when the faces were presented in visual arrays. We think that the smaller after-effect we found in paper 4 may be the result of decisional factors. However, there is reason to believe that the FDAE might not be the best way to investigate FRUs - the FDAE is less selective for identity than it is for expression (Tillman & Webster, 2012).

Within our model of face recognition using predictive coding, proposed in paper 2, FRUs predict patterns of activation within face-space. If a “robust-face effect” can be confirmed in subsequent investigations, then an interesting question is how this would fit in with our model? In paper 4 we suggest that the central tendency of face-space might be based on the faces for which we have lots of experience with. However, it is also possible that the figural distortion produces too much prediction error to be fully accounted for by an FRU. It could be that for a highly overlearned, robust face the distortion was too far removed to be considered an acceptable instance of that face. This could explain why robust faces are less affected by this type of distortion.

Overall the findings presented in this thesis inform the field in a number of ways. Firstly, they demonstrate that face adaptation is not purely the result of low-level picture properties: moving faces can produce FIAEs and recognition might play a role in determining how an image is encoded. This could provide a promising direction for future research. There is an increasing number of papers being published investigating how our hypotheses (and prior knowledge) about the world can influence our perception, therefore the present results are timely. Papers 2 and 3 also add to the literature on familiar face processing, which suggests that our representations for familiar faces are abstractive and contain view invariant information. The implications of the findings from papers 4 and 5 are less clear cut. They remind the reader that it is important to carefully control the procedure when conducting adaptation experiments. Variables, such as the timings of test stimuli, do play a part in the overall size of the FDAE.

1.8. Suggestions for Future Research

There are many different directions that could be taken to follow on from the work presented in this thesis. Firstly it is important to conduct the study reported in paper 5 again, using photographs taken under more controlled conditions. That way, a second experiment could be conducted with participants who were unfamiliar with the stimuli. This would allow us to explore whether a “robust-face effect” exists, or whether the “own-face effect” we found in paper 4 was due to decisional factors.

Secondly, work should also be conducted to test the predictions of a model of face processing using predictive coding. For example, an assumption of such a model is that our responses to lower-level attributes will be attenuated when a higher level percept is achieved (He et al, 2012). Therefore an interesting question is whether lower level properties are less salient for familiar faces than for unfamiliar faces (i.e. are we less able to *see* them). We already know that low-level properties such as lighting affect familiar face recognition less than unfamiliar face recognition (e.g. Burton et al, 2011).

Also, as mentioned in paper 2, further iterations of the model should aim to account for the findings using FDAEs (e.g. Carbon et al, 2007).

Another direction for future research could be to look at the role of experience in the FDAE. MacLin and Webster (2001) found that the FDAE was observed only for faces and not natural scenes – suggesting that we need to have experience with something in order to adapt to it. However, a problem with their study was that people were not very good at judging the normality of natural scenes, in the absence of any adaptation. Similarly, Daelli (2011) has also found that we need to have experience with something (a representation) in order to adapt to it. However, in that paper participants were familiarised with the stimuli within the course of the experiment. It is also difficult to differentiate between shape-generic adaptation and face-specific adaptation in the FDAE (e.g. Dennett et al, 2012). A way to address both of these issues would be to use the faces of dogs as stimuli, and look at the transfer of the FDAE across breeds by using different breeds of dog as the adapting and test faces. Dogs are one of the most morphologically-varied species (e.g. Boyko et al, 2010) and two dogs of different breeds can have very different face shapes. Using faces from different dog breeds would therefore reduce the contribution of shape-generic effects to the FDAE. By comparing dog owners and non-dog owners within the same experimental paradigm, any differences in the size of the FDAE between the two groups would be difficult to attribute to lower-level adaptation or learning within the experiment. Any differences would more likely to be a result of the amount of experience one has with a particular type of face (i.e. the face of a dog).

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CHAPTER 2:
IDENTITY SPECIFIC ADAPTATION WITH COMPOSITE FACES – PAPER 1

Abstract

A composite face, made from the top half of a celebrity face and the bottom half of an unfamiliar face, appears to be a single, "new" face (e.g. Young, Hellawell & Hay, 1987). Composite faces were used within the face identity after-effect (FIAE) paradigm, in which prolonged exposure to a face reduces sensitivity to it (adaptation). Adaptation occurred both with an intact face and with composites containing its upper half, but only when composites were explicitly recognised during the adaptation phase. Unrecognised composites produced no adaptation. These findings imply that the FIAE is a relatively high-level perceptual effect, given that identical stimuli either did or did not produce adaptation depending on whether or not they were recognised. They also suggest a perceptual locus for the "composite face effect".

2.1. Introduction

A composite face made from the top half of one face and the bottom half of another appears to be a single, "new" face (see Figure 2.1). In Young, Hellawell and Hay's (1987) original demonstration of this "Composite Face Effect" (CFE), participants viewed a composite comprised of halves from two famous faces, and attempted to name one half while ignoring the other. This was harder when the face halves were aligned than when they were misaligned. Subsequent investigations have generally used a matching task with unfamiliar faces: participants view two composites and decide whether or not corresponding face halves (usually the tops) are identical. Participants are slower to decide that matching top halves are the same when the bottoms differ; they are also biased towards falsely deciding that the tops are different. The CFE is abolished by inversion (Hole, 1994; Hole, George & Dunsmore, 1999) or lateral misalignment of the face-halves (Robbins & McKone, 2007; Taubert & Alais, 2009).

These findings can be taken as evidence that the CFE is a perceptual process, arising because upright faces are encoded "holistically" as unified wholes. However, an alternative interpretation is that it occurs because faces are represented as independent parts, but *decisions* about these parts cannot be made independently (Wenger & Ingvalson, 2002; Richler, Gauthier, Wenger & Palmeri, 2008; but see Richler, Tanaka, Brown & Gauthier, 2008).

The problem with conventional CFE demonstrations is they require participants to make explicit, speeded decisions about the relationship between face-halves. The CFE is defined in terms of impairments in the speed and accuracy of face processing; but as Richler, Gauthier et al point out, perceptual and decisional factors are confounded in these data.

We present an alternative technique that circumvents these problems, because participants are never required *at test* to make any explicit decisions about the composites themselves (e.g. in terms of speed and accuracy). Our technique capitalises on another face-processing phenomenon: the "face identity after-effect" (FIAE). Prolonged exposure to a face (adaptation) temporarily reduces sensitivity to that face but not others (Leopold, O'Toole, Vetter & Blanz, 2001). The FIAE can be demonstrated by showing participants a series of ambiguous morphs between two faces, A and B. After prolonged exposure to A, more of the morphs appear to resemble B, and vice versa. The FIAE is a high-level after-effect that persists even if the adapting and test stimuli are physically quite dissimilar, at least if familiar (celebrity) faces are used (Hills, Elward & Lewis, 2010; Hole, 2011).

We measured the FIAE produced by three different types of adapting face: complete views of a celebrity's face (Brad Pitt); and aligned or misaligned composites (comprised of the top half of Brad's face paired with the bottom half of an unfamiliar face). Participants in these three conditions performed two tasks. The first (actually the adaptation phase) involved inspecting a series of face images and deciding whether any were distorted. Different views of the adapting face were used in this phase to ensure that any adaptation effects were due to the identity depicted rather than from low-level pictorial attributes. (Adaptation effects can result from exposure to different views of a familiar face: e.g. Benton, Jennings & Chatting, 2006; Benton et al., 2007; Jeffery, Rhodes & Busey, 2006, 2007; Jiang, Blanz & O'Toole, 2007; Hole, 2011). In the second task, participants viewed a set of briefly-presented ambiguous morphs between Brad and another celebrity (Jude Law), and decided whether each one looked more like Brad or Jude. Participants in a control condition did not view any adapting stimuli, and performed only this second phase of the study.

If composites are processed holistically (i.e. representation of individual facial parts is less important for recognition), they should not produce adaptation effects for Brad's face at test. If the composite is being treated as a "new" face, it should not affect the representation of Brad's face more than any other. Conversely, if face parts are represented separately, composites might produce attenuated levels of adaptation to Brad compared to intact versions of his face, but they should still produce some adaptation because of their partial overlap with representations of him.

Using the FIAE paradigm with composite faces should thus enable us to determine whether composites are processed holistically, without requiring participants to make any judgements about the composites themselves at test, and thus sidestepping the decisional processes that complicate the interpretation of previous CFE studies. Using composite faces within the FIAE paradigm should also provide further insight into the nature of the underlying representations for familiar faces.

2.2. Method

2.2.1. Design and stimuli

The independent variable was the type of adapting stimulus set seen by participants. Each set contained six greyscale images of Brad Pitt (frontal view, distorted frontal view, 3/4 leftside view, 3/4 rightside view, left profile, right profile) derived from three photographs of him (frontal (260 by 320 pixels), 3/4 (433 by 564 pixels) and profile (234 by 271 pixels) views). The distorted frontal image was produced using the "pinch" function in Adobe Photoshop 7.0, set to 60%, to contract the middle of the face. Images were viewed from a distance of approximately 60cm.

Each participant was allocated to one of four conditions (see Figure 2.1):

2.2.1.1. Complete.

All of the adapting stimuli were intact images of Brad Pitt.

2.2.1.2. Aligned composites.

These consisted of the top half of Brad Pitt's face (in each of five orientations) aligned with the bottom half of a correspondingly-oriented unfamiliar face (from the RaFD-database, 2010). To discourage participants from realising faces were composites, Photoshop was used to equate the halves for contrast and blur their join.

2.2.1.3. Misaligned composites.

These were the same as in the *aligned composite* condition, except that the bottom half was shifted horizontally by half of the top's width. For the frontal images, the bottom was moved to the left. For all the other images, the bottom was moved in the opposite direction to which the face was pointing.

2.2.1.4. No adaptation.

This provided a baseline measure of the extent to which test faces were judged to resemble Brad Pitt in the absence of prior adaptation.

Image removed for copyright reasons.

Figure 2.1. frontal-view versions from the three sets of adaptation stimuli (from left to right): *aligned composite*, *complete Brad Pitt*, *misaligned composite*.

The FIAE's strength was measured by showing participants ambiguous morphs between images of Brad Pitt and Jude Law and asking them to decide whether each morph looked more like Brad or Jude (see Hole 2011). The image of Brad Pitt used to make the ambiguous morphs differed from any of the images in the adapting stimulus sets. Frontal images of Brad and Jude were cropped to an oval that displayed only the internal facial features. From these, Smartmorph 1.55 (Meesoft Ltd.) produced six stimuli containing 29%, 37.5%, 46%, 54%, 62.5% or 71% of Brad Pitt which were all 162 by 191 pixels in size. These were selected for their ambiguous resemblance to the two celebrities.

2.2.2. Participants

Seventy-five undergraduates participated for course credit (24 males and 51 females: mean age 23.05, SD 5.76). Participant numbers in each condition varied, depending on whether or not they rated the adapting stimuli as familiar (see the following section for the definition of "familiar"). 14 were adapted to a complete image of Brad Pitt (all of whom indicated that he was familiar); 27 to an aligned composite (10 of whom indicated the composite was familiar, and 17 that it was unfamiliar); 19 to a misaligned composite (14 of whom indicated the misaligned composite was familiar, and 5 that it was unfamiliar); and 15 experienced no adaptation.

2.2.3. Procedure

2.2.3.1. Familiarity check.

Participants first rated the familiarity of a frontal face image, by pressing “F" for familiar or "U" for unfamiliar on the keyboard. This was either an intact image of Brad Pitt (*complete* and *no adaptation* conditions) or a composite (*aligned* and *misaligned composite* conditions). Participants also rated the face's familiarity on a 6-point Likert scale (from 1, "highly unfamiliar", to 6, "highly familiar"). For all conditions except the *no adaptation* condition, the face remained visible until an "F" or "U" decision was made. (In the *no adaptation* condition, the face was shown for only 200 ms, to preclude adaptation). Participants who pressed "F" were asked to confirm the face's identity. No feedback was given about whether they were correct.

A face was considered "familiar" if (a) the participant pressed "F", (b) identified the face as Brad Pitt; and (c) gave a Likert scale rating of 4 or above.

2.2.3.2. Adaptation phase.

The three adaptation conditions consisted of two phases (see Figure 2.2). In the adaptation phase, participants saw different views of the face they had seen previously and pressed "SPACE" if a distorted version of it appeared (this ensured that participants concentrated on the adapting faces).

The 6 different images within each adapting stimulus set were presented in the centre of the screen. Each was shown eight times, except for the frontal and distorted frontal images (which were shown six times and twice respectively). Each participant saw these 40 images in a different random order. Each was shown for three seconds every time it was presented, to give a total of two minutes' exposure to the entire adapting stimulus set.

2.2.3.4. Test phase.

For the three experimental conditions, the test phase followed immediately after adaptation. (Participants in the *no adaptation* condition performed only this second phase). Each participant saw a different random sequence of 36 morphs (i.e., each of the test morphs shown 6 times). For each one, they pressed "B" or "J", according to whether they thought it looked more like Brad Pitt or Jude Law. Morphs were presented in the centre of the computer screen for 200 ms, each preceded by a fixation cross for 750 ms.

Upon completion, participants were asked if they were familiar with Brad Pitt and Jude Law. All participants were familiar with both. Participants in the *aligned* and *misaligned composite* conditions who had initially rated the composite as "unfamiliar" were asked whether the adapting images were still unfamiliar. This was to ensure they had remained unaware, throughout the experiment, that Brad Pitt's face was contained in the composites.

Image removed for copyright reasons.

Figure 2.2. the adaptation and test phases for the *aligned composite* condition.

2.3. Results

Each participant provided data on how many morphs (out of 36) they thought looked more like Brad Pitt or Jude Law. An FIAE for Brad Pitt would be reflected in fewer morphs being judged to resemble him.

A one-way ANOVA with six levels of adapting stimuli (*complete* images of Brad Pitt, *no adaptation*, recognised *aligned composite*, unrecognised *aligned composite*, recognised *misaligned composite* or unrecognised *misaligned composite*) found a significant effect of adapting face type on the number of morphs judged to look more like Brad Pitt, F (5, 69) = 5.55, MSE = 23.88, p =.0005, ω = 0.54 (see Figure 2.3). Significantly fewer morphs were judged to look like Brad in the *complete* condition than in the *no adaptation* condition (t (69) = 2.23, p =.03, r = .26), replicating the FIAE.

Following exposure to the *aligned composite* stimulus set, significantly fewer morphs were judged to look like Brad when he was recognised than when he was not recognised (t (69) = 2.77, p = .007, r = .32). The same was true for the *misaligned composite* stimulus set (t (69) =3.85, p =.0005, r = .42), although it should be noted that when the composite was misaligned, only five participants failed to recognise Brad. Thus for composite faces, adaptation occurred only if Brad was recognised in the adapting stimulus set. In fact there was no significant difference between the *no adaptation* and *unrecognised aligned composite* conditions (t (43) = -0.05, *ns*), or between the *recognised aligned composite* and *complete* conditions (t (36) = 0.74, *ns*).

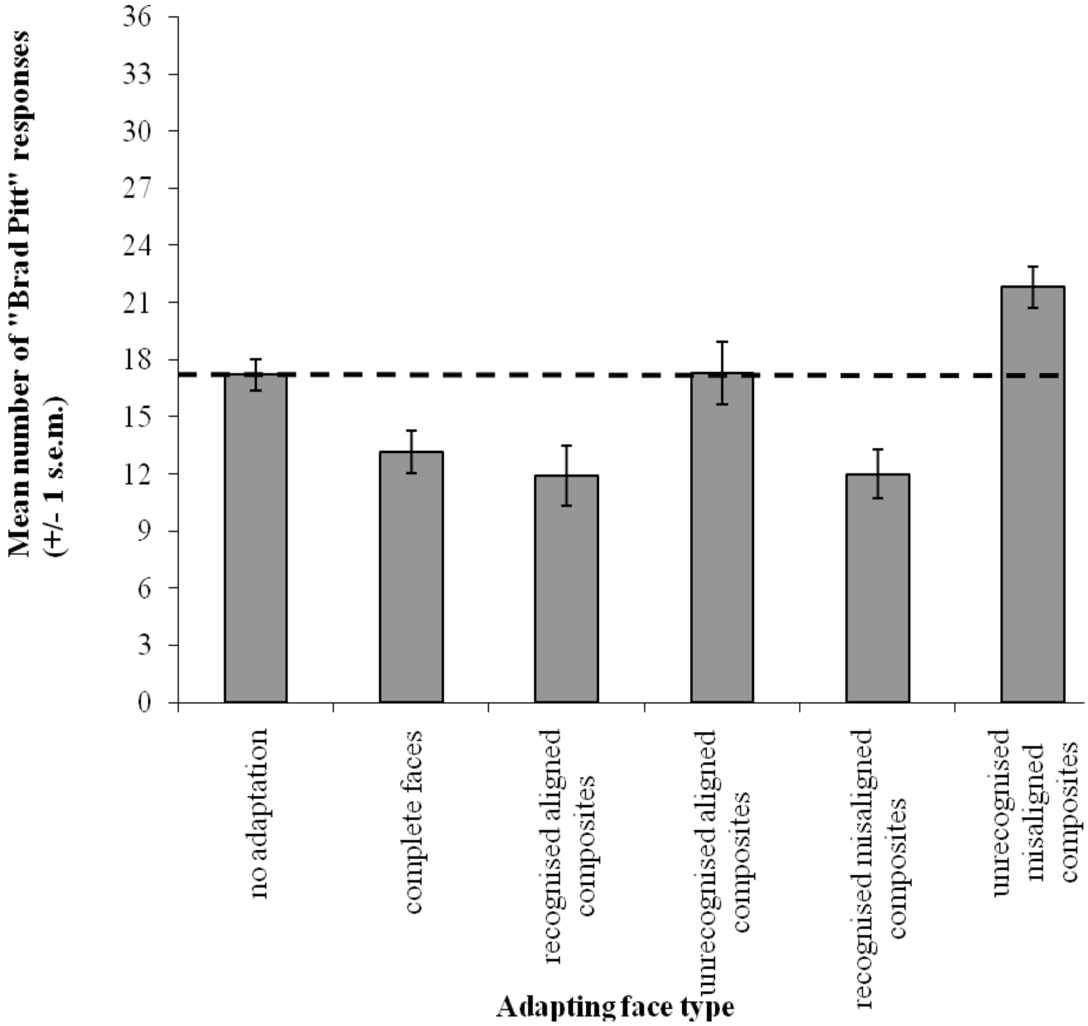

Figure 2.3. effects of adapting stimulus type on the number of "Brad Pitt" responses subsequently made to ambiguous morphs between Brad Pitt and Jude Law, collapsed across all morph levels. (NB. Lower scores represent stronger adaptation to Brad Pitt's face).

Figures 2.4a and 2.4b show the percentage of Brad Pitt responses made to each morph level. In all conditions, the number of "Brad Pitt" responses rose as the percentage of his face in the test morphs increased. There was also a trend for more Brad Pitt responses when he was unrecognised (Figure 2.4a) than when he was recognised (Figure 2.4b).

(a)

(b)

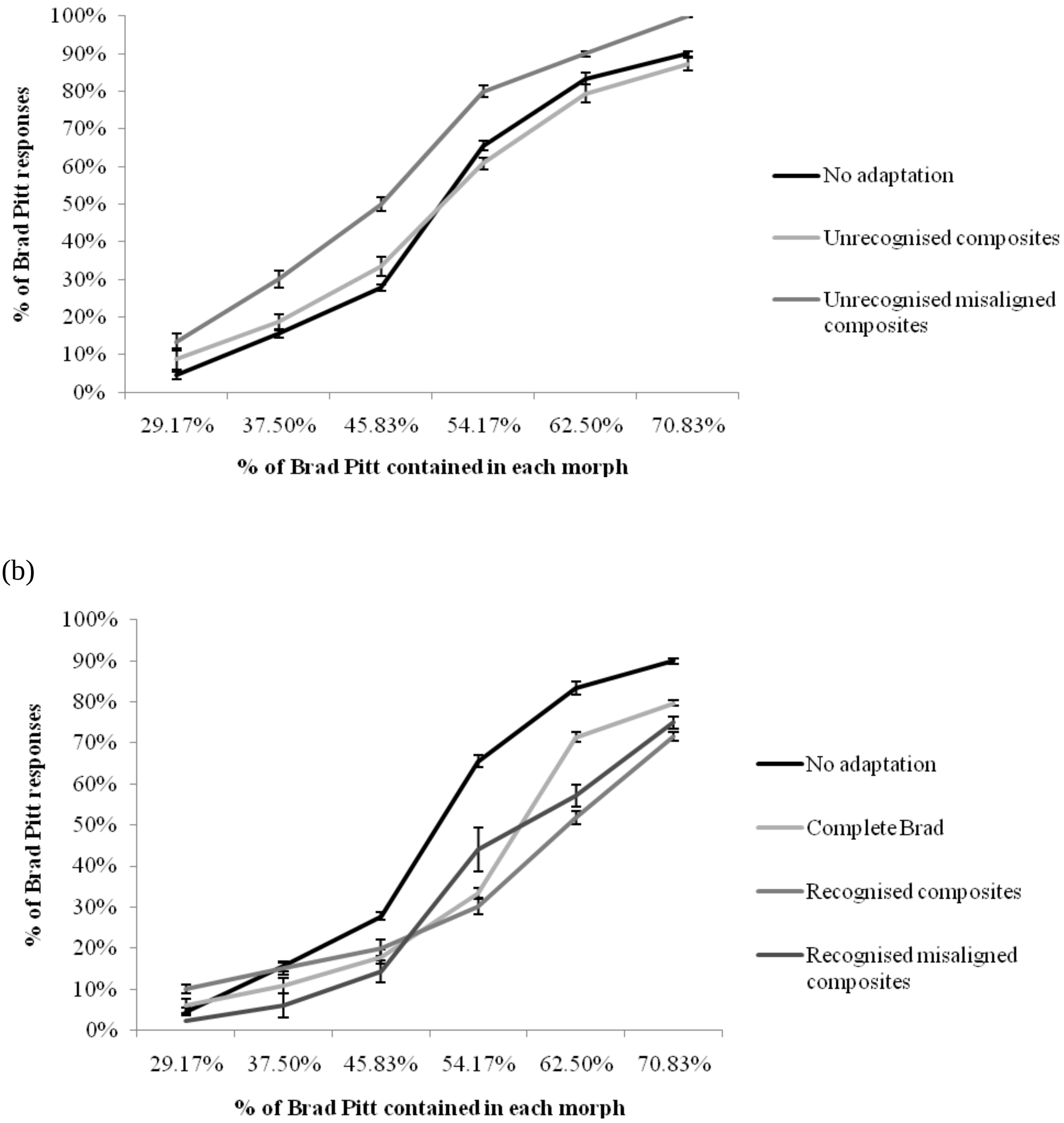

Figure 2.4a. effects of unrecognised adapting stimulus type on the percentage of "Brad Pitt" responses made to each morph, compared to unadapted participants.

Figure 2.4b. effects of recognised adapting stimulus type on the percentage of "Brad Pitt" responses made to each morph, compared to unadapted participants. (Error bars show +/- 1 S.E.M.).

2.4. Discussion

Adaptation effects occurred both with intact versions of Brad Pitt's face, and with composites containing only its upper half. However, composites produced adaptation only when Brad was explicitly recognised in the adapting stimulus set. Participants who remained unaware that the stimuli contained half of Brad's face showed no adaptation at all, despite the visual similarity between the composites and Brad's face.

These findings support previous studies suggesting that face adaptation effects involve more than just low-level, image-based adaptation (e.g. Yamashita, Hardy, DeValois & Webster, 2005; Fox, Oruç & Barton, 2008; Hills et al., 2010; Benton et al., 2007; Hole, 2011). Our adapting stimuli had minimal overlap with the test images, by virtue of being at different orientations to them (see also McKone, 2008). Also, the very same adapting stimuli (i.e. faces in the *misaligned* and *aligned composite* conditions) produced different adaptation effects depending on whether or not participants explicitly recognised their Brad Pitt component during the adaptation phase. This would be difficult to explain if the FIAE were determined solely by the adapting stimuli's physical properties. The powerful influence of recognition on adaptation levels implies that adaptation was affecting the high level representation of identity, rather than just affecting low-level structural encoding of the face.

These results complement those of Moradi, Koch and Shimojo (2005), who used binocular rivalry to demonstrate that adaptation occurred only with faces that reached conscious awareness. Our findings suggest that not only is it necessary to be aware of the existence of the adapting face, but one has to be aware of its identity too.

Secondly, our results suggest the CFE is perceptual in origin. Unlike previous studies, which required participants to make a decision as quickly as possible, our participants examined the composite faces for two minutes. During this time, participants made no explicit decisions about the composites other than judging whether any of them were distorted. Despite participants attending to the composites for a prolonged amount of time, the featural Brad Pitt information within them was often insufficient to activate the representation of his identity. Pichler, Dosani, Oruç and Barton (2011) found that adaptation did not occur if first-order configural relations were disrupted, implying that the FIAE depends on more than just featural information. Our data support this conclusion: although some featural information was available in the unrecognised composites, it was apparently insufficient to override the configural percept of a "new" face.

Our suggestion that the CFE is inherently a perceptual phenomenon does not contradict Richler, Gauthier, Wenger and Palmeri's (2008) argument that conventional CFE demonstrations reflect decisional processes as well as perceptual ones. In most CFE studies, participants see a pair of composite faces and decide as quickly as possible whether the tops are the same or different, trying to ignore the bottoms. "Holistic" processing is inferred from two effects produced by intact composites with identical top halves and different bottom halves: slower decision times, and a characteristic bias in error rates (a bias towards falsely deciding that the top halves are different). Here, by using an entirely different response measure (FIAE strength) we have shown that the CFE does not *necessarily* depend on participants' decisions about the composite faces themselves, at test. Our participants made decisions about the composites only insofar as they decided, at the study's outset, whether or not the composite was familiar. Thereafter, all decisions were made about *intact* faces - i.e. whether faces looked more like Brad Pitt or Jude Law. The existence of holistic processing is inferred from the strength of the FIAE for intact faces. This measure is less prone to strategic, explicit decisional processes than the speed and accuracy measures used in previous studies.

Our results have implications for the nature of representations of facial identity. Recent studies (e.g. Hills et al., 2010; Hole, 2011) have interpreted the FIAE in terms of Burton et al's (1990) "Interactive Activation and Competition" model of face recognition. This suggests that every familiar face has a Face Recognition Unit (FRU), activated by any recognisable view of that face. An activated FRU stimulates that individual's Personal Identity Node (PIN), which allows access to semantic information about them. Hills et al. (2010) suggest that the IAC model can explain both priming and adaptation as opposites on a continuum of the effects of stimulation. In repetition priming, brief exposure to a face lowers the threshold for FRU activation and/or facilitates the excitatory link between an individual's FRU and PIN. In the FIAE, prolonged exposure to a face ultimately fatigues an individual's FRU or PIN, and thus *raises* the threshold for future activation.

Spontaneous recognition is important for priming to occur both with complete famous faces (Brunas-Wagstaff, Young & Ellis, 1992) and with composites (Steede & Hole, 2006). We have shown that recognition is also essential for adaptation to occur - further support for Hills et al's idea that adaptation and priming are complementary processes. Both priming and adaptation studies imply that an FRU can be activated by face parts (as in a composite), but only if those parts are recognised as belonging to the individual concerned. Our findings suggest that the unrecognised composites do not activate any internal representation of Brad Pitt's face, at least not to any measurable extent.

Precisely how do recognised composites produce adaptation effects? Face parts might simply produce activation of the relevant FRU. However, there are other explanations. Hole (2011) suggested that familiar faces might be able to activate PINs either directly (via their associated FRUs) or indirectly (by activating semantic information about the person). Perhaps recognised composites produce adaptation via the indirect route: they could activate semantic information about their donors' identities, which in turn could lead to PIN stimulation, and ultimately, fatigue. Alternatively recognition may have resulted in participants *imagining* a complete version of the target face: this in itself can produce adaptation (e.g. Ryu, Borrmann & Chaudhuri, 2008; Hills et al, 2008, 2010). Future research may be able to decide between these different possibilities.

To conclude, the present research highlights how the decisional component of composite face tasks can be circumvented by using the FIAE. It also demonstrates that the FIAE is a high-level phenomenon that cannot be explained solely in terms of selective adaptation of low-level perceptual mechanisms. This technique is a useful tool for increasing our understanding of the underlying representations for familiar faces and in particular the nature of the holistic processing that seems to underpin face recognition.

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CHAPTER 3:

THE EFFECT OF EXPLICIT RECOGNITION ON THE FACE IDENTITY AFTER-EFFECT – PAPER 2.

Abstract

Exposure to one identity can result in a loss in sensitivity to that person's face: this type of adaptation is known as a face identity after-effect (FIAE). Other studies have shown that these effects depend on explicit recognition of the adapting identity. The aim of the present studies was to investigate further the role of recognition in the FIAE by using various cryptic stimuli as the adapting faces. A series of six experiments revealed that the FIAE can be obtained without explicit recognition, but only via selective adaptation of lower-level structural encoding processes. Explicit recognition of an identity attenuated the contribution of lower-level adaptation to the FIAE. The findings are interpreted within a hierarchical model of face recognition, using predictive coding.

3.1. Introduction

3.1.1. The Face Identity After-Effect

Prolonged exposure to a face produces a form of perceptual adaptation: the viewer becomes less sensitive to the particular face that they have been viewing, but not others. Ever since the first demonstrations of this "Face Identity After-Effect (FIAE)" by Leopold, O'Toole, Vetter and Blanz (2001), FIAEs have been used as a means of identifying the mechanisms that underpin our perception of facial identity.

Adaptation has long been fruitful in investigating the processing of relatively "low-level" perceptual properties (e.g. motion, orientation and colour) and research has shown that it can be used to study higher-level visual processing too (see Webster & MacLeod, 2011, for a review). One way that researchers have attempted to show that the FIAE is indeed a high-level after-effect is by trying to decrease the contribution of low-level adaptation to the overall adaptation effect, by reducing the similarity and/or spatial overlap between the adapting and test images. For example, adaptation has been found to transfer between different-sized images (e.g. Anderson & Wilson, 2005), between upright and inverted faces (Hole, 2011; Hills & Lewis, 2012) and between adapting and test faces separated by up to 6^o of visual angle (Leopold et al, 2001).

Fox, Oruc and Barton (2008) have shown that FIAEs are independent of facial expression (something which alters the structure of a face): after-effects occur for both familiar and unfamiliar faces when the adapting and test stimuli have different expressions. Hole (2011) found an FIAE for celebrity faces when the adapting stimuli consisted of varied views of the test face, even when these stimuli were vertically stretched to three times their normal height. A face may not even need to be present for identity adaptation to occur. Ghuman, McDaniel and Martin (2010) found that adapting participants to the body of a person resulted in a loss of sensitivity to their face. Finally, the FIAE can be produced by non-visual adaptors, such as voices and names, or even just imagining the target face (Hills, Elward & Lewis, 2008, 2010; Ryu, Borrmann & Chaudhuri, 2008).

Within the explanatory framework of the Bruce and Young (1986) model of face-processing, all of these findings are consistent with the idea that the FIAE for familiar faces operates at least at the level of the "Face Recognition Unit (FRU)" (which responds to any identifiable view of a familiar face). Adaptation from voices or names would imply that after-effects can occur at the level of the "Person Identity Node (PIN)" (a gateway to semantic information about a familiar person). A prediction of the Bruce and Young model is that an FIAE should occur only if the adapting face is recognised (so that the input selectively stimulates and ultimately fatigues the appropriate FRU). However, relatively few studies have investigated the extent to which the FIAE depends on explicit awareness of the adapting face's identity.

Laurence and Hole (2012) used different views of a composite face as adapting stimuli. Each view consisted of the top half of a famous face and the bottom half of an unfamiliar face. Significant identity after-effects were observed only if participants recognised the top half of the composite, and not if it remained unrecognised. The very same adapting stimuli produced quite different effects depending on whether or not they were recognised. Moradi, Koch and Shimojo (2005) also found that explicit recognition, this time in terms of actually seeing the adapting face, was required during adaptation. Using binocular rivalry, they found that FIAEs disappeared when the adapting face was suppressed from visual awareness. However, Moradi et al did find that lower-level orientation adaptation persisted when it was suppressed from awareness. The research from Laurence and Hole (2012) and Moradi et al (2005) leads to the conclusion that recognition (or awareness) is an important component of high-level FIAEs. However, composite faces, as used by Laurence and Hole (2012), are notable for their disruption of holistic processing, which has been demonstrated to be an important aspect of face processing (e.g. Young, Hellawell & Hay, 1987). Pichler, Dosani, Oruc and Barton (2011) have also found that a disruption to first order configural relations can abolish FIAEs. Therefore, a primary aim of this paper was to further investigate the role of explicit recognition (awareness) of an identity on the FIAE.

3.1.2. Towards a Model of Familiar Face Recognition, Using Predictive Coding.

A second aim of this paper was to investigate a hierarchical model of face processing, using predictive coding (based on unpublished work by Hancock). A considerable amount of the literature on face adaptation has been interpreted within a multidimensional face-space (MDFS) framework, in which every face is represented within a face-space as a point or vector, defined by the dimensions on which faces vary (Valentine, 1991). Valentine proposed two possibilities for how face-space might operate: norm-based coding and exemplar-based coding. Many of the empirical findings on face adaptation have been interpreted to lend support for norm-based coding models of face-space, in which each face we encounter is encoded relative to an internal norm (e.g. Rhodes & Jeffery, 2006; Robbins, McKone & Edwards, 2007; Jeffery et al, 2011; Short, Hatry & Mondloch, 2011). This encoding is said to operate via opponent coding, where there are pairs of pools of neurones, one tuned to above average values and the other to below average values. However, opponent coding does not necessarily assume that a norm is explicitly represented. It may be implicit, depending on the tuning of neurones around the central tendency (see Rhodes & Jeffery, 2006; Little, Hancock, DeBruine & Jones, 2012). Exemplar-based coding does not assume that faces are coded relative to a norm, rather it assumes that faces are coded relative to a set of stored exemplars (Valentine, 1991). This has been suggested to operate via multichannel coding where there are lots of channels tuned to different values along each dimension of face-space (see Robbins et al, 2007).

The Bruce and Young (1986) model of face processing suggests that early visual processing performs structural encoding, which forms the input to FRUs for familiar faces. A prediction of Hancock's (in prep) model of face recognition (see Figure 3.1) is that encoding may occur via predictive coding (e.g. Mumford, 1992; Friston, 2005; see Panichello, Cheung & Bar, 2013 for a review). At each level of processing there are both downward and upwards connections to other levels. The downwards connections attempt to predict and account for the information from the level below. Any residual input that is not accounted for is propagated forwards as an error signal (prediction error). The aim of such a system is to minimise prediction error by trying to identify the most likely cause of the input (e.g. Howhy, Roepstorff & Friston, 2008), in this context by recognising a familiar face. In Hancock's model, early structural encoding leads to some representation of the incoming face, possibly within a face-space (the “structural representation” in Figure 3.1). This structural representation could be an implicit or explicit norm in an opponent coding model, or a subset of active channels in an exemplar based model. At the highest level of the model are the FRUs which make predictions about the level below (the structural representation). FRUs contain view-invariant information and respond to any recognisable image of an identity.

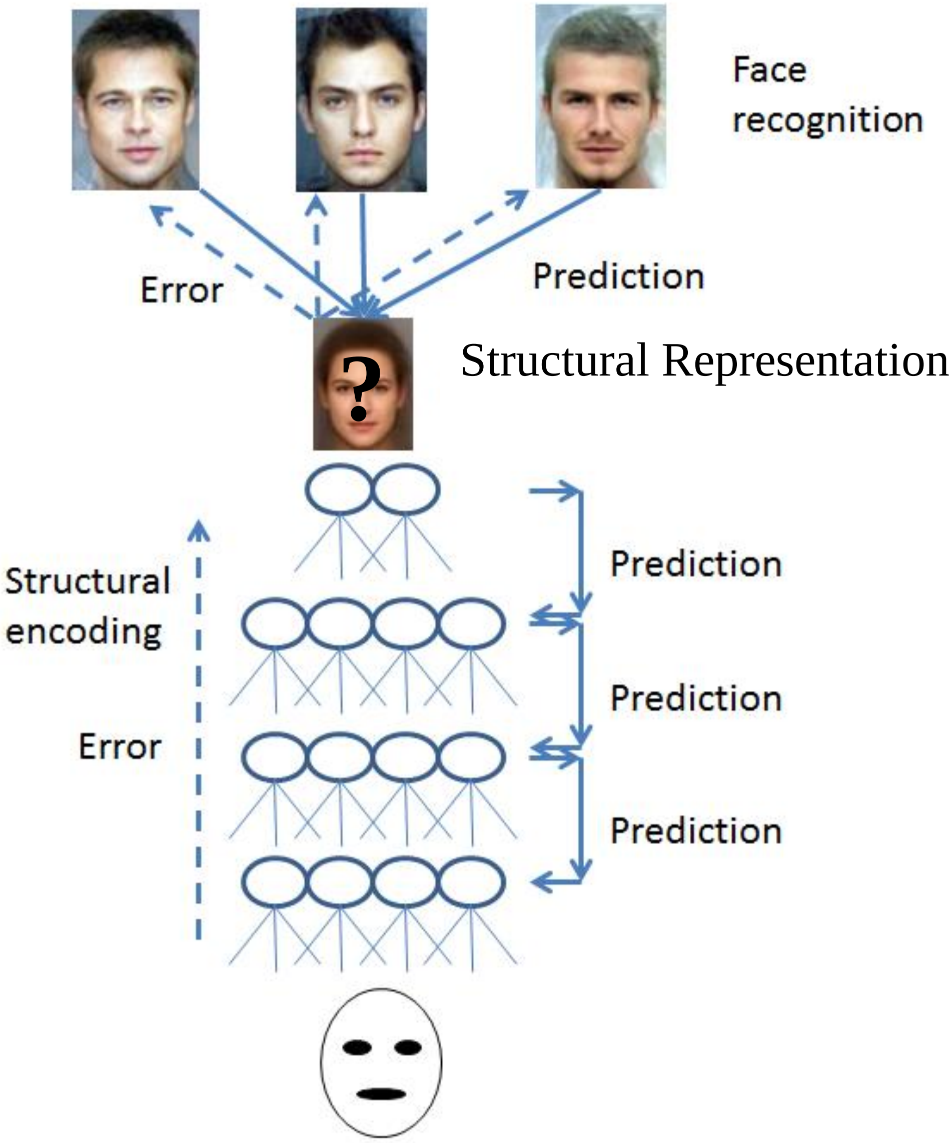

Figure 3.1. a hierarchical model of face recognition, using predictive coding. As information moves up from lower levels to higher levels it becomes increasingly abstractive. Higher levels actively predict the sensory input from lower levels. FRUs become active (i.e. a face is recognised) when the higher levels are able to make top-down predictions about the structural representation (e.g. a particular pattern of activation within a face-space) which minimise prediction error.

3.1.3. The Present Study

In order to investigate the role of recognition in the FIAE, studies 1- 4 in the present paper used a kind of cryptic stimulus, using a technique employed previously within a gender adaptation paradigm. Little, DeBruine and Jones (2005) conducted a series of studies examining sex-contingent face after-effects. In one of their experiments, they applied a subtle transformation to male and female faces that made them appear either slightly more or less male. This transformation affected test faces which were the same sex as the adapting stimulus. The initial aim of the present studies was to investigate whether FIAEs would also be observed for faces manipulated in a similar way to the faces used by Little et al, except within a facial identity paradigm. The advantage of using the transformed stimuli is that they are unrecognisable (see Figure 3.2), but they have been subtly transformed towards a familiar identity. To investigate further the role of recognition in FIAEs, we wanted to find out whether unfamiliar faces can activate the view-invariant representation (FRU) of a familiar face. To do this we exposed participants to: a) unfamiliar faces which were subtly transformed towards either David Beckham or Jude Law (experiments 1 – 4); or b) unfamiliar siblings of a familiar celebrity (experiments 5 & 6). We then tested whether exposure to these unfamiliar transformed faces or sibling faces resulted in a loss of sensitivity to their familiar donor/sibling.

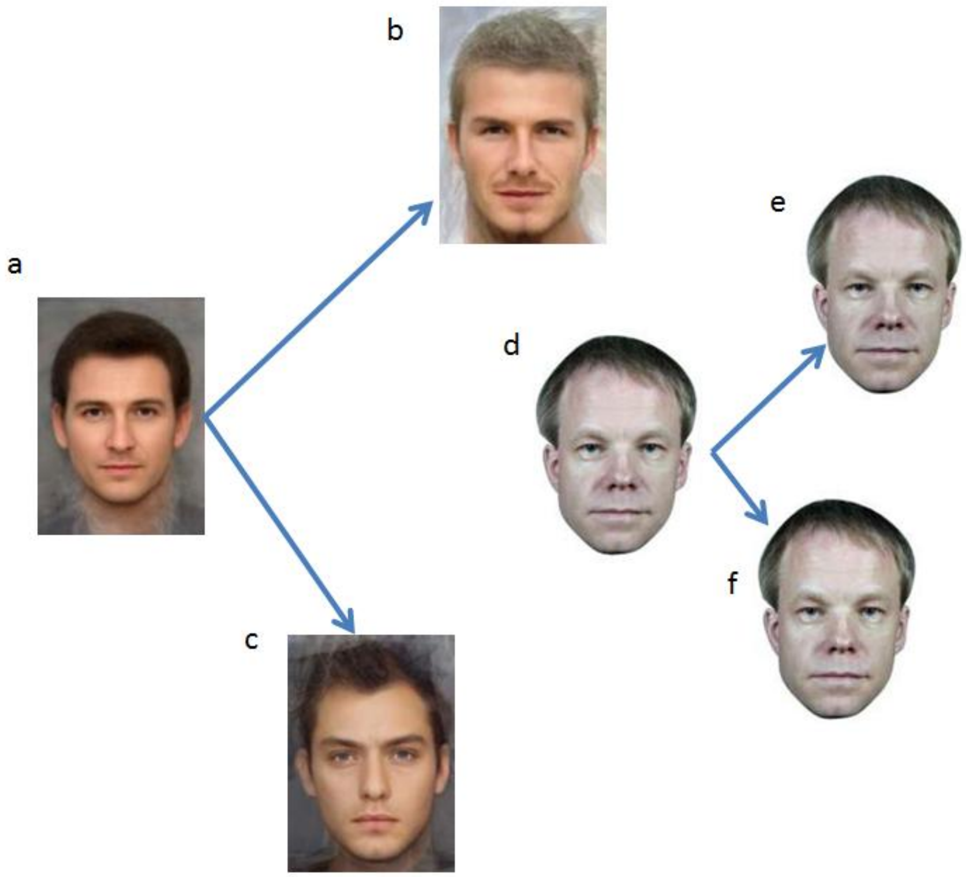

Figure 3.2. an example of how the adapting stimuli used in experiments 1-4 were made. Psychomorph computes a difference vector between an average male celebrity face (a) and average images of David Beckham (b) and Jude Law (c). It then transforms an unknown face (d) 30% of the same differences to produce a David Beckham plus (e) and Jude Law plus image (f).

In experiments 1-3 we used unfamiliar transformed faces as adapting stimuli, and manipulated the degree of physical similarity between the adapting and test faces. In experiment 1 the adapting and test faces were the same shape and orientation, and we found significant adaptation effects, even though the identity of the celebrities "contained" within the adapting faces remained unrecognised. This is seemingly at odds with past research suggesting awareness of an identity is needed for FIAEs to occur (e.g.

Laurence & Hole, 2012; Moradi et al, 2005). Experiments 2 and 3 were conducted to identify whether adaptation to the transformed faces, observed in experiment 1, was occurring at the level of identity processing or was adaptation at some lower level of processing (e.g. structural representation). In experiment 2, we varied orientation between adaptation and test by presenting test stimuli in a three-quarter view; and in experiment 3 we varied the shape by vertically stretching our test faces. Experiment 4 was conducted to find out whether the adaptation was picture adaptation or face adaptation, by using famous transformed faces. A secondary aim of experiment 4 was to explore whether the subtly transformed famous faces would produce after-effects for another familiar identity. If FRUs can account well for the transformed famous faces then a prediction of the hierarchical model is that activation of lower levels will be attenuated (e.g. Mumford, 1992). The purpose of experiments 5 and 6 was to replicate the findings from transformed faces with sibling faces which are, in effect, naturally occurring cryptic faces. The findings from all six experiments will be interpreted in terms of the predictive coding model of face-space proposed by Hancock (in prep).

3.2.Experiment 1: Investigating FIAEs with Unrecognisable Unfamiliar Adapting Faces

3.2.1. Method

3.2.1.1. Design and stimuli

The independent variable was the type of adapting stimulus set seen by each participant. Each set contained 20 frontal male face images. All images were of a neutral expression, were cropped to remove hair, had a width of 200 pixels and were presented in colour against a black background (see Figure 3.3).

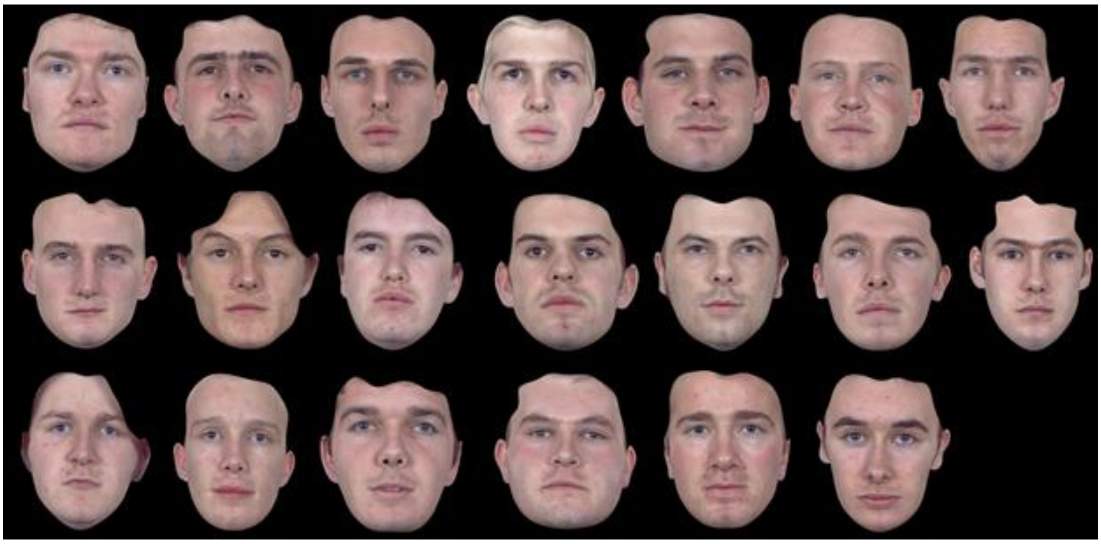

Figure 3.3. The adapting stimuli used for the David Beckham ‘plus’ condition.

Participants were adapted either to a set made up of different frontal views of a single celebrity face (David Beckham or Jude Law), or to a set of male faces where 30% of the difference between an average male face and an average image of either David Beckham or Jude Law was added to each face (see Figure 3.4). Production of these David Beckham ‘plus’ and Jude Law ‘plus’ sets was based on the method used by Leopold et al (2001) and Little et al (2005).

Figure 3.4. Four examples of faces used in the two ‘plus’ adapting conditions. The top row contains David Beckham ‘plus’ faces, and the bottom row contains Jude Law ‘plus’ faces.

The FIAE was measured by showing participants ambiguous morphs between David Beckham and Jude Law and asking them to decide whether each morph looked more like David Beckham or Jude Law (see Hole, 2011; Laurence & Hole, 2012). Frontal images of David Beckham and Jude Law (different from any of the images used as adapting stimuli) were cropped to an oval that displayed only the internal facial features (162 by 188 pixels). From these, Smartmorph v. 1.55 (Meesoft Ltd.) was used to produce six test stimuli, containing 29%, 37%, 46%, 54%, 62% and 71% of Jude Law. While the extremes of this range looked somewhat like Beckham and Law respectively, the identity of the middle values appeared fairly ambiguous (see Figure 3.5). All stimuli were viewed at a distance of approximately 60cm.

Image removed for copyright reasons.

Figure 3.5. The six morph faces used as test stimuli and the percentage of Jude Law contained in each of them.

3.2.1.2. Participants

Sixty four undergraduate students participated for course credits (12 males and 52 females: mean age = 20.67, S.D. = 4.37). Sixteen were adapted to David Beckham, 16 to Jude Law, 16 to David Beckham ‘plus’ and 16 to Jude Law ‘plus’. Participants were only included in the final analysis if they were familiar with both David Beckham and Jude Law, and rated all of the ‘plus’ faces as being unfamiliar.

3.2.1.3. Procedure

Each participant was tested individually. On-screen instructions told them that there would be two phases in the experiment, and explained what would be required in each phase (see Figure 3.6). The instructions explained that in the second phase the participant would have to decide whether each of a series of faces looked more like Person 1 or Person 2. They were instructed that just before they started the task, they would be told who Person 1 and Person 2 were, and how to indicate their decisions.

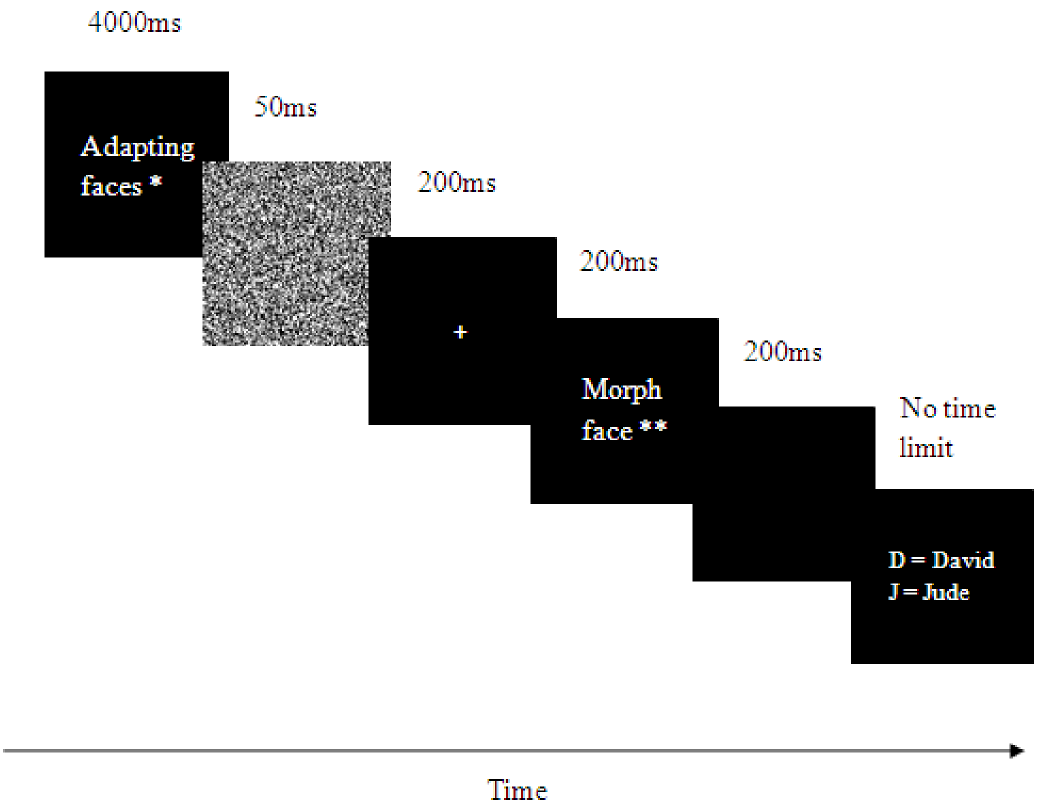

Figure 3.6. The procedure used for each trial.
*20 images shown for 200ms each (making a total of 4000 ms exposure). See Figure 3.4 for an example of the adapting faces used in the David Beckham ‘plus’ condition.
** For each trial, one of the six morphs (see Figure 3.5) was shown.

In the first phase (actually the adaptation phase) the participant was asked to rate the attractiveness of each of a series of 20 faces, using a 1 – 7 scale, where 1 = highly unattractive and 7 = highly attractive. (Which series of faces they saw depended on which of the four adapting conditions they had been allocated to: Beckham, Law, Beckham "plus" or Law "plus"). To ensure that they remained fixated on the adapting stimuli for the duration of their display, participants were asked to say their ratings aloud. Each adapting face appeared on the screen for 6 seconds, to produce a total of 2 minutes' adaptation.

The second phase (actually the test phase) followed immediately afterwards. Each trial consisted of the following events. First, there was a top-up adaptation procedure: each of the 20 faces seen in phase one was shown again for 200 ms, preceded by a fixation cross for 150 ms. The faces appeared in the same order on each trial. The participant was asked to say the word "new" aloud if they thought they had seen a novel face appear in this sequence, one that they had not encountered before. Secondly, the participant saw a morph face (a mixture between two faces) for 200 ms. This had a small white background to distinguish it from the other faces. The participant pressed D if they thought a morph looked more like David Beckham, and J if they thought it looked more like Jude Law. Each of the six morphs was shown 20 times, making a total of 120 trials.

Upon completion, participants were asked if they were familiar with David Beckham and Jude Law. Participants in the David Beckham ‘plus’ and the Jude Law ‘plus’ condition were also asked if these faces were unfamiliar to them, to ensure they had remained unaware of the relevant celebrity's face in the adapting phase.

3.2.2. Results

Each participant provided data on how many morphs (out of 120) they thought looked more like David Beckham or Jude Law. Adaptation to David Beckham or David Beckham ‘plus’, should be reflected in participants making fewer David Beckham responses to the morphs. Adaptation to Jude Law or Jude Law ‘plus’ should result in more David Beckham responses being made to the morphs.

Figure 3.7 shows the mean number of “David Beckham” responses made after prolonged exposure to each type of adapting face. Participants made more “David Beckham” responses when they were in the two Jude Law conditions, compared to the two David Beckham conditions. (Jude Law: M = 82.63, SE = 4.73; Jude Law ‘plus’: M = 71.31, SE = 2.56; David Beckham: M = 34.44, SE = 6.32; David Beckham ‘plus’: M = 61.75, SE = 3.37).

A one-way ANOVA with four levels of adapting face (David Beckham, Jude Law, Jude Law ‘plus’ or David Beckham ‘plus’) found a significant effect of adapting face type on the number of morphs judged to look more like David Beckham, F (3, 60) = 21.10, $p < .001$, $\omega = 0.70$.

Planned contrasts revealed that significantly more “David Beckham” responses were made after adapting to Jude Law than after adaptation to David Beckham, t (27.78) = 6.10, $p < .001$, $r = 0.76$. This is the standard FIAE. This was also the case for those adapted to Jude Law ‘plus’ compared to those adapted to David Beckham ‘plus’, t (28.01) = 2.26, $p = .03$, $r = 0.39$. Thus a significant FIAE was obtained with adapting faces which were not consciously identified as the celebrities concerned.

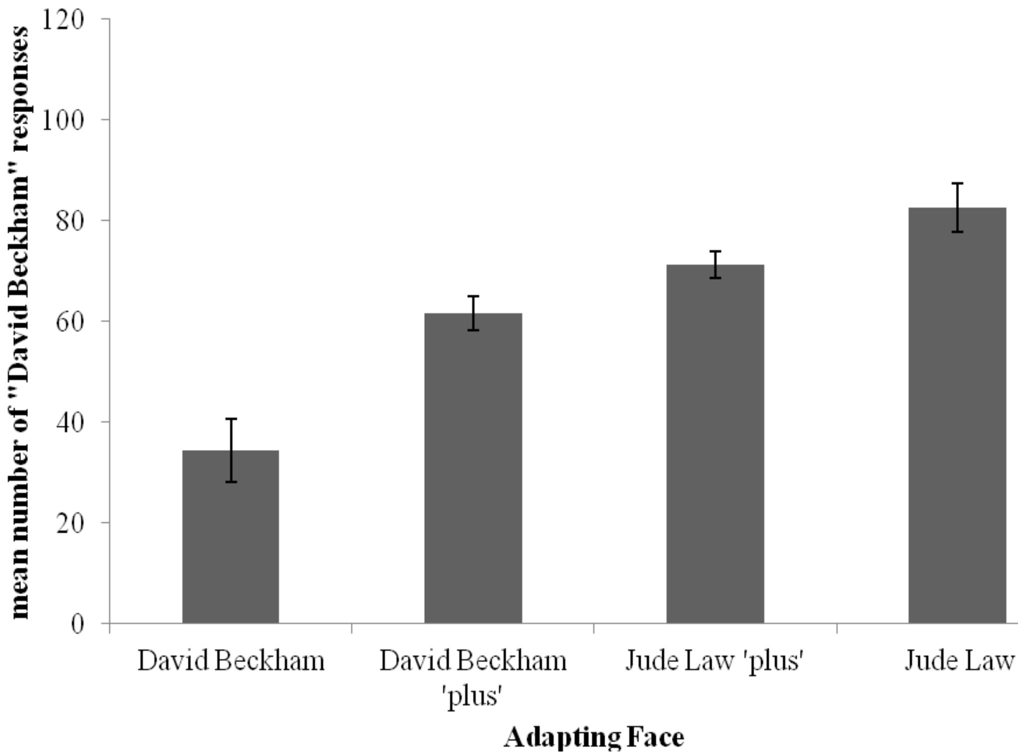

Figure 3.7. the effects of the adapting face type on the overall number of "David Beckham" responses to the 120 morphs between David Beckham and Jude Law. Error bars show +/- 1 S.E.M.

3.3. Experiment 2: Effects of Viewpoint Change Between Adaptation and Test

The results from experiment one suggest that significant identity adaptation to the ‘plus’ stimuli occurred without awareness of the identity contained within them. Even though participants were not aware that any identity information was present in the adapting images, they behaved in a way which suggested that the adapted identity had been processed. These effects were, however, weaker than when the identity was explicitly recognised in the adapting stimuli.

The finding that FIAEs can occur without awareness or recognition of an adapting identity apparently contradicts previous research (Moradi et al, 2005; Laurence & Hole, 2012). However, one possibility is that adaptation to an identity can occur partly at the structural level of an individual's facial representation. Although previous studies have suggested that FIAEs can occur at a higher level than image-based, low-level adaptation (e.g., Benton Jennings & Chatting, 2006; Fox, Oruc, & Barton, 2008; Hills et al., 2010; Hole, 2011; Yamashita, Hardy, De Valois, & Webster, 2005), perhaps the underlying structural information that was present in the 'plus' faces was sufficient to affect the associated identity's representation, and therefore resulted in an identity after-effect.

The aim of experiment 2 was to replicate the findings obtained from the 'plus' stimuli in experiment one, using stimuli that differed in viewpoint between adaptation and test. Faces with which we have had more experience may have different representations from newly learnt faces: the latter's representations are probably more tied to the specific views that have been encountered. Following on from Bruce and Young (1986), Burton, Jenkins and Schweinberger (2011) distinguish between "pictorial" and "structural" codes in facial representations. They suggest that pictorial codes are based on treating faces as patterns or pictures, and subsequent recognition may depend on information contained within the particular image being viewed. Structural codes are based on more abstractive representations and are not necessarily dependent on a specific view.

Findings from Jiang, Blanz and O'Toole (2007) suggest that faces which are more familiar produce greater FIAEs and also a stronger transfer of after-effects across viewpoint changes. This relates to the idea of Burton et al. (2011) that recognition of less familiar faces is based on pictorial codes that rely on specific views of a face. When a face is familiar, and has a more abstractive representation, adaptation after-effects transfer across viewpoints to a greater extent. Also brain areas such as the anterior fusiform cortex have been implicated in image-independent processing of familiar faces (Eger, Schweinberger, Dolan & Henson, 2005).

Jiang et al (2007) used faces with which participants were familiarised during the course of the experiment, but FIAEs have also been observed for faces that are highly familiar outside of an experimental setting, such as celebrities (e.g. Carbon & Leder, 2005; Carbon et al, 2007; Carbon & Ditye, 2010, 2012; Hole, 2011; Hills et al, 2010; Laurence & Hole, 2012; Little et al, 2012). Hills et al (2008) and Hole (2011) also obtained significant identity after-effects when the adapting and test stimuli were of different viewpoints. If prolonged exposure to the 'plus' faces does activate the view-invariant representation (FRU) associated with the familiar donor face, then this should transfer across viewpoint and an after-effect should occur.

If the adaptation observed in experiment 1 was occurring at a lower level of processing than FRUs (e.g. affecting a structural representation within face-space) then we would not expect the FIAE to transfer across viewpoint. In contrast to familiar faces, unfamiliar faces (or faces with limited exposure) have been found to produce less transfer of identity adaptation across viewpoint (Jiang et al, 2006, 2007, 2009; see also Jeffery, Rhodes & Busey, 2007). Favelle, Palmisano and Avery (2011) have also demonstrated that unfamiliar face processing is viewpoint-dependent and suggest that this may mainly be due to less availability of configural information for unfamiliar faces. Therefore if adaptation does not transfer, it may be that the ‘plus’ faces do not provide enough configural information to transfer across to a different viewpoint of a familiar face.

3.3.1. Method

3.3.1.1. Design and stimuli

The design and stimuli were exactly the same as in experiment one, except for the test stimuli used to measure the FIAE. Three-quarter view images of David Beckham and Jude Law were cropped to an oval that displayed only the internal facial features (152 by 182 pixels), and from these a series of morphs were produced (see Figure 3.8).

Image removed for copyright reasons.

Figure 3.8. The six three-quarter view morph faces used as test stimuli and the percentage of Jude Law contained in each of them.

3.3.1.2. Participants

Sixty eight undergraduate students took part in return for course credits or money (11 males and 57 females: mean age = 19.47, S.D. = 1.11). Seventeen were adapted to David Beckham ‘plus’, 17 to Jude Law ‘plus’, 17 to David Beckham and 17 to Jude Law.

3.3.1.3. Procedure

The procedure was exactly the same as in experiment one.

3.3.2. Results

As with experiment one, each participant provided data on how many morphs (out of 120) they thought looked more like David Beckham or Jude Law.

Figure 3.9 shows the mean number of “David Beckham” responses made after prolonged exposure to each type of adapting face. (Jude Law: M = 96.59, SE = 4.33; Jude Law ‘plus’: M = 71.59, SE = 3.93; David Beckham: M = 38.65, SE = 7.03; David Beckham ‘plus’: M = 69.24, SE = 4.97).

A one-way ANOVA with four levels of adapting face (David Beckham, Jude Law, Jude Law ‘plus’ or David Beckham ‘plus’) found a significant effect of adapting face type on the number of morphs judged to look more like David Beckham, F (3, 64) = 20.79, $p < .001$, $\omega = .68$.

Based on our a priori predictions, planned contrasts revealed that significantly more “David Beckham” responses were made after adapting to Jude Law compared to after adaptation to David Beckham, t (64) = -7.87, p < .001, r = 0.70. As in experiment 1, this demonstrates a standard FIAE. However, there was no significant difference in the number of "David Beckham" responses for those adapted to Jude Law ‘plus’ compared to those adapted to David Beckham ‘plus’, t (64) = 0.32, p = .75, r = .04. Thus the FIAE produced by unrecognisable faces in experiment one does not transfer across viewpoints, in contrast to the FIAE produced by recognisable celebrity faces.

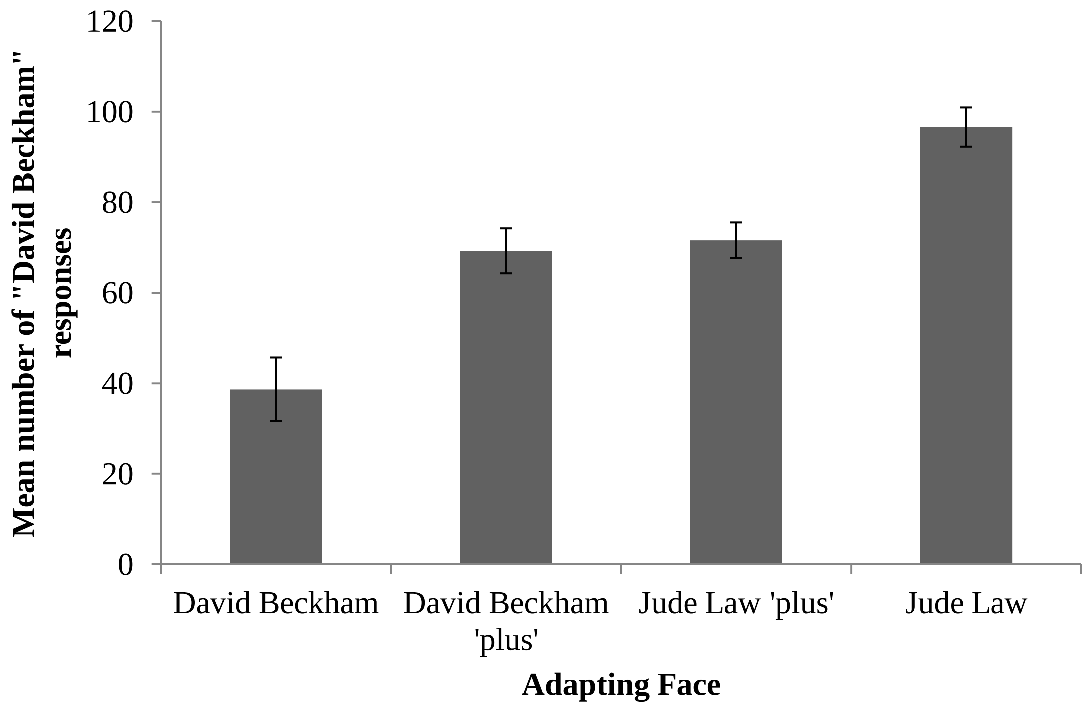

Figure 3.9. the effects of the adapting face type on the mean number of "David Beckham" responses to the morphs between three-quarter views of David Beckham and Jude Law. Error bars show +/- 1 S.E.M.

3.4. Experiment 3: Effects of Vertical Stretching Between Adaptation and Test

The results from experiment 2 suggest that when a highly familiar face is recognised during adaptation, the transfer of after-effects is view-invariant. This was not the case for the ‘plus’ faces. This suggests that the ‘plus’ faces did not activate a view-invariant representation of their familiar donors. The significant after-effects found in experiment one could have occurred because the unfamiliar ‘plus’ faces only affected a view-specific representation of their familiar donors. An alternative possibility is that the FIAEs observed for the ‘plus’ faces occurred at a low level of processing, perhaps due to pictorial overlap between the adapting and test stimuli.

In order to rule out low-level explanations for the FIAE, the test stimuli in experiment 3 were all stretched to twice their normal height. Stretching was used to reduce the physical overlap between the adapting and test images. Yet stretched faces are processed in much the same way as normal faces (Hole, George, Eaves & Rasek, 2002; Bindemann, Burton, Leuthold, & Schweinberger, 2008), and have been found to produce comparable FIAEs to normally-proportioned faces (Hole, 2011).

If FIAEs are occurring at a higher level of processing, based on view-specific information about the faces, then the findings observed in experiment one should be replicated with stretched test faces. Laurence and Hole (2012) suggest that recognition is essential for identity after-effects to occur at a high-level. If the FIAEs observed for the ‘plus’ stimuli are due to low-level adaptation, and high-level face after-effects are dependent on recognition, then there should be no difference in the number of “David Beckham” responses after prolonged exposure to the stretched David Beckham ‘plus’ and Jude Law ‘plus’ faces.

3.4.1.Method

3.4.1.1. Design and stimuli

As in experiment one, the independent variable was the adapting stimulus set seen by each participant, however in experiment three participants were only adapted to either the David Beckham 'plus' stimuli or the Jude Law 'plus' stimuli.

The FIAE was measured with the same morphs used in experiment 1, except that the morphs were stretched to twice their original height (162 by 376 pixels; see Figure 3.10).

Image removed for copyright reasons.

29% 37.5% 46% 54%, 62.5% 71%

Figure 3.10. The six stretched morph faces used as test stimuli and the percentage of Jude Law contained in each of them.

3.4.1.2. Participants

Thirty two students participated for course credits or money and were included in the final analysis (11 males and 21 females: mean age = 21.78, S.D. = 3.63). Sixteen were adapted to David Beckham ‘plus’ and 16 to Jude Law ‘plus’. As in experiment one, participants were only included in the final analysis if they were familiar with both David Beckham and Jude Law, and were unfamiliar with the ‘plus’ faces.

3.4.1.3. Procedure

The procedure was the same as in experiment one.

3.4.2. Results

Participants provided data on how many morphs (out of 120) they thought looked more like David Beckham or Jude Law.

An a priori independent measures *t*-test was conducted to test our predictions. It showed that participants who were adapted to stretched David Beckham ‘plus’ (M =

60.06, SE = 3.37) or stretched Jude Law ‘plus’ (M = 63.56, SE = 2.95) stimuli did not significantly differ in the number of morphs judged to look more like David Beckham, t (30) = 0.78, p = .44, r = .14. Thus whatever facial property gave rise to the FIAE in experiment one does not survive stretching of the image.

3.5. Experiment 4: Effects of Familiar ‘Plus’ Faces

An FIAE for a highly familiar face can be produced by exposure to unfamiliar faces that contain information from that identity (experiment 1). The findings from experiments 2 and 3, however, suggest that these after-effects are view specific (experiment 2) and depend largely on physical overlap between the images used as adapting and test materials (experiment 3).

The Bruce and Young (1986) model of face processing suggests that visual face processing involves low-level analysis, facial structure analysis, and activation of face recognition units (FRUs) which are connected to Person Identity Nodes (PINs). Low-level analysis is based on non-face-specific pictorial codes where image specific information is processed e.g. lighting or pose. Structural analysis is more face-specific, and allows us to distinguish one face from others. The structural codes for unfamiliar faces are limited to the particular view of the face that one is exposed to, making them view-dependent. In contrast, the FRU for a familiar face is a more abstractive, high-level representation. It is activated by any recognisable view of a familiar face, and allows access to semantic information about that person, via their PIN. Taken together, the findings across all three experiments suggest that the adaptation to the transformed faces which was found in experiment 1 may well have occurred during the earlier stages of processing, i.e. during either low-level analysis or structural encoding.

The results of experiments 1-3 show that adaptation effects with these transformed faces depend heavily on physical overlap between the adapting and test stimuli. It is therefore unlikely that adaptation was occurring at the level of the FRU, since familiar face recognition (FRU activation) is known to be highly tolerant of viewpoint changes (see Johnston & Edmonds, 2009 for a review), and also dependent on explicit recognition of the face to which the FRU responds (e.g. Laurence & Hole's, 2012 results). One possibility is that the transformed faces were eliciting their effect during face structure analysis. Prolonged exposure to the transformation distortion (e.g. to look a bit more like David Beckham or Jude Law) that we applied to each of the unfamiliar faces may have biased face-space so that the pattern of activation overlaps to some extent with the pattern of activation for the transformed identity. This is because all of the faces to which participants were exposed had this in common with each other. As mentioned in the introduction this effect could operate via opponent coding or multichannel coding. Jeffery et al (2007) suggest that faces without abstractive representations (unfamiliar faces) may be processed in a fairly view-specific manner. If our unfamiliar adapting faces did not have abstractive, view-independent representations, then the transformation distortion that we applied to the adapting faces would be specific to the view that it was induced in, and would not transfer to different viewpoints.

The argument for adaptation occurring during structural analysis is less clear cut when the findings with stretched faces (experiment 3) are considered. Evidence suggests that stretched faces and normal faces are processed in the same way (Hole et al, 2002; Bindemann et al, 2008; Hole 2011) so it is unclear why adaptation did not occur when stretched faces were used as test stimuli. One possibility is that the effect of the "plus" transformation was simply not strong enough to be detectable after stretching (however, the effect size was *r* = .14, suggesting a small effect). Taken together, the results suggest that adaptation to the transformed faces is probably happening during structural analysis or low-level visual analysis.

The purpose of experiment 4 was to replicate the findings from experiment 1, but using 20 transformed familiar (celebrity) faces as the adapting stimuli instead of transformed unfamiliar faces. The adaptation to transformed faces, in experiment 1, was not affecting David Beckham's representation because it did not transfer across viewpoint (experiment 2) or significantly survive stretching (experiment 3). This could be explained by a hierarchical model of face processing in which there is both a general face-space, and identity-specific representations for familiar individuals (see also Carbon & Ditye, 2010). The latter could be FRUs which predict patterns of activation within face-space. If adaptation was happening at a lower level than the FRUs, possibly during structural encoding of faces within face-space, then there should be no after-effect with transformed celebrity faces. This is because each celebrity would have their own separate FRU which would account well for the sensory information. Predictive coding suggests that when a higher level explanation is selected, the activity of lower levels will be attenuated (e.g. Mumford, 1992).

Stevenage, Lee and Donnelly (2005) suggest that familiarity can be signalled before completion of structural processing. This might be how FRU's can be updated without significantly affecting a general face-space for unfamiliar faces. Brief exposure (6 seconds then 200ms per trial) to a slightly manipulated version of a celebrity's face, in a "plus" version, might update their FRU but have no effect on a general unfamiliar face-space.

3.5.1. Method

3.5.1.1. Design and stimuli

The design was the same as in experiment 3: participants were adapted to David Beckham 'plus' stimuli or Jude Law 'plus' stimuli. The 'plus' stimuli were 20 images of different celebrities all resized to a width of 200 pixels (See Figure 3.11), rather than 20 unfamiliar faces as in experiments 1, 2 and 3.

Image removed for copyright reasons.

Figure 3.11. Four examples of faces used in the two 'plus' adapting conditions. The top row contains David Beckham 'plus' faces, and the bottom row contains Jude Law 'plus' faces.

The FIAE was measured with the same morphs between Beckham and Law as used in experiment 1. We also provided participants with a familiarity checklist for the familiar faces that they were adapted to.

3.5.1.2. Participants

Thirty students participated for course credits or money (3 males and 27 females: mean age = 20.4, S.D. = 4.73). 15 were adapted to David Beckham ‘plus’ and 15 to Jude Law ‘plus’. As in experiment one, participants were only included in the final analysis if they were familiar with both David Beckham and Jude Law, and were familiar with 16 or more of the ‘plus’ faces.

3.5.1.3. Procedure

The procedure was the same as in experiment one. Upon completion, participants were provided with a checklist and asked to indicate which faces from the experiment were familiar and which were unfamiliar.

3.5.2. Results

Each participant provided data on how many morphs (out of 120) they thought looked more like David Beckham or Jude Law.

An a priori independent measures *t*-test showed that participants who were adapted to David Beckham ‘plus’ faces (M = 63.07, SE = 3.13) or Jude Law ‘plus’ faces (M = 65.60, SE = 6.69) did not significantly differ in the number of morphs judged to look more like David Beckham, $t\ (28) = .34$, $p = .73$, $r = .06$. Adaptation to transformed famous faces produced no FIAE for the celebrities towards which they had been transformed. This contrasts with the results of experiment 1, in which there was significant adaptation after exposure to transformed unfamiliar faces.

3.6. Experiment 5: Effects of Adapting to Unfamiliar Sibling Faces

The findings from experiments 1 – 3 suggest that adaptation effects for the transformed faces may be happening either at a low-level or during structural encoding of faces. Experiment 4 has demonstrated that when the transformed faces are famous, adaptation does not occur. This might suggest that the observed after-effect in experiment 1 was not due purely to low-level picture adaptation. However, one might also argue that higher level FRUs could have provided feedback to early visual areas to attenuate their response. Fang, Kersten and Murray (2008) found that perceptual grouping of lines into a coherent shape reduced activity in the primary visual cortex and increased activity in the lateral occipital complex (a higher level object processing area). He, Kersten and Fang (2012) have also shown that perceptual grouping can modulate higher and lower level adaptation after-effects. He et al used diamond and a physically similar non-diamond stimulus as adaptors and measured both tilt after-effects and higher level shape after-effects. The diamond stimulus produced shape after-effects whereas the non-diamond did not produce shape after-effects. In contrast, the non-diamond stimulus produced significantly greater tilt after-effects than the diamond stimulus. He et al suggest that these findings indicate that higher level representations can attenuate low-level feature representations.

Experiment 5 further investigated the effects of cryptic stimuli on the FIAE by using unfamiliar sibling faces rather than transformed stimuli. In effect the face of a sibling of a famous person represents a naturally occurring transformed face for that celebrity. The aim of the study was to find out if an unfamiliar sibling face can produce a FIAE for their celebrity sibling in the absence of any explicit recognition that the two are related.

We looked at sibling FIAEs both within and across genders, by using same-sex siblings and opposite-sex siblings. It has already been shown (with computer generated faces) that adaptation can transfer from an unfamiliar face to its unfamiliar cross-gender sibling, suggesting a shared neural population for coding male and female faces (Griffin, McOwen & Johnston, 2011). If the after-effects in the present studies are occurring due to similarity between the adapting and test faces, we should find more adaptation with same-sex siblings than with opposite-sex siblings. Similarity ratings for same-sex adult siblings are higher than those for opposite-sex siblings (DeBruine et al, 2009). However, if sibling FIAEs are occurring at a structural level within a general face-space for unfamiliar faces, where all faces are coded in the same way, gender should not affect the size of the FIAE. This would result in equivalent FIAEs when adapting and testing occur with either same-sex siblings or opposite-sex siblings.

A secondary aim of the study was to find out whether sibling FIAEs were related to explicit sibling detection. To do this we gave our participants a kin detection test by presenting them with pairs of unfamiliar faces, half of which were related. If sibling FIAEs occur via a kin detection mechanism then we might expect a relationship between performance on the two tasks.

3.6.1. Method

3.6.1.1. Design

3.6.1.1.1. Adaptation. There were three independent variables. The first was time of testing, which was a repeated measures variable: participants were tested both before and after two minutes of exposure (adaptation) to the unfamiliar sibling of a celebrity. The second IV was the identity of the unfamiliar sibling to which they were adapted: Doug Pitt (Brad Pitt's brother); Nicholas Cowell (Simon Cowell's half-brother); James Haven (Angelina Jolie's brother); or Amy Stiller (Ben Stiller's sister).

The third IV was whether or not the unfamiliar sibling was identified. Participants were divided into three groups: "recognisers", "misidentifiers" and "non-recognisers". "Recognisers" were those who identified the celebrity's sibling as being familiar and resembling the celebrity, e.g. identifying that Doug Pitt was familiar and resembled Brad Pitt. "Misidentifiers" indicated that the celebrity's sibling was familiar but did not indicate that it resembled the correct celebrity or identified the face as someone else, e.g. identifying that Doug Pitt was familiar and resembled John Travolta. "Non-recognisers" were those who simply identified the celebrity's sibling as unfamiliar, without claiming that it resembled anyone else.

Testing involved presenting participants with six ambiguous morphs between the celebrity sibling and another celebrity. The morphs were either between Brad Pitt and Jude Law; Simon Cowell and David Beckham; Angelina Jolie and Scarlett Johansson; or Ben Stiller and Johnny Depp. Each morph was randomly presented six times, making a total of 36 trials. Participants had to indicate whether they thought each morph looked more like one celebrity or the other.

3.6.1.1.2. Sibling test. We gave participants a kin-recognition test. Participants were presented with pairs of unfamiliar sibling or non-sibling faces and asked to decide whether each pair were related or unrelated. Pairs were displayed until the participant made a response. The dependent variable was the number of correct identifications of kin relationships.

3.6.1.2. Stimuli

3.6.1.2.1. Adapting stimuli. Adapting stimuli were eight different images of the target celebrity's sibling (see Figure 3.12a). The images were taken from the internet via a Google search. In order to limit the contribution of low-level adaptation, images were chosen that varied in expression, pose[9] and size (the size of the images ranged from 105 by 110 pixels to 150 by 167 pixels). The images were cropped to show the whole head (including the hair).

3.6.1.2.2. Test stimuli. Test stimuli were six ambiguous morphs between images of the celebrity sibling and another famous identity (see Figure 3.12b). For example in the Doug Pitt condition, morphs were between Brad Pitt and Jude Law. The morphs were constructed in the same way as in experiment 1 and they were all resized to a width of 162 pixels [10].

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[9] At the time of conducting experiment 5, we had not yet analysed the results of experiments 1 and 2, and so did not appreciate the extent to which any sibling-induced after-effects might depend on a close match between the poses of the adapting and test stimuli. After all of the experiments were finished and the data analysed, we re-examined our adapting stimuli, and found that in the case of each sibling, most of the images were full-face or near-full face. Our interpretation is that these stimuli (the ones that physically overlapped with the test stimuli) were, fortuitously, sufficient to produce the observed after-effects; the minority of different-view faces probably contributed little to the overall results (e.g. in the case of Doug and Brad Pitt, it was probably images 1-4 and 6-7 in Figure 3.12 that were responsible for the observed after-effect, rather than images 5 and 8). The net effect of this failure to control for adapt-test viewpoint similarity in experiment 5 is that the size of the after-effects may have been somewhat underestimated.

[10] No formal steps (e.g. a pilot study) were taken to ensure that the four morph continua were perceptually equivalent, in terms of how much of each identity was contained in each morph. Steps were taken, however, when conducting our statistical analysis to ensure that any direct comparison between the morphs was done once the data had been standardised across our conditions.

Image removed for copyright reasons.

Figure 3.12. an example of the stimuli used in the Doug Pitt condition, a) the adapting stimuli, b) the test stimuli.

3.6.1.2.3. Sibling stimuli. Thirty face pairs were produced. Half of the pairs were genetic siblings, and half were non-siblings. These images were obtained from a separate study on kin recognition that had been performed in our laboratory and were all approximately between 300 and 325 pixels in width. All stimuli were viewed from a distance of about 60cm.

3.6.1.2.4. Questionnaire. Participants were given four questions to answer during the course of the experiment (see the procedure below for a description of the questions).

3.6.1.3. Participants

Participants were 130 members of the public (33 males, 97 females: mean age = 31.28, SD = 15.57) who attended an open day visit to the University of Sussex. Thirty-six participants recognised the adapting face as looking like its celebrity sibling and 94 did not recognise the adapting face. Table 3.1 contains a breakdown of how many participants were recognisers, misidentifiers or non-recognisers in each adapting condition. There were fewer participants who recognised the adapting face because we had no control over spontaneous recognition in our participants. There were also fewer participants in the James Haven condition because more participants in that condition failed to recognise both of the test faces (i.e. Angelina Jolie and Scarlett Johansson) and so were therefore eliminated from the analysis.

Table 3.1

The number of recognisers, people who misidentified the sibling and non-recognisers in each adapting condition.

	Adapting Face			
	Doug Pitt	Nicholas Cowell	James Haven	Amy Stiller
Recognisers	12	12	6	6
Misidentified	6	2	2	8
Non-recognisers	17	23	17	19

3.6.1.4. Procedure

The procedure below is described for participants in the "Doug Pitt" condition. The procedure was exactly the same for those adapted to the other celebrity siblings (e.g. those adapted to Amy Stiller) except that the morphs and adapting stimuli were of different identities (e.g. the adapting stimuli were images of Amy Stiller and test stimuli were morphs between Ben Stiller and Johnny Depp).

Initial on-screen instructions asked participants to indicate if they knew who Brad Pitt and Jude Law were. If participants knew who both identities were, they were asked to press Y for yes. Those who did not know both identities were asked to raise their hand and wait for further instructions: the experimenter then pressed N for no, and told participants to make guesses for the duration of the experiment. (These participants were later excluded from the final analysis).

3.6.1.4.1. First test phase. Participants were told that they would be presented with a series of morphed faces (a mixture of two faces) and that they would need to indicate whether each morph looked more like Brad Pitt or Jude Law. They were instructed to press B if they thought that the morph looked more like Brad Pitt or press J if they thought it looked more like Jude Law. Each participant saw a random sequence of morphs. There were a total of 36 trials as each of the six morphs was shown six times. Morphs were presented in the centre of the computer screen for 200 ms, each preceded by a fixation cross for 750 ms. For the first trial only, the fixation cross was displayed for 2750ms so that participants did not miss the first morph.

3.6.1.4.2. First familiarity check. On-screen instructions told participants that they would be shown an image of a face for a few seconds and that they should then answer questions 1 and 2 on the questionnaire. A frontal image of Doug Pitt was then shown for 4000ms. The questionnaire asked them to firstly indicate whether the face that they has just been shown was familiar or unfamiliar (Question 1). Secondly they were asked to indicate if they thought the face looked like anyone familiar (by circling yes or no: Question 2a). If they answered "yes", they were instructed to indicate who they thought the face looked like (participants were given space to write an answer: Question 2b).

3.6.1.4.3. Adaptation and second test phase. Participants were instructed that the next phase of the experiment would be in two parts. In part one they would see different views of the face that they had just seen and they should concentrate on the face at all times. They would be told when part two was about to begin. The instructions for part two were the same as for the first test phase. Participants were then given a summary of the two parts before they started part one.

On-screen instructions informed participants that part one was about to commence. They then viewed eight images of Doug Pitt, each shown three times for 5 seconds making a total of 2 minutes. This was the adaptation part of the experiment. Participants were then prompted that part two was about to begin and completed the second test phase (this had exactly the same procedure as the first test phase).

3.6.1.4.4. Second familiarity check. On-screen instructions told participants that they should complete questions 3 and 4 on the questionnaire. These questions asked participants whether the face from part one was familiar or unfamiliar, and whether it looked like anyone familiar (similar to questions 1 and 2a and 2b). This was to check whether those who initially indicated that the face was unfamiliar still thought that it was unfamiliar.

3.6.1.4.5. Unfamiliar kin detection test. Participants were instructed that they would see a series of pairs of faces. They were told to decide whether each pair were siblings or non-siblings, by pressing "s" or "n" respectively.

Participants then viewed 30 faces pairs (half of which were siblings and half non-siblings) in a random order. Each face pair was presented for 10 seconds, preceded by a fixation cross for 1000ms.

When participants had completed this they were asked to complete the remainder of the questionnaire. This asked for their age, gender, whether they had any siblings and, if so, whether they were the eldest child.

3.6.2. Results

For each participant the number of morphs (out of 36) that they judged to look like the sibling of the face to which they were adapted was recorded twice, first during the baseline block and then again in the first test session. For example, if participants were adapted to Doug Pitt, the number of morphs judged to look more like Brad Pitt was recorded before and after adaptation. If prolonged exposure to Doug Pitt resulted in a loss in sensitivity (adaptation) to his brother then fewer Brad Pitt decisions should be made after the first test session, compared to the pre-adaptation baseline. The results are described separately for "non-recognisers" and "recognisers": there were too few "misidentifiers" for any meaningful data analysis.

3.6.2.1. Non recognisers

Firstly we wanted to find out whether after-effects would be produced when participants did not identify that the adapting face looked like its celebrity sibling.

A series of repeated measures *t*-tests was conducted to find out whether significant after-effects occurred in each adapting condition. We compared the number of celebrity sibling responses made at baseline and during test. There were significantly fewer celebrity sibling decisions made for all adapting conditions at test compared to baseline: Doug Pitt (baseline M = 22.24, SE = 1.67; test M = 19.24, SE = 1.44; t (16) = 2.21, p = .04, d = .54); Nicholas Cowell (baseline M = 19.30, SE = 1.69; test M = 14.17, SE = 1.43; t (22) = 2.54, p = .02, d = .53); James Haven (baseline M = 25.12, SE = 1.94; test M = 21.65, SE = 1.93; t (16) = 2.63, p = .02, d = .64); and Amy Stiller (baseline M = 25.21, SE = 1.65; test M = 18.89, SE = 1.68; t (18) = 4.71, p < .001, d = 1.09). Significant FIAEs thus occurred for each condition, even though our participants did not explicitly identify any resemblance between the non-famous adapting face and its celebrity sibling.

We computed a FIAE score. To do this we subtracted the number of familiar sibling decisions to the morphs which were made during the test session, from the number made at baseline. If no after-effect occurred then the difference score should be zero. If, on the other hand, after-effects did occur, then the difference score should be greater than zero, reflecting fewer sibling decisions at test compared to baseline. A one-way ANOVA on these data showed that there was no significant difference in the size of the FIAE between the four adapting conditions (Doug Pitt vs. James Haven vs. Nicholas Cowell vs. Amy Stiller), F (3, 107) = .79, p = .50, ω = .01.

3.6.2.2. Recognisers

Due to the nature of the experiment we were not able to control how many participants recognised each celebrity's sibling. As can be seen from Table 1, few people recognised the siblings of Angelina Jolie and Ben Stiller. ANOVA found no difference in the size of the FIAE between the four adapting conditions (Doug Pitt vs. James Haven vs. Nicholas Cowell vs. Amy Stiller), F (3, 32) = .18, p = .18, ω = .06. We therefore combined all conditions and performed a repeated measures t-test to compare the number of celebrity sibling responses made at baseline and during test. There were significantly fewer celebrity sibling responses at test (M = 18.61, SE = 1.20) compared to baseline (M = 23.08, SE = 1.28), t (35) = 4.47, p <.001, d = .75. This suggests that participants who identified the unfamiliar face as resembling its celebrity sibling, had a FIAE to that celebrity.

3.6.2.3. Explicit kin detection test (non-recognisers)

We used signal detection theory to estimate performance on the kin detection task. A *d'* value of 0 would suggest our participants were performing at chance and a value of 3.5 suggests perfect performance. A one-sample Wilcoxon signed rank test showed that participants' performance was significantly different from zero, $p < .05$. However, the median *d'* value obtained was .16 which suggests that performance on this task was poor.

To investigate further, we used C to compare our participants' performance with that of an ideal participant (an ideal participant would have few misses and few false alarms). A negative value of C would indicate that participants were biased towards responding “sibling” , while a positive value of C were positive would reflect a bias towards responding “non-sibling”. A one-sample Wilcoxon signed rank test showed that our obtained value of C was significantly different from a value of 0, $p < .05$. The median value of C was -.16 which indicates that our participants had a significant bias towards indicating the face pairs were siblings.

Performance on the explicit kin detection task was not significantly related to the size of the sibling FIAE, r_s = .05, *p* = .64. Therefore the sibling FIAEs we found were not related to how good participants were at making explicit decisions about kinship in unfamiliar faces. There was also no significant difference in performance on the kin detection test between participants who were first-born (n = 36, *Mdn* = .16) and those who were second-born (n = 33, *Mdn* = .16), *U* =533.50, *z* = -.73, *p* = .47, *r* = .09.

3.7. Experiment 6: Effects of Viewpoint Change for Unfamiliar Sibling Faces

The findings from experiment 5 suggest that an unrecognised sibling face can produce an FIAE for its celebrity sibling. Using naturalistic stimuli we have shown that unfamiliar faces, which share both genetic and environmental components with a familiar face, also produce perceptual after-effects. Using different images of their siblings as the adaptors, which all varied in their lighting and pose, reduces the contribution of low-level image properties. These effects occur across gender, and were of the same size. These findings suggest that unrecognised cryptic faces were probably exerting their effect during structural encoding. FIAEs might be occurring at a structural level within a general face.

Little et al (2005) and Bestelmeyer et al (2008) suggest that there are distinct norms for gender. The present findings suggest, assuming adaptation was occurring at a structural level, if there are norms, then these norms are perhaps not that distinct from one another, as equally large sibling after-effects were observed across and within gender. We also failed to replicate the findings of Kaminski, Ravary, Graff and Gentaz (2010), who found a later born (compared to first born) advantage for kin detection in strangers’ faces.

Experiment 5 replicated experiment 1. However, due to the method of testing it is unclear whether the sibling-induced after-effects were happening within a general face-space or because the non-famous faces affected FRUs. Participants saw multiple different views of the sibling and most of these views were frontal (the same viewpoint as the morphs). Experiment 2 indicates that the best way to test whether a familiar person's view-invariant representation has been accessed is to use adapting and test images of different views. Therefore experiment 6 was conducted with frontal view adapting faces and ¾ view test faces.

3.7.1. Method

3.7.1.1. Design

The design was the same as in experiment 5, except that participants were only adapted to one celebrity's sibling (Doug Pitt).

3.7.1.2. Participants

Participants were 28 undergraduates at the University of Sussex who took part for course credits (4 males, 24 females: mean age = 20.18, SD = 3.79). Four participants recognised the adapting face as looking like Brad Pitt, nine misidentified the adapting face as looking like an unrelated celebrity and 15 did not detect that the adapting face was famous.

3.7.1.3. Stimuli

3.7.1.3.1. Adapting stimuli. Adapting stimuli were six different frontal view images of Doug Pitt.

3.7.1.3.2. Test stimuli. Test stimuli were constructed in the same was as in all previous experiments, except that ¾ views of Brad Pitt and Jude Law were used (250 by 322 pixels; see Figure 3.13).

Image removed for copyright reasons.

Figure 3.13. the ¾ view morphs between Brad Pitt and Jude Law used as test stimuli.

3.7.1.4. Procedure

The adapting and test procedure was the same as in experiment one, except that the adapting images were each shown five times and for 4000ms, making a total of two minutes of adaptation duration.

3.7.2. Results

There was no significant difference in the number of Brad Pitt decisions made before and after exposure to Doug Pitt when the adapting faces were judged to be unfamiliar, (baseline M = 14.13, SE = 1.79; test M = 16.87, SE = 1.24; t (14) = -1.81, p = .09, d = -.49). The same was true when Doug Pitt was misidentified as a different celebrity (baseline M = 16.67, SE = 2.71; test M = 18.22, SE = 2.97; t (8) = -.27, p = .80, d = -.09). This suggests that there was no adaptation to Brad Pitt in either of these conditions. An independent means t-test revealed a non-significant difference in FIAE score between participants who did not recognise Doug Pitt, and those who misidentified him, t (22) = -.86, p = .40, r = .18.

A one-way ANOVA compared the FIAE score across all conditions (recognised vs. unfamiliar vs. misidentified) and was significant, F (2, 25) = 7.21, p = .003, ω = .55. Bonferroni post-hoc comparisons showed a significant difference between when Doug was recognised as resembling Brad Pitt and when he was not recognised (Mean difference = 12.48, SE = 3.29, p = .003) or misidentified (Mean difference = 10.01, SE = 3.52, p = .02). The post-hoc tests replicated the independent t-test, showing a non-significant difference between the unfamiliar and misidentified conditions (Mean difference = 2.18, SE = 2.47, p = 1.00). These findings suggest that adaptation occurred only when Doug Pitt was identified as resembling his brother, and not in any other condition.

3.7.3. Discussion

There was no after-effect when Doug Pitt was unrecognised or misidentified. The findings suggest that unfamiliar siblings produce after-effects during structural encoding and do not affect their familiar sibling's FRU. Brad Pitt's view-invariant representation does not seem to have been accessed during experiment 5. It is possible that the misidentified faces did not produce after-effects for the same reason as the familiar transformed faces in experiment 4: if Doug Pitt was misidentified as John Travolta, then John Travolta's FRU would be accessed and updated, rather than adaptation occurring by affecting some representation during structural encoding.

3.8. General Discussion

The main findings of the experiments are as follows. Prolonged exposure to a sequence of unfamiliar faces, each subtly transformed towards the same celebrity face, produced a significant reduction in sensitivity to that particular celebrity. This adaptation effect occurred despite participants failing to recognise the celebrity concerned. Adaptation to these unfamiliar transformed faces only occurred when the test stimuli were the same shape and viewpoint as the adapting stimuli (experiment 1). The effect disappeared when the adapting and test stimuli differed in viewpoint (experiment 2) or if the test stimuli were vertically stretched (experiment 3). In contrast, no adaptation occurred for familiar (famous) transformed faces, even when the adapting and test stimuli were the same size and view-point (experiment 4). The same pattern of results emerged for unfamiliar sibling faces. Unfamiliar siblings produced after-effects for their familiar siblings, regardless of gender, when adapting and test stimuli had similar view-points (experiment 5). The sibling-induced after-effect disappeared when the adapting and test stimuli differed markedly in viewpoint (experiment 6).

The unfamiliar cryptic faces (whether computer-transformed or sibling) seem not to be affecting their familiar donor's/sibling's view-invariant representation. If the adapting stimuli were affecting David Beckham or Jude Laws' view-invariant, abstractive representations then adaptation across view-point should have been observed. When David Beckham or Jude Law were explicitly recognised, there were after-effects of a similar magnitude when testing on the same or a different view (experiments 1 and 2). This is consistent with findings from Hole (2011), who also found viewpoint-independent identity adaptation. Overall, this suggests that explicit recognition is needed to access an identity's FRU and that the cryptic stimuli did not access it. This is in line with findings from Laurence and Hole (2012) and Moradi et al (2005), who suggest conscious awareness of an identity (explicit recognition) is needed for identity adaptation.

Explicit recognition of an identity seems to be an important influence on how a face will be encoded. Famous transformed faces (experiment 4) did not produce after-effects, and neither did the unfamiliar sibling faces when they were misidentified as belonging to an unrelated celebrity (experiment 6). Unfamiliar cryptic faces (transformed and sibling faces) did produce adaptation, under certain conditions. According to predictive coding theorists, once a higher level of processing (e.g. in this case an FRU) can account for the data it might attenuates the responses at lower levels (e.g. Mumford, 1992). This could explain the findings from these experiments: once a FRU has been activated, then this might reduce activity (and adaptation after-effects) in lower areas (He et al, 2012).

Within a hierarchical model of face recognition, using predictive coding, the FIAE for recognised famous faces happens at the level of FRUs (experiment 1, 2 and 5). FRUs try to predict deviations from the information signalled by structural encoding. If a prediction by a higher level FRU matches the lower level structural representation then the FRU might send back information to the lower level, and lessen its activity. Adaptation results in a FRU becoming less likely to respond to ambiguous morphs (e.g. exposure to David Beckham results in Jude Law's FRU being better able to respond). In experiment 4 the transformed faces were familiar and in experiment 6 Doug Pitt was misidentified. Feedback (from FRUs) might lessen activity in lower levels and this could be why no adaptation was observed: the FRUs were able to account well for the information. In experiment 5, the FRUs for the celebrities become active: their FRUs can't account for all of the information, however, the sibling faces activate the FRUs enough to trigger recognition. Adaptation may occur at the level of the FRUs, just as for the famous faces.

When a face is unknown then there is no FRU to respond (as a result there is no feedback to lessen the activity at the level of structural encoding) so patterns of activation produced by structural encoding within a general face-space are not accounted for. In experiment 1 and 5, participants were exposed to faces that all looked a bit like a celebrity e.g. David Beckham. This might result in a structural representation in face-space overlapping a bit with Beckham’s representation (but not enough for him to be recognised and his FRU to be activated). Through adaptation, an ambiguous morph will now be more likely to resemble Jude Law. This type of adaptation could occur via opponent or multichannel coding (by changes to the relative contribution of pools of channels). If the test morphs were physically different (shape and viewpoint) to the adapting faces then they were too dissimilar to observe any effect (experiment 2, 3 and 6). Unfamiliar face processing is said to be more image specific and is less tolerant to image transformations (e.g. Hancock, Bruce & Burton, 2000).

In experiment 5, unfamiliar faces produced after-effects for their celebrity siblings. Thus prolonged exposure to Doug Pitt produced an after-effect for his famous brother, Brad Pitt. However, unrecognised composite faces, containing half of Brad Pitt's face, do not produce after-effects (Laurence & Hole 2012). These apparently contradictory findings can tell us something about how unfamiliar faces are encoded. The cryptic faces might be exerting their effect in face processing regions of the fusiform gyrus. Using composite faces and fMRI, Schiltz, Dricot, Goebel and Rossion (2010) found that face processing regions of the right middle fusiform gyrus (including the FFA) represented faces holistically. Composite faces have a quite different overall configuration from their donors. Presumably this results in the composites being actively encoded as entirely unfamiliar faces, rather than as faces that have "some similarity" to their donors. That may be why the sibling faces produced different effects from Laurence and Hole's composite faces.

Overall the findings suggest that explicit recognition of a face as belonging to a familiar identity seems to override structural encoding mechanisms that unfamiliar and unrecognised faces are subject to. It has also been shown that perceptual awareness is important for categorical processing of identity. If one is made aware that an identity is present, this can affect how it is subsequently processed (Gardelle, Charles & Kouider, 2011). Elsewhere in the face adaptation literature (e.g. by Carbon & Ditye, 2010) it has been suggested that there might be a general face-space and separate identity specific representations for familiar faces. Support for the existence of a general face-space for unfamiliar faces comes from findings from prosopagnosics. Despite being unable to recognise identities, there is evidence that some prosopagnosics can nevertheless adapt to faces, and seem to code faces using a face-space (Susilo et al, 2010; Nishimura, Doyle, Humphreys & Behrmann, 2010).

An issue that Hancock's (in prep) model has yet to take account of is Carbon et al's (2007) finding, that face distortion after-effects (FDAE) transfer from a famous face to other famous identities (also see Carbon & Ditye, 2010, 2012). Our results show that after-effects are identity-specific. It is possible that the FDAE and the FIAE exert their effects in different ways (e.g. Storrs & Arnold, 2012). A difference between the FDAE and the after-effects used in our study could be that our stimuli looked more natural. We have assumed that FRUs were able to account for the transformation distortion used in experiment 4 and 6, so there was no adaptation within a general face-space used for structural encoding. Carbon et al used grossly distorted faces as adaptors. This might result in lots of error at every level of encoding. If the FRUs were not able to fully account for all of the information (because the faces were so unnatural) then this could have affected face-space too. An assumption of Hancock's model is that FRUs predict patterns of activation within face-space. If the face-space is distorted by adaptation then this could explain why other FRUs are affected. Through adaptation within face-space, all faces that appear to look normal are ones with high up eyes, therefore in order to prevent prediction error from increasing, the FRU for a novel familiar face shifts too. This is something that future iterations of the model will need to take into account.

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CHAPTER 4:

LECTURERS' FACES FATIGUE THEIR STUDENTS: FACE IDENTITY AFTER-EFFECTS FOR DYNAMIC AND STATIC FACES – PAPER 3.

Abstract

Face adaptation has been used as a tool, to probe our representations for facial identity. However, it has also been claimed to play a functional role in face processing, perhaps calibrating the visual system towards the faces it encounters. However, for this to be the case, it is essential that face after-effects can be demonstrated to occur with ecologically-valid stimuli, not just static images. We examined whether after-effects occurred after exposure to videos of lecturers' faces with real-world personal familiarity for our participants. Adaptation to either a video, several images, or a single image produced significant, and equivalent, face identity after-effects. This shows that after-effects are not confined to static images and can occur after exposure to more naturalistic stimuli such as videos. It is also further evidence that face adaptation effects cannot be explained solely in terms of low-level visual processing.

4.1. Introduction

Prolonged exposure to a face can produce a face identity after-effect (FIAE): a loss in sensitivity to that particular face (Leopold, O'Toole, Vetter & Blanz, 2001). Since Leopold et al's pioneering study, a huge amount of research has been conducted on the FIAE, reflecting an appreciation of its usefulness as a tool for investigating face processing: at the time of writing, PsycINFO generated 972 peer-reviewed articles for the term "face adaptation". However, a major limitation of previous studies on FIAEs is that they have used static images as their adapting stimuli and ignored the role of facial motion. This is an important omission, because it has been claimed that face after-effects are functional rather than epiphenomenal; i.e. they are not just a by-product of selective fatigue of neural systems, but instead reflect the processes by which the visual system fine-tunes itself to the perceptual environment (e.g. Clifford & Rhodes, 2005). For after-effects to be functional, it is essential that they can be demonstrated to occur with ecologically-valid stimuli – i.e. incorporating movement[11]. To our knowledge, the only adaptation study to use moving faces was by de la Rosa, Giese, Bülthoff and Curio (2013): moving adaptor stimuli produced smaller after-effects than static ones. However, this was a study of facial expression rather than identity processing. Given that identity and expression are subserved by largely independent processing systems (Bruce & Young 1986), it is possible that motion might affect the FIAE differently.

The present study therefore aimed to establish whether naturally moving faces produce FIAEs, or whether FIAEs occur only with static images. To investigate the role of motion in the FIAE, we used faces that were personally familiar to our participants.

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[11] Note that if after-effects *were* restricted to static stimuli, this would have implications only for the issue of whether after-effects produce functional effects within the face-processing system: it would not negate their usefulness as a practical tool for investigating face-processing.

Again, ecological validity dictated our choice of stimuli. Most FIAE studies have either used unfamiliar faces (familiarised to participants during the experiment) or famous faces (as a proxy for “familiar” faces). However, there is extensive evidence that famous, personally familiar and unfamiliar faces may be processed in different ways (e.g. Carbon, 2008; Herzmann, Schweinberger, Sommer & Jentzsch, 2004; Hills & Lewis, 2012; Laurence & Hole, 2011; Megreya & Burton, 2006, 2007; Tong & Nakayama, 1999; Walton & Hills, 2012). With increased facial familiarity, the FIAE is both stronger (Jiang, Blanz & O’Toole 2007) and shows greater transfer across viewpoints (Jiang, Blanz & O’Toole, 2009). These findings are consistent with the idea that familiar faces have abstractive representations which depend less on precise overlap between the visual image being processed and the stored representation for that face (Hole, 2011; see Burton, Jenkins & Schweinberger, 2011 for a review).

We exposed participants to one of three different adapting face conditions: viewing a video of a naturally moving face, viewing a series of static images of a face, or viewing a single static image of a face. We used two lecturers (Andy Field and Sam Hutton) who were highly familiar to our undergraduate participants. Andy Field was used as the adapting face, and the test faces were morphs between Andy Field and Sam Hutton. Participants judged whether each morph looked more like Andy Field or Sam Hutton, before and after two minutes' exposure to Andy Field (adaptation). An FIAE to Andy Field would result in fewer of the morphs being judged to resemble him post-adaptation, compared to before adaptation.

4.2. Method

4.2.1. Design

There were two independent variables: type of adapting stimulus (either a two minute film clip, 24 static images or a single static image) and time of testing (pre-adaptation baseline; after a first adaptation session; after a second adaptation session). Type of adapting stimulus was an independent-measures variable and time of testing was repeated-measures. The dependent variable was FIAE strength, measured by the number of test images identified as the adapting face.

4.2.2. Participants

Forty-eight (5 males and 43 females: mean age 20.21, SD 1.96) participants from the University of Sussex received course credits for taking part. Sixteen adapted to a video clip; 16 adapted to several static images; and 16 adapted to a single static image.

4.2.3. Stimuli

4.2.3.1. Adapting stimuli. All pictures/videos of Andy Field and Sam Hutton were taken using a tripod-mounted Panasonic SDR-S70 Camcorder. Their faces were filmed against a black background with natural lighting plus artificial top lighting. They wore black clothing and were seated. Andy Field was used as the adapting face. There were three types of adapting stimuli. All stimuli were presented with the black background that Andy Field was filmed against (917 by 524 pixels). The exact dimensions of Andy Field's face varied depending on pose, however, the static image condition had a size of 278 by 348 pixels. All images were viewed at a distance of approximately 60cm.

4.2.3.1.1. ***Video.*** Andy Field was instructed to tell a story as if he were telling it to another individual, while maintaining fixation on the camera lens throughout. This was to ensure that his motion would be similar to that produced when interacting with students. Using Adobe Premiere, a 2-minute video (without soundtrack) was produced from 5 minutes of initial footage. This was divided into 24 five-second clips, which were used for top-up adaptation.

4.2.3.1.2. ***Multiple images.*** 24 still images were taken from the video, at 5 second intervals.

4.2.3.1.3. ***Single image.*** A single still of a neutral expression was taken from the video.

4.2.3.2. Test stimuli. Pictures used as test stimuli were derived from frontal views of Andy Field and Sam Hutton, both with a neutral expression and cropped to an oval displaying only the internal facial features (142 by 187 pixels). Smartmorph v. 1.55 (Meesoft Ltd.) was used to produce six morphs, containing 29%, 37.5%, 46%, 54%, 62.5% or 71% of Andy Field's face (see Figure 4.1).

Figure 4.1. morphs between Andy Field (left) and Sam Hutton (right).

The experiment was administered to participants using EPrime 2.0, and took around 20 minutes to complete.

4.2.4. Procedure

4.2.4.1. Baseline. Participants were tested individually, after first checking they were familiar with both Andy Field and Sam Hutton. On each trial, a fixation cross for 750 ms was followed by a morph between the two lecturers' faces for 200 ms. The screen then went blank until the participant decided whether the morph looked more like Andy Field or Sam Hutton, by pressing “a” for Andy Field or “s” for Sam Hutton. Each of the six morphs was shown eight times, in a random order, making a total of 48 trials (see Figure 4.2).

4.2.4.2. First Adaptation Phase. Participants saw an image/images/video of Andy Field (depending on what condition they were assigned to) for 120 seconds, during which they were asked to press ‘space’ if they believed the face became distorted[12]. In the *single image* condition, a single image was presented for the entire duration; in the *multiple images* condition, participants viewed each of the 24 stills, one after another, for 5 s each; and in the *video* condition, participants viewed the video for the duration.

4.2.4.3. First Test Phase. This was identical to the baseline phase, except that each morph was preceded by a 5s top-up adaptation image or video (according to condition).

4.2.4.4. Second Adaptation and Test Phase. Participants then completed a second adaptation phase and test phase, identical to the previous ones.

[12] This was a ruse to ensure participants concentrated on the video/images/image for the duration of their display.

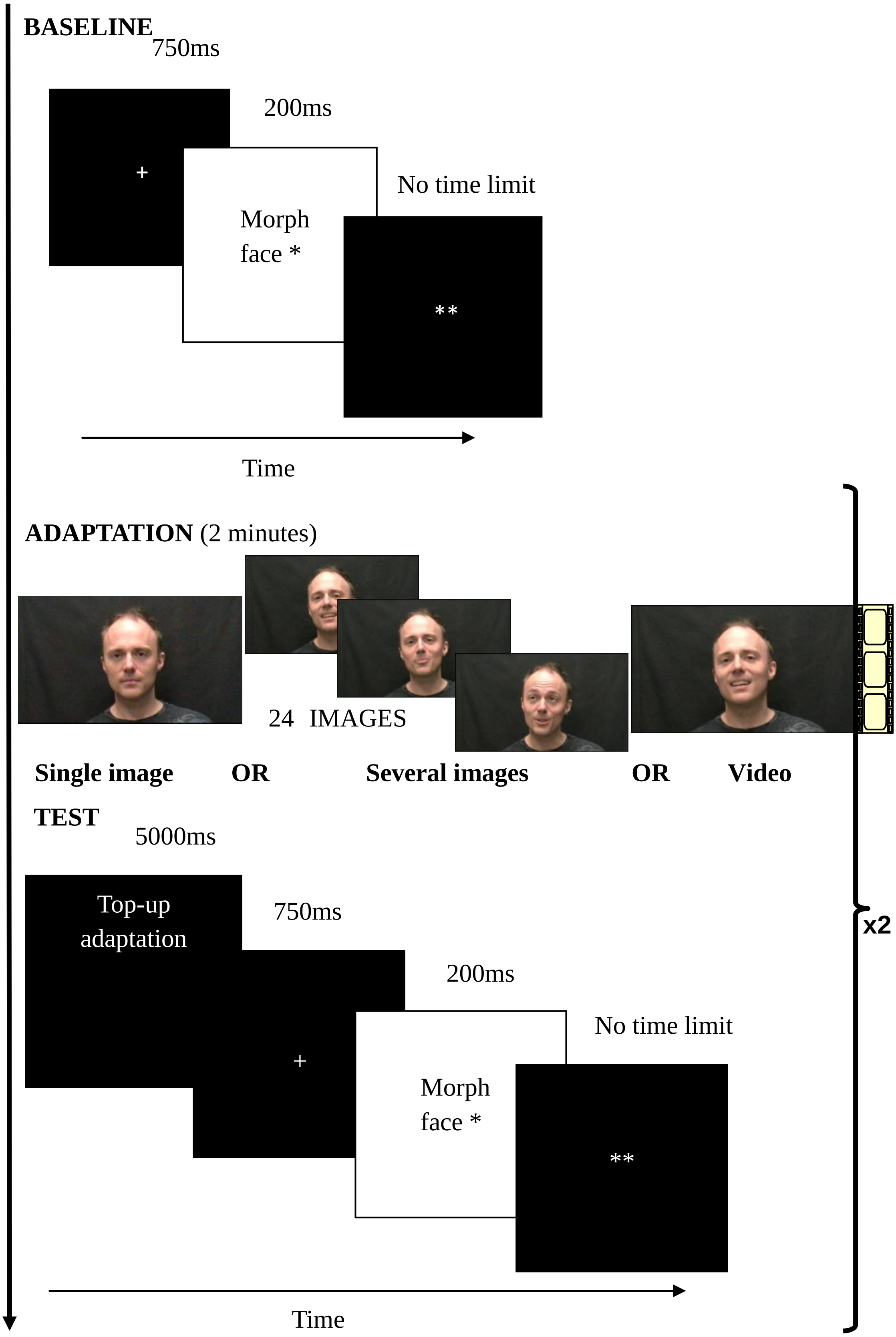

Figure 4.2. The experimental procedure. Baseline and test both show an example of the procedure used for one individual trial.
* One of the six morphs (see Figure 4.1) was shown.
** Participants indicated which identity they thought the morph looked more like.

4.3. Results

Each participant provided data on how many morphs (out of 48) they thought looked like Andy Field in the three test sessions: the pre-adaptation baseline; after the first adaptation phase (test 1); and after the second adaptation phase (test 2). An FIAE to the adapting face should be reflected by participants making fewer Andy Field responses in the first test session, compared to their pre-adaptation baseline.

To circumvent individual differences in pre-adaptation responding, each participant's FIAE was measured by calculating two difference scores. The first difference score was obtained by subtracting the number of “Andy Field” responses made during the first test phase from the number made during the pre-adaptation baseline. An FIAE would be demonstrated by a mean score > 0, indicating that fewer morphs were judged to look more like Andy Field after the first adaptation phase. If no adaptation took place, there should be a mean of 0, reflecting no reduction in the number of morphs judged to look more like Andy Field after the first adapting session.

To determine whether the FIAE increased after the second adaptation phase, a second difference score was calculated: we subtracted the number of Andy Field responses made during the second test session from the number made during the first. If the FIAE increased after the second test session, this score should be > 0. A mean of 0 would suggest that the after-effect had remained stable and a mean < 0 would suggest the after-effect had worn off.

One sample *t*-tests were conducted to find out if an FIAE occurred for each condition (see Figure 4.3) after the first adaptation phase. The difference scores were compared to zero: a mean difference of zero would indicate that no adaptation had taken place. There were significant FIAEs for Andy Field's face presented as a video (Mean = 7.81, SE = 2.51), t (15) = 3.11, p = .007, r = .63; as multiple images, (Mean = 6.38, SE = 2.34), t (15) = 2.73, p = .02, r = .58; and as a single image (Mean = 6.81, SE = 2.90), t (15) = 2.35, p =.03, r = .52. These findings suggest FIAEs occurred for personally familiar faces viewed as a video, a series of images or a single image.

One sample t-tests were also used to see if the size of the FIAE changed for each condition after the second adaptation phase. A mean difference of zero would indicate that no change in the size of the FIAE had taken place after the second test session. There was a non-significant change in the size of the FIAE after the second adapting phase when Andy Field was presented as a video (Mean = -0.81, SE = 1.74), t(15) = -0.47, p = 0.69, r = .12; as multiple images (Mean = -2.38, SE = 1.41), t(15) = -1.69, p = .11, r = .40; and as a single image (Mean = 1.13, SE = 0.86), t(15) = 1.31, p =.21, r = .32, suggesting that for all three types of adapting stimulus, maximal adaptation had been reached after 2 minutes of adaptation.

To compare the strength of the FIAE between the types of adapting stimulus, a 3 x 2 mixed ANOVA was conducted, with three levels of adapting stimulus (single image vs. images vs. video) and two levels of adaptation phase (baseline-test 1 vs. test 1-test 2). There was a non-significant main effect of adapting stimulus, F (2, 45) = 0.53, p = .59, $\eta\rho^2$ = .02, suggesting that adapting to videos, images or a single image produced similar effects. There was a significant effect of adaptation phase, F (1, 45) = 19.06, p < .001 $\eta\rho^2$ = .30. Bonferroni-corrected post-hoc tests showed that the difference score for the first adaptation phase was significantly larger than for the second (Mean difference = 7.69, SE = 1.76, p < .001). The interaction between adapting stimulus and adaptation phase was not significant, F (2, 45) = .32, p = .73, $\eta\rho^2$ = .01.

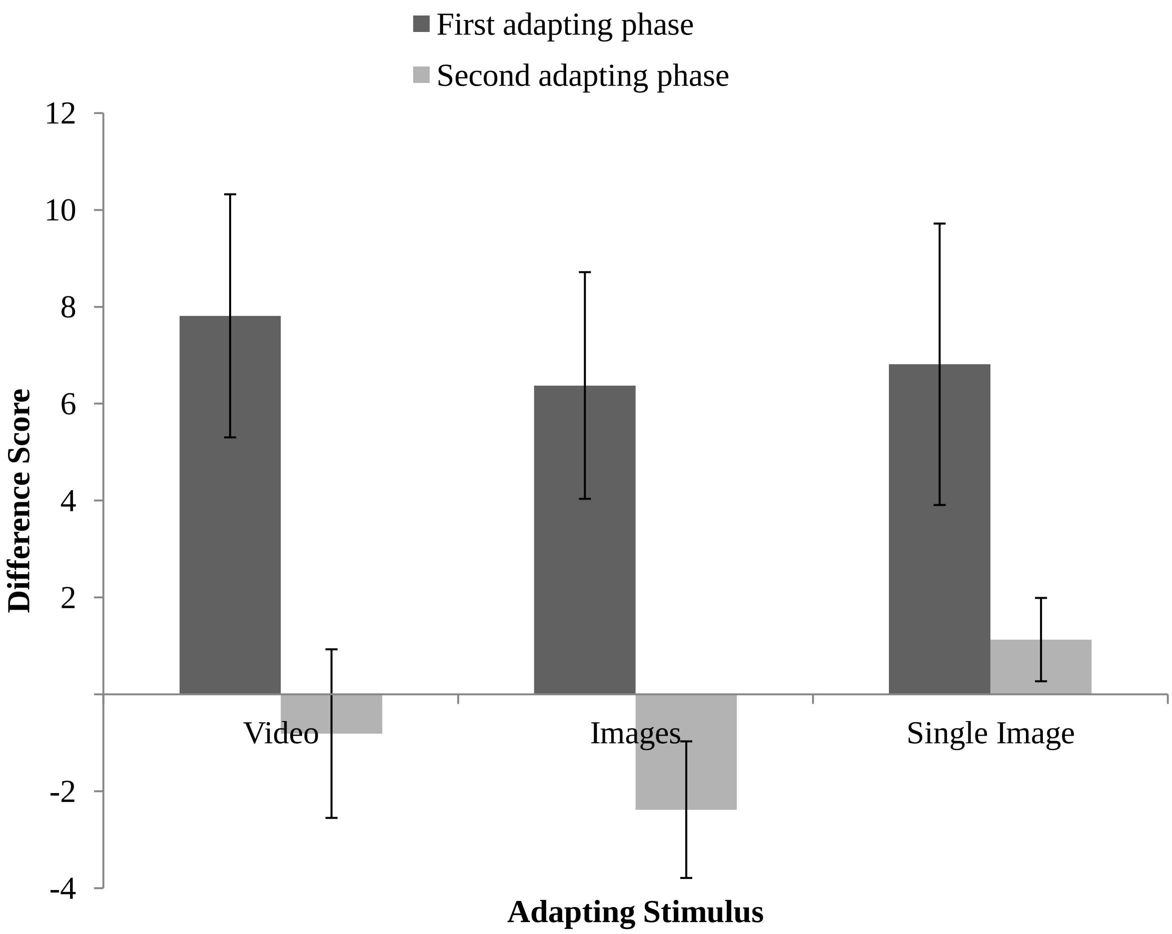

Figure 4.3. The difference score for the first (baseline - test) and second (test1-test2) adaptation phases. The difference score was calculated by subtracting the number of "Andy Field" responses made after an adaptation phase, from the number of "Andy Field" responses made before it. A positive score indicates that fewer "Andy Field" decisions were made after 2 minutes of exposure to him, compared to the test session immediately before (error bars show +/- 1 S.E.M.).

4.4. Discussion

The main finding from this experiment is that FIAEs for personally familiar faces were equivalent in size regardless of whether the adapting stimuli consisted of a moving face or a series of static images. This addresses an important issue, which is whether face adaptation studies are tapping into mechanisms employed when viewing faces in the real world. If face adaptation plays a functional role in face perception, it must be observable for faces under natural viewing conditions and not just with static images. When we see faces in the real world, they are moving. The present findings are consistent with the idea that adaptation effects are not merely epiphenomenal: they do occur for more ecologically valid, moving faces (see also Carbon & Ditye, 2012).

A separate benefit of using moving faces as adapting stimuli is that it reduces the contribution of low-level pictorial adaptation to the overall FIAE. A longstanding issue has been the extent to which face adaptation effects can be explained in terms of selective fatigue of low-level mechanisms, rather than adaptation of face-specific systems. Hills and Lewis (2012) found that FIAEs for famous and unfamiliar faces were greatest when adapting and test stimuli matched (also see Hills, Elward, & Lewis, 2010). They suggest that in their experiment approximately half of the observed after-effect was attributable to fatigue of low-level mechanisms. It is therefore important to minimise the physical overlap between adapting and test materials when investigating higher-level adaptation effects. The FIAEs reported in the present study demonstrate that adaptation is not necessarily just a result of low-level pictorial adaptation for static pictures of faces. If it were, one would expect the size of the after-effect to decrease with decreasing similarity between the adapting and test images, especially in the case of the *video* condition, but this was not observed.

It has previously been shown that FIAEs can occur for famous faces when the adapting and test stimuli are very different from each other, e.g. in terms of expression, viewpoint and orientation (e.g. Fox, Oruç & Barton, 2008; Hills et al., 2010; Hole, 2011; Laurence & Hole, 2012). The present study shows that the same is true of more ecologically-valid, dynamic stimuli. These findings have been interpreted using existing models of face processing (e.g. the Bruce & Young (1986) model) where familiar faces have abstractive face representations ("Face Recognition Units") associated with them.

Bruce and Young’s (1986) model suggests that we have "pictorial" and "structural" codes for faces. Pictorial codes are based on image specific properties like lighting, view-point and expression. Structural codes are more abstractive and are not tied to a particular image of a face. Unfamiliar face processing seems to depend more on low-level image comparisons (Hancock, Bruce & Burton, 2000). As a face becomes familiar, its processing changes from relying on pictorial codes to using structural ones (Burton, Jenkins & Schweinberger, 2011). Using static images with different physical characteristics, Hole (2011) showed that FIAEs are not tied to the physical properties of the faces being viewed and suggested this is because familiar faces have abstractive codes. The present findings suggest the same is true of personally familiar faces.

4.5. References

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CHAPTER 5:

THE EFFECT OF FAMILIARITY ON FACE ADAPTATION – PAPER 4

Abstract

Face after-effects can provide information on how faces are stored by the human visual system (e.g. Leopold, O'Toole, Vetter & Blanz, 2001), but few studies have used robustly represented (highly familiar) faces. The present study 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 after-effects were significantly smaller when participants were adapted to their own face than when they were adapted to the other faces (i.e. their own face appeared significantly less distorted than famous or unfamiliar faces). 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 after-effects.

5.1. Introduction

Selective adaptation has been described as the “psychologist’s microelectrode” (Frisby 1979), providing information about the mechanisms underlying visual perception. After-effects produced by adaptation can result not only from prolonged exposure to low level properties like line orientation (e.g. He & MacLeod, 2001), but can also occur for natural images such as faces. Face after-effects can provide information about how faces are stored and encoded by the human visual system (see Clifford & 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 after-effects" have been found to transfer to the faces of individuals other than the adapting identity (Webster & MacLin, 1999; Robbins, McKone & Edwards, 2007; Yamashita, Hardy, De Valois & Webster, 2005). However, after-effects can also be identity-specific: Leopold et al (2001) used a different adaptation methodology, based on Valentine's (1991) multidimensional face space (MDFS) framework. The MDFS 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. After-effects 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 after-effects can be explained in terms of an “opponent-process” model. The model proposes that there are pairs of pools of neurones that code opposite facial dimensions around a norm. Adaptation may result in a shift of the norm due to the selective fatigue of those neurones 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 (e.g. Leopold et al, 2001; Rhodes & Jeffery, 2006). Rhodes, Robbins, Jaquet, McKone, Jeffery and Clifford (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 (e.g. Webster & MacLin, 1999), or faces to which they were familiarised during the experiment itself (e.g. Leopold et al, 2001). However, facial familiarity needs to be taken into account, given that it is now well established that familiar and unfamiliar face recognition differ 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, Bruce & Burton, 2000; Megreya & 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 after-effect was not equivalent when the adapting and test faces were from different famous individuals. This suggests that figural after-effects for familiar faces are significantly influenced by the identity of the face. More recently, Carbon and Ditye (2010) have shown that whereas figural after-effects for unfamiliar faces are generally reported to be quite short-lived, comparable after-effects 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 affects has also been highlighted by Ryu and Chaudhuri (2006). They compared Fang and He's (2005) viewpoint after-effects 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 after-effects were found for both familiar and unfamiliar faces. However, although view-point after-effects transferred between two different unfamiliar faces, they did not transfer between two different familiar faces. Further to this, findings from Jiang, Blanz and O'Toole (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 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 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 & 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 changes 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 3D instances of them. Neuroimaging studies also show that different brain regions are activated when making judgements about faces that are either novel, personally familiar or one's own (e.g. Platek et al, 2006; Sugiura, Mano, Sasaki & Sadato, 2010). A number of studies (e.g. Mohr, Landgrebe & Schweinberger, 2002; Collin & Byrne, 2010) suggest that, in contrast to unfamiliar faces, familiar face recognition appears to be mediated bilaterally, perhaps by "Transcortical Cell Assemblies" (Pulvermüller & Mohr, 1996).

Findings such as this 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 after-effects are affected by facial familiarity (e.g. Carbon et al, 2007; Ryu & Chaudhuri, 2006), to our knowledge, none has used personally familiar (and therefore truly robustly represented) faces.

The present studies 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 after-effects from distorted familiar (famous: e.g. Carbon et al, 2007) and unfamiliar (non-famous: e.g. Webster & MacLin, 1999) faces, by examining whether comparable after-effects 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 after-effect should be smaller, perhaps because a face of this nature requires fewer attentional resources (Tong & 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 after-effects 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.

5.2. Experiment 1

5.2.1. Method

5.2.1.1. 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 their 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[13]. In total each participant experienced six pairs of adaptation and test phases.

The strength of the adaptation effect was measured by presenting participants with a 3x3 grid containing nine faces with various levels of figural distortion, and recording which face was perceived to be the most "normal".

5.2.1.2. Participants

The participants were students at the University of Sussex, who participated voluntarily. Overall 40 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 ≥ 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 ≥ 4); non-

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

recognition of unfamiliar faces (by familiarity ratings of ≤ 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. 30 participants' data 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 (mean age = 22.8 years, SD = 4.2). Only Caucasian female faces were used, since evidence suggests that there may be distinct norms and face spaces for different facial categories (e.g. for males and females, and for different races: Rhodes & Jeffery, 2006).

5.2.1.3. Stimuli

5.2.1.3.1. Familiarity check

As a check on facial familiarity, three undistorted images were presented to each participant: their 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 their face that they were most familiar with[14], 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 greyscale. 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 (i.e. undistorted) versions of the faces were presented in the centre of the screen.

[14] While it is impossible to know for certain how much experience an individual has had with seeing their own face in a mirror as opposed to in photographs, it seems reasonable to assume that most people will have had more experience with their mirror-reversed images as a consequence of their daily grooming rituals.

5.2.1.3.2. 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 using Adobe Photoshop 7.0. The internal features of each face were selected using an oval marquee and then distorted (contracted in the middle and expanded towards the periphery) using the “Pinch” function set to 60%. Figural after-effects are known to occur after adaptation to both expanded and contracted faces (Webster & 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.

5.2.1.3.3. Test stimuli

The stimuli used in the test phase were nine images of the face shown in the adapting phase, each varying in its amount of figural distortion, and presented in a 3x3 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.

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 nine 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 ten minutes to complete, excluding the time taken to add each participant's own face into the presentation. All images were viewed at a distance of approximately 60cm.

5.2.1.4. Procedure

Each participant was tested individually. A photo was taken of the participant's face on their arrival and they were then given reading material whilst the experimenter uploaded and manipulated their photograph. The participant was 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.

5.2.1.4.1. Familiarity check

In the first task participants were required to rate how familiar three undistorted faces were (their own face, a famous face and a non-famous face) on a scale from 1-7 (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. Secondly, it helped to control for the participant being primed to see their own face due to having just been photographed. Thirdly, it confirmed that the famous face was familiar to them and that the non-famous face was unfamiliar. Each face was preceded by the name of the individual for three seconds. (A fake name was given to the non-famous face). It was explained to each participant that they would see three faces and that after each face they would be required to rate how familiar it was to them. Each face was presented for three seconds 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 (e.g. 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.

5.2.1.4.2. 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 them with the procedure used in the main experiment.. This trial consisted of being adapted to a distorted face (the actress Hilary Duff) for 30 seconds. During this period, the participant was asked to look for a mirror-reversed version of this face and to press the space bar if they detected one. (The fifth face in the sequence was always mirror reversed). The practice trial ended with the presentation of an array of nine version of Hilary Duff's face that varied in their level of distortion. The participant 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.

5.2.1.4.3. Adaptation phase

In the experiment proper, 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 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 three seconds at a time. Thus there was a total of 1 minute's exposure to each adapting face.

5.2.1.4.4. 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 nine 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 their own face, twice to a celebrity face and twice to a non-famous face. After being adapted to each identity once, they were subsequently tested on the same identity or on an average face (see Figure 5.1). The order in which trials occurred was randomised for each participant. The entire experiment took about ten minutes to complete.

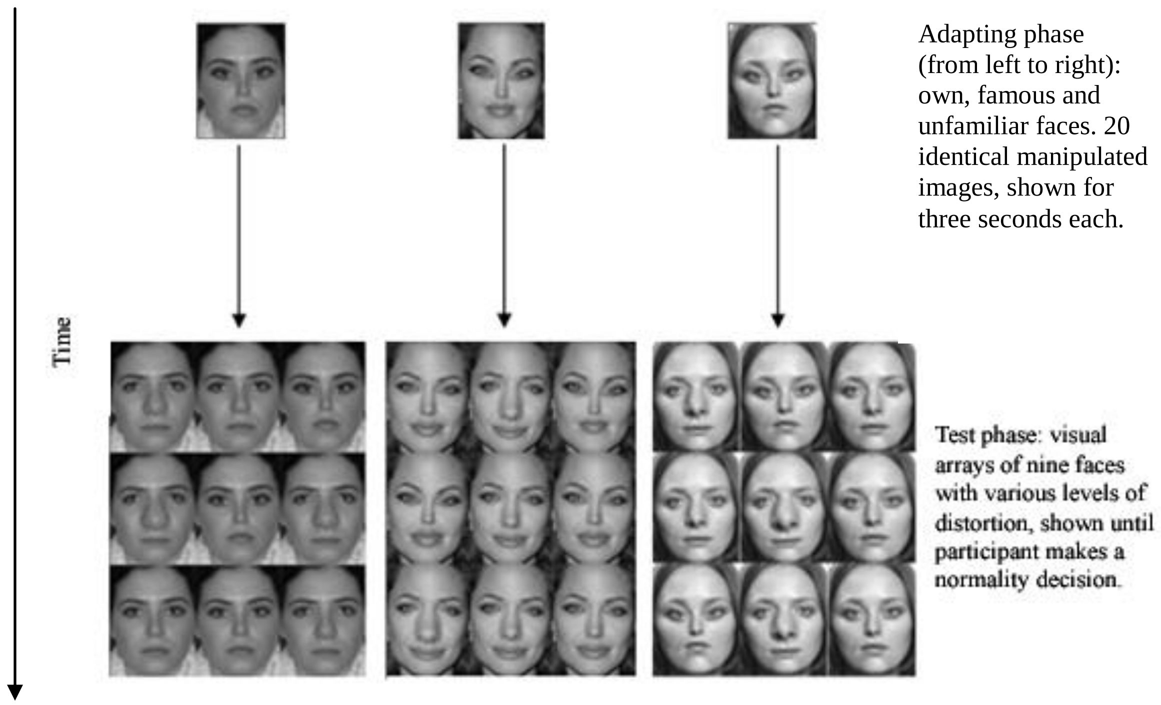

Figure 5.1. diagram of the adaptation and test procedures for one participant.

5.2.2. Results

Each participant provided data on which face they thought looked the most 'normal' (i.e. the least experimentally distorted) out of an array of nine 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 & MacLin, 1999). In terms of our mean ratings, the stronger the after-effect, the higher the (positive) rating should be. Figure 5.2 shows the mean distortion level chosen by participants as a function of adapting face (own face, famous face or non-famous face) and test face (same identity as the adapting face, or an average face). When participants were tested on the same identity as that to which they had been adapted, their own face 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 < .05). Planned contrasts revealed that the mean amount of adaptation following exposure to the participant's own face (M = 10.00, SD =13.83), was significantly different from the amount of adaptation following exposure to both familiar and unfamiliar faces combined (M = 18.50, SD = 14.97: F (1, 29) = 4.66, p < .05). Planned contrasts also revealed that familiar faces (M = 19.00, SD = 13.61) and unfamiliar faces (M = 18.00, 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 while participants were making their decision, the adaptation effect would be wearing off. In fact, a one-way repeated-measures on decision times showed that there were no significant differences between the three conditions (mean own-face = 7.05 seconds, SD = 0.58; mean familiar face = 6.96 seconds, SD = 0.47; mean unfamiliar face = 7.06 seconds, SD =0.61: F (2, 58) = 1.29, *ns*)[15].

[15] 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.

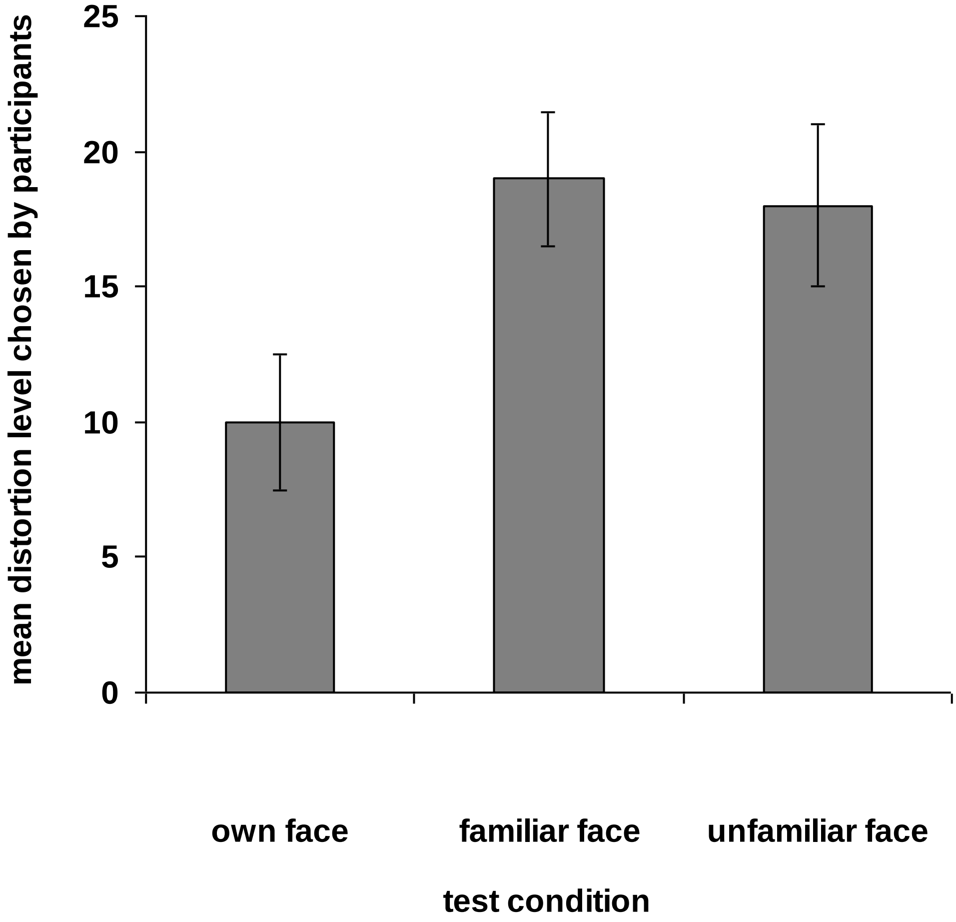

Figure 5.2. Experiment 1: the mean distortion level chosen by participants as a function of adapting face (own face, familiar face or unfamiliar face) and test face (same identity as adapting face, or an average face). Error bars indicate mean +/- SEM..

5.3. Experiment 2

Experiment 1 suggested that there was an ‘own face-effect’: after-effects were smaller when participants were adapted to their own face compared to 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 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 after-effects 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 after-effect should differ between the two groups.

5.3.1. Method

5.3.1.1. 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.

5.3.1.2. Participants

There were two groups of participants (overall mean age 22.5 years, SD = 4.0 years). The "own-face" group consisted of 25 participants who had taken part in experiment 1. The criteria for inclusion in experiment 2 were (a) that they had been included in the final analysis of experiment 1, and (b) that they consented to their name and face being shown to one other person (c) 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 25 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), except that they were not familiar with the faces of the "own-group" members. None of these participants had taken part in experiment 1.

5.3.1.3. 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 3x3 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 five minutes to complete.

5.3.1.4. Procedure

The adaptation and test procedures were exactly the same as in experiment 1, except that the participants only experienced one familiarity check and 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 face. 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 their own face while for the other group these represented the faces of different people.

5.3.2. Results

An independent-measures *t*-test revealed that there was a significant difference in the size of after-effect, depending on whether the face was the participant's own (mean amount of adaptation = 7.80, *SD* = 13.77) or not (*M* = 18.60, *SD* = 16.93: *t*(48) = -2.47, *p* = .008, one-tailed test). After-effects 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 after-effect 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 seconds, SD = 0.61; mean other-face = 6.82 seconds, SD = 0.19: *t* (28.61) = 1.66, *ns*).

5.4. Experiment 3

Experiments 1 and 2 suggest that figural after-effects are moderated by an "own face" effect: after-effects were smaller when the adapting face belonged to the participant, compared to 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. This 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.

5.4.1. Method

5.4.1.1. Design

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

Testing phase was also a repeated-measures variable. For each of the three 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 nine faces (3x3) 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 was used (a 17-inch Iilayama ProLite T17305) and the participant touched the face in the array that they considered to be most "normal".

5.4.1.2. Participants

The participants were students at the University of Sussex, who received course credits for taking part. Overall 22 participants were tested, but their data were only retained if they satisfied the following criteria: they had not completed experiments 1 or 2; satisfactory recognition of their own face (as shown by familiarity ratings of ≥ 4 on a 6-point scale); satisfactory recognition of celebrity faces (by familiarity ratings of ≥ 4); non- recognition of unfamiliar faces (by familiarity ratings of ≤ 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 19 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).

5.4.1.3. Stimuli

All aspects of stimulus preparation were identical to those used in experiment 1.

5.4.1.4. Procedure

The procedure differed from that used in experiment 1 in the following ways. First, the familiarity check used a six-point rather than seven-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 seconds at a time. Thus there was a total of 1 minute's exposure to each adapting face.

Participants were told that the other task required them to identify, as quickly as possible, which face looked the most normal, from an array of nine faces that were distorted to varying degrees. Participants used the touch screen to indicate their decision. Each of the three adapting trials was both preceded (pre-adaptation baseline) and 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 seconds 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 nine 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 a pre-adaptation baseline, an adaptation phase 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. They were tested before and after adaptation on the same identity that they were adapted to. The order in which trials occurred was randomised for each participant.

5.4.2. Results

A 2x3 repeated measures ANOVA revealed a significant main effect of test phase (F (1, 18) = 34.79, p < .0001). Overall, participants perceived faces to be more contracted after adaptation (M = 12.14, SD = 13.51) than before adaptation (M = -0.36, 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 < .01). As can be seen from Figure 5.3, these results reflect the fact that the strength of the figural after-effect was affected by the familiarity of the face. Before adaptation took place, participants gave similar ratings of normality to all three faces (i.e., 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, preadaptation and post adaptation ratings of normality were compared. A significant adaptation effect was found with participants' own faces (mean difference = 6.32 , SD = 10.39: t (18) = 2.65, p < .02). However, adaptation effects were much more pronounced for familiar faces (mean difference = 13.42 , SD = 12.14: t (18) = 4.82, p <. 0001) and unfamiliar faces (mean difference = 18.16, SD = 15.48: t (18) = 5.12, p < .0001). There was no significant difference in the strength of the adaptation effect for the latter two conditions (t (18) = 1.29, *ns*).

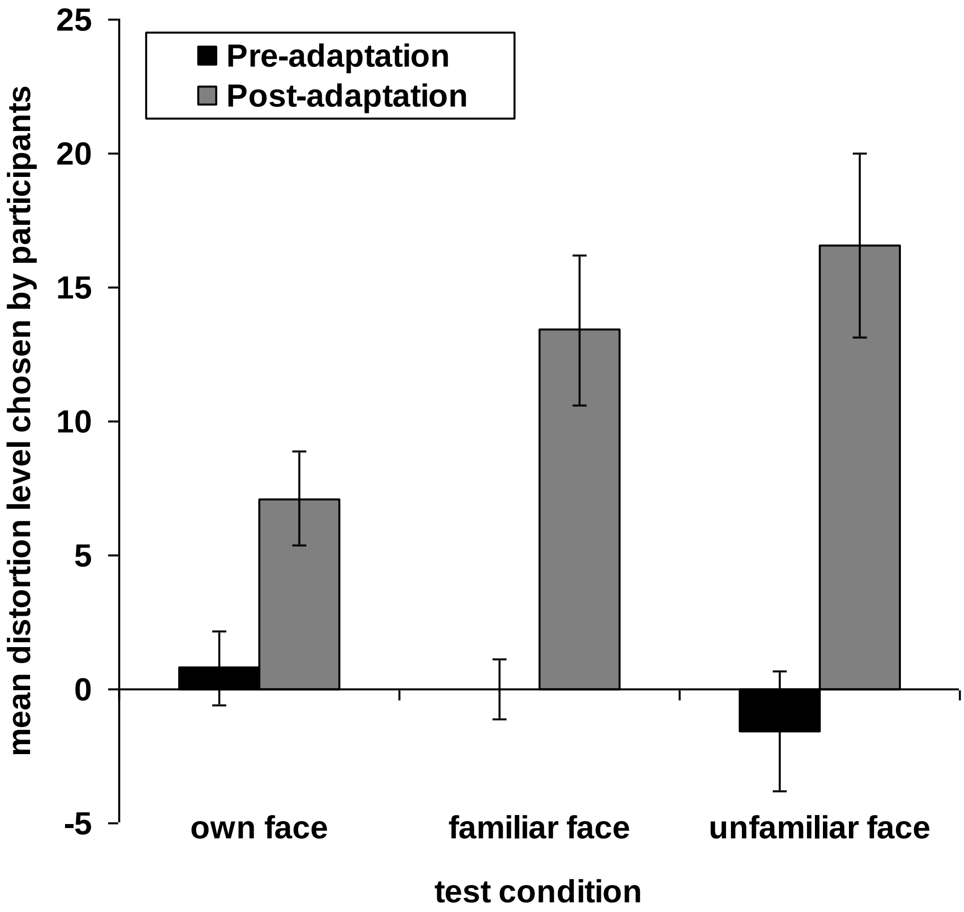

Figure 5.3. Experiment 3: mean distortion level chosen by participants before and after adaptation to a distorted version of either their own face, a familiar face or an unfamiliar face. Error bars indicate mean +/- SEM.

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 seconds, *SD* = 0.31; mean familiar face = 6.93 seconds, *SD* = 0.28; mean unfamiliar face = 6.88 seconds, *SD* = 0.30: F (2, 36) = 0.47, *ns*).

5.5. Discussion

The aim of the current study was to investigate figural after-effects 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 after-effect than when they were adapted to other faces (famous or non-famous). Experiment 2 showed that this reduction in the size of the after-effect 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 neurones coding it. However, attentional differences seem an unlikely explanation in practice. Firstly, the adapting image of each participant's face was grossly distorted and not an image that they would have had experience with prior to the experiment. Secondly, 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) has 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 (i.e. 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 self-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" (pp. 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 their 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, Jones, Little & Perrett, 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, Giorgio, Freund & Pascual-Leone, 2000; Keenan, Wheeler, Gallup & Pascual-Leone, 2000; Ma & 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 finds 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 may 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 (Platek & Kemp, 2009; DeBruine et al, 2008). 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 the self-face. However, this does not necessarily rule out that an average face may reside in the center 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 (i.e. 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, e.g. 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 & Ditye, 2010; Hole, 2011; Hills, Elward & Lewis, 2010).

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 after-effects: not all faces are equal, as far as face adaptation is concerned.

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CHAPTER 6:

EQUAL ADAPTATION AFTER-EFFECTS FOR THREE HIGHLY FAMILIAR FACES: SELF, SISTER AND FRIEND – PAPER 5.

Abstract

Following exposure to a grossly distorted face, subsequently-viewed distorted faces appear to look normal: the "face distortion after-effect" (FDAE). Laurence and Hole (2011) found that the FDAE for one's own face was smaller than for famous or unfamiliar faces, and speculated that there might be an "own face" effect (i.e. that our own face was especially resistant to the FDAE). Alternatively the FDAE might be smaller for any robustly-represented, personally-familiar face. To decide between these explanations, the present study compared the size of the FDAE for three highly familiar faces: one's own face, a sibling's face and a friend's face. All three faces produced significant and equivalent FDAEs, implying that all highly familiar faces are equally adaptable. However, the FDAEs were much bigger than we would have predicted on the basis of Laurence and Hole's (2011) results, possibly as a result of methodological differences between the two studies.

6.1. Introduction

Face adaptation is a useful tool for probing the mechanisms underlying our visual perception of faces. It occurs when exposure to a face affects our perception of faces viewed subsequently (see Webster & MacLeod, 2011 for a review). One type of face adaptation effect that has been used in this way is the face distortion after-effect (FDAE). This technique was first used by Webster and MacLin (1999) who found that prolonged looking at a distorted face (adaptation) makes a normal face appear to be distorted in the opposite direction (after-effect). For example, exposure to a face with contracted features makes a normal face appear to be expanded.

It has been suggested that FDAEs show how our perception of faces is constantly updated and calibrated by experience (e.g. Clifford & Rhodes, 2005), even for faces that we have a lot of experience with. Carbon and Leder (2005) showed that FDAEs could occur for famous faces. Carbon and colleagues suggest that our memory for the adapted face has been updated as the FDAE has been found to persist for 24 hours (Carbon et al, 2007), or even for up to a week (Carbon & Ditye, 2010), even when adapting and testing in different environments (e.g. adaptation in the lab and testing in an “informal leisure room setting”). The latter finding suggests that the FDAE is not merely a lab-biased effect and that it can occur in more ecological settings (Carbon & Ditye, 2012). These effects have identity-specific components: FDAEs were bigger when the same identity was used at both adaptation and test, rather than two different identities. Carbon et al also showed that category contingent opposing after-effects can occur for different familiar identities: opposing distortions applied simultaneously to different categories (or identities) of faces (e.g. expanded Brad Pitt and contracted Jude Law) produced shifts in judgements for these faces in opposite directions. Taken together these findings suggest that FDAEs update both the representation of an individual's face (as shown by opposing after-effects and bigger within-person adaptation) and affect more general face processing mechanisms (shown by the fact that after-effects transfer to a different identity).

FDAEs have been found for highly familiar faces with real world familiarity. It is important to consider personally familiar faces as well as famous faces, because of the former's "robust" representation (Tong & Nakayama, 1999). Tong and Nakayama suggest that personally-familiar faces have "robust" representations: they are highly overlearned faces which have been encountered under a wide range of viewing conditions and contexts. Robust representations require lots of visual experience to develop. To our knowledge, there are only a few studies which have investigated FDAEs for personally familiar faces, e.g. one's own face, a family member's face or a friend's face. Laurence and Hole (2011) found smaller FDAEs after adapting to one's own face, compared to famous and unfamiliar faces. In their experiment, participants were adapted to and tested on the same identity (within-identity adaptation). Laurence and Hole (2011) suggest an "own-face effect": that the self-face has a more stable, less adaptable, representation than other faces. However, Rooney, Keyes and Brady (2012) found equally sized FDAEs after adapting to distorted unfamiliar faces, and testing on one's own face or a friend's (across-identity adaptation). They also showed category contingent after-effects for one's own face and a friend's: participants who were adapted to a compressed version of their own face and an expanded version of their friend's face experienced opposite after-effects. Rooney et al. suggest that shared neural populations code these identities, and that perhaps our representation of our own face is no more stable than that of other robustly-represented faces.

The studies by Laurence and Hole (2011) and Rooney et al (2012) differ as they consider within-identity adaptation and across-identity adaptation respectively. These two methods have, however, been incorporated into a single study. Walton and Hills (2012) adapted participants to a distorted version of a parent's face, a famous face and an unfamiliar face. Participants were tested on each of these three identities: participants were tested on both the same face that they had adapted to (within-identity adaptation), and on a different face (across-identity adaptation). For example after adapting to their parent's face, a participant was tested on their parent's face, a famous face and an unfamiliar face. The pattern of after-effects was different for the parent's face, compared to the famous or unfamiliar face. After-effects were larger when participants were adapted to an unfamiliar face and tested on a parent's face, than vice versa. Walton and Hills also found smaller within-identity adaptation for parents' faces than for famous or unfamiliar faces (similar to the "own-face effect" found by Laurence and Hole (2011)).

The findings from Laurence and Hole (2011), Rooney et al (2012) and Walton and Hills (2012) are inconclusive in determining whether all robustly-represented faces (self, family or friend) have equally stable representations. No single study has considered whether the FDAE is the same for one's own face, family faces and friends' faces. Walton and Hills (2012) showed that across-identity adaptation was greater for personally familiar faces than within-identity adaptation, compared to the famous or unfamiliar faces. Therefore the finding of equal across-identity adaptation for self and friend (Rooney et al, 2012) might not be the same as for within-identity adaptation, especially when one considers the brain areas involved in the processing of robustly-represented faces.

There is a distributed neural network for the processing of robustly represented familiar faces (see Natu & O'Toole, 2011 for a review). Pierce, Haist, Sedaghat, and Courchesne (2004) found that the so-called "fusiform face area" (FFA) responded bilaterally to both personally familiar (family member/friend) faces and unfamiliar faces. There are, however, areas that respond more strongly to faces of family and friends, such as the anterior paracingulate cortex, the left posterior cingulate (Gobbini, Leibenluft, Santiago, & Haxby, 2004) and the right FFA (Pierce et al, 2004), or one's own face (see Devue and Brédart, 2011 for a review). Carbon and Ditye (2010) suggest that FDAEs involve updates both to an identity-specific representations for familiar people and to a more general face processing mechanism. The across-identity adaptation in Rooney et al (2012) might be affecting more general face processing mechanisms for both unfamiliar and familiar faces (e.g. in the FFA), rather than their identity-specific representations (e.g. the anterior paracingulate cortex).

The purpose of the present study was to investigate whether the "own-face effect" found by Laurence and Hole (2011) was specific to one's own face or whether it was a "robust-face effect" that would be observed for other highly familiar faces: one's own face, a sibling's face and a friend's face. More specifically, will within-person adaptation be the same for different types of robustly-represented face? Using within-identity adaptation, we will be able to investigate whether viewing highly distorted versions of familiar faces can alter our representation for that identity, even if that person is the self.

6.2. Method

6.2.1. Design

There were two independent variables: the identity of the adapting and test face, and time of testing. The identity of the adapting and test face was a repeated-measures variable: each participant was adapted and tested on their own face, their sister's face and a friend's face. Time of testing was also a repeated measures variable: participants were tested by asking them to judge normality before adaptation (baseline), and after adapting to each of the identities (test).

Normality decisions at baseline and test were measured by presenting participants with nine faces, varying in their levels of figural distortion (see Figure 6.1), and asking them to judge whether each face looked “normal” or “odd”. An adaptation after-effect would result in two things: 1) more of the contracted faces would be judged to look “normal” after adaptation, compared to before adaptation; 2) fewer of the expanded faces would be judged to look “normal” after adaptation, compared to before adaptation. Each test face was shown six times during each test session.

An initial aim had also been to compare the size of the after-effects for robust faces with after-effects for unfamiliar faces. However, this was not possible for practical reasons which will be outlined in the discussion.

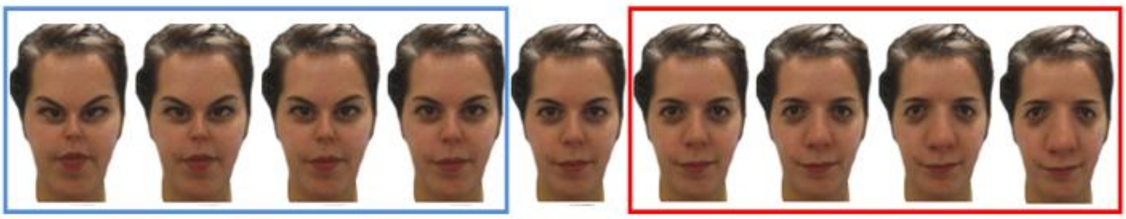

Figure 6.1. An example of the nine test faces which vary in their levels of distortion (from left to right: 60, 45, 30, 15, 0, -15, -30, -45, -60). The four faces on the left (in the blue box) have been contracted and the four faces on the right (in the red box) have been expanded.

6.2.2. Participants

Participants were 30 students at the University of Sussex, who participated in return for being entered into a £25 prize draw. Only 29 participants were included in the final analysis: the data from one participant were excluded because they did not judge any images as looking normal, at baseline. As in Laurence and Hole (2011), all participants included in the final analysis were Caucasian females aged between 18 and 35 (mean age = 22.69 years, SD = 2.66) who had a full biological sister, and a female friend. None of them wore glasses (or anything else that concealed the face) on a day-to-day basis. We also ensured that their sister (mean age = 22.07 years, SD = 3.88) and friend (mean age = 22.28 years, SD = 2.71) fell within the same age bracket and were also Caucasian.

6.2.3. Stimuli

Each participant was asked to provide a passport quality photograph (except bigger in size) of their own face, their sister's face and a friend's face. Each photograph had to be a frontal view, in colour, with nothing obscuring the face (e.g. hair, glasses), a neutral facial expression, and as large as possible. Images provided by participants of their own face were mirror reversed so that during the experiment they were presented with a view of themselves that they were most familiar with. Each image was cropped to show just the face. All images were presented on a white background.

6.2.3.1. Adapting stimuli

Each image (self, sister and friend) was resized to a width of 150 pixels. Figural distortions were produced using Adobe Photoshop CS2, in the same way as in Laurence and Hole (2011). An oval marquee selected the internal features of the face and the distortion was applied using the "Pinch" function set to 60%.

6.2.3.2. Test stimuli

Test stimuli were nine different images for each of the faces shown in the adapting phase (self, sister and friend), making a total of 27 test images for each participant. Each of the nine test images for each identity varied in its level of distortion (see Figure 6.1). The distortion was produced using the Photoshop “pinch” function set to varying levels, in the same way as for the adapting stimuli. All test images had a width of 200 pixels.

The script for the experiment was produced using EPrime 2.0. The experiment took approximately 25 minutes to complete. All stimuli were viewed from a distance of approximately 60cm.

6.2.4. Procedure

Participants were tested individually.

6.2.4.1. Baseline (pre-adaptation) phase

Participants were told that they would be presented with a series of briefly-presented faces, and that they should judge whether each face looked normal (by pressing “N”) or odd (by pressing “O”). At this point it was explained to them what “normal” and “odd” meant (“normal” was a version they were used to seeing in the real world).

The baseline test phase consisted of three testing blocks (self, sister and friend), the order of which was counterbalanced. Within each block the nine test faces for that identity were each shown six times for 200ms. Each test face was preceded by a fixation cross for 750ms, and was followed by a prompt indicating that the participant should indicate their decision. In total there were 162 trials during the baseline test phase (54 for each identity).

6.2.4.2. Adaptation and test phases

On screen instructions then told participants that there would be two tasks in the next part of the experiment. Initially they would see a familiar face and they should examine this carefully. (This was the adaptation phase). There would then be lots of trials, each of which would involve two tasks: the participant would see the face again briefly, before being asked to indicate whether another version of the face was normal or odd (pressing "N" for normal, or "O" for odd).

There were three adaptation and test blocks (self, sister and friend) which were in the same order as the baseline testing blocks. In each block participants then viewed the distorted adapting face for 1 minute before starting the test phase. Testing was done in exactly the same was as during the baseline phase, except each trial started with top-up adaptation. During top-up adaptation, each adapting face was shown for 4000ms.

To reduce retinotopic adaptation, images in the adaptation phases were presented 400 pixels to the left of the centre of the screen. During the test phases, both the top-up adaptation and the test faces were presented at the centre of the screen. (Because the test stimuli were presented so briefly (200ms), the top-up adaptation needed to be located in the same location so that participants continued to fixate at the same part of the screen).

6.3. Results

Each participant provided us with the number of “normal” decisions that they made for the contracted test faces (15, 30, 45 60) and for the expanded test faces (-15, -30, -45, -60). Each test face was shown a total of six times during each test phase. They did this before and after adaptation, for each of the identities. If participants had adapted, then more of the contracted faces, and fewer of the expanded faces, should look normal after adaptation. This would suggest a shift in their perception of normality towards the adapting distortion, i.e. an after-effect. Participants were only included in the final analysis if they had indicated that at least one of the test faces looked normal in each condition. This resulted in the data from one participant being excluded because they didn’t think that any of the test faces for their own face, or their sister's face looked normal at baseline.

We conducted a repeated measures ANOVA with three levels of identity (self, sister and friend) for the number of "normal" responses made for the contracted faces at baseline. This was in order to check that there were no pre-existing differences in the number of "normal" responses made for contracted images of the three identities i.e. to ensure that our participants weren’t better at judging normality of their own face, compared to their friend or sisters’ face. There was a non-significant effect of identity on the number of normal decisions made for the contracted faces, F (2, 56) = .50, p = .61, $\eta\rho^2$ = .02 . The same was true of the expanded faces, F (2, 56) = .83, p = .44, $\eta\rho^2$ = .03. This suggests that there are no pre-existing differences in participants' ability to judge normality of their own face, their sister’s face, or their friend’s face (see Figure 6.2). There were, however, significantly more "normal" responses made for the contracted faces than the expanded faces, F (1, 56) = 6.39, p = .01, $\eta\rho^2$ = .19. This might be an artefact of the photographs that participants supplied to us which may have been slightly distorted (expanded) due to being taken on smart phones or webcams.

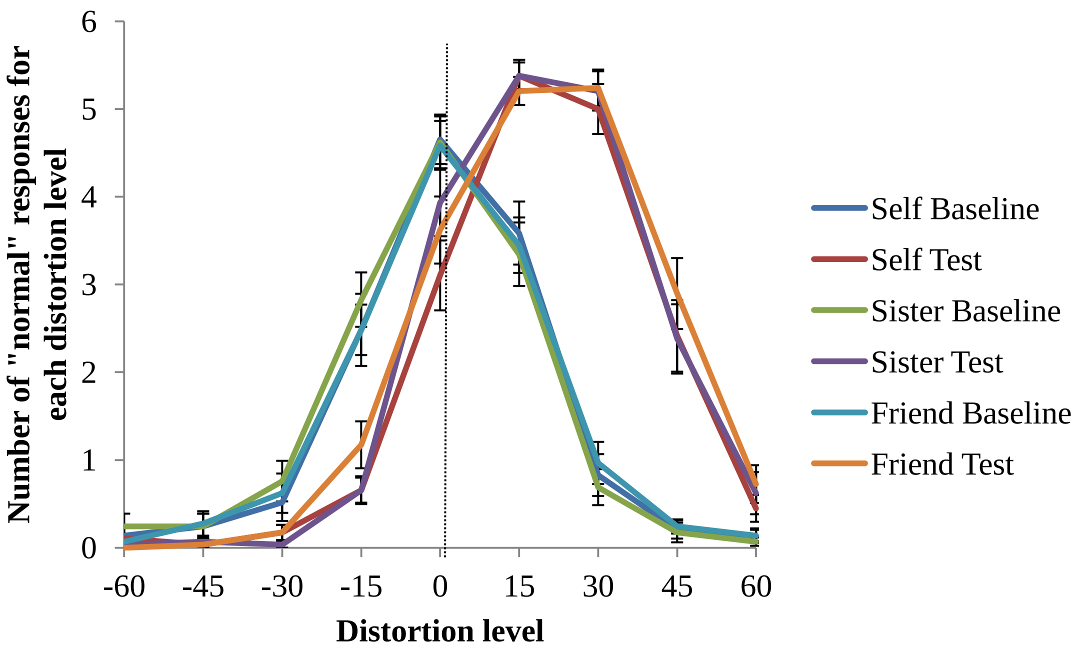

Figure 6.2. The number of “normal” responses made for each test face, for each identity (self, sister and friend), before and after adaptation (error bars show +/- 1 SEM).

A repeated measures ANOVA with three levels of identity (self, sister and friend) and two levels of time of testing (before and after adaptation) was conducted. The number of contracted faces judged to look normal was the dependent variable. There was a non-significant main effect of identity, F (2, 56) = .76, p = .47, $\eta\rho^2$ = .03, and a significant main effect of time of testing, F (1, 56) = 403.14, p <.001, $\eta\rho^2$ = .94. Figure 6.2 indicates that significantly more of the contracted test faces were considered to look normal after adaptation, compared to before. This demonstrates that significant adaptation had taken place. There was, however, no difference in the size of the after-effect depending on whether the face was one’s own, a sister or a friend’s face.

A second repeated measures ANOVA was conducted, except this time the dependent variable was the number of expanded faces that were judged to look normal.

There was no significant main effect of identity, F (2, 56) = .30, p = .74, $\eta\rho^2$ = .01, and there was a significant main effect of time of testing, F (1, 56) = 29.62, p < .001, $\eta\rho^2$ = .51. The findings show that fewer expanded faces were considered to look "normal" after adaptation, again suggesting that adaptation had taken place.

6.4. Discussion

The results of this experiment indicate that significant adaptation took place after looking at grossly distorted versions of one’s own face, the face of a sibling and a friend’s face. The size of the after-effect was equivalent for each of these identities. These findings suggest that exposure to highly distorted versions of highly familiar faces can alter our subsequent perception of these faces.

Laurence and Hole (2011) found smaller within-person adaptation after-effects for one’s own face, compared to famous and unfamiliar faces. Walton and Hills (2012) found a similar pattern, except the personally familiar face in their study was the face of a parent. The present study is the first to directly compare the size of after-effects for three different types of robustly-represented faces when adapting and testing occurred with the same identity. The findings suggest that the representation for our own face is no less adaptable than that of other highly familiar faces. All robustly represented faces, be it the face of a friend, a sibling or even one’s own face, are equally adaptable. This is a similar conclusion to that of Rooney et al (2012), except the present study used within-person adaptation. Jenkins, White, Van Montfort and Burton (2011) report that when a face is unfamiliar, two images of the same person can look like pictures of two different people. In contrast, viewing photographs taken under different conditions (e.g. lighting, pose, camera etc.) does not impair familiar face recognition (also see Burton, Wilson, Cowan & Bruce, 1999). Carbon et al (2007) suggests that our representations for familiar identities are flexible, in order to accommodate the variation in appearance that we see of them. Experience with distorted versions of a face can rapidly update what is perceived to be normal. The present experiment replicates these findings, suggesting that even faces which are highly familiar to us can have highly flexible representations.

It has been proposed that faces are processed within a multidimensional face-space which reflects our experiences with faces (e.g. Valentine, 1999). A few seconds or minutes of exposure to a distorted face can rapidly update our perception of subsequent faces. According to Rhodes and Leopold (2011), adaptation might be functional in fine tuning face-space to the diet of faces to which we are exposed. In a norm-based coding model (where incoming faces are encoded relative to an internal norm) adaptation is said to bias the norm towards the adapted dimension. An alternative to norm-based coding is exemplar-based coding, where faces are encoded relative to a set of stored exemplars in face-space, rather than in relation to a norm. Familiar face recognition is more abstractive than unfamiliar face recognition (e.g. Megreya & Burton, 2006, 2007). It is therefore possible that highly familiar faces may be represented differently in face-space from faces with which we have less experience. It is possible that there are identity regions in face-space (e.g. Voronoi cells proposed by Lewis & Johnson, 1999) and the region is defined by what is an acceptable instance of a particular face. Walton and Hills (2012) suggest that perhaps the figural distortion in their experiment fell outside of the restrictions placed on a robust face's representation, which is why it was less adaptable.

The size of the after-effect in the own-face condition of the present study was a lot larger than what we expected to obtain on the basis of Laurence and Hole's (2011) results. While it is still possible that after-effects are smaller for robustly-represented faces than they are for famous or unfamiliar faces (e.g. Walton & Hills, 2012) there are a few possible explanations for why we have found a considerably bigger after-effect for one's own face in this study. Methodological differences between the two studies may be the principal reason for the differences. For example, Laurence and Hole (2011) tested the size of the effect using arrays of nine test images, representing the same levels of distortion that we used in this study. From each array, participants had to simply decide which face looked the most normal, which encourages a decision strategy based on making relative judgements. In the present study each test face was shown in isolation and participants had to decide whether each test image looked normal or odd, a task which requires participants to make more "absolute" judgements. It is plausible that there may be decisional factors driving the size of the effect found in Laurence and Hole (2011). Other research has shown a self-face advantage on visual search tasks containing arrays of one's own face, compared to other faces (e.g. Tong & Nakayama, 1999). Rather than picking up on a purely perceptual effect, Laurence and Hole's (2011) participants may have used a more efficient strategy for deciding which test face was veridical in an array containing one's own face, compared to arrays containing other faces (perhaps using a process of elimination which may be more efficient for one's own face). Another possibility is that perceptual adaptation decays more quickly when a face is personally familiar. The test faces were shown for only 200ms in this experiment, whereas in Laurence and Hole's (2011) study, the arrays were visible until participants made a decision - about 7 seconds in practice. Rhodes, Jeffery, Clifford and Leopold (2007) have shown that the size of after-effects can be modulated by test face duration. In their study, the biggest FDAEs were found when the test face was presented for 200ms. It could be that FDAEs decay more quickly for personally familiar faces. Walton and Hills (2012) did not report how long participants took to respond to the test faces (the test faces were presented until participants made a response) however, they suggest that it was about 500ms (P. J. Hills, personal communication, June 2013).

We had initially intended to run a fourth "unfamiliar face" condition, with participants who were wholly unfamiliar with the faces used in this experiment. In practice we did not do this because the "undistorted" photographs in this experiment were perceived to be distorted by our participants (as indicated by them making more 'normal' responses to the contracted faces at baseline) compared to what they would consider to be "normal" based on their real world experience. We applied a distortion to those faces which we used as our adapting stimuli. If participants were unfamiliar with those faces, they would have no real world reference against which to compare the faces. The undistorted image of the face would be truly distorted to them, therefore the adapting distortion we applied to the faces might be perceived to be bigger. Robbins, McKone and Edwards (2007) have shown that the size of the FDAE increases as the size of the distortion in the adaptor increases. We reasoned that because of this, we could not be sure if an FDAE to unfamiliar faces was due to the size of the distortion or due to the relative familiarity of the face. The only fair way to compare the size of the FDAE for personally-familiar and unfamiliar faces would be to photograph all of the faces under highly-controlled conditions (in which factors such as the focal length of the lens and the distance between the camera and the face were known). We could then be certain that the face images were undistorted. In practice, we had to make do with the images supplied to us by our participants, many of which were captured under informal conditions using smartphones and small digital cameras. The wide-angle lenses on these cameras introduce some distortion into the resultant face image. People who are highly familiar with the face can make allowances for this, but people who are unfamiliar with the face cannot. In assessing normality, the latter group can only make their judgements based on the image supplied to them. Therefore, if this "normal" image is actually somewhat distorted (as is quite likely, given the wide-angle lenses on most camera phones and small digital cameras) assessments of normality will be affected by this.

After-effects for robustly-represented faces may be smaller than for other faces: Walton and Hills (2012) found this, and used a similar adaptation procedure to that used in this study. However, the present results raise the possibility that the own-face effect from Laurence and Hole (2011) could be a product of the methodology that they used. Future research should systematically investigate whether FDAEs are smaller for robustly-represented faces, using more established, conventional methods for testing adaptation that minimise decisional factors and control the length of time that a test face is presented for. Overall, it seems that all highly familiar faces are as adaptable as each other, but future research should test the size of the effect at longer time points after adaptation, in order to pin down whether our representation of a face has changed.

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CHAPTER 7:

CONCLUDING REMARKS

7.1.Broader Implications

The findings reported in this thesis have implications beyond the face adaptation literature. This final section will outline the broader implications of the work presented.

It is only relatively recently that adaptation has been used to explore higher level visual properties, and there has been debate about whether these effect do indeed tap into higher level or lower level processing (see Webster & MacLeod, 2011 for a discussion). The findings suggest that adaptation can be used as a tool to investigate higher-level visual processing. We found significant adaptation, even when the adapting and test stimuli had minimal physical overlap.

Secondly, the findings provide further support for the idea of abstractive representations for familiar faces. This is important because the data from some brain imaging studies have not yet found the location of where our abstractive representations for faces are stored (e.g. Davies-Thompson, Newling & Andrews, 2012). Most theories of familiar face processing, based on the behavioural literature, do provide support for abstractive representations (see Burton & Jenkins, 2011 for a discussion). The advantage of the present studies is that they use another technique for testing these theories.

Finally, the findings lend themselves to a novel model of face processing using predictive coding where predictions about the world can affect our perception. Familiar face recognition is less affected by low-level image transformations (e.g. lighting) and predictive coding theorists might explain this as feedback from higher areas reducing activity in lower visual areas (e.g. Mumford, 1992). This explanation has already been offered for our perception of shape (e.g. He, Kersten & Fang, 2012) and other properties (see Panichello, Cheung & Bar 2013, for a review). It will be of great interest to use other techniques, as well as adaptation, to investigate and refine a model of face processing, using predictive coding.

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