Cross-modal face identity aftereffects and their relation to priming

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Abstract

We tested the magnitude of the face identity aftereffect following adaptation to different modes of adaptors in four experiments. The perceptual midpoint between two morphed famous faces was measured pre- and post-adaptation. Significant aftereffects were observed for visual (faces) and non-visual adaptors (voices and names) but not non-specific semantic information (e.g., occupations). Aftereffects were also observed following imagination and adaptation to an associated person. The strongest aftereffects were found adapting to facial caricatures. These results are discussed in terms of cross-modal adaptation occurring at various loci within the face-recognition system analogous to priming.

1. Introduction

While one's perception of faces is relatively robust, in that one can identify a familiar face under a large variety of viewing conditions, it has been demonstrated that prolonged exposure to distorted faces leads to a strong and systematic aftereffect in the direction opposite to the adaptor face (e.g., Fox and Barton, 2007; Hurlbert, 2001): adaptation to an expanded face will make a subsequent average face appear contracted (Webster and MacLin, 1999). This is known as the Face Distortion Aftereffect (FDAE; Rhodes, Jeffery, Watson, Clifford, and Nakayama, 2003; Rhodes and Jeffery, 2006). Additionally, adaptation to a particular face identity causes an average face to take on aspects of the "opposite" identity (Leopold, O'Toole, Vetter, and Blanz (2001). The present article focuses on this second type of adaptation, known as the Face Identity Aftereffect (FIAE). Similarities are drawn between adaptation and priming processes, although priming has been found to occur in many more situations than have been tested in the adaptation literature. The remainder of the paper concerns four experiments that explore adaptation under a range of conditions for which priming effects have been found.

1.1. Adaptation

Adaptation is the process where perceptual experience is affected by constant stimulation of a particular characteristic creating an aftereffect distinctly different from previous exposure (e.g., Sekuler and Blake, 2001). For example, adaptation to specific spatial frequencies causes them to be more difficult to detect post adaptation (Menees, 1988). Such a low-level adaptation appears quite similar to high-level adaptation involving faces. Leopold et al. (2001) conducted a pioneering study into FIAEs. In their study, 200 faces were morphed together to produce a single average face. This was assumed to be the centre of the face-space (see Valentine, 1991). Due to the morphing process, each face identity could then be measured in terms of Euclidean distances from the average face. Some of the faces were selected to be used as targets and a series of morph faces were constructed that ranged from the average face to each target face identity, each differing in identity 'strength'. Identification thresholds (the required identity strength to perceive the face identity) were taken before and after adaptation to an anti-face identity (opposite from the face-identity in terms of the Euclidean geometry). Post adaptation to an anti-face (e.g., anti-Adam), the identification threshold for the face (e.g., Adam) was lowered by an average of 12.5% suggesting it was easier to perceive the identity following adaptation to the anti-identity.

The magnitude of the FIAE is typically measured in terms of difference in identification thresholds pre- and post-adaptation and is dependent on the presentation duration of both the adaptor and the test stimuli (Leopold, Rhodes, Müller, and Jeffery, 2005). Stronger FIAEs are observed when the adaptor is presented for longer durations (16000 ms) than shorter durations (1000 ms). Moreover, FIAEs are significantly stronger when the test stimuli are presented for shorter durations (100 ms) than longer durations (1600 ms). Face aftereffects are partially size-tolerant since the FDAE transfers from an adaptor of one size to test stimuli of different sizes (Zhao and Chubb, 2001) and also across parts of the retina (Anderson and Wilson, 2005). Jiang, Blanz, and O'Toole (2006) demonstrated that the FIAE transfers across a substantial change in viewpoint (30^0 rotation) indicating the mechanisms for the FIAE are of a higher-level nature (see also, Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005, but see Jeffery, Rhodes, & Busey, 2006, for a different result described further below).

Face aftereffects are more robust for familiar faces than unfamiliar faces (Carbon & Leder, 2005; Jiang, Blanz, and O'Toole, 2007). Jiang et al. (2007) specifically tested the degree of familiarity that participants' have with a face and the magnitude of the FIAE in within- and between-viewpoint adaptation. They trained 90 participants on a set of 16 faces to varying degrees of familiarity. In the low-familiarity condition, the participants only saw the face in a frontal view twice. In the high-familiarity conditions, participants saw the faces eight times each in frontal views only, rotated views only or half frontal and half rotated views. An extreme familiar condition was also included where participants saw the faces 16 times in frontal views and 16 times in rotated views. This highly controlled study demonstrated that, although the magnitude of adaptation was greater for within-viewpoint adaptation, there was still significant adaptation for between-viewpoint adaptation. Moreover, the largest FIAEs were observed for the most familiar faces. Indeed, the difference between the FIAE to same- and different-viewpoint adaptation was smallest for the extremely familiar condition. This suggests that familiar and unfamiliar faces are represented differently (c.f., Megreya & Burton, 2006; Ryu & Chaudhuri, 2006, consistent with neuroimaging evidence by Eger, Schweinberger, Dolan, & Henson, 2005) and that adaptation to familiar faces is based on a three-dimensional representation of a face, whereas adaptation to an unfamiliar face is based on two-dimensional image qualities.

In a review of how FDAEs in unfamiliar faces are affected by image adjustments from adaptation to test, Yamashita, Hardy, De Valois, and Webster (2005), noted that the magnitude of adaptation was dependent on visual similarities between the adaptor and the test stimuli. The more similar the adaptor was to the test stimuli the greater the magnitude of the aftereffect. In addition there were classes of image adjustments that affected the magnitude of the aftereffects more than others. Specifically, size and colour differences between the adaptor and the test stimuli reduce the magnitude of adaptation significantly less than spatial frequency and contrast differences between the adaptor and test stimuli.

According to Moradi, Koch, and Shimojo (2005), the FIAE requires conscious perception, since it is significantly reduced if the adapting face is not consciously visible to participants. Moradi et al. tested the effect different types of suppression had on the magnitude of the FIAE. Though the FIAE transferred from the adapted retina to the unadapted retina, it disappears when the participants are attending to the eye that is not adapted. For example, one eye is being adapted to a face identity, while the other eye is presented with a pattern of moving random dots. Participants who attended to the moving pattern often ignored the face and failed to show the FIAE.

Moradi et al. (2005) also tested whether imagination can cause the FIAE. Six participants were trained to associate names with the anti-faces of Leopold et al. (2001). This training lasted 300 trials. They were then asked to imagine one of the faces and were asked how clear their mental image was. Participants reported that their visualisation was vivid and yet demonstrated no FIAE even after prolonged visual imagery. This observation is surprising given that there is activation in the visual cortex during mental imagery (e.g., Kosslyn et al., 1993; Slotnick, Thompson, & Kosslyn, 2005). In addition, the fusiform gyrus (the face specific area of the inferotemporal cortex, Kanwisher, McDermott, and Chun, 1997) is active during perception *and* mental imagery of faces (Kreiman, Koch, and Fried, 2000; O'Craven and Kanwisher, 2000) and even without awareness of presented faces (Marois, Yi, and Chun, 2004; Moutoussis and Zeki, 2002). Additionally, the FIAE activates the fusiform gyrus (Loffler, Yourganov, Wilkinson, & Wilson, 2005). Since there is significant individual differences in the ability to mentally visualise (e.g., Amedi, Malach, & Pascual-Leone, 2005; Bywaters, Andrade, & Turpin, 2004; Hasnain & Husain, 1980; Issac & Marks, 1994; Richardson, 2000; Richardson & McAndrew, 1990; Zarrinpar, Deldin, & Kosslyn, 2006) and in the activation of the visual cortex during imagery (c.f., Cui, Jeter, Yang, Montague, & Eagleman, 2007;

Ishai, Schmidt, & Boesiger, 2005), it is possible that the small sample (6 participants) tested by Moradi et al. was affected by a single participant unable to accurately visualise a particular face. Additionally, training participants to associate a name with a two-dimensional digitised face that has only ever been seen in one pose is unlikely to lead to an accurate face representation (c.f., Burton, Jenkins, Hancock, & White, 2005). Moreover, the assessment of visualisation clarity was not based on previous mental imagery work (e.g., Marks, 1973; McKelvie, 1994). Indeed, Hills, Elward, and Lewis (2009) have shown that the FIAE can be caused by imagined adaptation and even to name stimuli.

Hills et al. adapted participants to an image of a famous person. Subsequently, they presented a morph between the two identities, and asked participants to state who the morph looked like. Each participant participated in a single trial. Their results indicated that an image adapted 90% of participants whereas a name stimulus adapted 75% of participants. Hills et al. also included a condition in which participants were told to imagine a particular identity. This condition produced greater magnitude of adaptation than the name stimulus, but only in participants who were better able to mentally visualise.

To summarise the work on adaptation within face recognition: largest aftereffects are noted for adaptors that are most similar to the test stimuli; smaller, but still significant, aftereffects are noted for adaptors that are in a different pose than the test stimuli; and adaptation may or may not require presentation of the actual stimulus. Given the potential for cross-modal adaptation implied by Hills et al. (2009), in this work, we extrapolated the stimuli that may cause adaptation based on parallels with priming. In the next section, priming will be discussed and those parallels will be drawn.

1.2. Priming

Priming is defined as a change in the processing of a stimulus caused by prior exposure to the same or a related stimulus (Gabrili, 1998). Broadly speaking there are two forms of priming: perceptual (repetition) and conceptual (semantic: Roediger & McDermott, 1993; Tulving & Schacter, 1990). Perceptual priming results in an enhanced ability to identify or recall a stimulus (Graf, Squire, & Mandler, 1984) and its effectiveness depends on the similarity of the prime to the subsequent stimulus, where greater similarity results in greater priming (Jacoby & Dallas, 1981). Conceptual priming results in facilitated processing of the meaning of a stimulus (Meyer & Schvanevedlt, 1971). The prime can be subliminal or supraliminal (Nisbett & Ross, 1980) and depends less on the perceptual similarity between the prime and the target than perceptual priming. Within the face recognition literature there have been many studies published exploring perceptual and conceptual priming.

A. Ellis, Young, Flude, and Hay (1987) reported three studies where participants were instructed to state whether or not a face was familiar. When participants had seen a photograph of a familiar face in a preceding stage of the experiment they were faster at identifying that the face was familiar by 71 ms than if they had not seen the face in the experimental session (Experiment 1). Furthermore, familiarity judgements were not made quicker if the participant had seen the face’s written name prior to the face (Experiment 2). Experiment 3 compared the speed of familiarity judgements when the prime photograph was identical to, similar to (same viewing angle of the same person), or dissimilar to (different viewing angle of the same person) the target photograph. If the prime photograph was the same as that used as the target, the familiarity judgement was made more quickly by 196 ms, compared to 163 ms faster if the photograph was only similar. Reaction times were reduced by 104 ms when a dissimilar photograph was the prime. These results indicate the importance of perceptual similarity in the repetition priming effect (see also Ellis, D. Ellis, & Hosie, 1993).

These results are slightly different from those subsequently found by Young, Flude, Hellawell, and A. Ellis (1994), where written names sped up familiarity judgements of faces if the prime preceded the face by a short period of time. Moreover, Ellis, Jones, and Mosdell (1997) found that voices can prime faces. However, this cross-modal repetition priming effect only occurs if the prime precedes the target face by a maximum of five seconds. Johnston and Barry (2006) have shown that cross-modal repetition priming effects are significantly smaller than within-modal priming effects, but are still significant themselves.

In addition to perceptual (repetition) priming, Bruce and Valentine (1986) found that there are also associative (semantic) priming effects, where the face or name of a person will speed up the identification of a name or face of a related person. For example, presentation of the face of Ronnie Barker sped up familiarity judgements made to Ronnie Corbett's face – since they are a comedy duo and often seen together. Furthermore, Young, Hellawell, and de Haan (1988) have shown an associative form of cross-modal priming, where the name of a famous person speeds up recognition of a highly associated famous face. For example, reading the name of "Stan Laurel" will speed up the recognition of the face of "Stan Laurel" and the recognition of the face of "Oliver Hardy". Semantic priming has also been shown by Burton, Kelly, and Bruce (1998) who showed that subsequent semantic judgements made about a face are faster following initial semantic judgements being made. These subsequent semantic judgements could be of the same or different kind (i.e., nationality and alive/dead).

Another form of semantic priming is that of category priming. Category priming (Carson and Burton, 2001) is where priming of the category label speeds up recognition of all known exemplars of that category. For example, the category label "comedians" will speed up recognition of “Stan Laurel” and all other known comedians. Category priming is a weaker variant of semantic priming. Possibly a related effect is that of stereotype priming, in which unfamiliar faces that resemble the prototype of a particular occupation are recognised more accurately if they are encoded with the relevant stereotype presented as a word (Hills, Lewis, & Honey, 2008).

The face priming studies reported here are similar in kind to the general priming studies (such as word priming). Priming effects are larger if the modality of the prime and the target stimulus is the same. Nevertheless, priming effects are observed if the prime and target stimulus differ in modality. Repetition and semantic priming are clearly observable within the face processing system.

1.3. The loci of priming and adaptation within the Interactive Activation and Competition model

The Interactive Activation and Competition (IAC) model contains a number of pools that represent the different aspects of the face recognition system. At the lowest level is the visual input. Though generally underspecified, the perception and coding of a face is done here. Burton et al. (1999) have used principal component analysis to model this front-end. This principal component analysis front-end may be represented by Valentine’s face-space (Hancock, Burton, & Bruce, 1996; Turk & Pentland, 1991; Valentin, Abdi, Edelman, & O’Toole, 1997). Following the visual input level is the face recognition pool, where nodes representing all the faces within memory are stored. There is a Face Recognition Unit (FRU) for every face that is stored within memory, and each is purely visual. It may be an average for all the many views of a particular person, or it may contain all possible views encountered of that person. Burton et al. (1990) suggest that the FRUs store the visual structural descriptions of faces which allow views of one known face to be distinguished from views of other faces, known or otherwise. Some researchers have indicated that the FRU pool is best represented by the face-space (e.g., Valentine, Chiroro, and Dixon, 1995). Connected to each FRU, through Person Identity Nodes (PINs), is person-specific information in terms of many Semantic Information Units (SIUs). These nodes provide all the semantic information concerning that identity. Each aspect represents a different characteristic of someone's identity connected to the visual face store. A basic architecture is shown in Figure 1.

Figure 1 about here

The priming effects described in the previous section have been succinctly explained within the interactive activation and competition model (IAC) of face recognition (Burton, Bruce and Johnston, 1990) or the model of Farah, O'Reilly, and Vecera (FOV, 1993). The IAC model is based upon neural network architecture (c.f., Grossberg, 1978; McClelland, 1981) and comprises processing units organised into hierarchically arranged pools. Each unit is connected to other units within the same pool by inhibitory links which are all of equal strength (Burton & Bruce, 1993), but less strong than excitatory links between units that cross pools (Burton, Bruce, & Hancock, 1999). Each unit takes on an activation level between fixed maximum and minimum values which are updated with each processing cycle. The model is stabilised by a global decay function which drives all units to a resting level of activation. All the links are bi-directional (Burton et al, 1990). Activation of units can be external or internal. External input is through processing something in the real world, whereas internal input is activation spreading from other units. The activation level of a particular unit is proportional to the product of the strength of activation of the connected units and the connection strengths. The ease of recognition is based upon the number of processing cycles required to reach the threshold value (Burton et al., 1990).

Priming occurs when the activation level of one node raises the activation level of a connected node above the threshold level. External activation activates a node and through internal activation, all nodes connected through excitatory links become active. Thus, the internal activation can be cross-modal. From this analysis it is clear how the priming effects explained in Section 1.2 can be explained within the IAC framework.

When presented with a visual input, the visual nodes become active and their activation threshold is lowered until the global decay function brings the system back to a stable resting level. If the same visual input is presented before the global decay function brings the system back to the resting level, then less external input is required for the same output from that node. Thus, within-modal repetition priming (and specifically where the prime is identical to the target stimulus) can be explained in the perceptual front-end of the IAC model.

The situation is slightly different if the prime image does not match the test image exactly (i.e., pose change). Simple image-based priming is not sufficient to explain this. Instead, the priming is occurring at the FRU level as the FRUs contain 3-dimensional, viewpoint independent representations of the face (Burton et al., 1990). It must be accepted that priming involving identical primes and targets may involve the FRU, but this is not required since it may not differ from object priming. In other words, when there is no change in image from prime to test, the mechanisms do not need to be face-specific.

To explain cross-modal repetition, semantic and associative priming, the level of explanation must be higher, at the PIN level. Here, activation of a name (NRU), voice (VRU), or semantic information (SIUs) causes activation in the PIN and this causes activation in the FRU. Cross-modal priming thus involves extra levels. Due to this additional processing level and the limitation of spreading activation by the IAC framework (inhibitory links within pools and the global decay function) these priming effects are usually weaker than within-modal priming effects.

Whereas priming usually improves subsequent identification and recognition, adaptation usually produces the opposite effects: identification and recognition is less likely following adaptation. In the face recognition research summarised in Sections 1.1 and 1.2, priming of faces speeds up identification of faces whereas adaptation causes identification to be less likely in a morph. Similarities between the two can be drawn given the observation that both priming effects and aftereffects depend on the perceptual similarity between the prime or adaptor and the test stimulus (A. Ellis et al., 1987; Jiang et al., 2006). Although this similarity exists, priming appears to cause an effect opposite to adaptation. There are two potential factors that may explain this: differences in presentation time; and the interval between adaptor/prime and the test stimuli. Priming usually has short presentation time (less than 1s), whereas adaptation has longer presentation times (see e.g., Leopold et al., 2005). In terms of the interval between the adaptor/prime and test stimuli, it is usually considered that the adaptor must be presented immediately before the test (Leopold et al., 2005), whereas certain forms of priming can be longer lasting (see e.g., Young et al., 1988).

Having explained priming within the IAC and described similarities in the within-modal perceptual priming and adaptation, it seems sensible to employ the IAC to explain adaptation. The locus of explanation for adaptation and priming may be parallel. Viewpoint dependent adaptation only requires the front-end of the IAC and thus is unlikely to be face-specific (Jiang et al., 2006). Viewpoint independent adaptation requires a 3-dimensional representation of the face and thus the locus for this is the FRU pool. Since this is a one level abstraction from the actual perception then it would be predicted by the IAC and is observed that viewpoint independent adaptation is of a smaller magnitude than viewpoint dependent adaptation (Jeffery et al., 2006; Jiang et al., 2006). Broadly speaking, the number of pools the prime or adaptation passes through the smaller the effect.

The above explanation of within-modal perceptual priming and adaptation in terms of the perceptual front-end and the FRU pool of the IAC suggests that the IAC can be used to suggest how cross-modal adaptation may take place. Given that the IAC explains cross-modal priming, it is conceivable that the same analysis could be applied to predict cross-modal adaptation. The priming parallel of adaptation allows clear predictions as to the magnitude of aftereffects due to different classes of adaptors. If we consider that, like priming, adaptation can occur in every pool of the IAC then we might expect adaptation to occur in the NRU, VRU, SIU, PIN, and the FRU pools. Aftereffects observed in face perception could thus be caused by adaptation to the NRU through the PIN. In fact, adaptation to any stimulus that could be used to uniquely recognise an individual would lead to aftereffects of that FRU. Hence cross-modal adaptation is predicted such that adaptation to a name or a voice would lead to reduced recognition threshold for faces of that person.

Though the IAC model can be used to predict what classes of stimuli will cause aftereffects and to what degree of magnitude, the current mechanisms does not explicitly allow for adaptation (Bruce, personal communication). That is, though we have drawn parallels between priming and adaptation in terms of the classes of stimuli that may cause them based on the IAC model, there is no mechanism within the IAC model that allows for adaptation. It may be that the mechanisms for adaptation are not based on face-specific mechanisms (Jiang et al., 2006) and will not include person specific information. In other words, it may be that cross-modal adaptation is not possible. If cross-modal adaptation does occur, however, then it is important to explore how this may occur.

One mechanism that seems plausible is that the presentation of a name causes the face to be imagined. While Moradi et al. (2005) found that imagination does not cause aftereffects, this explanation cannot be ruled out for reasons expressed earlier and the results of Hills et al. (2009). Thus, prolonged presentation of a name causes prolonged imagination of a face and this causes adaptation in the FRU. Additionally, there is evidence that face memory is not veridical (Harvey, 1986). Instead, memory may distort faces and emphasize more distinctive features (Rhodes, Brennan, & Carey, 1987). Thus, if there is some memory based component in adaptation to faces then non-veridical images of faces could cause adaptation. One method for assessing this is the use of caricatures.

Caricatures of faces are often recognised and identified faster and more accurately than veridical faces (Mauro & Kubovy, 1992; Rhodes, Byatt, Tremewan, & Kennedy, 1997). Rhodes et al. (1987) found that using line-drawing caricatures a recognition advantage for 16% caricatures was found. Using photographic caricatures, Benson & Perrett (1991a, b) calculated that the caricature advantage was observed for caricatures distorted by 4.4%, based on the average performance on caricatures around this value (i.e., 3% caricature produced a smaller recognition advantage than 4%, but greater than 6%). Rhodes (1993) found the caricature advantage to be 5.5% caricature. These results indicate that memory may distort faces by between 4.4% and 16% in the direction away from the average. Thus, cross-modally driven FIAEs based on memory and imagination will be larger following adaptation to a caricature than to a veridical image.

In this section, we have suggested that perceptual priming is analogous to adaptation in faces in terms of how the magnitude of the effects depends on the perceptual similarity between the prime or adaptor and test. This analogy was taken further using the IAC model of face perception and it was hypothesised that cross-modal adaptation could occur and this could be based on imagery of non-veridical face memory.

1.4. The Present work

We have described how priming and adaptation may be analogous in terms of the classes of stimuli that can cause them and the difference in magnitude of the effects these classes will have. The present work aimed to explore, using parallels to priming, cross-modal adaptation. We tested whether cross-modal adaptation could cause FIAEs and whether they are similar in their form to the priming effects in terms of the types of stimuli that will cause them. Thus, faces, names, voices, semantic information, and associated people were used to adapt the perception of a target face. Additionally, we tested whether this was based upon non-veridical memory and imagery by using imagination and caricatures as adaptors

Two faces morphed together are characterised by categorical perception between the two (Beale and Keil, 1995; Rotshtein, Henson, Treves, Driver, and Dolan, 2005). The perceptual midpoint between the two is where participants perceive the amount of each identity in the morph is the same (the perceived stimulus equality point, PSE). The change in this point pre- and post-adaptation is used as the measure of the magnitude of adaptation. The PSE is equivalent to the identity threshold of a particular facial identity when in a morph continuum of two identities (c.f., Leopold et al., 2001). Thus, a higher identity threshold following adaptation is evidence of adaptation. Psychometric functions were fitted to calculate the PSE.

Familiar (famous) faces are used in the present Experiments since they have established semantic, visual and often auditory information associated with them. This is a slight deviation from the methodology of Leopold et al. (2001), however, it was felt that this was easier to test cross-modal adaptation, given that training participants to associate names, voices, and semantic information is dissimilar to everyday face recognition.

This paper presents four experiments that test adaptation using the priming analogy. The four experiments represent different classes of priming that have been defined within the face perception literature: Experiment 1 assessed repetition adaptation (involving multimodal identity specific information, such as names and voices); Experiment 2 assessed category and semantic adaptation; Experiment 3 assessed associative adaptation; and Experiment 4 assessed whether aftereffects are memory based using imagination and caricatures.

2. Experiment 1: Repetition Adaptation

From the priming analogy, FIAEs may be observable following adaptation to several modes of identity-specific information. Within-modal repetition priming is stronger when the same image is used as the prime and that used at test than when a different image of the same face is used as the prime to that used at test. Analogously, it would be expected that the magnitude of observed aftereffects will be significantly greater when the same image is used as the adaptor and as that used to construct the test morphs than when a different image of the same face is used as the adaptor to that used to construct the test morphs. Cross-modal repetition priming can be caused by non-visual stimuli such as names and voices and this produces significantly smaller priming effects than priming due to images. Using this parallel, it may be expected that cross-modal adaptation is possible. Specifically, adaptation to names and voices may occur. Such adaptation may cause aftereffects in the perception of faces. The magnitude of adaptation due to names and voices should be smaller than adaptation due to images, based on the observations in priming. Experiment 1 aims to explore the possibility of this cross-modal adaptation analogous to priming in terms of the stimuli that cause it.

2.1. Method

2.1.1. Participants

Participants were 48 psychology undergraduate students who undertook this experiment as partial fulfilment of a course requirement. All participants had normal or corrected vision and were Caucasian British nationals who were familiar with the target identities. Participants were randomly divided into one of the conditions with the pre-requisite that an equal number of participants participated in each condition (N = 12).

2.1.2. Materials

Adaptor – Same image

Images of four famous faces were collected from the Internet. These were George Bush, Tony Blair, Harrison Ford, and Pierce Brosnan. All images were matched for pose (frontal), lighting (lit from above), dimensions (100 mm by 160 mm), resolution (72 dpi). The images were cropped to remove the background of the image and any clothing.

Adaptor – Different image

Different images of the same four famous people as above were collected from the Internet. These images were not matched for pose or lighting but were matched for dimensions (100 mm by 160 mm) and resolution (72 dpi). These images were in ¾ poses with lighting from one side. The images were cropped to remove the background and any clothing.

Adaptor – Voice

For the voice stimuli, sound clips were collected from Internet of the four identities described above. They were of speeches or interviews and recorded in 2005. The clips were cut down to 1 minute in length, chosen to be the second to third minute of the recording. This meant that the clip came in mid sentence, and cut out mid sentence. These clips contained no interruption from the audience or interviewer. Two further five second clips were made from the next minute of the clips in the same manner. Voices were played into the laboratory using headphone speakers at a comfortable volume.

Adaptor – Names

Names of the four identites were displayed on screen in Palatino Font, size 20, black on white.

Morph Continua

To measure identity thresholds, morph continua from one identity to a second identity were constructed using Smartmorph™ Software, using 186 key anchor points (c.f., Brennan, 1985). The morph continua ranged from 100% Identity 1 to 100% Identity 2 in 50 equal increments of 2% identity strength. The images used to construct the morphs were those described in the "Adaptor– same image" section above. Morph continua were made between all four identities described above, creating six continua.

General Apparatus

All stimuli were presented from a Toshiba Tecra M4 Tablet PC running SuperlabPro 2 Research Software™ onto a high resolution colour monitor (refresh rate 60 Hz).

2.1.3. Design

The type of adaptor was manipulated between-subjects, creating a four level univariate design. These were: same image as that used to construct the test morphs (hereafter *same image*); different image to that used to construct the test morphs (hereafter *different image*); *name*; and *voice*. There were six test morph continua, with two identities making up each continuum. Participants were randomly allocated to tested in one of the continua such that the same number of participants were tested on each continuum (N = 2, in each of the adaptor conditions). Thus, participants were tested on one pair only. Participants were then randomly allocated to be adapted to one end of continuum such that both ends were used as the adaptor identity. The order of presentation of the morphs during the baseline and the test phases of the experiment was randomised. Each participant saw a morphed continuum made up of only two identities and was adapted to one adaptor. In no condition or Experiment was there a significant effect of identity on the magnitude of the FIAE, thus the data has been collapsed across this variable in all Experiments.

2.1.4. Procedure

Participants were brought to a darkened laboratory individually and sat 50 cm from the computer screen. The Experiment had three consecutive phases: baseline, adaptation, and test. The baseline phase involved the participants seeing all 50 morphs in the particular morph continuum they had been allocated to 10 times each in a random order. Thus, they received 500 trials. For each trial, the participants had to decide whether the morph looked more like Identity 1 or Identity 2 of the continuum they had allocated to, by pressing the appropriate key[1]. This method is based on the procedures discussed in Levitt (1971). Thus, the design implemented was a two-alternative forced-choice psychometric paradigm. Each trial was response terminated. Between each trial a 100 ms white noise mask was on screen.

[1] The response keys were: G for George Bush; T for Tony Blair; H for Harrison Ford; P for Pierce Brosnan. Each participant only had two identities to choose from.

Once the baseline phase had finished, the participants were instructed to rest for two minutes. Following their rest, participants were presented with the adaptor and told to “examine the image that was on screen” (c.f., Rhodes et al., 2003). When the adaptor was a voice, the screen was blank and the sound clip was played through headphone speakers. The adaptor was presented for 60 seconds.

Immediately following the adaptor, participants began the test phase. This was similar to the baseline phase. Participants were presented with all 50 morphs from the relevant morph continua 10 times in a random order. Thus, they received 500 test trials. Preceding each test face, participants were presented with the adaptor for another five seconds (c.f., Rhodes et al., 2003). When the adaptor was the voice, the screen was blank for five seconds, and the voice clip was played into the laboratory through headphone speakers. Participants were instructed to respond as in the baseline procedure. Each trial was response terminated. A representation of the procedure is shown in Figure 2.

Figure 2 about here

2.2. Results

The magnitude of the aftereffects was calculated by the required identity strength to perceive an identity post-adaptation subtracted from the identity strength to perceive the same identity pre-adaptation (c.f., Moradi et al., 2005). The identity strength is equated to the PSE in a psychometric function and these were calculated pre- and post-adaptation using MatLab™, for each of the 48 participants. Due to space limitations these are not presented. In all cases, psychometric functions produced a good fit with the fiducial limits having a maximum range of 5%. The differences between the PSE pre- and post-adaptation are summarised in Figure 3. There were more opposite identity responses post-adaptation than pre-adaptation. The perceived perceptual boundary between the two identities was thus shifted in the direction toward that identity which the participants had been adapted to.

Figure 3 about here

The data summarised in Figure 3 were subjected to a 4-level univariate ANOVA with the single factor being the type of adaptor. This revealed a significant effect of type of adaptor, $F(3, 44) = 21.672$, $MSE = 19.227$, $p < .001$. Tukey HSD *post hoc* tests were run to explore this effect fully. These showed that the magnitude of FIAE was greater for the *same image* than: the *different image* (mean difference = 5.224, $p < .05$); *name* (mean difference = 12.317, $p < .001$); and *voice* (mean difference = 9.593, $p < .001$). In addition, the magnitude of the FIAE was greater for *different image* than: *name* (mean difference = 7.093, $p < .001$); and *voice* (mean difference = 4.368, $p < .05$). The difference between *name* and *voice* was not significant.

One-sample t-tests were conducted on the data to discover if significant aftereffects were observed in each condition. Throughout this paper, the one-sample t-tests were compared to zero (i.e., no aftereffect). These showed that significant aftereffects were observed when the adaptor was the: *same image*, $t(11) = 16.621$, $p < .001$; *different image*, $t(11) = 9.490$, $p < .001$; *name*, $t(11) = 6.679$, $p < .001$; and *voice*, $t(11) = 13.774$, $p < .001$. Thus, aftereffects were observed following adaptation to all the stimuli tested here.

2.3. Discussion

Significant FIAEs were observed for all the types of adaptor tested here. These results indicate that FIAE can be caused by non-facial information (i.e., voices and names) in addition to facial information. The adaptation observed here crossed modalities from names and voices to faces. Within-modal (and specifically within-viewpoint) adaptation caused larger aftereffects than cross-modal adaptation. Indeed, there was not a significant difference in the magnitude of the FIAE caused by either of the two non-visual modalities tested here. These results parallel those of priming studies closely:- the effects are greatest when there is greater visual similarity between the adaptor/prime and the test; the effects are greater for within modal than cross modal adaptation/priming. The mechanisms for this shall be discussed in more detail in the General Discussion.

3. Experiment 2: Semantic Adaptation

Experiment 1 demonstrated that adaptation to non-visual identity specific information can cause FIAEs. Arguably a name is a special type of semantic information (Young, McWeeny, Ellis, & Hay, 1986). Thus, it is possible that other types of semantic information may be able to cause adaptation to a particular identity. In terms of priming, semantic and category priming have been known to exist, where priming of category information speeds up familiarity judgements of members of that category (e.g., “actor” speeding up the judgements made to Tom Hanks, Carson & Burton, 2001). Here we test the existence of semantic/category adaptation. The same face identities used in Experiment 1 were used in Experiment 2. Four levels of semantic information were chosen. These were: specific role (President, Prime Minister, Indiana Jones, and James Bond); occupation (Politicians and Actors); and nationality (American and

British[2]). Specific role semantic information is only relevant to a small number of people (few people will be able to name fewer than 2 and more than 5 other identities for these roles[3]). Occupation semantic information characteristically fits many more people than specific role information and less than nationality. Two additional adaptors were included as controls and comparators: face image and name. Thus, the magnitude of aftereffects for each level of semantic information can be compared to the unique form of semantic information (name). It is predicted that the more specific the piece of semantic information the greater the magnitude of the aftereffect observed.

3.1. Method

3.1.1. Participants

Participants were 40 psychology undergraduate students who undertook this experiment as partial fulfilment of a course requirement. All participants had normal or corrected vision and were Caucasian British nationals who were familiar with the target identities. Participants were randomly divided into one of the conditions with the pre-requisite that an equal number of participants participated in each condition (N = 8 in each of the adaptor conditions).

3.1.2. Materials

Morph stimuli were collected and constructed as in Experiment 1. The same image adaptors used in Experiment 1 were used in Experiment 2. All the semantic information stimuli were displayed

[2] Although Pierce Brosnan is Irish, few people were aware of this and thought he was British.

[3] Although all other actors that have played the character of Indiana Jones have played him at a different age and that Indiana Jones is an iconic character played by Harrison Ford, it was felt that Harrison Ford has played sufficient other roles to make this piece of semantic information sufficiently different to a name.

on screen in Palatino Font, size 20, black on white. Only morph continua crossing category boundaries (actors – politicians) were used (e.g., Harrison Ford to Tony Blair was used, but not Harrison Ford to Pierce Brosnan). Thus, four morph continua were used in Experiment 2.

3.1.3. Design & Procedure

The type of adaptor was manipulated between-subjects, creating a five level univariate design. These were: *image*; *name*; *specific role*; *occupation*; and *nationality*. There were four test morph continua, with two identities making up each continuum. Participants were randomly allocated to tested in one of the continua such that the same number of participants were tested on each continuum (N = 2, in each of the adaptor conditions). Participants were then randomly allocated to be adapted to one end of continuum such that both ends were used as the adaptor identity. The order of presentation of the morphs during the baseline and the test phases was randomised. Each participant saw a morphed continuum made up of only two identities and was adapted to one adaptor. The procedure was identical to Experiment 1 with the different adaptors (no auditory adaptors).

3.2. Results

The data was treated as it was in Experiment 1. The mean PSE changes pre- to post-adaptation are presented in Figure 4. This shows that for the image and name adaptor, more responses were of the non-adapted identity post-adaptation. However, for the semantic information, there is a trend for less specific information to cause smaller aftereffects than more specific semantic information. These data were subjected to a five-level univariate ANOVA.

Figure 4 about here

The ANOVA revealed that there was a significant effect of adaptor type on the magnitude of the FIAE, $F(4, 35) = 66.770$, $MSE = 7.549$, $p < .001$. Tukey *post hoc* comparisons were used to explore this effect further and these revealed that the magnitude of adaptation was significantly greater for the *image* than: *name* (mean difference = 11.029, $p < .001$); *specific role* (mean difference = 15.781, $p < .001$); *occupation* (mean difference = 18.601, $p < .001$); and *nationality* (mean difference = 19.327, $p < .001$). Aftereffects were significantly greater for name than: *specific role* (mean difference = 4.752, $p < .001$); *occupation* (mean difference = 7.572, $p < .001$); and *nationality* (mean difference = 8.298, $p < .001$).

As in Experiment 1, one-sample t-tests were used to assess whether adaptation was observed for any of the stimuli. These showed significant adaptation when the adaptor was: the *image*, $t(7) = 44.392$, $p < .001$; the *name*, $t(7) = 5.629$, $p < .001$; and the *specific role*, $t(7) = 3.481$, $p < .05$). Significant PSE changes were not observed when the adaptor was the *occupation*, $t(7) = 0.940$, $p > .37$, or the *nationality*, $t(7) = 0.069$, $p > .94$.

An additional analysis was run on these data that compared the level of specificity of the semantic information and the magnitude of the FIAE in a correlation. Data for the image condition was not included in this analysis. This analysis is clearly non-parametric, since the level of specificity was rather arbitrarily ranked thus: *name* was coded as the most specific (given a value of 1); *specific role* was coded as the second most specific (rank of 2); *occupation* was given a rank of 3; and *nationality* was given a rank of 4. A Spearman's *Rho* test was run on these data and revealed a correlation between specificity of semantic information and the magnitude of the FIAE, r (31) = -.654, p < .001. This correlation was negative due to the coding strategy.

3.4. Discussion

These results have indicated that FIAE can be caused by face and name stimuli and by specific role information. No aftereffects were observed for less specific semantic information. Indeed, there is a correlation between the specificity of the semantic information and the magnitude of the FIAE in which the aftereffect is greater for more specific semantic information. Although this was a non-parametric correlation, it was strong, suggesting that the effect of specificity of semantic information has a strong effect on the magnitude of the FIAE. That is, the greater the level of specificity, the stronger the aftereffect. Additionally, this relationship appears to be linear. This indicates that the connexions between semantic information and visual information are stronger for more specific semantic information than less specific semantic information. These results parallel those of priming where category information can cause priming effects, but these are much smaller than specific semantic information and identity priming.

There is one concern with these data and that is that the role specific information may actually be identity specific and act like a name. The present data indicate that this is unlikely since aftereffects caused by the name stimulus were significantly larger than aftereffects caused by the specific role information. If they were acting in the same manner, one would have predicted no difference in the magnitude of adaptation between these two types of semantic information. Of course, one cannot rule out that for some participants and some identities, specific role information may act as a name. For example, some people are unaware that there are other actors who have played Indiana Jones and there are many people who will never have seen James Bond films without Pierce Brosnan (at least at the time of testing). Future research may explore whether knowledge of a particular person influences the magnitude of the FIAE in regards to semantic information. For example, would fans of the classic Doctor Who television show less adaptation to the name stimulus “The Doctor” and a morph continuum containing David Tennant (the present Doctor) than those who only know the modern Doctor Who.

4. Experiment 3: Associative Adaptation

Experiments 1 and 2 have demonstrated that adaptation to non-visual identity specific semantic information can cause FIAEs analogous to semantic priming. Similar to semantic priming is associative priming which is where the presentation of a particular individual facilitates processing of someone who is highly associated with that person. For example, Bruce (1983) showed that priming Eric Morcambe would speed up familiarity judgements to Earnie Wise (a British comedy duo from the 1970s). The present experiment thus aimed to use this as an analogy in an adaptation experiment. Participants were adapted to one identity from an associated pair and aftereffects measured in a morph continuum containing the other identity from the pair and a third identity. If associative adaptation occurs, then adaptation to one identity in a double act should cause observable aftereffects in the perception of the other identity in the double act. Associative adaptation is expected to cause smaller aftereffects than perceptual repetition adaptation since it is semantic and thus will be similar in magnitude to name adaptation shown in Experiment 2.

This design also allowed for an additional assessment, directly comparing perceptual repetition adaptation with semantic associative adaptation. Conditions were run in which participants were adapted to one identity from an associated pair and aftereffects measured in a morph continuum containing both identities in the associated pair. Thus, perceptual adaptation due to the specific identity would be in competition with adaptation to the associated person. Several outcomes were possible in this scenario: the aftereffect could be the result of perceptual adaptation only; the aftereffect could be the result of associative adaptation only, thus be in the opposite direction to perceptual adaptation; the two forms of adaptation could balance each other out and result in no adaptation; or the two forms of adaptation could combine producing a smaller perceptual adaptation effect (due to its effects being reduced by the opposite effects caused by associative adaptation). The double-acts chosen were well known contemporary comic double-acts. Both name and images were used as adaptors.

4.1. Method

4.1.1. Participants

Participants were 96 psychology undergraduate students who undertook this experiment as partial fulfilment of a course requirement. All participants had normal or corrected vision and were Caucasian British nationals who were familiar with the target identities. Participants were randomly divided into one of the conditions with the pre-requisite that an equal number of participants participated in each condition (N = 16).

4.1.2. Materials

Face images were collected from the internet of two double acts: Anthony McPartlin and Declan Donnelly from British television show “Saturday Night Takeaway”; and David Walliams and Matt Lucas from the British television show “Little Britain”. Morph continua were created as in Experiment 1 from the 100% Identity 1 to 100%

Identity 2. Two types of continua were constructed. The first involved pairing one member of the double act with one member of the other double act (e.g., Ant McPartlin with David Walliams). Four cross-double act morph continua of this make-up were constructed. The second involved morphing between the members of the double act (e.g., David Walliams with Matt Lucas). Two within-double act morph continua of this make-up were constructed. Thus, six morph continua were created in total. The adaptors were the 100% images. The name stimuli were displayed on screen in Palatino Font, size 20, black on white.

4.1.3. Design & Procedure

A 2 by 3 design was employed in which the type of adaptor was manipulated between-subjects: the first variable was the mode of the adaptor (name or face) and the second was the relation between the adaptor and the identities used to construct the morph – These were: same person tested in a morphed continuum with a non-associated person (hereafter *same person in different*, e.g., adapted to Matt Lucas, aftereffects measured in the Matt Lucas – Declan Donnelly morph continuum); *associated person* (e.g., adapted to Matt Lucas, aftereffects measured in David Walliams – Declan Donnelly morph continuum); same person tested in a morphed continuum with the associated person (hereafter *same person in associated*, e.g., adapted to Matt Lucas, aftereffects measured in Matt Lucas – David Walliams morph continuum). The four morphed continua involving cross-double act identities were used as the test stimuli for the first two conditions (*same person in different continuum*, and *associated person*). The two morphed continua involving within-double act identities were used for the third condition (*same person in associated continuum*). Two identities made up each morph. Participants were adapted to one identity used to construct the morph continuum for the *same* *person in different continuum* and *same person in associated continuum*, but were adapted to the associated identity of one of the identities used to construct the test morph continuum for the *associated person* condition. Participants were randomly allocated to be tested in one of the continua such that the roughly the same number of participants were tested on each continuum (N = 4 in each of the adaptor conditions for the cross-double act morphs, or N = 8 in each of the adaptor conditions for the within-double act morphs). Participants were then randomly allocated to be adapted to one end of continuum such that both ends were used as the adaptor identity an equal number of times. The order of presentation of the morphs during the baseline and the test phases was randomised. Each participant saw a morphed continuum made up of only two identities and was adapted to one adaptor. The procedure was identical to Experiment 1 with the different adaptors (no auditory adaptors) and with different response keys[4].

4.2. Results

The data was treated as it was in Experiment 1. The mean PSE changes pre- to post-adaptation are presented in Figure 4. This shows that aftereffects were observed for all types of adaptor, though they appear to be greater when the adaptor was an image than a name. These data were subjected to a 2 x 3 between-subjects ANOVA with the factors: adaptor modality (face or name); and adaptor identity in relation to test continua.

Figure 5 about here

[4] Response keys were A for Anthony McPartlin, D for Declan Donnerly, L for Matt Lucas, and W for David Walliams

The ANOVA revealed a significant main effect of modality, $F(1, 90) = 173.779$, $MSE = 9.636$, $p < .001$, where aftereffects were greater following adaptation to the face image than the name (mean difference = 8.353). There was also a significant effect of adaptor identity, $F(2, 90) = 41.655$, $MSE = 9.636$, $p < .001$. Tukey *post hoc* comparisons explored this main effect revealing that the aftereffect due to the *associated person* was significantly less than the aftereffect due to *same person in different continuum* (mean difference = 6.455, $p < .001$) and *same person in associated continuum* (mean difference = 5.753, $p < .001$). The difference between *same person in different* and *same person in associated* was not significant (mean difference = 0.703, $p > .63$).

These main effects were qualified by a significant interaction between modality and adaptor, $F(2, 90) = 14.337$, $MSE = 9.636$, $p < .001$. Simple effects show that when image was the modality the magnitude of the aftereffect was less for *associated person* than for *same image in different continuum* (mean difference = 10.342, $p < .001$) and for *same image associated continuum* (mean difference = 8.969, $p < .001$). The difference between *same image in different continuum* and *same image in associated continuum* was not significant (mean difference = 1.374, $p > .49$). When the name was the modality of the adaptor, there was no significant differences across the three types of adaptor (largest difference = 2.568, $p > .05$), though the pattern of results was the same.

As in Experiment 1, a series of one sample t-tests were conducted on these data to see if aftereffects were observed for all these stimuli. These revealed that significant aftereffects were observed for: *same image in a different continuum*, t (15) = 27.389, $p < .001$; *associated image*, t (15) = 24.801, $p < .001$; *same image in associated continuum*, t (15) = 13.500, $p < .001$; *same name in a different continuum*, t (15) = 9.193, $p < .001$; *associated name*, t (15) = 7.299, $p < .001$; and *same name in associated continuum*, t

(15) = 11.476, $p < .001$. Thus, all the adaptors produced significant aftereffects.

4.3. Discussion

Adaptation to an associated person (be it the name or the face) causes an FIAE. These results indicate that activating one part of a double act will also activate the other part of a double act (priming) and if this activation is prolonged then adaptation will occur. The magnitude of the aftereffect due to adaptation to the associated person is half that of the aftereffect due to adaptation to the same person, irrespective of the morph continuum being tested. In the condition where participants were adapted to one member of the double act and tested in the morph continuum containing both members of the double act, it would seem that the adaptations might cancel each other out. This is because there would be adaptation to the person presented (e.g., Matt Lucas) and it would cause adaptation to the associated person (e.g., David Walliams). So in the test morph continuum ranging between the two members of the double act (Matt Lucas and David Walliams), the adaptation to one end (due to the image being presented: e.g., Matt Lucas) should be balanced by adaptation to the other end (due to the associated person: e.g., David Walliams). This does not happen, and the aftereffect appears to be solely due to the image being presented. This result is discussed further in the general discussion.

The data from the present study seem to indicate that when adaptation is occurring that is at the image or face level and it is in competition with adaptation that is occurring at the identity level, they do not combine. There is no addition, deletion, or multiplying factor between these two adaptation processes. Instead, the perceptual adaptation completely swamps the identity adaptation. This suggests two distinct mechanisms are involved in the FIAEs observed here: one perceptual and one identity-based.

At this juncture, it becomes necessary to offer a possible theoretical analysis of what these two distinct mechanisms are in the FIAE. One seems to be a simple visual adaptation similar in form to adaptation to contrast or spatial frequency, albeit to a more complex shape. This may or may not involve structural information about faces and thus may or may not be face-specific. The mechanisms for this may be neuronal fatigue. However, with cross-modal adaptation, one must consider how the visual cortex becomes activated (if indeed it does) during the processing of identity information. One possible mechanism is that of imagery and thus is memory based. Experiment 4 aims to explore imagery as a possible mechanism of this cross-modally driven FIAE.

5. Experiment 4

The previous experiments in this manuscript have demonstrated that the FIAE can be caused by adaptation to non-visual information. The present experiment explores two possible albeit related mechanisms for cross-modal adaptation. The first mechanism to be explored is that of mental imagery. When participants are presented with a name, or hear a voice, they may think about that individual. Imagination is known to activate the visual cortex for scenes and colours (Ganis, Thompson, & Kosslyn, 2004) and also faces (O'Craven & Kanwisher, 2001). Thus, it does seem distinctly plausible that imagination may mediate the cross-modal adaptation (Hills et al., 2009). For imagery to cause adaptation face memory is required. Given that memory for faces may not be veridical and may be better represented by caricaturisation (e.g., Lee, Byatt, & Rhodes, 2000; Rhodes et al., 1987; 1997), caricatures may be able to cause adaptation. From this assumption, adaptation based on memory, imagination, and caricatures should thus be greater than adaptation based on veridical images. In the previous experiments, adaptation to names was lower than veridical images suggesting that the name does not link as strongly to memory for the face. Alternatively, caricaturisation may represent a super-identity (Rhodes, 1996) which lies along a particular identity trajectory, simply further away from the average (Rhodes et al., 1997). Leopold et al.'s (2001) work has shown that adapting to a face along an identity trajectory affects the perception of an average face. Thus, assuming that the caricatures are simply further from the average face along the same identity trajectory also suggests that adaptation to caricatures ought to cause aftereffects. Thus, Experiment 4 explores aftereffects caused by adaptation to imagination and caricatures and compared to aftereffects caused by adaptation to the veridical image.

Two types of caricature present themselves to be used for such a study. Photographic caricatures are realistic computer-generated images that have been exaggerated according to a mathematical formula. Alternatively, there are artist drawn caricatures, drawn by caricature artists. These are not as similar to veridical images as photographic caricatures, and may contain the artists own 'filling in.' There is, however, a great deal of consistency in the way different artists draw caricatures of the same person (Goldman & Hagen, 1978). Additionally, the caricature advantage is greater for line-drawn caricatures than photographic caricatures (e.g., Rhodes, 1996). It could be argued that photographic caricatures would be more similar to veridical images in terms of skin reflectance and as similarity is a factor in the magnitude of adaptation and priming, that photographic caricatures would produce larger effects than artist drawn caricatures. Additionally, artist drawn caricatures were easier to obtain. Thus, artist-drawn caricatures were used in the present experiment. These will compared to FIAEs caused by veridical face images.

5.1. Method

5.1.1. Participants

Participants were 48 psychology undergraduate students who undertook this experiment as partial fulfilment of a course requirement. All participants had normal or corrected vision and were Caucasian British nationals who were familiar with the target identities. Participants were randomly divided into one of the conditions with the pre-requisite that an equal number of participants participated in each condition (N = 16). Participants were excluded if they scored less than 12 on Marks' (1973) Visual Imagery Questionnaire (VIQ) as this helped ensure the participants were able to mentally visualise faces (see, Hills et al., 2009).

5.1.2. Materials

The face identities used in Experiment 3 were used in Experiment 4. Caricature images of Anthony McPartlin, Declan Donnelly, David Walliams and Matt Lucas were collected from the Internet (these cannot be presented due to copyright) and these were used as the adaptors in the caricature condition. The morph continua that paired one member of one double act with one member of the other double act constructed (cross-double act continua) in Experiment 3 were used here. There were four of these continua.

5.1.3. Design & Procedure

The three types of adaptor were manipulated between-subjects. These were: veridical face image, imagination, and caricatured face image. Participants were randomly allocated to be tested in one of the continua such that the same number of participants were tested on each continuum in each condition (N = 4 in each of the adaptor conditions). As two identities made up each morph, participants were randomly allocated to be adapted to one end of continuum such that both ends were used as the adaptor identity an equal number of times (N = 2, in each of the adaptor conditions). The order of presentation of the morphs during the baseline and the test phases was randomised. Each participant saw a morphed continuum made up of only two identities and was adapted to one adaptor.

The procedure was similar to Experiment 1, except for the imagined condition. In this condition, during adaptation, participants were verbally given the instructions:

> *Mentally visualise [identity] as vividly and as clearly as you can for this and all remaining blank screens.*

These instructions allowed participants to think about the person in any situation that they wanted. During the test phase, when the adaptor was on screen between each test morph, the screen went blank for 5 seconds for the imagined condition. The participants were reminded to visualise the identity during all blank screens during the first of these intervals. A post-test question was administered asking the participants how vivid their mental images were (c.f., Moradi et al., 2005) in the form of *"How vivid was your mental image of [name]?"*. All participants reported vivid mental images[5]. All other aspects of the procedure were identical to those described in Experiment 1.

5.2. Results

The data was treated as it was in Experiment 1. The mean PSE changes pre- to post-adaptation are presented in Figure 6. This shows that aftereffects were observed for all types of adaptor, though these appear to be greater when the adaptor was a caricature than imagined. These data were subjected to a three – level univariate ANOVA.

[5] We did not explicitly ask whether the participants had visualised the person they were supposed to. We assumed that the participants would report an unclear mental image of a particular identity if they had visualised the incorrect person.

Figure 6 about here

The ANOVA revealed a significant effect of adaptor, $F(2, 45) = 44.102$, $MSE = 22.314$, $p < .001$. Tukey *post hoc* comparisons were used to explore this effect. These showed that adaptation to the caricature produced a larger aftereffect than the veridical image (mean difference = 4.083, $p < .05$) and imagined adaptation (mean difference = 15.157, $p < .001$). In addition adaptation to the veridical image produced a larger aftereffect than imagination (mean difference = 11.074, $p < .001$).

As in Experiment 1, a series of one-sample t-tests were conducted on these data. These revealed there was significant adaptation for the veridical image, $t(15) = 36.141$, $p < .001$, the caricature, $t(15) = 16.068$, $p < .001$, and the imagined adaptation, $t(15) = 6.322$, $p < .001$. Thus, significant adaptation was observed for all adaptors tested here.

5.3. Discussion

Aftereffects were observed following imagined adaptation, adaptation to veridical and caricatured faces. The magnitude of aftereffects was greater following adaptation to a caricature than to a veridical image. This finding is intriguing since caricatures are not veridical images and thus should not cause such strong perceptual adaptation. The results are consistent with the hypothesis that memory for faces caricaturises them (e.g, Rhodes et al., 1987, 1997), such that the stored representation is not the veridical image (Harvey, 1986). Thus, a caricature will activate the stored representation of a face more strongly than a veridical image (Lee et al., 2000). The conclusion is that the FIAE is larger if memory is activated along with perception

These results also indicate that imagination is sufficient to cause adaptation. These results are consistent with the evidence that visual imagination activates the visual centres of the brain but are inconsistent with the results of Moradi et al. (2005). The reason for this discrepancy is probably based on the different methodologies. In the present study, we used highly familiar faces that participants could visualise in a multitude of poses, views, and actions. The visualisation is likely to be more elaborate than a visualisation of a facial image that has only been seen in one pose. Additionally, we ensured that our participants were actually able to visualise by measuring their visualisation abilities using an objective measure (the VIQ, Marks, 1973). Thus, the results of the present study are likely to reflect a more realistic effect of mental imagery on adaptation than that presented in the Moradi et al. paper.

6. General Discussion

Four studies explored adaptation based on the stimuli that cause priming as a means of generating stimuli that may cause it. FIAEs were observed following adaptation to faces, names, and voices (Experiment 1) and to identity specific semantic information (Experiment 2). FIAEs were not observed following adaptation to non-specific semantic information, though there was a graded decline in the magnitude of observed aftereffects depending on the specificity of the semantic information. Experiment 3 demonstrated that adaptation to highly associated people can also cause FIAEs. Experiment 3 also noted that visual adaptation from the actual person swamped or masked adaptation that was derived semantically, from the associated person. Experiment 4 demonstrated that adaptation was possible by imagination and that adaptation to caricatures produced aftereffects that were greater than adaptation to veridical images. Together these findings extend our knowledge of the FIAE in three particularly important ways: the locus of adaptation; the involvement of imagination; and the competition between the visual and associative adaptation.

The adaptation effects reported in the present study are similar in nature to the priming studies discussed in the introduction. The effect of priming is dependent on the perceptual similarity between the prime and the target and is greatest when the prime and target are perceptually identical (Johnston and Barry, 2006). Similarly, aftereffects due to adaptation are dependent on perceptual similarity between the adaptor and test (Yamashita et al., 2005) and is greatest when the when the adaptor and target are identical. Nevertheless, priming and adaptation does occur for when the prime/adaptor does not match the test stimulus.

Cross-modal repetition priming is significantly smaller than within-modal priming (Ellis et al., 1997) and cross-modal adaptation is significantly smaller than within-modal adaptation (Experiment 1). In semantic priming, the effectiveness of the prime is dependent on the uniqueness of the semantic information (contrast semantic priming of Bruce and Valentine, 1986, with the category priming of Carson and Burton, 2001). Experiment 2 demonstrated a similar effect where unique semantic adaptors produced larger aftereffects than less unique semantic adaptors. Here, however, we failed to observed category adaptation similar in nature to category priming. Experiment 3 in the present studies demonstrated adaptation to an associated person could cause an aftereffect and this was similar in nature to associated priming. Taken together, these findings suggest that our assertion that there may be parallels in the loci within the IAC model of priming with those of adaptation was justified.

In the introduction three loci of adaptation were theorised within the IAC framework: the visual level, the FRU, and the PIN. Magnitude of priming effects is larger at the former levels as the prime activation does not have to spread through many pools. The results of the present study have demonstrated adaptation at all of these levels and that adaptation is greater at the former levels than the latter levels. From this theoretical analysis it would seem plausible to suggest that the loci of adaptation are similar to the loci of priming, albeit the reverse outcome. The mechanism may be different however. At the visual level, adaptation has been convincingly explained within the face-space framework (e.g., Hurlbert, 2001; Robbins, McKone, & Edwards, 2007). Currently, there are no models of face perception that allow for adaptation to occur at the identity levels. Both the IAC and the FOV allow for cross-modal priming but do not include an adaptation mechanism. Here we shall describe possible mechanisms for this within the IAC.

The IAC explains priming in terms of the activation of one node spreading by excitatory links to connected nodes in other pools. This spreading of activation occurs vertically (in that it crosses pools), but not horizontally (within pools) due to inhibitory links between nodes in the same pool. A global decay function ensures that the activation returns to a resting level (Burton et al., 1990). The spread of activation lowers the threshold of the connected nodes. However, with a large number of nodes the spread of activation passes through, the effect is smaller. That is, for nodes further from the initially active note, the threshold for activation is not reduced by as much as for nodes close to the initially active node. Thus, priming within the IAC is limited. Adaptation produces similar effects, except the threshold for future activation is raised rather than lowered, making it harder to activate a particular node.

Prolonged activation of a particular node causes that node to become active and through spreading activation, nodes connected to it also become activated. Thus, these nodes become over-activated. Adaptation may be such that after prolonged activation of a node, its threshold for activation is raised sufficiently to make it harder to activate for a short while after. That is, the nodes subsequently become under-activated or fatigued. Thus, those nodes connected to the adapted node will also become adapted due to the spreading activation. This is limited by the same principles as the limitation of priming: the spread of activation is limited by the number of nodes connected, such that the activation is greatest for nodes connected by one link than by many links.

This explanation of adaptation within the IAC has one limitation: the global decay function ensures that activation level of the model is reduced to the resting level. The IAC does not contain an element that can raise the activation level of all the nodes to the resting level. Thus, a modification to the global decay function which would cause activation within the model to be brought back to the resting level from either under-activation or over-activation is required. Future computational work could address this interpretation and assess this possibility.

The data from Experiment 4 suggesting that imagination can cause adaptation suggests one plausible mechanism for how adaptation can spread. Within the IAC, presenting a name (an NRU) activates the PIN and this activates the FRU. Imagination may work in a similar vein. When participants are asked to think about an individual, this causes activation in the PIN and thus the FRU. Prolonged imagination may thus cause adaptation and will be of a similar magnitude to adaptation to a name given that the activation has to spread through the same number of nodes. Alternatively, imagination may work directly on the FRUs. However, because it is based upon a non-veridical image from memory it may have less effect on the FRU. The imagination, for example, could be the face in a different, specific, and/or experienced context (such as a film). The imagined face is unlikely to be still and thus may potentially cause less activation of the FRU. To establish whether the type of visualisation has an effect, it may be possible to instruct participants to visualise the faces in different situations and analyse the magnitude of any observed aftereffects.

One of the most important findings related to the loci of the adaptation effects is that visual adaptation was pitted against semantic adaptation in Experiment 3. Here, adaptation to Identity A should cause an aftereffect in the perception of Identity A. However, since Identity A was so closely associated with Identity B, that adaptation to Identity A causes an aftereffect in Identity B. Thus, in the morph continuum made up of Identity A and Identity B, adaptation to Identity A should cause aftereffects observable in Identity A (adaptation to the FRU) *and* 'the opposite' identity in the continuum, Identity B (adaptation to the PIN). Figure 7 shows a demonstration of this using Ant and Dec. Adaptation to Ant causes a visual (FRU) adaptation to Ant and will shift the perceived midpoint in the morph toward Ant. It also causes associative (in the PIN) adaptation to Dec and will shift the perceived midpoint in the morph toward Dec. In Experiment 3, we demonstrated that FRU adaptation completely swamps the alternative PIN adaptation, such that the overall adaptation is as if the PIN adaptation does not occur. This suggests that the FRU adaptation completely overrides the PIN adaptation and this may be expected for two reasons described below.

Figure 7 about here

If imagery is the mechanism behind adaptation at the identity level, one must acknowledge that activation of the visual cortex due to imagery is smaller than activation of the visual cortex due to actual perception (e.g., Kosslyn et al., 1994). Thus, the adaptation due to imagery will not be as strong as adaptation due to the actual perception. Nevertheless, this would suggest that the aftereffect due to perceptual adaptation would be smaller if there was 'opposite' PIN adaptation occurring. This was not observed. The implication is that the perceptual adaptation is based on different mechanisms from the semantic adaptation and when they are in opposition the perceptual adaptation takes priority. Jiang et al. (2006) have suggested that aspects of visual adaptation are unlikely to be face-specific. Specifically, any stimulus that preserves the underlying "conglomeration of shape- and reflectance-based features and their configuration" of faces, but not valid faces should be effective in adapting facial identity (p. 495). That is, low-level neural channels (such as shape and reflectance) combine in such a way to cause adaptation. These non-face specific systems may override the person identity based adaptation. One explanation for this would be that processing of one identity so completely prevents another identity from being activated as fully. Visual presentation of a face is thus hypothesised to create more activation than association. These rather hypothetical suggestions require future work and greater elaboration before firm conclusions can be drawn.

The final important finding is that adaptation to caricatures produced greater aftereffects than adaptation to veridical images. An explanation for this may be based upon the same explanation for the caricature advantage in face recognition (e.g., Rhodes et al., 1987). That is memory for faces is not veridical. It may exaggerate the most distinguishing features (e.g., Harvey, 1986). Caricatures may thus be a more veridical image of the representation of a face stored in memory. This is especially true for computer generated caricatures (i.e., realistic photographs stretched by a computer programme potentially involving morphing). From this analysis, it would suggest that adaptation involving some memory component (a stored FRU) causes greater aftereffects than those based on visual characteristics only. In this way, adaptation of the perceptual front-end of the IAC and the FRU pool causes greater adaptation than perceptual adaptation alone. This idea is partially in contrast with the suggestion given above for associative adaptation in which the semantically based adaptation does not add or interfere with visual based adaptation.

Since the present study used artist drawn caricatures rather than computer generated ones, an alternative suggestion may be drawn. Caricatures exaggerated features that are often talked about and joked about (for example, Prince Charles has big ears). These exaggerated features may become semantic information in their own right. Thus, it may be that caricatures also contain identity-specific semantic information that can add to the visual adaptation effects. In this way, there is a visually coded and a semantic coded adaptation occurring (using the terminology of Bruce, 1982, and Bruce & Young, 1986). These two types of adaptation add together to form a greater adaptation effect. Nevertheless, this explanation still suggests that visual based adaptation does add to other forms of adaptation.

From the explanations provided thus far, it seems as if there are multiple mechanisms in the FIAE reported here. Visual adaptation occurs when the adaptor and the test stimuli are identical and may not be face specific (Jiang et al., 2007). Identity adaptation occurs through the person recognition system and is significantly weaker than perceptual adaptation. Caricatures may cause larger aftereffects than veridical images due to adaptation involving perception and memory combined. However, the associative adaptation discussed earlier seems to suggest that visual adaptation is stronger than semantic or identity adaptation. In this way, these two types of adaptation do not add together (or more accurately, the semantic adaptation does not remove any visual adaptation if they are in the opposite direction). Thus, it seems as if the aftereffects are based on visual adaptation primarily and only include identity adaptation if it is consistent with the visual adaptation, otherwise the face recognition system ignores it.

The cross-modal adaptation reported here indicates that identities can be selectively adapted within the brain. This is consistent with evidence suggesting the fusiform gyrus is a multimodal processing region (Kung, 2007). Aftereffects are observed in the perception of faces, where the recognition of a face is more difficult following prolonged stimulation of identity-specific information that is visual, auditory, or semantic. This research advances our knowledge of adaptation effects in face processing by demonstrating that they can be caused by non-visual identity information. Prior research on adaptation indicated face identity aftereffects. The current study furthers this by reporting *identity*-specific aftereffects (regardless of mode of presentation), which may implicate adaptation to specific neuronal populations representing a particular identity.

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Figures and Tables

Figure 1. A schematic representation of the IAC based upon Burton and Bruce (1993). The perceptual front-end of the IAC links to the FRUs, VRUs and Word Recognition Units, which link to the PINs (through the NRUs for WRUs). The PINs are also connected to the NRUs and the SIUs. All the links shown are bi-directional.

Figure 2. The procedure for the adaptation paradigm employed in Experiments 1 to 4, with the same image as adaptor as that used to construct the test morphs.

Figure 3 Mean percentage shift toward the adaptor post adaptation for the four types of adaptor in Experiment 1 (repetition adaptation). Error bars represent standard error. Zero is indicative of no adaptation.

Figure 4. Mean percentage shift toward the adaptor post adaptation for the five types of adaptor in Experiment 2 (semantic adaptation). Error bars represent standard error. Zero is indicative of no adaptation.

Figure 5. Mean percentage shift toward the adaptor post adaptation for the five types of adaptor in Experiment 3 (associative adaptation). Error bars represent standard error. Zero is indicative of no adaptation.

Figure 6. Mean percentage shift toward the adaptor post adaptation for the five types of adaptor in Experiment 4 (non-veridical adaptation). Error bars represent standard error. Zero is indicative of no adaptation.

Figure 7. Morph continua from Identity A (Ant) to Identity B (Dec) in increments of 25% Dec. Arrow X shows the direction of the change in perceived midpoint due to visual adaptation to Ant. Arrow Y shows the change in perceived midpoint due to identity adaptation to Ant.