Eye Movement Strategies During Face Matching

Catriona Havard

Department of Psychology

University of Glasgow

Submitted for the Degree of Ph.D. to the higher Degree Committee of the Faculty of Information and Mathematical Sciences, University of Glasgow

September 2007

Abstract

Although there is a large literature on face recognition, less is known about the process of face matching, i.e., deciding whether two photographs depict the same person. The research described here examines viewers' strategies for matching faces, and addresses the issue of which parts of a face are important for this task.

Consistent with previous research, several eye-tracking experiments demonstrated a bias to the eye region when looking at faces. In some studies, there was a scanning strategy whereby only one eye on each face was viewed (the left eye on the right face and the right eye on the left face). However, viewing patterns and matching performance could be influenced by manipulating the way the face pair was presented: through face inversion, changing the distance between the two faces and varying the layout.

There was a strong bias to look at the face on the left first, and then to look at the face on the right. A left visual field bias for individual faces has been found in a number of previous studies, but this is the first time it has been reported using pairs of faces in a matching task. The bias to look first at the item on the left was also found when trying to match pairs of similar line drawings of objects and therefore is not specific to face stimuli.

Finally, the experiments in this thesis suggest that the way face pairs are presented can influence viewers' accuracy on a matching task, as well as the way in which these faces are

viewed. This suggests that the layout of face pairs for matching might be important in real world settings, such as the attempt to identify criminals from security cameras.

Acknowledgements

I would like to thank Professor A. Mike Burton for his continued support and supervision. I would also like to thank Dr. Ahmed Megreya for sharing ideas and answering many questions I had. I also very much appreciate Dr. Gillian Bruce, Kate and Denis Havard for proof reading some of the chapters.

Finally, I would also like the thank Andriy Myachykov for all of his help with the EyeLink eye tracker used for a number of experiments within this thesis.

The Ph.D. studentship was funded with a 3 year studentship from the Economic and Social Research Council award number PTA 030 2004 00166.

Declaration

I declare that this thesis is all my own work carried out under the normal conditions of supervision.

……………………………………………….

Catriona Havard

Publications

Experiments 3, 4 and 6 have been presented as a poster at 29th European Conference on Visual Perception, St Petersburg, Russia. And the abstract has been published, Havard C. & Burton A. M. (2006) Eye movement strategies performed during a face matching task. *Perception* 35 *pp 210*.

Table of Contents

Chapter One

Face Matching and Eye Movements: A General Introduction.

Introduction

Being able to determine whether two different images of a face are the same person is extremely important for a variety of forensic and security tasks; for example determining whether the bearer of a passport owns it, matching criminals captured on CCTV with suspects, confirmation of identity when opening a bank account, or proof of age when buying restricted products such as alcohol. The issue of face matching is also extremely important with the forthcoming implementation of ID cards, as from 2010 every person who applies for a passport will automatically receive an ID card. The purpose of ID cards is to reduce identity theft, fraud and illegal immigration; ID cards will contain a photograph of a face, and may contain other biometric data such as a fingerprint or iris scan. However, most organisations that will use ID cards such as banks, the Royal Mail and retailers will check whether the photograph on the card resembles the person carrying it and therefore ID cards will only be effective if people can accurately match the photograph on an ID card to the person carrying it.

The aim of this thesis is to investigate how accurately people can perform face matching tasks; that is viewing two faces simultaneously and deciding whether they are the same person. I use eye-tracking methods to investigate which features need to be viewed to make an accurate decision and whether a particular viewing strategy is employed for the matching task. Throughout the thesis the presentation of face pairs are manipulated to examine the influence this has on matching performance and the viewing strategies whilst conducting the task. The presentation manipulations will cover four main themes, although there will be the ongoing theme of familiarity, and also face match, i.e. whether the faces are the ‘same’ or ‘different’.

The first main theme will be face inversion, where the faces will be presented upside down, as this has been shown to disrupt normal face processing (Yin, 1969). The second theme involves presentation layout of face pairs and various manipulations are employed such as; varying the distance between the faces when they are side-by-side, and presenting the faces vertically one above the other, or misaligned. The third theme focuses on reducing the quality and information in the images by filtering the faces to display only low spatial frequency information, masking the eye regions of the face and a matching task using only the eye regions. The fourth theme investigates the perceptual bias for face pairs and examines whether this is present for other stimuli by extending the matching paradigm to include pairs of objects. The aim of this chapter is to review the research that has employed face-matching tasks and examine the dissociation between familiar and unfamiliar face recognition and finally to review research that has employed eye movement methodologies.

Face Matching

Determining whether two faces are the same person is quite different from face recognition, with recognition there is memory component, whereas when faces are presented simultaneously matching uses perceptual processes. However there does seem to be an influence of recognition, as the more familiar a face is, the more quickly it can be matched (Clutterbuck & Johnson, 2002). There is a vast amount of research that has explored how accurately we can match two different images of a face simultaneously and match one target face to an array of faces, to simulate a line up procedure. Studies that presented pairs of faces simultaneously report when given either the internal (eyes, nose and mouth), or external features (forehead, chin and hair) of a face, to compare with a whole face, reaction times were faster for the internal features for familiar faces as compared to unfamiliar faces, but for the external features there were no significant differences between the familiar and unfamiliar faces (Young, Hay, McWeeny, Flude, & Ellis, 1985). This is congruent with face recognition research that reported higher identification rates of famous faces from internal versus external features, whereas for unfamiliar faces recognition performance was equivalent for the internal and external features (Ellis, Shepherd, & Davies, 1979).

Clutterbuck and Johnston (2002) extended the work of Young et al. (1985) and reported that highly familiar faces can be matched more quickly than moderately familiar faces, and both are matched more quickly than unfamiliar faces. In another study they report that famous faces can be matched more quickly than newly learnt or unfamiliar faces on their internal features, although newly learnt faces were also matched more quickly than unfamiliar faces (Clutterbuck & Johnston, 2004). In a further study Clutterbuck and Johnson (2005) reported that participants were faster at matching familiar faces than unfamiliar faces, on internal features. Also responses for 'same' judgements for external features for the familiar faces, were slower and more error prone than the 'same' judgements for external features for unfamiliar, or newly learnt faces. Another finding was it was more advantageous to see previously unfamiliar faces many times for a short duration (ten presentations of 2 seconds) than for fewer longer duration presentations (five instances, for 4 seconds).

Bonner, Burton and Bruce (2003) also investigated how faces become familiar and presented unfamiliar faces and conducted face-matching tasks on three consecutive days. They reported that as the faces became familiar the matching performance for internal features improved and became as proficient as matching for the external features, whereas performance for the external features remained constant. Other research that supports the shift to internal feature processing as faces become familiar was conducted by O'Donnell and Bruce (2001). They presented novel faces via video for participants to learn, until they could be correctly identified and then carried out a face-matching task where participants had to decide if a pair of faces were the same or different. The different pairs had one original face and a face that had one feature which had been manipulated (e.g. the eyes, mouth, chin and hair). Performance for pairs where the eyes had been altered was greater for the familiarised faces as compared to the unfamiliar faces, whilst familiarity appeared to have no influence on noticing changes to the other features.

The advantage of matching the external features for unfamiliar faces has also been found using a slightly different paradigm. Bruce et al., (1999) presented a target face that was either a whole face, or a face that was masked to show only the internal or external features, and participants had to decide which face it matched from a 10-face array (see figure 1.1). The target face was always present in the 10-face array. They reported that matching performance for the external features (73 %) was significantly more accurate than matching when presented with the internal features (49 %).

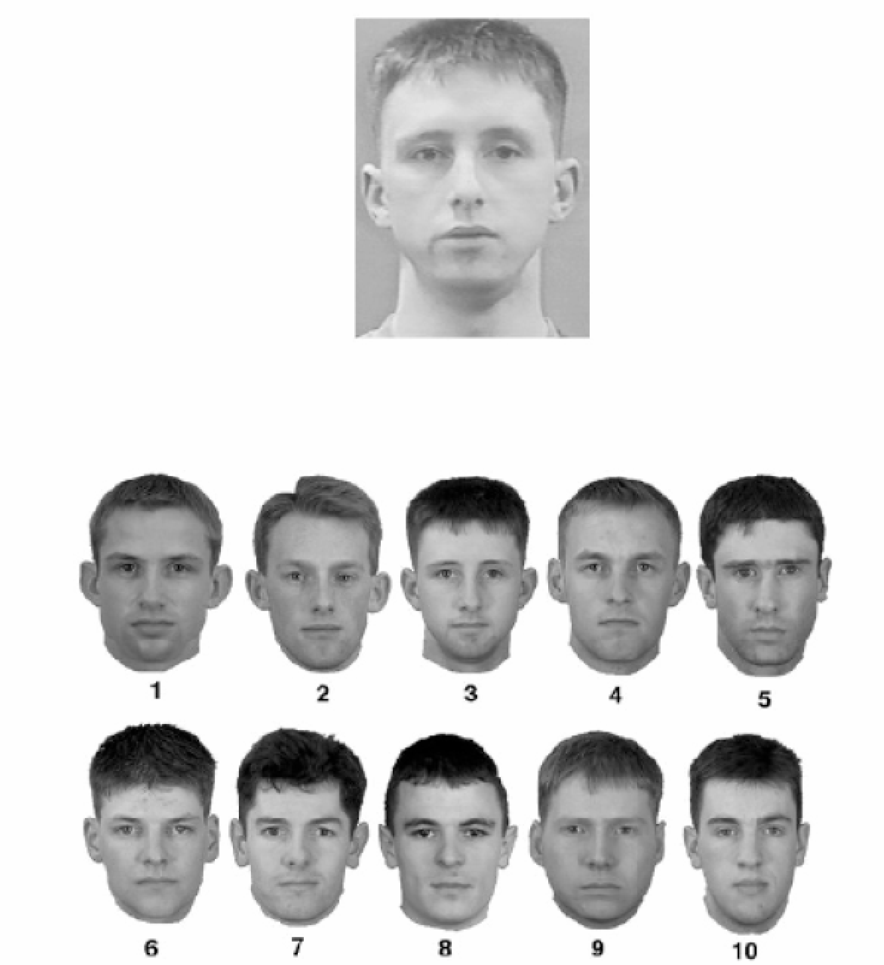


Figure 1.1 An example of the stimuli used by Bruce et al. (1999), using a whole target face, the correct match is number 3.

In another experiment using the same paradigm Bruce et al. (1999) presented a whole target face along with a 10-face array and participants had to decide if the face was present in the array and if so which face it matched, the target face was only present on half the trials. They reported that even when the faces were matched for expression and viewpoint, a correct match was made only 70 % of the time, and this decreased if expression and viewpoint were changed. They also reported that for approximately 10 % of trials the wrong person was picked and on about 20 % of trials the participants wrongly stated that the person was not present. When the target face was absent from the line up, participants incorrectly chose a person on 30 % of trials. This shows that matching performance was surprising low, and the images used were of a high quality, using the same lighting and taken on the same day therefore there were no variations in age and hairstyle, the only difference was the images were taken with different cameras.

Megreya and Burton (2006) also reported that matching target faces to a 10-face array was extremely error prone, with correct matches only made 70% of the time. They extended the paradigm to present pairs of target faces and reported that this reduced the accuracy to match one the faces to a face from an array to 54 % of the time. They also reported that when the target pair was presented closer together this further impaired matching performance (50 %) than when the pair was presented further apart (58%). They suggest that when face pairs are close together this impairs matching performance to an array, however the type of target image used might also influence performance for recognition and matching tasks.

Matching faces from a video clip to an array can also be extremely error prone. Henderson, Bruce and Burton (2001) showed participants a mock bank raid with two actors posing as robbers. They then presented participants with two 8-face arrays, each array contained a still image of the robber and similar distracter faces. They reported that robber 1 was only correctly matched 26% of the time and robber 2 was only matched 31% of the time. In a second experiment to place fewer demands on memory, participants were shown a still photograph of each robber in place of the CCTV images, whilst simultaneously being presented with the corresponding array. They reported that for robber 2 there was a significant increase in correct matches (76%), however the matching rate for robber 1 was still very poor (33 %).

In a further experiment, Henderson et al. (2001) asked participants to match the robbers from the video footage to a pair of faces. The pairs always contained a photo of the robber and another face that had previously been the one most confused, or second most confused with the robber. They found that although matching performance was greatly increased, accuracy still varied from 95 % to 65 % depending on the face pair combination. In a final experiment a pair of static faces were presented, that were either two different images of the robber, or the robber and a similar distracter face. Even in this task performance for some combinations was very error prone and accuracy ranged from 45 % to 75 %. Overall 27.5 % of participants thought that the robber matched an image of a different person and 45 % of the time the two images of the robber were classed as two different people. These studies seem to show that even when presented with only two images for a matching task, performance for unfamiliar faces can be very error prone, especially if the faces appear to be rather similar in appearance.

In a real life study that investigated whether introducing photographs onto credit cards would reduce credit card fraud, cashiers in a supermarket were tested to see if they were able to match the photograph on a credit card to the cardholder (Kemp, Towell, & Pike, 1997). The results reported that over 50 % of the time fraudulent cards were accepted. This study suggested that producing credit cards with a photograph would not necessarily reduce credit card fraud, as cashiers could not accurately match people to their photographs. This has huge implications for the advent of ID cards, as it appears that most people will be unable to accurately match the person carrying the card to the photograph on the card. However, is unfamiliar face matching so error prone due to differences in the quality/resolution between two different images, or are we just poor at matching faces per se?

In another study the quality of the photographic images was manipulated to investigate whether this would influence matching performance. The premise was that face matching performance could be error prone due to discrepancy between image quality, for example, when the police try to match live suspects to low quality images on CCTV. Liu, Seetzen, Burton, and Chaudhuri (2003) presented faces that were either high quality images, or poor quality images (congruent), or a combination of both (incongruent), to examine the influence on matching performance. They found that matching performance was sometimes enhanced when images were incongruent, as participants were more conservative in their responses. They suggested that if one of the images has a poor resolution that identification is more likely if the other image has a higher resolution. However there is another issue that should be noted, unlike Bruce et al. (1999) they did not use faces that were rated as looking similar to one another for the matching task, but faces were paired randomly and therefore their task may have been easier due the faces looking less similar to one another. This study reported there was no reduction in matching performance when images of different resolutions were used for a matching task, and in some circumstances using two dynamic images was worse than static images, when the video was low quality. This raises the question of how well can people perform a matching task when shown moving or static images?

Processing moving and static images of faces.

A number of studies have investigated whether presenting static or moving images influences how well participants perform face matching and recognition tasks. Bruce et al. (1999) presented a target face that was either a static image, or a video clip that was displayed either for a limited time (5 seconds), or an unlimited time period, along with a 10-face array. In the unlimited condition participants were allowed to rewind, pause and replay the clip until they felt confident about their decision. They reported that for the unlimited condition participants correctly matched the target face 79 % of the time, whilst the hit rate for the static images (68 %) and limited video (67 %) were significantly less. Pike, Kemp, Towell and Phillips (1997) also found an advantage for face recognition when participants were shown moving images in the learning phase, as compared to single static images and a sequence of static images showing differing viewpoints of a face.

However, not all studies have found a beneficial effect of moving images of faces. Bonner, Burton and Bruce (2003) reported that faces could be learnt equally well from both moving and static images. Christie and Bruce (1998) also found no advantage for studying moving images of faces, as compared to static images prior to a recognition test. The majority of studies that used unfamiliar faces, have found no advantage for moving images, as compared to static ones, however there does seem to be some evidence that movement can facilitate familiar face recognition. Advantages of moving images of famous faces have been found for repetition priming studies (Lander & Bruce, 2004) and when images are degraded (Lander & Bruce, 2000; Lander, Bruce, & Hill, 2001). This seems to show that moving images should be beneficial for recognising faces that are already familiar, but not necessarily those that are unfamiliar. These studies and a variety of other studies seem to suggest that familiar and unfamiliar faces maybe processed in different ways and this next section will explore this issue.

The dissociation between familiar and unfamiliar face processing.

Face recognition research has reported that memory for familiar faces is significantly better than unfamiliar faces, even if the name of the person cannot be retrieved (Klatzky &

Forrest, 1984). Familiar faces can also be recognised from changes in expression and view-point. When presented with a series of familiar and unfamiliar faces and then different images of those faces with variations in expression and viewpoint, responses for the unfamiliar faces are significantly less accurate, whereas responses for familiar faces remain unaffected by these manipulations (Bruce, 1982). As mentioned previously there is also evidence that different facial features maybe important depending on whether the face is familiar or unfamiliar (Bonner, Burton & Bruce, 2003; Clutterbuck & Johnston, 2005; Ellis et al, 1979; Young et al., 1985).

Familiar faces can also be recognised from low quality video footage. Burton, Wilson, Cowan and Bruce (1999) presented CCTV footage of lecturers walking into a building to participants who were either familiar with the targets (from the same department), or unfamiliar with the targets. They then showed the participants a series of high quality stills and the task was to rate each photograph as having previously appeared in the video clip. They reported a marked benefit for participants who were familiar with the targets, whereas those who were unfamiliar with the targets performed very poorly.

Bruce, Henderson, Newman and Burton (2001) also found a benefit of familiarity when matching a person from CCTV footage to high quality photographs. They presented participants with three types of target stimuli; a video clip, a still image, or 3 different images from the video clip. They were also shown a static photograph that was either the same as the target or a similar distracter, and their task was to decide if both depicted the same person. Half the participants were familiar with the targets and half were unfamiliar with the targets. Participants who were familiar with the targets made highly accurate responses, whereas those unfamiliar with the targets performed very inaccurately. Another study also reported the benefit of familiarity using a face matching task. Megreya and Burton (2006) presented unfamiliar faces and faces that had been familiarised through the presentation of video clips, along with a 10 face array. They reported unfamiliar face matching accuracy was 74 %, whereas matching familiar faces was significantly more accurate at 88 %.

Neuro-imaging studies have also reported differences in activation for familiar and unfamiliar faces. Begleiter, Porjesz and Wang (1995) found differences in ERPs between recognition of familiar and unfamiliar faces. There have also been reported differences in activation during PET scans for familiar and unfamiliar faces (Dubois et al., 1999). A behavioural study investigating hemispheric co-operation reported a weak, but significant effect of inter-hemisphere cooperation for familiar, but not unfamiliar faces (Mohr, Landgrebe, & Schweinberger, 2002).

The studies described so far, seem to support the view that familiar and unfamiliar faces are processed differently. It has been suggested that unfamiliar face processing does not engage face perception processes, but employs processing more akin to that used for processing visual patterns (Hancock, Bruce, & Burton, 2000). There is evidence from neurological research which proposes that familiar and unfamiliar face processing may involve different brain mechanisms (Benton, 1980). Malone, Morris, Kay and Levin (1982) report two cases of prosopagnosia (an impairment in face processing ability). In one case the person could recognise familiar faces, but could not match two unfamiliar faces. Whereas the other case was unable to recognise familiar faces, but was able to match unfamiliar faces. If familiar faces are processed differently to unfamiliar faces then are they also viewed differently when carrying out a recognition task? The next section will be a brief review of eye movement research followed by a review of literature that has used eye movement methods to investigate face recognition and matching.

Eye movement Research

The purpose of this section is to describe a few studies that have used eye movement measures. As there is a vast amount of research within this area, only selected topics and publications will be covered as a detailed review of the research is beyond the scope of this chapter. Eye movements have been used to investigate a variety of tasks, such as reading text and music, visual search and scene perception (for a review of early research see Rayner, 1998). With the advent of more wearable systems, eye tracking methods have been used to investigate where people look when driving, flying a plane and carrying out every day tasks (for a review of more recent literature see Duchowski, 2002).

When we look at text, scenes or objects, visual acuity is best at the point of fixation and the visual system exploits this by actively controlling gaze to direct fixations towards important regions and in real time. The high quality visual information is acquired from only a limited spatial region surrounding the centre of gaze (the fovea) and resolution declines in regions beyond this area (Para fovea and periphery). Using eye movement measures, that is investigating where people fixate, can inform us as to what visual information is important when carrying out a particular task and where people are attending, although it should also be noted that attention can sometimes be diverted away from a where a person is looking (Posner, 1980).

What we have learnt so far from eye movement research is when reading English, fixations last about 200-250ms and the mean saccade size is 7-9 letters. Also, eye movements are influenced by the quality of print, line length and text spacing and when text becomes more difficult to read, fixation lengths are increased and saccade lengths decreased. Although most saccades are made from left to right for English text, approximately 10-15% of saccades are regressions (right to left movements) these may be carried out if the reader has made too long a saccade, or did not understand the text and needs to re-read it (Rayner, 1998). Eye movements for reading appear to follow clear patterns, e.g. left to right and top to bottom for English, or right to left for Arabic and Hebrew, however there appears to be no specific strategies for viewing scenes (Duchowski, 2002).

According to Henderson (2003) eye movements are important for researching scene perception for at least three reasons. Firstly, vision is an active process where the viewer seeks out task relevant stimuli and eye movements are essential to acquire visual information when conducting a complex visual task. Secondly, as attention plays a central role in visual and cognitive processing, using eye movements can help investigate attentional processes. Thirdly, eye movements provide an unobtrusive online measure of visual and cognitive processing. By using eye movement measures it should be possible to determine what specific visual information is needed for certain tasks and if people use clear patterns of viewing strategies.

Early eye movement research by Buswell (1935) investigated how we look at pictures and scenes found that if a human figure was present it would receive proportionately more fixations than other objects (cited in Findlay and Gilchrist, 2003). Other research by Loftus and Mackworth (1978) reported that when presented with a scene, participants looked initially and for longer at objects that contextually did not fit into the scene (e.g. an octopus on a farm) as compared to objects that would be predicted to be in the scene (e.g. tractor on a farm). Loftus and Mackworth (1978) suggested that objects in a scene could be analysed in relation to scene context and also to a high level using peripheral vision. However more recent research by Henderson and Hollingworth (1999) and Hollingworth and Henderson (1998) failed to replicate Loftus and Mackworth's results.

Eye movement research that has investigated how we perform visual searches also has found different results from the early to more recent research. Norton and Stark (1971) seemed to suggest that viewing was a serial process, whereas more recent research reports that searching for specific items can be carried out in parallel (Findlay, 1997). Differences between viewing patterns for reading, visual search or scene perception could relate to the tasks themselves. In reading experiments the task is usually apparent, however when shown an array, or a scene, participants must be given a specific task and according to Yarbus (1967) viewing behaviour and eye movements can change as a function of the task given (cited in Duchowski, 2002).

Eye movement measures have also been employed within a change blindness paradigm, where a scene is shown and an object within the scene is changed and participants are asked to report what the change was. O'Regan, Deubel, Clark, and Rensink (2000) found that when participants were directly fixating on the changed object, they were more likely to detect a change, however 40 % of the time when they were directly fixating at the changed location (within 1°), they still failed to see the change. This led O'Regan et al. (2000) to suggest that looking at something does not necessarily guarantee that you can see it. In addition Henderson and Hollingworth (1999b) found that changes were more likely to be noticed if they occurred at the location to which a saccade was directed, than at the location of its launch.

Most of the research mentioned so far has used eye movements in an experimental setting, however with the advent of new mobile eye trackers it is also possible to measure eye movements whilst carrying out motor tasks and compare how experts and novices perform tasks to improve training. Eye movement measures have been employed to compare where novices and experienced drivers look whilst driving (Crundall, Underwood, & Chapman, 1999; Underwood, Chapman, Bowden, & Crundall, 2002; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003), where the police look when in a high speed pursuit (Crundall, Chapman, Phelps, & Underwood, 2003) and where pilots look when landing a plane (Anders 2001, cited in Duchowski, 2002). Everyday tasks have also been investigated using eye movements, such as; making a cup of tea and making a sandwich (Land & Hayhoe, 2001). This research has shown us that even for tasks that are automated and involve little conscious awareness the eyes closely monitor every step of the process. Land and Hayhoe (2001) argue that the eyes provide information on an ‘as needed’ basis and the relevant eye movements usually precede a motor action by a fraction of a second.

All the research described so far has shown how important studying eye movements are to learn where we look whilst carrying out various tasks, even when they are automated and not under conscious control. The next section explores eye movement studies that have investigated how we look at individual faces for recognition and also how we view pairs of faces for a matching task.

Eye movements and Face Processing.

The early eye-tracking research using face stimuli centred on the theory discovering "scanpaths". Norton and Stark (1971) defined a scanpath as "*a repetitive sequence of eye movements*". Scanpaths can be described as a fixed pattern of eye movements that are established in the learning phase of stimulus presentation and then repeated in the recognition phase. Norton and Stark (1971) also state that an individual makes an internal representation of a picture or a 'feature ring', which consists of the visual memory traces of the image and the motor memory traces of the saccades (eye movements) that make up the scanpath. These experiments used line drawings of faces that were not very realistic (see figure 1.2), and therefore the faces may not have been processed the same way as photographic images of faces (Bruce, Hanna, Dench, Healey and Burton, 1992), however some research has used photographic images of faces.

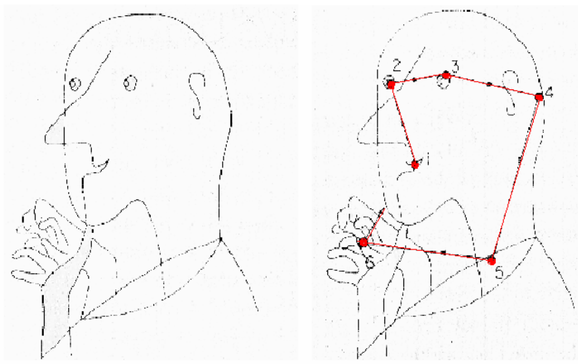


Figure 1.2 An example stimulus and eye movements from Norton & Stark (1971)

Walker-Smith, Gale and Findlay (1977) investigated the scanpath hypothesis and presented participants with a target face and then four faces consecutively, they had to decide whether these additional faces were the same as the target face. They reported that instead of using all the available time to view all areas of the stimuli, participants' fixations returned to areas they had already viewed. Also when participants produced the same sequences of fixations, e.g. left eye-right eye-nose, which they had used in the study phase, they also performed more accurately in the test phase. However, this finding was not statistically significant and participants did not always perform the same sequence of fixations from study to test.

Walker-Smith, Gale and Findlay (1977) suggest that instead of eliciting scanpaths, participants were using a feature comparison approach, whereby they fixate on a particular set of features (e.g. eyes and nose) during the study phase and again on these same features when making a decision about whether the face is the same as the one previously viewed. They found that for all 3 participants the fixations were confined nearly entirely to the eyes, nose and mouth regions in all trials. However, as they used a small sample of participants and stimuli (5 trials) their results should not be over generalised. It is also unclear if they used the same images in the study phase as was used in the test phase and if this is the case then participants may have been carrying out an image match, rather than identity match (Bruce, 1982).

Another study investigating face recognition using eye movements presented participants with a series of faces and then one week later they performed a recognition task (Groner, Walder and Groner, 1984). When viewing the face the most common triplet sequence of fixations was; left eye to right eye to left eye and vice versa. This study also used a very small sample of participants (7), although the stimuli set was of a reasonable size (25 faces in study and 50 for test). Another study also showed the importance of the eye region and reported that when presented with a face, 43 % of the time was spent looking at the eyes and 12 % of the time was spent looking at the mouth. The nose, ears and hair received less proportion of looking time (Janik, Wellens, Goldberg, & Dell'Osso, 1978).

None of the research described so far has specifically investigated whether familiar or unfamiliar faces are viewed differently, however there is some evidence that faces that are familiar are viewed in a different way to faces that are unfamiliar. Luria and Strauss (1978) presented participants with pictures of faces that were either positive or in negative form and then gave a recognition test for both types of faces. Their results found that the fixation patterns were different for negative and positive faces, with the more fixations to external features on the negative pictures, such as ears, chin, cheeks and top of the head and fewer to internal features, e.g. eyes, nose and mouth. They found that this correlated with the poorer recognition of the negative faces and concluded that the participants were not performing their regular scanning strategies with the negative faces. This also seems to lend support to the theory that we use the internal features when the face is familiar and when the face is unfamiliar we use the external and internal features equally (Ellis et al., 1979; Young et al., 1985). However, it could also be argued that using faces that were negative images might not engage normal face recognition processes and previous research has found these images more difficult to recognise than inverted faces (Bruce & Langton, 1994).

There is some additional evidence to support the assumption that familiar faces may be viewed differently to unfamiliar faces, however this study reported a high proportion of fixations directed to the internal features of unfamiliar faces, as well as the familiar ones. Althoff and Cohen (1999) investigated face recognition using eye movements as a method of indirectly investigating memory for faces. In this study participants were presented with famous and non-famous faces for 5 seconds, and had to make a fame judgement or an emotion judgement (happy or not happy), then two weeks later they carried out whichever task they had not done previously. They reported that the majority of fixations were to the eyes, followed by the nose and then mouth. The famous faces received fewer fixations to the mouth and more to the eyes, compared to the non-famous faces. They also used Markov transition matrices to calculate the extent to which fixations to particular regions were constrained by the location of prior fixations. They reported for the fame task the non-famous faces produced more fixations, with less symmetry, more constraint in the transitions amongst the fixations, and to more regions of the face, than the famous faces. In the emotion task, viewing of non famous faces also differed from famous faces, but only in that they produced more constrained and less symmetrical samplings of the regions of the face. The conclusions drawn were that prior exposure to a face, or its familiarity can change the way the face is viewed regardless of the task at hand, although the task may itself also have an influence on the way a face is viewed.

In another study cited by Althoff et al., (1999), they investigated whether viewing patterns changed as faces became familiar. Participants were presented with previously unfamiliar faces, either once, twice, three times or five times, whilst monitoring their eye movements and then given a recognition task. When participants were given only three presentations there were significant differences in the fixation patterns between those faces compared to completely novel faces. Repeated exposure produced fewer fixations to fewer regions of the face and the face was viewed in a more feature dependent fashion, with the internal features taking precedence.

There is also eye movement research with participants with impaired facial processing who show different viewing patterns for faces that were familiar and unfamiliar. Rizzo, Hurtig, and Damasio (1987) reported that when participants with impaired facial learning were repeatedly shown faces whilst their eye movements were monitored, their scanning strategies did not differ from normal control subjects. Additionally, it was found that the patients with the impaired facial processing produced different eye movements for faces that should have been familiar (i.e. close family members or famous individuals), compared to those elicited from non familiar faces, although they could not consciously recognise the faces. Althoff, Maciukenas and Cohen (1993) also found a similar effect in amnesic patients, who although could not consciously distinguish between famous and non-famous faces, produced eye movements that did distinguish between the two types of faces.

Not all eye movement research investigating face recognition has found differences in how familiar and unfamiliar faces are viewed. Stacey, Walker and Underwood (2005) presented familiar and unfamiliar faces for a recognition task and found that the majority of gaze was to the internal features, e.g. eyes, nose and mouth (97%) and there were no significant differences in gaze for the familiar and unfamiliar faces. In a second experiment they measured eye movements for faces during a learning phase and a test phase. They reported that again there were no significant differences in gaze to internal features as a function of familiarity. This study showed that there was more gaze to the internal features of faces regardless of familiarity, which does not support earlier research that suggested the external features are more useful for processing unfamiliar faces (Ellis et al., 1979; Young et al., 1985).

Henderson, Williams and Falk (2005) also found little evidence to support the theory that familiar and unfamiliar faces are viewed in different ways. In one study they presented faces for a learning phase and either allowed participants to view the faces freely, or restricted their eye movements, this was to investigate whether eye movements are functional for learning faces. Participants then performed a recognition task and it was reported that performance was significantly lower when eye movements were restricted during learning (52.5 %), as compared to the free viewing condition (81.3 %). They also found that viewing patterns in the free viewing learning condition were very similar to those in the test phase, overall the eyes received most of the proportion of gaze (> .5), followed by the nose and mouth. The other features (ears, chin, cheeks and forehead) received very little gaze.

Henderson et al. (2005), however did find some slight differences in gaze from the free viewing learning phase to the recognition phase. For the learning phase there was more time spent looking at the ears, chin and forehead, as compared to the recognition phase, however in the recognition phase there was more time spent looking at the eyes and nose. They suggest that this pattern supports Althoff and Cohen's (1999) suggestion that eye movements become more restricted during recognition than during learning. One point that is important to note about the Henderson et al. (2005) study is that the faces were viewed for 10 seconds in the learning phase, whereas they were only viewed for approximately 2 seconds in the recognition phase, therefore any differences in viewing patterns could also relate to the differences in presentation duration of the stimuli.

Another study also found no differences in viewing patterns for familiar and unfamiliar faces. Henderson, Williams and Falk (2005) presented faces for a learning session that were upright and inverted, and then participants performed a recognition test. They were trying to investigate whether face inversion would produce different viewing patterns, as research has shown that inverting a face can disrupt normal face processing (Yin, 1969). They reported that the distribution of fixations over the faces was very similar with the same features receiving the same proportion of total fixation time in both the study and recognition phase. The eyes were the features that received the most amount of fixations and over 50 % of the time was spent looking at the eyes, whilst the other features received significantly less gaze. They also reported that inversion had little effect on the distribution of fixations over the faces; the same features were viewed for the same length of time in both orientations. They suggest that their data does not support the theory that there is a transition from global/holistic processing to local/featural processing, because the viewing patterns were very similar for both orientations.

There is some research that has found differences in viewing patterns as a function of face inversion and familiarity. Barton, Radcliffe, Cherkasova, Edelman and Intriligator (2006) presented famous and non famous faces, which were morphed in varying degrees from one identity to another (e.g. Julia Roberts/Demi Moore) and presented either upright or inverted. The participants' task was to firstly make a fame judgement, and then they were shown an array of eight faces and had to decide which one was the same as that previously presented. They reported that participants scanned novel faces more than famous faces and that inverted faces were also scanned more than upright faces, however the fixation durations were very similar for all types of stimuli, they suggest the effect of scanning comes from the total number of fixations, rather than their duration, as gaze durations were similar for all conditions. In contrast to Althoff and Cohen's (1999) study they reported that participants made more fixations to the eyes and nose regions of unfamiliar faces, as compared to familiar faces.

Barton et al. (2006) also reported differences in viewing patterns to the facial features as a function of orientation, although the majority of fixations were made to the eyes and nose, followed by the mouth, brow, chin and cheeks. The inverted faces had more fixations to the mouth and chin, and fewer to the brow. There was also a preference for whichever eye was on the left of space, so the left eye in the upright condition and the right eye in the inverted condition, received more gaze than the adjacent eye. This seems to suggest that there was a bias towards the top and left side of space.

The left perceptual bias for faces has been found in a number of other studies that have used eye movements. These studies report that when allowed to freely view faces, the majority of first saccades are made to the left side of the faces and in many cases more saccades are made to the left side (Butler et al., 2005b; Butler & Harvey, 2005; Heath, Rouhana, & Ghanem, 2005; Leonards & Scott-Samuel, 2005; Mertens, Siegmund, & Grusser, 1993; Phillips & David, 1997b; Vaid & Singh, 1989). It is still being debated whether the left perceptual bias is due to the right hemisphere superiority for face processing (Rhodes, 1985b), or a relates to a cultural bias from reading direction (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989), this issue will be explored further in Chapter 5.

The majority of eye movement research described so far has investigated how we view individual faces; however there are two reported studies to date that have presented two faces simultaneously for a matching decision. Walker-Smith et al, (1977) presented pairs of faces vertically one above the other and asked participants to make a 'same' or 'different' judgement. They reported that the majority of fixations were confined to the top halves of the faces and suggested that the same features must be fixated on each face before a decision could be made.

In another more recent study familiar and unfamiliar face pairs were presented side-by-side, one was a full-face image and the other a three-quarters view (Stacey et al, 2005). The face was divided into two areas; the internal features (eyes, nose and mouth) and the external features (chin, forehead, hair and ears). They reported that over 92.5 % of the time was spent looking at the internal features, however there were some slight variations according to familiarity and whether the faces matched. For familiar faces proportionately more time was spent looking at the internal features (.96) than for the unfamiliar faces (.92). When the two faces matched, proportionately more time was spent looking at the internal features (.94), than when the faces mismatched (.91). This study does seem to lend some support to early research that reported the internal features are more important for familiar face processing (Ellis et al., 1979; Young et al., 1985), although it does not support the theory that the external features are important of unfamiliar face processing (Bruce et al., 1999).

There are still a variety of questions that previous research has not fully answered; for example which internal features are important for face matching? Do viewers use a specific viewing strategy when carrying out a matching task? Does manipulating the way the face pairs are presented change matching performance, and if so does this also influence viewing strategies?

Structure of this thesis

The aim of this thesis is to investigate how well viewers can carry out a face matching task when the face pairs are manipulated during presentation. Another aim is to determine whether participants use a specific viewing strategy when carrying out a simultaneous face matching task and if the viewing pattern changes if the presentation of a face pair is manipulated. There are some main themes that will be explored and one is familiarity, whether familiar faces are viewed differently to unfamiliar faces. Another is face match; are two faces that are the same person viewed in the same way, as two faces that are different people? There are also the various manipulations of the face pairs that will now be explained in more detail.

Chapter 2 focuses on the face inversion effect, in Experiment 1 single upright and inverted familiar and unfamiliar faces are presented for a familiarity task. In Experiments 2 & 3, pairs of familiar and unfamiliar faces are presented for a matching task and participants have to decide whether they are the same person. Experiment 2 uses identical images for the same identities, whereas Experiment 3 uses two different images of the same person.

Chapter 3 investigates whether the layout of the face pair can influence matching performance and also the way the faces are viewed. Experiment 4 presents faces side by side and manipulates the distance between the faces, so they are either close together or further apart. Experiment 5 places the faces vertically one above the other, or misaligned, so that either the left or the right face is higher than the other face.

Chapter 4 investigates how well participants can accurately match faces when some of the visual information is unclear, or missing. Experiment 6 presents faces that are filtered to contain only low spatial frequency information, and compares this to matching normal or full bandwidth images. Experiment 7 masks the eye regions of the faces to investigate the influence this has on face matching and whether the participants have to look at other facial features to make an accurate decision. Experiment 8 uses only the eye regions for a matching task, to investigate how well participants can determine whether these isolated features are the same person.

The final experimental chapter will involve investigating the perceptual bias for face pairs and whether participants are drawn to look at the face on the left or the right first. This will entail a re-analysis of the data from Experiments 3, 4 and 6 and examine the location of the first fixation (left face/right face). The matching paradigm will also be extended to include pairs of similar looking objects, to determine whether there is bias to look initially at the object on the left or right side.

Chapter Two

Is the Face Inversion Effect reflected in Eye Movements Patterns?

Introduction

As the preceding chapter has shown we are very good at recognising faces that are familiar when they are upright, however when a face is inverted so that it is upside down our ability to recognise it is greatly impaired. The aim of this chapter is to investigate how people look at upright and inverted faces for recognition and matching. Research has shown that visual stimuli that are usually shown in one particular orientation, such as handwriting or maps, are more difficult to recognise when inverted (Rock, 1974). However when faces are inverted, recognition is disproportionately impaired as compared to other inverted objects such as; houses, landscapes, aeroplanes, stick figures and even images of dogs (Diamond & Carey, 1986; Scapinello & Yarmey, 1970; Yin, 1969). As a result of this phenomenon the Face Inversion Effect (FIE) has been the source of numerous studies (see Bartlett, Searcy & Abdi, 2003; Valentine, 1988) and a variety of explanations have arisen to account for why we find inverted faces so difficult to process and recognise.

Explanations for the Face Inversion Effect

The different accounts for the Face Inversion Effect (FIE) include; having to mentally rotate the facial features one at a time for recognition (Rock, 1974), an inability to judge facial expressions from inverted faces (Yin, 1969), and that inversion impairs face perception by adding noise to the encoding process (Valentine, 1988, 1991). The most accepted explanation for the FIE and with the greatest amount of evidence, is that faces are processed holistically or/and configurally when they are upright, whereas when they are inverted they are processed more analytically or in a piecemeal fashion. Holistic processing involves processing the face as a unified whole, rather than its constituent parts (Farah, Tanaka, & Drain, 1995; Farah, Wilson, Drain, & Tanaka, 1995; Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993, 2003), and configural processing involves coding the spatial relationship between the features, as well as the features themselves. Bruce and Humphreys (1994) state “it seems to be difficult or impossible to code a particular feature independently without the influence of other features” (p152).

Diamond and Carey (1986) suggest that faces contain two types of relational information; first order relationships and second order relationships. The former involves spatial information between the constituent parts of an object e.g. the eyes above the nose, this defines the object as a face. The second order relations involve the specific spatial relations of the features with respect to a prototype. When we become experts at processing specific visual objects we use this type of information, therefore according to Diamond and Carey (1986) faces are just visual objects that we have developed an expertise for. This view was supported by a study where they reported that inverted pictures of dogs impaired dog breed recognition, but only for dog experts (Diamond & Carey, 1986). However more recent research using dog experts reported a smaller inversion effect for images of dogs, as compared to image of faces and the conclusion was that face processing is not simply expertise in object processing (Robbins & McKone, 2007). Although Diamond and Carey (1986) and Robbins & McKone (2003) studies appear to oppose one another, they both emphasise the role of configural processing for upright faces.

It appears that holistic and configural processing must be somewhat related, although configural processing does not necessarily have to be holistic, and many studies investigating the FIE have supported both types of processing (Bartlett, Searcy, & Abdi, 2003). Studies that support holistic processing of faces have shown that when upright and inverted faces are learnt and then either whole or part faces are used as test items, subjects perform less accurately for upright part faces, whereas for inverted faces there is no difference if the test stimuli are whole or part faces (Tanaka & Farah, 1993, 2003). However, according to Leder and Bruce (2000) these studies do not necessarily rule out the possibility "…that relational information, rather than 'holistic' information is crucial of face recognition" p516

There is a vast amount of research that supports the view that face recognition involves configural processing and that inversion somehow disrupts this type of processing. Young, Hellawell and Hay (1987) compared naming rates for composite faces, created by joining the top half of one face to the bottom half of a different face, and non composite faces where the two halves of the different faces were misaligned (see figure 2.1). They found reaction times were significantly slower for the composite faces, as compared to the non composite faces and suggested that the new facial configuration of the composites interfered with the identification of the constituent parts. However when the faces were inverted so that they were upside down, there was no difference in reaction times for the top and bottom halves of the inverted composite and non composite faces. This was seen as showing that the configural information was not interfering with identification of inverted faces.

Figure 2.1. An example of the composite and non composite faces, the top halve of the face is David Beckham and the bottom half is Gary Lineker.

Another study supporting the configural processing account for face recognition found that when the eyes and mouth of faces were inverted the faces looked grotesque when they were upright, however when the faces were inverted the grotesqueness disappeared, see figure 2.2. This effect became known as the Thatcher Illusion.

Figure 2.2 An example of the Thatcher illusion.

More recent studies have tried to focus on the specific information that is lost when faces are inverted. When faces are learnt featurally i.e. more by the separate features (e.g. hair colour, or eye colour) inversion does not seem to affect performance, but if faces are recognised by configural information (e.g. distance between the eyes and nose) inversion significantly impairs recognition (Farah, Tanaka, & Drain, 1995; Leder & Bruce, 2000).

Face-matching tasks also support the different processing mechanisms employed for upright and inverted faces. If a discrepancy between a pair of faces is related to a spatial distortion by moving the features (e.g. the mouth or eyes up or down), inversion impairs matching decisions; however when variations are due to featural distortion (blackening teeth or discolouring the eyes), then inversion does not impair matching performance (Freire, Lee, & Symons, 2000; Searcy & Bartlett, 1996). Friere et al. (2000) found matching decisions for configurally changed faces were 88 % in the upright condition and 55 % when they were inverted, however Searcy and Bartlett (1996) found subjects had an accuracy rate of 70 % for the inverted and 92 % for upright faces. The difference in performance between these two studies could relate to differences in the stimuli sets they used. Friere et al. (2000) used a stimuli set derived from one face that was slightly altered eight times (e.g. nose or mouth moved 3 pixels up or down etc.) and was therefore rather homogenous. Whereas Searcy and Bartlett (1996) used 24 different identities and made larger changes in the distance between features and their stimulus set was therefore more diverse.

In a similar study Murray, Yong and Rhodes (2000) changed faces either configurally making them ‘thatcherised’ or featurally (blackening the teeth or whitening the eyes) and then rotated the faces from 0 degrees to 180 degrees. They asked participants to rate the faces for bizarreness on a 7 point scale and found that the configurally altered faces had reduced bizarreness as they were rotated, but the featurally altered faces did not. They claim that the shift in processing from configural to featural (analytical) processing appeared to occur at about 90-100 degrees. Sturzel and Spillman (2000) also found that 'thatcherised' faces loose their grotesqueness after being rotated about 100 degrees. These studies seem to show that there is a shift in processing from configural to analytical processing after rotation of 90-100 degrees.

Overall these studies appear to show that faces are processed differently from other types of visual objects and that inversion can impair face processing proportionately more than other visual objects. Does this however mean that the brain processes upright and inverted faces differently, and are different regions used for faces as compared to other objects?

Neurological studies of FIE

There is evidence from neurological studies that faces and objects maybe processed using different brain regions. People with a neurological impairment called prosopagnosia are unable to recognise familiar faces and usually do poorly on face recognition tasks, whereas people with visual agnosia have impairments in recognising objects, but not usually familiar faces. One study with a person with prosopagnosia found that on a face matching task he performed better with inverted faces, as compared to upright faces (Farah, Wilson, Drain, & Tanaka, 1995). There are other studies that have found people with prosopagnosia seem to process inverted faces more easily than upright faces (Behrmann, Avidan, Margotta, & Kimchi, 2005; De Gelder, Bachoud-Levi, & Degos, 1998; De Gelder & Rouw, 2000; Le, Raufaste, & Dermonet, 2003). However, not all prosopagnosics have superior processing for inverted faces, some show no significant differences in processing upright and inverted faces (Boutsen & Humphreys, 2002; Delvenne, Seron, Coyette, & Rossion, 2004).

More evidence for the different processing mechanisms for upright and inverted faces comes from a study of a person called CK with visual agnosia. CK was impaired at object recognition and reading, but could recognise familiar faces, although he was much worse at recognising inverted faces as compared to control subjects (Moscovitch, Winocur, & Behrmann, 1997). This seems to suggest that inverted faces are processed more like other visual objects, whereas upright faces are processed differently.

Neuro-imaging studies of the FIE.

There is also evidence from neuro-imaging research that upright and inverted faces are processed in different ways, (Rossion & Gauthier, 2002). Some fMRI studies have found when viewing inverted faces there was a decrease in activation to the fusiform face area (FFA), an area of the brain area known to be involved in face and object perception (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Haxby et al., 1999). Whilst another brain area known to be involved in scene and object perception the parahippocampal place area (PPA), had greater activation for inverted faces as compared to upright faces (Haxby et al., 1999). These studies seem to suggest that inverted faces are processed more like objects, as they activate brain areas usually associated with object perception, this also supports the use of configural processing for faces and analytical processing for inverted faces as analytical processing is thought to be used for most objects, although some researchers believe that both analytical and holistic representations are used for object recognition (Hummel, 2003).

Eye movement studies of the FIE

Although there have been a variety of behavioural and neuro-imaging studies that have explored the FIE there are very few eye movements studies that have investigated whether upright and inverted faces are viewed differently. Studies that have used upright faces have found that the internal features generally receive more gaze than the external ones (Althoff et al., 1999; Luria & Strauss, 1978; Stacey, Walker, & Underwood, 2005; Walker-Smith, Gale, & Findlay, 1977) and that the eyes in particular appear to receive the most amount of gaze (Henderson et al., 2001; Janik, Wellens, Goldberg, & Dell'Osso, 1978).

Eye movement research investigating the FIE has not always produced consistent results. Henderson et al., (2001) presented upright faces during a study phase and both inverted and upright faces for the test phase. They found that although performance was poorer for the inverted faces, there were no significant differences in fixation locations as a function of face orientation. They claim that the eye gaze data does not support a transition from configural processing to featural processing as a function of inversion. However, Le, Raufaste and Dermonet (2003) found that viewing patterns varied between upright and inverted faces, and the upright faces received significantly more fixations than those that were inverted. Gallay, Baudouin, Durand, Lemoine and Lecuyer (2006) found that infants explored upright and inverted faces differently, with more gaze the internal features (eyes, nose and mouth) of upright faces as compared to inverted faces (63 % versus 51.8 %). Infants also looked longer at the nose and mouth of upright faces and although it appeared that the eye region received more gaze in the inverted faces, this was found not to be statistically significant. When the faces were inverted infants looked mainly at the eyes and for longer at the external features.

Another study using adults also found that viewing patterns varied for upright and inverted faces. Barton et al. (2006) presented upright and inverted faces for a fame judgement and then presented participants with an 8-face array from which participants had to decide which face had been previously presented. They reported that the inverted faces had more fixations to the lower parts of the face (mouth and chin) and these areas were also looked at for longer, whereas the upright faces had more gaze to the upper parts of the face (brow and eyes). They also report that there was a bias for the eye that was on the left side of space; the left eye in the upright condition and the right eye in the inverted condition. These results seem to suggest that there was an overall bias to look at the top half of space, and towards the left, regardless of inversion.

In this chapter I will be exploring whether inverting a face changes the way it is viewed. The aim is to discover if changes in perceptual processing such as; configural for the upright faces, and featural for inverted faces, reflect different viewing strategies when either recognizing, or discriminating between faces. The first experiment is a familiarity task and the second and the third experiments both involve face-matching, for all experiments accuracy and eye tracking data were analysed.

Experiment 1

In the first experiment the aim was to investigate how upright and inverted faces were viewed for a recognition task, as it is well known that inverting faces makes them particularly difficult to recognise (Scapinello & Yarmey, 1970; Yin, 1969), and it has been suggested that this is because viewers do not use ‘configural’ or ‘holistic’ processing for inverted faces (Farah, Tanaka & Drain, 1995). If inversion leads to more featural processing, this may be observable in the scanning strategies used by subjects trying to recognise the faces.

There are a variety of studies that have used eye movement measures to investigate how upright faces are viewed and from them we know that the internal features seem to be very important (Stacey et al, 2005) and the eyes are also important (Henderson, et al., 2001; Henderson et al., 2005; Janik et al., 1978). One study found the most frequent sequences of fixations when viewing a face was the left eye-right eye-left eye and vice versa (Groner, Walder, & Groner, 1984). However eye movement research using inverted faces has been less consistent, some studies have found differences in viewing patterns for upright and inverted faces (Barton et al., 2006; Le et al., 2003: Gallay et al, 2006) whereas others have not (Henderson et al., 2001).

Another issue that will be investigated is whether there are differences in the gaze to features of familiar and unfamiliar faces, as half the faces will be familiar and half unfamiliar. Some previous studies have found differences in how familiar and unfamiliar faces are viewed. Luria and Strauss (1978) found that when faces were recognized there were more fixations to the internal features (eyes, nose & mouth), whereas when the faces were not recognized there were more fixations to the external features (ears, chin and top of head). Other research found familiar faces receive more asymmetrical fixations patterns, with more fixations to the eyes and less to the nose and mouth compared to unfamiliar faces (Althoff & Cohen, 1999). However some research found no differences in viewing patterns for newly learnt and unfamiliar faces during a recognition task (Henderson et al., 2005, Stacey et al., 2005).

Method

Participants

24 participants took part in the study (15 female). All were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 40 faces half were celebrities and half unfamiliar people from an in-house database. All the faces were male, half were inverted (so they were upside down) and half were upright. All the images were converted to grey scale and cropped around the faces, so they were presented on a white background (see figure 2.3). They were all approximately 17cm by 21.5cm, subtending a visual angle of 9.7 and 12.3 degrees and a resolution of 72 pixels per inch. The stimuli were presented on 21 inch Belinea TFT flat screen monitor, 1 meter from the participant using E-Prime software.

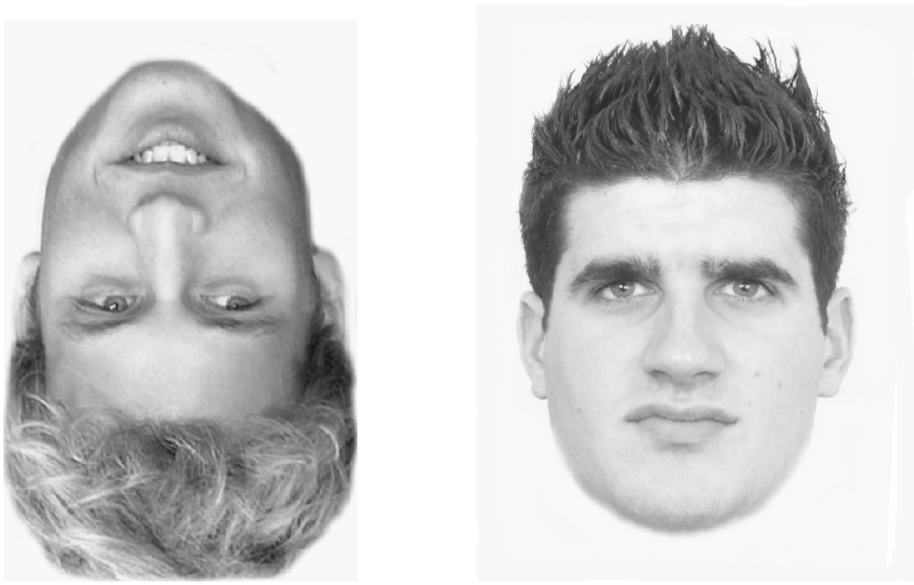


Figure 2. 3 Examples of inverted familiar and upright unfamiliar stimuli

Apparatus

Eye tracking data were recorded using a non-invasive remote eye tracking device (RED) from Senso-Motor Instruments, which was placed on a table below the monitor. Eye movements were captured using Iview version 2.3 software and the participants were calibrated using a 9-point display screen, before stimuli presentation. Participants had Asden HS35s headphone/ microphone combination headsets, so that they were able to communicate with the experimenter in the other room.

Design & Procedure

The experiment employed a 3-factor within subjects design. The first factor was familiarity (familiar/unfamiliar), the second was orientation (upright/inverted) and the third was the features viewed (rightmost eye, leftmost eye, nose, mouth, forehead, chin and hair). The participants were instructed that they would be presented with 40 faces, half upside down and half upright, and their task was to verbally indicate whether the face was familiar or unfamiliar. Each face was presented for 5 seconds. The experimenter recorded the verbal responses.

Analysis

The preliminary analysis of eye gaze data began by ascertaining whether there was a sufficient capture rate of all eye gaze data for each participant. Using the Iview 2.3 software, the viewing time for each face was analysed to see how much of the data was undefined, (i.e. gaze not recorded within the areas of interest). If the undefined data was higher than 30 percent, then the subject's data was discarded. The eye gaze data loss may occur through head movement, blinking, hand gesticulation obscuring the infrared beam, or untraceable eyes. Data will also be classified as undefined if within areas outside of the AOI, ie.e other uninformative areas of the screen. 29 participants were tested, however 5 had to be discarded, as the undefined data were above 30 percent. 24 participants were used in the final analysis.

The faces were divided into 7 areas of interest (AOI) created using Iview 2.3. The 7 AOI were; the rightmost eye, leftmost eye, nose, mouth, forehead, chin and hair (see figure 2.4). Separate AOI were created for each individual face, as the faces varied in regards to configuration. The AOI were from the perspective of the viewer, therefore the rightmost eye and leftmost eye were always on the right or left from the viewer's perceptive, irrespective of the orientation of the face (upright or inverted).

Eye gaze data with fixations shorter than 100 ms were discarded, in line with comparable studies (Baron, 1980; Fischer, Richards, Berman, & Krugman, 1989). Only the data for faces that were correctly categorised as being ‘familiar’ or ‘unfamiliar’ were used in the analysis. Eye gaze data was converted to proportions of gaze per feature for each face, as gaze duration and number of fixations could differ across subjects. The proportions of gaze were created for each trial therefore sum of the gaze for each face was equal to 1.

Figure 2.4. AOI created for each face.

Results

Task performance

Figure 2.5 shows the mean accuracy for upright and inverted faces. A 2-factor ANOVA; Orientation (upright/ inverted) and Familiarity (familiar/unfamiliar) was conducted to examine the accuracy of responses. The results from the analysis found there were main effects of orientation ($F(1, 23) = 27.5$, $p < 0.01$), and of familiarity ($F(1, 23) = 26.7$, $p < 0.01$). There was also a significant two-way interaction between orientation and familiarity ($F(1, 23) = 31.6$, $p < 0.01$).

The simple main effects for the orientation and familiarity interaction found that when the familiar faces were inverted, responses were significantly less accurate than when they were upright ($F(1, 23) = 64.9$, $p < 0.01$), however there were no significant differences in accuracy rates for the unfamiliar faces as a function of orientation ($F < 1$). Additionally responses for inverted familiar faces were significantly less accurate than the inverted unfamiliar faces ($F(1, 23) = 57.7$, $p < 0.01$).

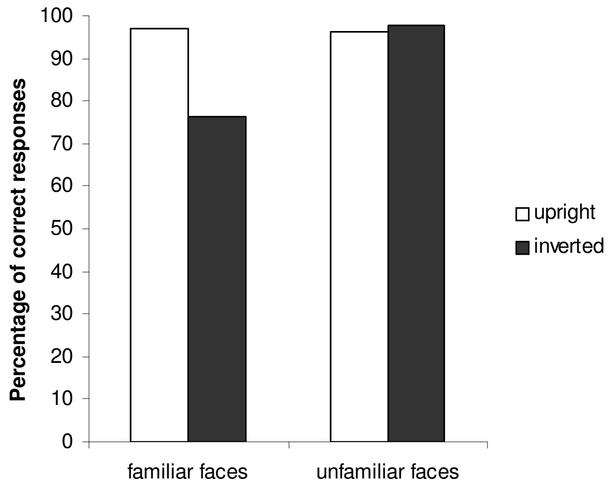


Figure 2.5 Mean percent correct for upright and inverted familiar and unfamiliar faces

Proportion of gaze to features

Figure 2.6 shows the mean proportion of gaze to the features of the upright and inverted faces. A 3-factor ANOVA; Orientation (upright/inverted), Familiarity (familiar/unfamiliar) x Features (leftmost eye, righmost eye etc…) was performed on the eye gaze data. The results showed a main effect of features ($F(6, 138) = 12.7$, $p < 0.01$). The leftmost eye (.30) received significantly more proportion of gaze than the nose (.16), mouth (.14), forehead (.07), chin (0.05) and hair (.05). The rightmost eye (.22) received more gaze than the forehead, chin and hair. There was also a significant two-way interaction between orientation and features ($F(6, 138) = 6.9$, $p < 0.01$). There was however, no main effect or interaction that involved familiarity.

The orientation and features interaction found that some features received more gaze when the faces were upright, whilst others received more gaze when the faces were inverted. A series of planned comparison t-tests were carried out on the separate features comparing proportions of gaze for the upright and inverted orientation. The results found that the right eye received significantly more gaze when the faces were upright ($t(23) = 2.96$, $p < 0.01$), the same pattern was found for the hair ($t(23) = 4.21$, $p < 0.01$) and the forehead ($t(23) = 1.93$, $p = 0.066$), although this was only marginally significant. However the mouth received more gaze when the faces were inverted ($t(23) = 5.10$, $p < 0.01$).

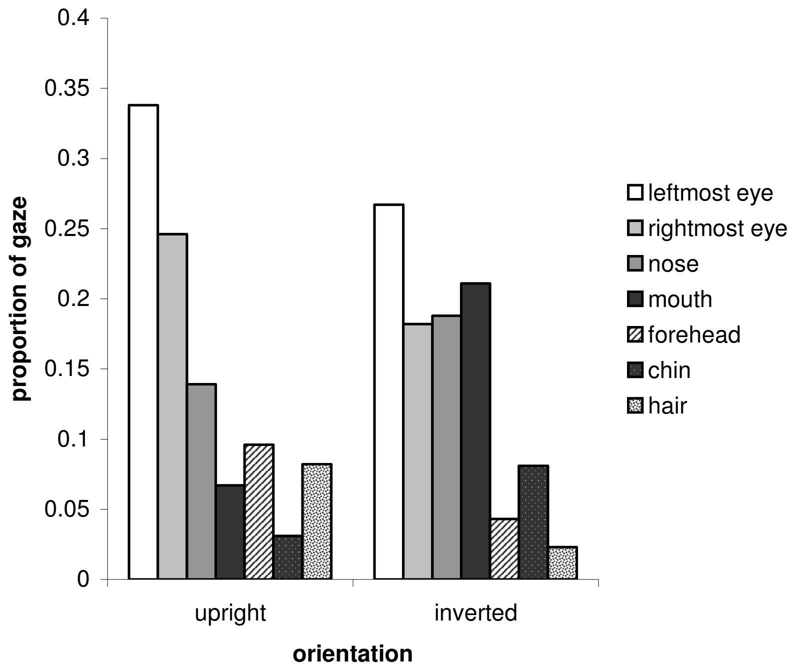


Figure 2.6 Proportion of gaze to features on upright and inverted faces.

Two separate 1-factor ANOVAs were conducted for the features; one for the upright faces and one for the inverted faces. The analysis for the upright faces found a main effect of features ($F(6, 138) = 10.7$, $p < 0.01$) with some features receiving more gaze than others. Planned comparison t tests found the leftmost eye received more gaze than nose ($t(23) = 3.75$, $p < 0.01$), as did the rightmost eye ($t(23) = 2.24$, $p < 0.01$) and comparisons with the other features produced larger t values. The nose also received more gaze than the chin ($t(23) = 2.26$, $p < 0.05$).

The 1-factor ANOVA for the inverted faces found a main effect of features ($F(6, 138) = 11.8$, $p < 0.01$) and planned comparison t tests found the leftmost eye, received more gaze than the nose ($t(23) = 2.08$, $p < 0.05$) and comparisons with the other features produced higher t values except the mouth. The nose received more gaze than the chin ($t(23) = 2.78$, $p < 0.01$) and comparisons with the forehead and hair produced higher t values. This pattern was also found for the mouth.

Discussion

The results from the first experiment appear to show that familiarity had no effect on the amount of gaze to the features; this was also a finding by Henderson et al. (2005). Other studies have however found differences in the viewing patterns for familiar and unfamiliar faces (Althoff & Cohen, 1999; Luria and Strauss, 1978). In contrast, face inversion did change how the faces were viewed. Some features received more gaze on the upright faces (right eye, forehead and hair), whereas the mouth received more gaze when the faces were inverted. This seems to suggest that there was an overall bias towards the top half of space with the features residing in the top half receiving more gaze. This was a finding that was also reported by Barton et al (2006), who also discovered that there were more fixations and for a longer duration to features in the top half of space. This bias towards the top half of faces and face-like objects has been shown in a variety of other studies (Caldara et al., 2006; Turati, Macchi Cassia, Simion, & Leo, 2006; Turati, Simion, Milani, & Umilta, 2002).

Overall there was a bias towards the internal features (eyes, nose and mouth) regardless of inversion; this was a finding by Stacey et al. (2005) although they only used upright faces. When the faces were upright the internal features received 79 % of gaze and when they were inverted this increased to 85 %. So unlike Gallay et al. (2005) there was no increase in gaze to the external features, or decrease in gaze to the nose and mouth for the inverted faces, in fact there was an increase in gaze to the mouth as a function of inversion. Differences in these results and those by Gallay et al. (2005) could be related to the participants tested, as Gallay et al. (2005) used four-month old infants and my experiment used adult participants. There does seem to be some evidence that young children and adults' process faces in different ways (Campbell & Tuck, 1995; Campbell, Walker, & Baron-Cohen, 1995; Diamond & Carey, 1977) and this could well be reflected in eye movement patterns.

The proportion of gaze to features for the upright and inverted faces did vary. Overall when the faces were upright 59 % of the time was spent looking at the eye regions, whereas when the faces were inverted 45 % of gaze was to the eye regions. The bias to look at the eyes of upright faces supports findings from other studies that have found the eyes are looked at more than any other feature (Henderson et al, 2001, Henderson et al., 2005, Janik et al., 1978).

There was also a bias for the leftmost eye, which was apparent in both orientations, but especially for the inverted faces. The bias to look more at the eye on the left side of space has been found by Barton et al. (2006), they found the left eye received more gaze when the faces were upright, whereas the right eye received more gaze when the faces were inverted. The bias for the left eye (on upright faces) has been found in other studies using the bubbles technique, and is believed to be due to the right hemisphere specialisation for face processing (Schyns, Bonnar, & Gosselin, 2002; Vinette, Gosselin, & Schyns, 2004). The bubbles technique is used to investigate what visual information is used for a specific categorisation task by embedding stimuli such as faces in visual noise and randomly revealing small parts of the stimuli at different time intervals.

Another effect of inversion was the gaze to the mouth region, which significantly increased from 6 % to 21 %, and the gaze to the nose increased from 14 % to 19 %, but this was not statistically significant. The gaze to the right eye significantly decreased from 25 % to 19 %. This seems to suggest that the nose and mouth were more important for the recognition of inverted faces, than they were for the upright faces. It could be that when the faces were upright viewers only really needed to look at the eyes to obtain a holistic impression of the face, whereas when the faces were inverted the configural or holistic processing was disrupted and processing had to be more on a featural bias, by looking at more of the internal features.

The task performance showed that inverting the faces impaired familiar face recognition and this corroborates the face inversion effect found in previous studies (Scapinello &

Yarmey, 1970; Yin, 1969). Inversion however did not seem to effect familiarity decisions for unfamiliar faces. It appeared that inverting faces made participants more likely to say a face was unfamiliar, therefore they performed better for the unfamiliar faces, as opposed the familiar faces in this condition.

Experiment 2

In the second experiment the aim was to investigate how pairs of faces are inspected for a face-matching task. Face-matching is extremely important in a variety of situations, such as deciding if a person is the bearer of a passport, matching criminals caught on CCTV footage and proof of age when buying restricted products such as alcohol. There have been very few studies that have used eye-movement measures to investigate how faces are viewed during a face-matching task. One study presented faces vertically one above the other and found most fixations were to the top half of the faces and the conclusion was the same features on both faces had to be fixated upon to make a matching decision (Walker-Smith, Gale and Findlay, 1978). Another study that presented pairs of faces for a matching task used one that was front facing and another in a three-quarters view. The findings were that more time was spent looking at the internal features of the faces, as compared to the external features regardless or familiarity (Stacey et al., 2005).

The second experiment proposed to find which internal features are important for face matching and whether viewers use any specific strategy when carrying out a matching decision. Do viewers carry out a feature-by-feature comparison as suggested by Walker-Smith, Gale and Findlay (1978), or do they use more of a global strategy by obtaining a holistic impression of the faces? In the matching-task, faces were presented side by side and as a comparison to the normal upright faces inverted faces were also used. This was to examine whether the different viewing strategy observed for inverted faces in the recognition task, and also other studies using inverted faces (Barton et al., 2006) could also be observed in the face-matching task.

Methodology

Participants

24 participants took part in the study (14 female), all were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 24 pairs of male faces, half were celebrities and half were unfamiliar faces from an in-house database. The face pairs were either two images of the same person or two different images of different people, half were upright and half were inverted (see figure 2.7). All the images were grey scaled and cropped around the faces, so they were presented on a white background and each face was approximately 16cm by 13cm subtending to a visual angle of 9.1 by 7.4 degrees, with a resolution of 72 pixels per inch.

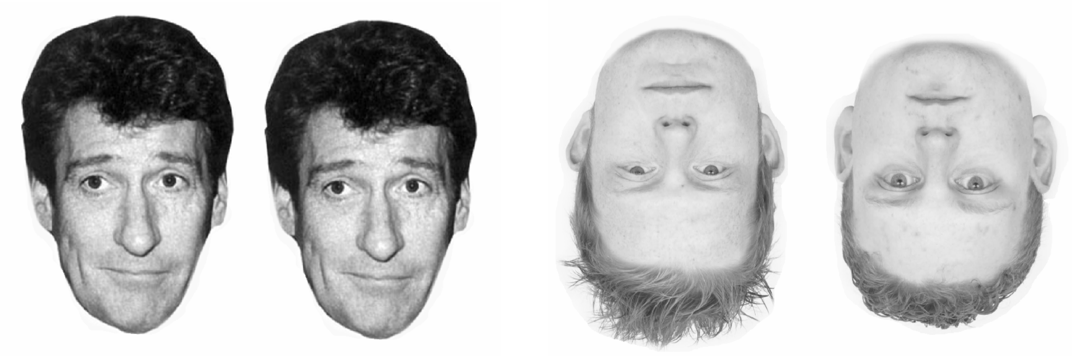


Figure 2. 7. Upright matched familiar and inverted mismatched unfamiliar stimuli.

Apparatus

The same apparatus and experimental set were used as for Experiment 1.

Design and Procedure

The experiment employed a 5-factor within subjects design. The first variable was face (leftmost/rightmost), the second was familiarity (familiar/unfamiliar), the third was match (match/mismatch), the fourth was orientation (upright/inverted), and the fifth features viewed (leftmost eye, rightmost eye, nose and mouth). The participants were instructed that they would be presented with pairs of faces, half of which would be upright and half upside down. The participants' task was verbally to indicate whether the pair was the 'same' or 'different', and each pair was presented for 5 seconds. The experimenter recorded the verbal responses given by the participants by inputting them into the E-Prime software whilst simultaneously recording the eye movements.

Analysis

The analysis procedure was the similar to Experiment 1, except the faces were divided into 4 areas of interest (AOI), the leftmost eye, rightmost eye, nose and mouth. In Experiment 1 the majority of gaze was to the internal features and other face-matching research has shown the majority of gaze is to the internal features of faces (Stacey et al. 2005), therefore it seemed logical to use only these features for the analysis. The gaze duration was also converted into proportions of gaze and for this was calculated for each trial, therefore the sum of gaze for both faces was equal to 1. In total 30 participants were tested, however 6 had to be discarded as the eye gaze data fell below capture criteria of 70 percent, leaving 24 participants for the analysis.

Results

Task performance

A 3-factor ANOVA; Familiarity (familiar/unfamiliar), Match (match/mismatch) and Orientation (upright/inverted) was performed on the response data. The results found that there were no significant effects or interactions, and the participants performed at ceiling levels with a mean accuracy of 97.5 %.

Proportion of gaze to features

Data were analysed by a 5-factor ANOVA: Face (leftmost/rightmost) x Familiarity (familiar/unfamiliar) x Match (same/different) x Orientation (upright/inverted) x Feature (leftmost eye, rightmost eye, nose, and mouth). The results from the analysis revealed a main effect of features ($F(3, 69) = 14.4$, $p < 0.01$) the rightmost eye (.16) and leftmost eye (.18) received significantly more gaze than the nose (.10) and they all received more gaze than the mouth (.07). There was also a significant 4-way interaction for familiarity, match, face and features ($F(3, 69) = 3.3$, $p < 0.05$), therefore the data was split into four sets and four separate 3-factor ANOVAs were performed for the familiar matched, familiar mismatched, unfamiliar matched and unfamiliar mismatched faces.

Familiar Matched Faces

Results from the 3-factor ANOVA performed for the familiar matched faces found a main effect of features ($F (3, 69) = 26.1$, $p < 0.01$); the left eye (.22) received more gaze than the right eye (.16), and both eyes received more gaze than the nose (.07) and mouth (.05). There were two significant 2-way interactions; for face and features ($F (3, 69) = 33.1$, $p < 0.01$) and orientation and face ($F (1, 23) = 7.7$, $p < 0.05$).

Figure 2.8 shows the mean proportion of gaze to the features of the leftmost and rightmost face. The face and features interaction found that some features received more gaze on the leftmost face, whereas others received more on the rightmost face. To determine if differences in the amount of gaze to the features were significant as a function of face side (right/left), a series of planned comparison t tests were performed. Results from the analyses found the rightmost eye received significantly more gaze on the leftmost face ($t (23) = 6.75$, $p < 0.01$), as did the mouth ($t (23) = 4.23$, $p < 0.01$). However the leftmost eye received significantly more gaze on the rightmost face ($t (23) = 5.90$, $p < 0.01$).

Two separate 1-factor ANOVAs were conducted, one for the leftmost face and one for the rightmost face. The analysis for the leftmost face found a main effect of features ($F (3, 69) = 13.6$, $p < 0.01$) and planned comparison t tests found the rightmost eye received more gaze than the leftmost eye ($t (23), = 4.5$, $p < 0.01$) and comparisons with all the other features produced larger t values. The analysis for the rightmost face also found a main effect of features ($F(3, 69) = 56.7$, $p < 0.01$) and planned comparison t tests found the leftmost eye received more gaze than the nose ($t(23) = 7.59$, $p < 0.01$) and comparisons with all the other features produced larger t values.

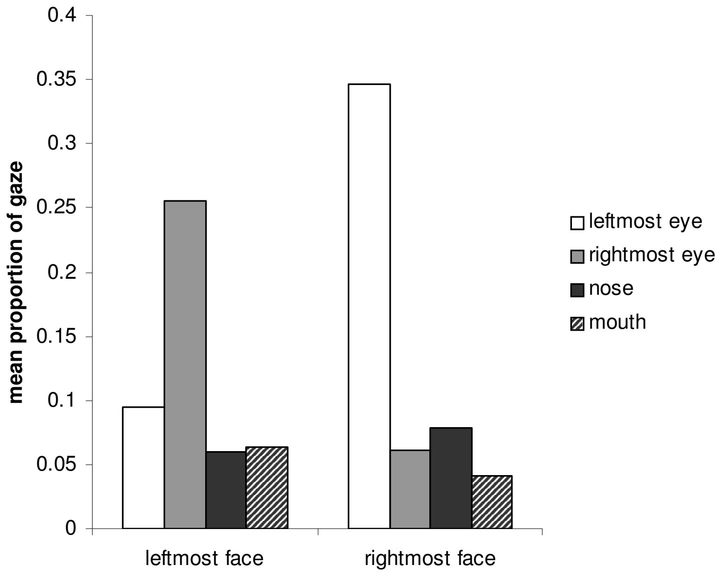


Figure 2. 8 Proportion of gaze to the features of the leftmost and rightmost familiar matched faces.

Figure 2.9 shows the mean proportion of gaze for the leftmost and rightmost upright and inverted faces. The orientation and face interaction found that inversion had different effects on the amount of gaze (per feature) for the leftmost face and rightmost face. Two t tests revealed the leftmost face received more gaze per feature when upright ($t(23) = -2.76$, $p < 0.05$), whereas the rightmost face received significantly less gaze when the faces were upright ($t(23) = 2.76$, $p < 0.05$).

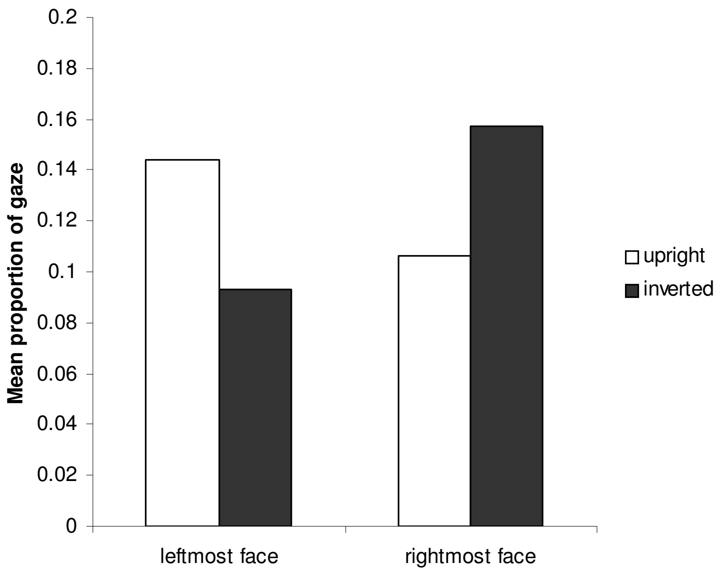


Figure 2. 9 Mean proportion of gaze to the leftmost and rightmost upright and inverted familiar matched faces.

Familiar Mismatched Faces

Results from the 3-factor ANOVA performed for the familiar mismatched faces found a main effect of features ($F (3, 69) = 26.1$, $p < 0.01$); the rightmost eye (.17) received more gaze than the nose (.10) and mouth (.09), but not the leftmost eye (.15). There were three significant 2-way interactions for; orientation and features ($F (3, 69) = 2.8$, $p < 0.05$), face and features ($F (3, 69) = 14.2$, $p < 0.01$) and orientation and face ($F (1, 23) = 8.7$, $p < 0.01$).

Figure 2.10 shows the mean proportion of gaze to features on the upright and inverted faces. The orientation and features interaction found that some features received more gaze on upright faces, whereas others received more gaze on inverted faces. A series of t tests found the only significant difference was for the mouth, which received more gaze when the faces were inverted ($t (23) = 4.76$, $p < 0.01$).

Two 1-factor ANOVAs were conducted on the features, one for the upright and one for the inverted faces. The analysis for the upright faces found a main effect of features ($F (3, 69) = 6.2, p < 0.01$) and planned comparisons revealed the leftmost eye ($t (23) = 3.59, p < 0.01$) and rightmost eye ($t (23) = 3.71, p < 0.01$) received more gaze than the mouth for upright faces. The rightmost eye also received significantly more gaze than the nose ($t (23) = 2.08, p < 0.05$). The analysis for the inverted faces found no significant main effect of features ($F < 1$).

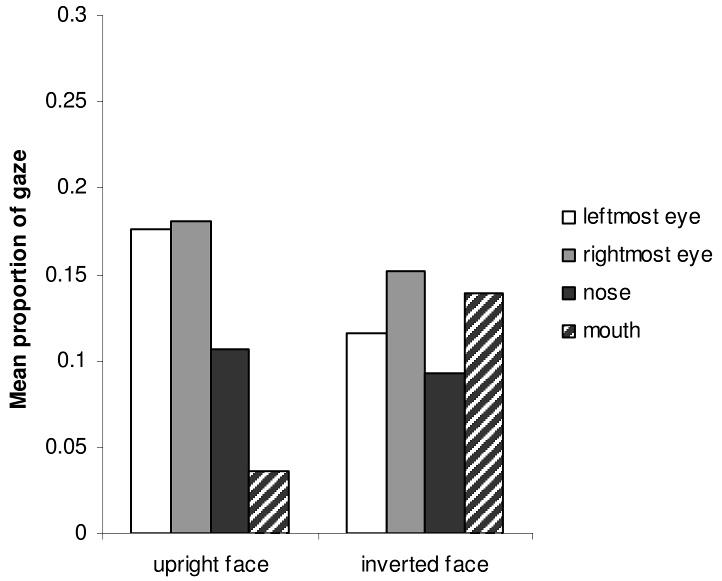


Figure 2.10 Proportion of gaze to the features upright and inverted familiar mismatched faces.

Figure 2.11 shows the mean proportion of gaze to features on the leftmost and rightmost faces. The face and features interaction for familiar mismatched faces discovered a similar pattern as was found for the familiar matched faces. A series of t tests revealed the rightmost eye received more gaze on the leftmost face ($t (23) = 3.26, p < 0.01$) and the opposite pattern was found for the leftmost eye, it received more gaze on the rightmost face ($t (23) = 5.68, p < 0.01$). Two 1-factor ANOVAs were conducted for the leftmost and rightmost faces. The analysis of the leftmost face found a main effect of features ($F (3, 69) = 10.5, p < 0.01$) and planned comparison t tests found the rightmost eye received the more gaze than the mouth (t (23) = 3.46, p < 0.01) and comparisons with the other features on the leftmost face, produced even higher t values. However, the analysis for the rightmost face did not find a significant main effect of features (F (3, 69) = 2.4, p = 0.074).

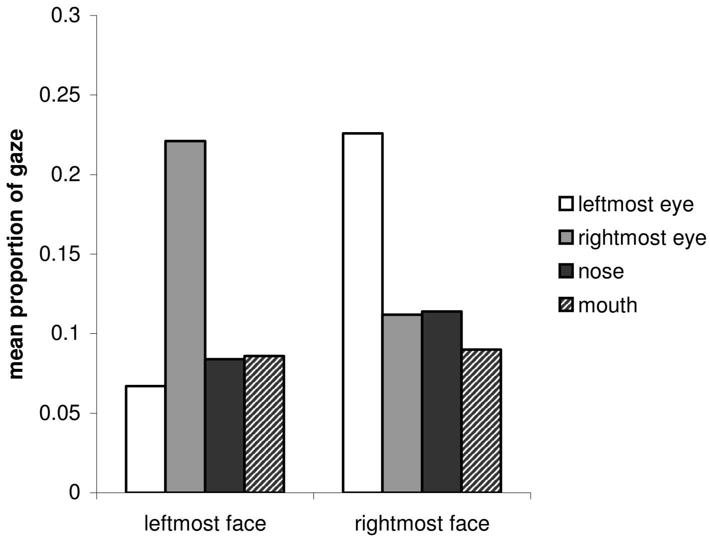


Figure 2. 11 Proportion of gaze to the features of the leftmost and rightmost familiar mismatched faces.

The orientation and face interaction discovered the same pattern as was found for the familiar matched faces. Two t tests were conducted which found the leftmost face received more gaze when upright (.14 vs. 09; t (23) = 2.94, p < 0.01) and the opposite pattern was found for the rightmost face, it received significantly less gaze when the faces were upright (.11 vs. .06; t (1, 23) = 2.94, p < 0.01).

Unfamiliar Matched Faces.

Results from the 3-factor ANOVA performed for the unfamiliar matched faces found a main effect of features, (F (3, 69) = 15.4, p < 0.01); the leftmost eye (.17) received more gaze than the nose (.1) and mouth (.07), whilst the rightmost eye (.16) received more gaze than the mouth. There were three 2-way interactions; orientation and features, ($F(3, 69) = 3.3$, $p < 0.05$), face and features ($F(3, 69) = 12.3$, $p < 0.01$) and orientation and face ($F(3, 69) = 6.5$, $p < 0.05$).

Figure 2.12 shows the mean proportion of gaze to features on the upright and inverted faces. The orientation and features interaction found that some features received more gaze when the faces were upright, whilst others received more when the faces were inverted. A series of t-tests found the nose ($t(23) = 2.20$, $p < 0.05$) and mouth ($t(23) = 2.41$, $p < 0.05$) received more gaze when the faces were inverted, but there was no differences in gaze to the eyes.

Two 1-factor ANOVAs were conducted, one for the upright faces and one for the inverted faces. The analysis for the upright faces found a main effects of features ($F(1, 23) = 8.31$, $p < 0.01$) and planned comparison t tests found the leftmost eye ($t(23) = 3.21$, $p < 0.01$), and rightmost eye ($t(23) = 3.03$, $p < 0.01$) both received more gaze than the nose, and comparisons with the mouth produced even higher t values. The 1-factor ANOVA with the inverted faces did not find any significant effect of features ($F < 1$).

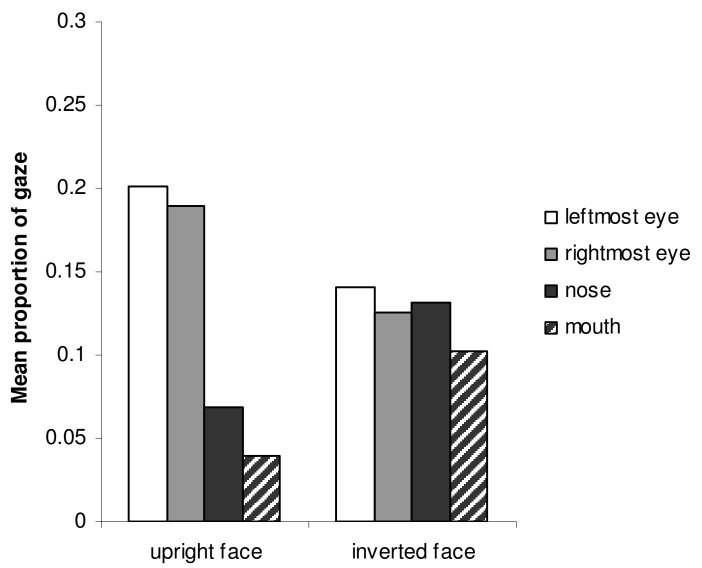


Figure 2. 12 Mean proportion of gaze to the feature of the upright and inverted unfamiliar matched faces.

Figure 2.13 shows the mean proportion of gaze to the rightmost and leftmost faces. The face and features interaction discovered a similar pattern as was found for the familiar faces. A series of t tests were conducted comparing the amount of gaze to the separate features as a function of face side (left/right). Results from the analyses found the leftmost eye received more gaze on the rightmost face ($t(23) = 3.91$, $p < 0.01$), whereas the rightmost eye received more gaze when on the leftmost face ($t(23) = 3.21$, $p < 0.01$). Face side had no significant effects on the amount of gaze to the nose and mouth.

Two 1-factor ANOVAs were conducted, one for the features on the leftmost face and one for the feature on the rightmost face. The analysis for the leftmost face found a main effect of features ($F(3, 69) = 9.9$, $p < 0.01$), and planned comparison t-tests found the rightmost eye received more gaze than the nose ($t(23) = 4.18$, $p < 0.01$) and comparisons with the other features produced even higher t values. The analysis for the rightmost face also found a main effect of features ($F(3, 69) = 10.6$, $p < 0.01$) and the planned comparisons found the leftmost eye received more gaze than the nose ($t(23) = 3.79$, $p < 0.01$) and comparisons with the other features produced even higher t values.

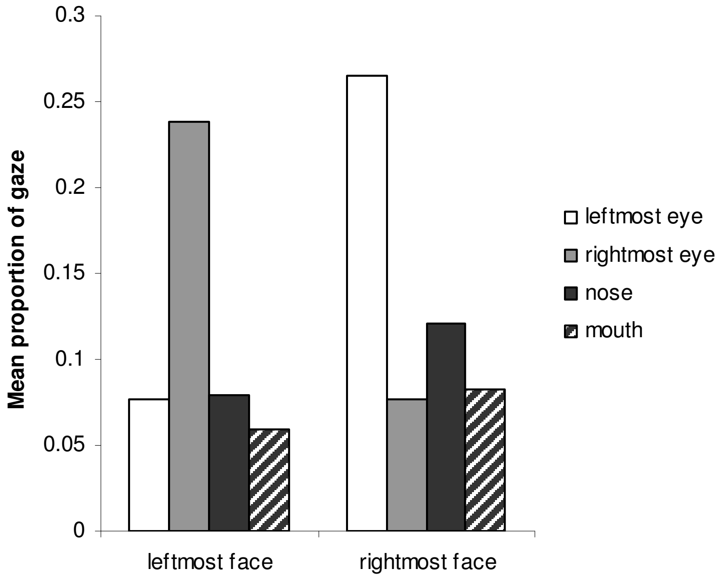


Figure 2. 13 Mean proportion of gaze to the features of the leftmost and rightmost of unfamiliar mismatched faces

The orientation and face interaction discovered the same pattern was found for the familiar faces. Analyses using t-tests found the leftmost face received significantly more gaze when upright (.13 vs. .09; t (23) = 2.53, p < 0.05), whereas the rightmost face received significantly less when upright (.12 vs. .16; t (23) = 2.53, p < 0.05).

Unfamiliar Mismatched faces

Results from the 3-factor ANOVA performed for the unfamiliar matched faces found a main effect of features, (F (3, 69) = 7.9, p < 0.01); the leftmost eye (.17), rightmost eye (.15) and nose (.14) all received more gaze than the mouth (.05). There were three 2-way interactions; orientation and features, (F (3, 69) = 23.5, p < 0.01), face and features (F (3, 69) = 2.9, p < 0.05) and orientation and face (F (1, 23) = 14.5, p < 0.05).

Figure 2.14 shows the mean proportion of gaze to features of the upright and inverted faces. The orientation and features interaction found that some features received more gaze when the faces were upright, whereas others received more when they were inverted. A series of t-tests found the rightmost eye ($t(23) = 2.73$, $p < 0.05$), received more gaze when the faces were upright, whilst mouth ($t(23) = 2.82$, $p < 0.01$) received more gaze when the faces were inverted.

Two 1-factor ANOVAs were conducted looking at the gaze to features on the upright and inverted faces. For the upright faces there was a main effect of features ($F(3, 69) = 9.2$, $p < 0.01$) and planned comparisons found the rightmost eye received more gaze than the nose ($t(23) = 2.5$, $p < 0.01$) and the mouth ($t(23) = 4.6$, $p < 0.01$), and leftmost eye received more gaze than the mouth ($t(23) = 4.08$, $p < 0.01$). The analysis for the inverted faces did not produce a significant main effect of features ($F < 1$).

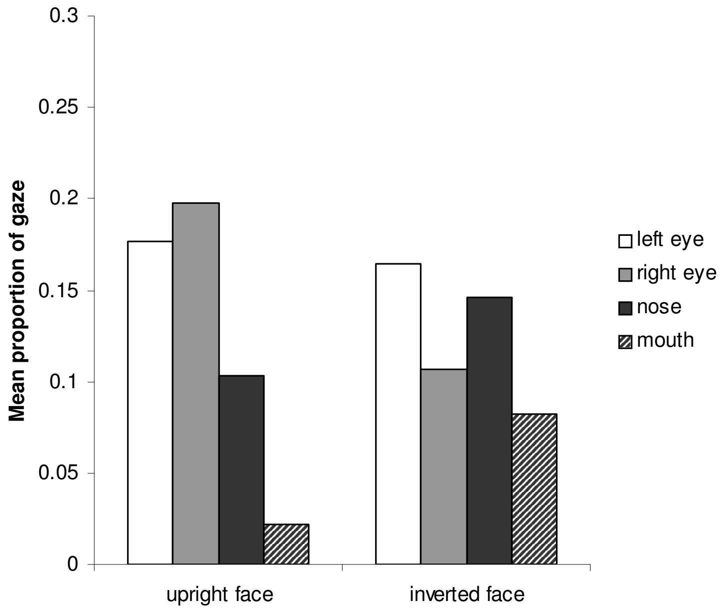


Figure 2.14 Mean proportion of gaze to the features on the upright and inverted unfamiliar mismatched faces

Figure 2.15 shows the mean proportion of gaze to the features of the leftmost and rightmost faces. The face and features interaction discovered a similar pattern as was found for the familiar faces and unfamiliar matched faces. T-tests found the rightmost eye received more gaze on the leftmost face ($t(23) = 5.08$, $p < 0.01$), whereas the leftmost eye ($t(23) = 5.42$, $p < 0.01$) received more gaze on the rightmost face.

Two 1-factor ANOVAs were conducted; one for the leftmost face and one for the rightmost face. The analysis for the leftmost face found a main effect of features ($F(1, 23) = 12.9$, $p < 0.01$) and planned comparison t-tests found, the rightmost eye received more gaze than the nose ($t(23) = 4.34$, $p < 0.01$) and comparisons with other features produced higher t values. The analysis for the rightmost face also found a main effect of features ($F(1, 23) = 15.4$, $p < 0.01$), and the planned comparisons found the leftmost eye received more gaze than the nose ($t(23) = 3.05$, $p < 0.01$) and all the comparisons with the other features produced higher t values.

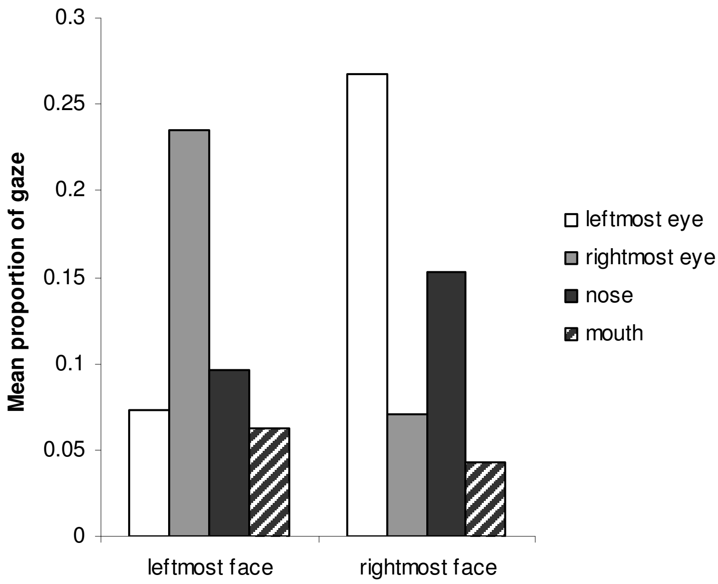


Figure 2.15 Mean proportion of gaze to the features of the leftmost and rightmost of unfamiliar mismatched faces

The orientation and face interaction discovered the same pattern as was found for the familiar faces and the unfamiliar matched faces. T-tests found the leftmost face received more gaze when upright (.15 vs. 09; $t(23) = 3.8$, $p < 0.01$) and the rightmost face received significantly less gaze when upright (.10 vs. .16; $t(23) = 3.8$, $p < 0.01$).

Results summary

Although there was a 4-way interaction for familiarity, match, face and features the patterns across familiarity (familiar/unfamiliar) and match (match/mismatch) were very similar. There was a main effect of features across all conditions, which found the eyes were looked at more than any other features, except for the unfamiliar mismatched faces where the nose received similar amounts of gaze.

There were 2-way interactions for face and features and orientation and face which were significant for both levels of familiarity and match. There was also an orientation and features interaction, which was significant for the familiar mismatched and unfamiliar faces, but not the familiar matched faces.

Effect of inversion

Across familiarity and face match the leftmost face received more gaze per feature when upright, whereas the rightmost face received more gaze per feature when inverted and this was significant across familiarity and match. Another consistent pattern that emerged when the faces were inverted was the mouth received more gaze, and this was significant for the familiar mismatched and all the unfamiliar faces. The nose received more gaze when the faces were inverted, but this was only significant for matched unfamiliar faces. The rightmost eye received more gaze when the faces were upright, but this was only significant for the unfamiliar mismatched faces.

When the faces were upright the eyes received more gaze than the mouth for the familiar mismatched and unfamiliar faces and more gaze than the nose for the unfamiliar matched faces. The rightmost eye also received more gaze than the nose for the unfamiliar mismatched faces. When the faces were inverted there were no significant differences in the amount of gaze the features received and all obtained similar amounts.

Effect of face side (left or right of the screen)

The face and features interactions revealed that there was a bias to look at the rightmost eye on the leftmost face and the leftmost eye on the rightmost face and this was regardless of familiarity and match. These features received more gaze than the other features on the face across the conditions. The face location appeared to have no effect on the amount of time spent looking at the nose and mouth.

Discussion

The eye gaze results found the upright faces were looked at differently to those that were inverted. There was a bias for the eyes on the upright faces and they received more gaze than the other features for the unfamiliar faces. Whereas when the faces were inverted, the mouth received more gaze for mismatched familiar and unfamiliar faces and the nose received more gaze for unfamiliar matched faces. This seems to show that overall there was a bias towards the top half of space and that viewing was increased to whichever features happened to be in the half. This bias towards the top half of faces and face-like objects has been found in previous research that has used eye movements (Barton et al., 2006) and other studies (Caldara, et al., 2006; Turati, 2004; Turati, et al., 2002).

Previous research has found differences in how upright and inverted faces are viewed Gally et al. (2006) found that infants looked more at the nose and mouth of upright faces, and more at the external features of inverted faces. Whereas Barton et al. (2006) found that viewers looked more at the features in the top half of the face when the faces were upright (eyes and forehead) and more at the features that usually reside in the lower half of the face (chin and mouth) when the faces were inverted. Differences in the viewing patterns between these two studies could be due to the participants used, Gally et al. used infants, whereas as Barton et al. used adults. There is some evidence that children process faces more featurally than holistically (Diamond & Carey, 1977; Freire & Lee, 2001; Mondloch, Le Grand, & Maurer, 2002) and use the external features more than the internal features (Campbell & Tuck, 1995; Campbell, Walker, & Baron- Cohen, 1995). However not all research has reported differences in viewing patterns for upright and inverted faces, some research found no differences in the way upright and inverted faces were viewed (Henderson et al., 2001).

Overall the eyes appeared to be the most important features for face-matching when the faces were upright and they were looked at significantly more than the nose and mouth, this has also been found by other studies using single faces (Henderson et al, 2001; Henderson et al., 2005; Janik et al, 1978). Although the eyes were important for face-matching, viewers did not look at the same eyes on both faces, they looked more at the rightmost eye on the leftmost face and the leftmost eye on the rightmost face. It therefore seems that viewers were not making a feature-by-feature comparison as suggested by Walker-Smith, Gale and Findlay (1978), but were looking at the two eyes that were centre of the screen and scanning between them. An eye-movement study using single faces reported that of all the triplet sequences of fixations viewers could make, the most frequent was left eye-right eye-left eye and vice versa (Groner, Walder, & Groner, 1984). Could viewers be pairing the inner eyes of the faces as they would when viewing a single face?

An alternative explanation for viewers using only the ‘inner’ eyes of the two faces is that the task may have been so easy for upright faces; viewers did not need to look at all the features on each face to make a matching decision. However, when the faces were inverted the task became more difficult, and more features had to be inspected. Another explanation is that when the faces were upright, viewers were using more holistic processing and therefore only needed to look at the inner eyes to build up a holistic representation of the faces. Then when the faces were inverted viewers had to use more of a featural approach and had to look at all the internal features equally.

There were also differences in the viewing patterns for face on the left of the screen, and on the right of the screen. The leftmost face received more gaze per feature when upright, whereas the rightmost face received more gaze per feature when inverted and this was regardless of familiarity, or if the faces matched. There is left visual field bias for faces that has been well documented (Burt & Perrett, 1997; Butler et al., 2005; David, 1989; Mertens, Siegmund, & Grusser, 1993), and this could explain why the upright faces received more gaze when on the left of the screen, however the right bias for the inverted faces, still poses some interesting questions.

The task performance revealed the experiment was very easy for the participants, this could be a result of the same images being used for the same person and the long stimulus presentation of 5 seconds. Previous research has shown that when the same images are used for learning faces and then for a recognition test, performance is much higher (90%) than when different images are used from study to test phases (60%) (Bruce, 1982). This seems to suggest when the same images are used for faces then participants may be carrying out an image matching process, rather than determining if the faces have the same identity. To determine how viewers carry out a face-matching task and increase the ecological validity of the experiment two different images of the same person should be used.

Experiment 3

In this experiment, the aim was to establish the scanning strategy used by subjects when asked to match two faces using different images of the same person or two different people, as this has more reflection on face matching in real life situations. I was interested in whether eye movements suggest a feature-by-feature comparison, such as that observed by Walker-Smith et al (1978), or whether subjects use a more global approach, perhaps looking into regions of the face which allow a more holistic impression, and perhaps not fixating the same features in each face.

As a comparison to normal face matching, I also examined eye movements when subjects were asked to match inverted faces. This was to determine whether the different viewing patterns that had been observed in Experiment 2 for the upright and inverted faces could be replicated.

Method

Participants

24 participants took part in the study (17 female). All were students or members of staff at the Department of Psychology, University of Glasgow, and were paid for their time.

Stimuli

The stimuli consisted of 60 pairs of male faces, half were celebrities and half unfamiliar people. The images of the familiar faces were obtained through Internet searches and the unfamiliar faces were high quality images taken from an in-house database. Half were presented as upright pairs and half were inverted. The face pairs were either different identities, or two different images of the same person (taken with different cameras, see figure 2.16). All images were presented in grey scale, cropped around the face, and shown against a white background. Each face was approximately 12 cm by 9 cm, subtending a visual angle of 6.8 by 5.1 degrees. The face pairs were placed 5 cm apart, this distance was chosen as previous research has shown that face that are placed to close to one another may impair face matching (Megreya & Burton, 2006). The stimulus presentation time was reduced to 2 seconds, as responses from Experiment 2 revealed that participants were able to respond within this time period and did not need 5 seconds to make an accurate decision.

Figure 2. 16 Upright mismatched unfamiliar and inverted matched unfamiliar.

Apparatus

The participants' eye movements were measured using the head-mounted SR Research EyeLink System; data was recorded from only the right eye. The stimuli were presented on 17 inch screen monitor using Experiment Builder, SR Research.

Design and Procedure

The experiment employed a 5-factor within subjects design. The first variable was face (leftmost/rightmost), the second was familiarity (familiar/unfamiliar), the third was match (match/mismatch), the fourth was orientation (upright/inverted), and the fifth features viewed (leftmost eye, rightmost eye, nose and mouth). Participants were instructed that they would be presented with pairs of familiar and unfamiliar faces, half of which would be upright and half upside down, and their task was to indicate with a button response whether the faces were the 'same' person, or two 'different' people.

Analysis

The analysis procedure was same as the previous two experiments except the eye tracking data were analysed using Eyelink Dataviewer 1.7, SR Research. There was also an additional measure along with the proportion of gaze to features, and that was the location of the first fixation (i.e. rightmost or leftmost face).

Results

Task performance

A 3-factor ANOVA: Familiarity (familiar/unfamiliar) x Match (same/different) x Orientation (upright/inverted) was performed on the response data. It revealed that there was a main effect of familiarity, familiar faces received more correct responses than unfamiliar faces (85 vs 78 %; $F (1, 23) = 142.9$, $p < 0.01$). There was also a main effect of orientation, upright faces received more correct responses than inverted faces (91 vs. 71 %; $F (1, 23) = 21.3$, $p < 0.01$) and a two-way interaction between familiarity and match ($F (1, 23) = 21.2$, $p < 0.01$). The simple main effects for the interaction revealed that when the faces matched there was no significant differences in correct responses for the familiar and unfamiliar faces (82 vs 83 %; $F < 1$), however when the faces mismatched, the familiar faces received more correct responses than the unfamiliar faces (88 vs 72 %; $F (1, 23) = 49.9$, $p < 0.01$).

Location of first fixation

The location of the first fixation for each trial was examined to see if viewers looked initially at the rightmost or leftmost face. A paired sample t-test found that viewers made significantly more first fixations to the leftmost face, than the rightmost face (82.8 % vs. 17.2 %; $t (23) = 7.06$, $p < 0.01$). This was an extremely strong effect and will be explored further in chapter 5 where a full analysis will be carried out.

Proportion of gaze to features

Data were analysed by a 5-factor ANOVA: Face (rightmost/leftmost) x Familiarity (familiar/unfamiliar) x Match (same/different) x Orientation (upright/inverted) x Feature (rightmost eye, leftmost eye, nose and mouth). There was a main effect of features ($F(3, 69) = 12.95$, $p < 0.01$) and the leftmost eye on each face (mean .21) received proportionately more eye gaze than the rightmost eye (.13), nose (.12) and all these features received more gaze than the mouth (.04). There were two significant 4-way interactions: familiarity, orientation, face and features, ($F(3, 69) = 3.3$, $p < 0.05$), and face match, orientation, face and features, ($F(3, 69) = 4.2$, $p < 0.01$). For convenience, the data was split into four separate sets; familiar matched, familiar mismatched, unfamiliar matched and unfamiliar mismatched faces and separate 3-factor ANOVAs were carried out on each set.

Familiar Matched Faces

Results from the 3-factor ANOVA performed on the data for the familiar matched faces found a main effect of features ($F(3, 69) = 13.3$, $p < 0.01$), the left eye (.22) received more gaze than the right eye (.13), and nose (.12) and all received more than the mouth (.04). There were three significant 2-way interactions; for orientation and features ($F(3, 69) = 19.4$, $p < 0.01$), face and features ($F(3, 69) = 32.7$, $p < 0.01$) and orientation and face ($F(1, 23) = 13.8$, $p < 0.01$).

Figure 2.17 shows the mean proportion of gaze to features of the upright and inverted faces. The orientation and features interaction found that some features received more gaze when the faces were upright, whereas others received more gaze when the faces were inverted (see figure 2.16). A series of t-tests were carried out on the features and found the leftmost eye ($t(23) = 4.48$, $p < 0.01$) and rightmost eye ($t(23) = 4.82$ $p < 0.01$) received significantly more gaze when the faces were upright. Whereas the opposite pattern was found for the nose ($t(23) = 4.61$, $p < 0.01$) and mouth ($t(23) = 1.91$, $p < 0.01$), which received more gaze when the faces were inverted.

Two 1-factor ANOVAs were conducted, one for the upright faces and one for the inverted faces. The analysis for the upright faces found a main effect of features ($F(3, 69) = 30.8$, $p < 0.01$) and planned comparisons found the leftmost eye received more gaze than the rightmost eye ($t(69) = 3.76$, $p < 0.01$) and comparisons with the other features produced even higher t values. The rightmost eye received more gaze than the nose ($t(69) = 3.72$, $p < 0.01$) and comparisons with the mouth produced even higher t values. The analysis for the inverted faces found a main effect for features ($F(3, 69) = 5.9$, $p < 0.01$) and planned comparison t-tests found, the leftmost eye ($t(69) = 2.47$, $p < 0.05$) and nose ($t(69) = 2.22$, $p < 0.05$) both received more gaze than the rightmost eye, and comparisons with the mouth produced even higher t values.

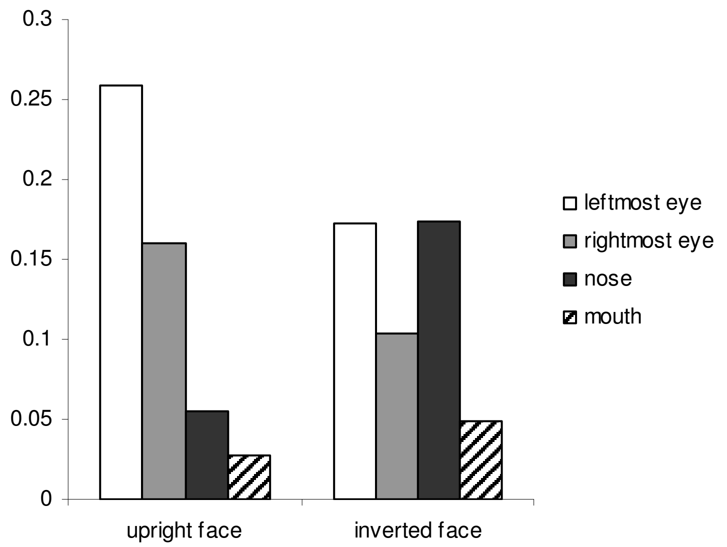


Figure 2.17 The mean proportion of gaze to features for upright and inverted familiar matched faces.

Figure 2.18 shows the mean proportion of gaze to features on the leftmost and rightmost faces. The face and features interaction found that some features received more gaze on the leftmost faces, whereas other features received more gaze on the rightmost faces. A series of t-tests revealed that the rightmost eye received more gaze on the leftmost face than on the rightmost face, ($t(23) = 6.91$, $p < 0.01$), whereas the opposite pattern was found for the leftmost eye, it received more gaze on the rightmost face, ($t(23) = 5.17$, $p < 0.01$). Face location had no significant effects upon the nose and mouth ($F < 1$).

Two 1-factor ANOVAs were conducted, one for the leftmost face and one for the rightmost face. Analyses for the leftmost face found a main effect of features ($F(3, 69) = 8.3$, $p < 0.01$) and planned comparisons found the leftmost eye ($t(69) = 4.40$, $p < 0.01$) and rightmost eye ($t(69) = 4.37$, $p < 0.01$) received more gaze than the mouth.

The analyses for the rightmost face found a main effect of features ($F(3, 69) = 22.463$, $p < 0.01$) and planned comparisons revealed the leftmost eye received significantly more gaze than the nose, ($t(69) = 5.33$, $p < 0.01$, and when compared to the other features it produced higher t values. The nose received more gaze than the mouth ($t(69) = 2.49$, $p < 0.05$).

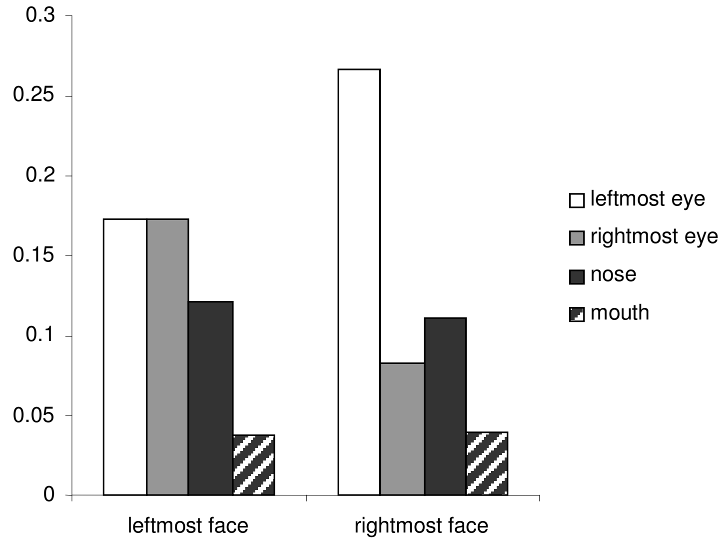


Figure 2.18 The mean proportions of gaze to features for the leftmost and rightmost matched familiar faces.

Figure 2.19 shows the mean proportion of gaze per feature for the upright and inverted leftmost and rightmost faces. The orientation and face interaction found that there were differences in proportions of gaze per feature as a function of face side and orientation. T-tests revealed the leftmost face received more gaze when it upright ($t(23) = 2.76$, $p < 0.05$), whilst the opposite pattern was found for the rightmost face, it received significantly less gaze when the faces were upright ($t(23) = 2.76$, $p < 0.05$).

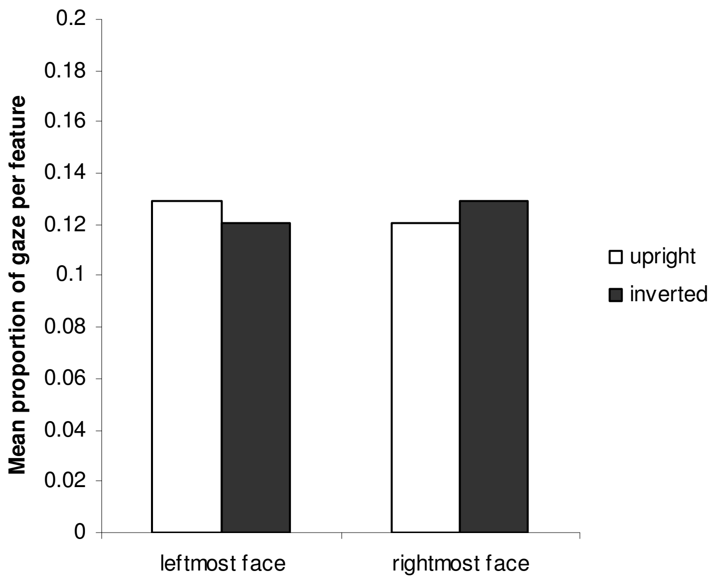


Figure 2.19 Mean proportion of gaze per feature to the leftmost and rightmost upright and inverted familiar matched faces.

Familiar Mismatched Faces

Results from the 3-factor ANOVA performed on the data for the familiar mismatched faces found a main effect of features ($F(3, 69) = 13.6$, $p < 0.01$), the leftmost eye (.21) received more gaze than the rightmost eye (.14) and nose (.11), and all the features received more gaze than the mouth (.04). There were three significant 2-way interactions; for orientation and features ($F(3, 69) = 15.7$, $p < 0.01$), face and features ($F(3, 69) = 27.3$, $p < 0.01$) and orientation and face ($F(1, 23) = 22.0$, $p < 0.01$).

Figure 2.20 shows the mean proportion of gaze to the features on the upright and inverted faces. The orientation and features interaction found that some faces received more gaze when the faces were upright whereas other features received more gaze when the faces were inverted. A series of t-tests revealed the leftmost eye ($t(23) = 6.39$, $p < 0.01$) and rightmost eye ($t(23) = 4.18$, $p < 0.01$) received more gaze when the faces were upright, however the nose ($t(23) = 5.38$, $p < 0.01$) and mouth ($t(23) = 2.22$, $p < 0.05$), received more gaze when the faces were inverted.

Two 1-factor ANOVAs were conducted, one for the upright faces and one for the inverted faces. The analysis for the upright faces found a main effect of features ($F(3, 69) = 37.7$, $p < 0.01$) and planned comparisons found the leftmost eye received more gaze than the rightmost eye ($t(23) = 3.96$, $p < 0.01$) and comparisons with the other features produced higher t values. The rightmost eye received more gaze than the nose ($t(23) = 4.5$, $p < 0.01$) and mouth ($t(23) = 5.63$, $p < 0.01$). The analysis for the inverted faces found a main effect of features ($F (3, 69) = 5.3, p < 0.01$) and planned comparison t-tests revealed the leftmost eye ($t (23) = 3.31, p < 0.01$) and nose ($t (23) = 3.91, p < 0.01$) both received more gaze than the mouth.

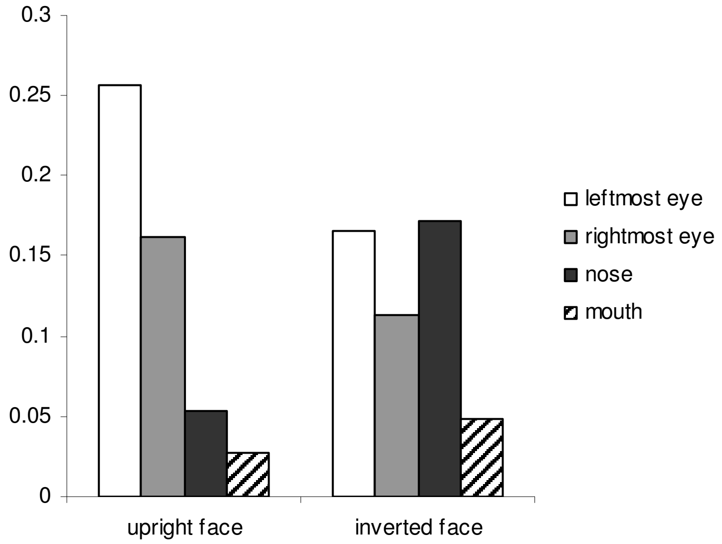


Figure 2. 20 Proportion of gaze to the features upright and inverted familiar mismatched faces.

Figure 2.21 shows the mean proportion of gaze to features on the leftmost and rightmost faces. The face and features interaction for familiar mismatched faces found some features received more gaze on the leftmost face, whereas others received more on the rightmost face. A series of t-tests revealed the rightmost eye received more gaze on the leftmost face ($t (23) = 5.31, p < 0.01$), and the opposite pattern was found for the leftmost eye and it received more gaze on the rightmost face ($t (23) = 3.4, p < 0.01$).

Two 1-factor ANOVAs were conducted, one for the leftmost face and one for the rightmost face. Analyses for the leftmost face found a main effect of features ($F (3, 69) = 9.9, p < 0.01$) and planned comparisons revealed the leftmost eye received more gaze than the nose ($t (69) = 2.08, p < 0.05$) and comparisons with the mouth produced an even higher t value. The rightmost eye also received more gaze than the mouth (t (69) = 4.67, p < 0.01). The analyses for the rightmost face found a main effect of features (F (3, 69) = 17.3, p < 0.01) and planned comparisons revealed the leftmost eye received more gaze than the nose (t (69) = 4.54, p < 0.01) and comparisons with the other features produced higher t values. The nose (t (69) = 2.42, p < 0.05) and rightmost eye (t (69) = 2.11, p < 0.01) received more gaze than the mouth.

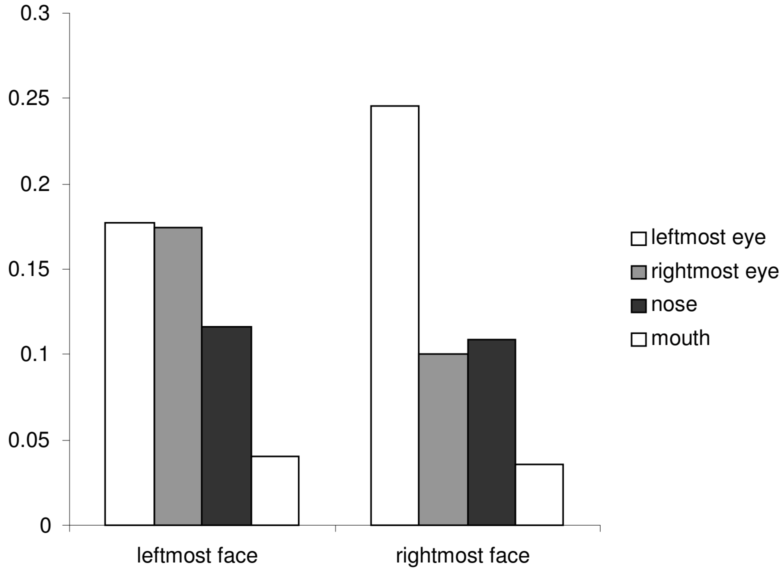


Figure 2.21 Proportion of gaze to the features of the leftmost and rightmost familiar mismatched faces.

The orientation and face interaction found the same pattern as for the familiar matched faces. T-tests revealed the leftmost face received more gaze when upright (.13 vs. .12; t (1, 23) = 4.8, p < 0.01) and the opposite pattern was found for the rightmost face, it received less gaze when the faces were upright (.11 vs. .13; t (23) = 4.8, p < 0.01).

Unfamiliar matched faces

The results from the 3-factor ANOVA performed on the data for the unfamiliar faces revealed a main effect of features, (F (3, 69) = 12.1, p < 0.01), and 3-way interaction for orientation, face and features, (F (3, 69) = 4.2, p < 0.01). The main effect of features revealed the leftmost eye (.21) received more gaze than the rightmost eye (.12), and nose (.13), and all these features received more gaze than the mouth (0.04).

Figure 2.23 shows the mean proportion of gaze to features on the upright leftmost and rightmost faces and figure 2.24 shows the mean proportion of gaze to features for the inverted leftmost and rightmost faces. To analyse the orientation, face and features interaction the data was split and two 2-factor ANOVAs were conducted, one for the upright faces and one for the inverted faces.

The analysis for the upright faces found a main effect of features ($F(23) = 21.7$, $p < 0.01$) and a significant interaction for face and features ($F(32) = 26.0$, $p < 0.01$). The analysis for the simple main effects for the interaction found the rightmost eye received more gaze on the leftmost face ($t(23) = 91.4$, $p < 0.01$) and the opposite pattern was found for the leftmost eye and it received more gaze on the rightmost face ($t(23) = 102.8$, $p < 0.01$). Planned comparisons for features on the leftmost face revealed the leftmost eye ($t(23) = 2.75$, $p < 0.01$) and rightmost eye ($t(23) = 3.9$, $p < 0.01$) received more gaze than the nose and comparisons with the mouth produced higher t values. For the rightmost face, the leftmost eye received more gaze than the rightmost eye ($t(23) = 4.78$, $p < 0.01$) and comparisons with the other features produced higher t values.

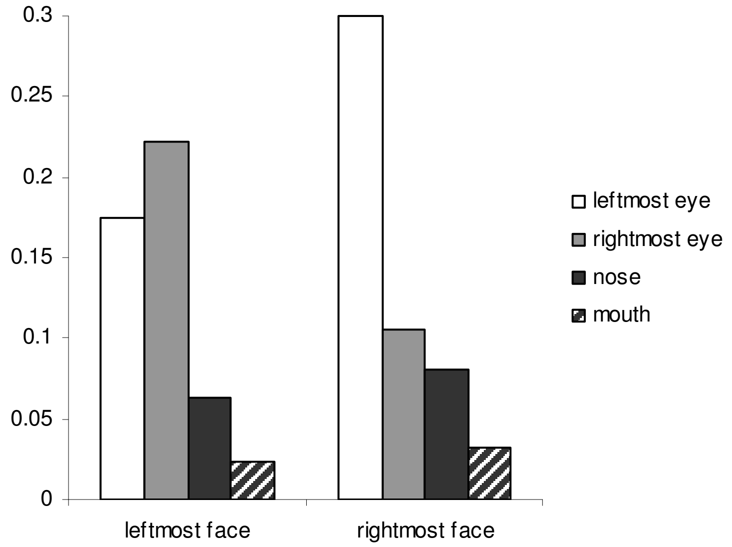


Figure 2.23 Mean proportion of gaze to features for upright unfamiliar faces matched faces.

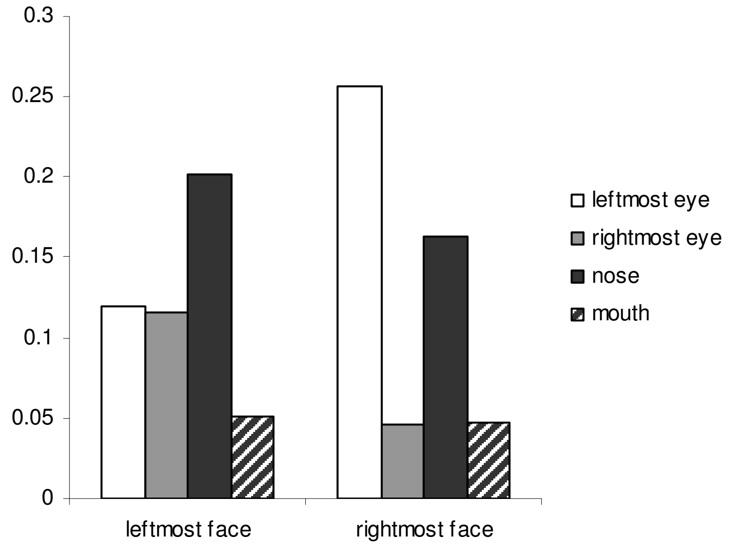


Figure 2.24 Mean proportion of gaze to features for inverted unfamiliar faces matched faces.

The analysis for the inverted faces found a main effect of features ($F(3, 69) = 8.1$, $p < 0.01$) and a significant interaction for face and features ($F(3, 69) = 27.1$, $p < 0.01$). The analysis of the simple main effects for the interaction revealed the rightmost eye received significantly more gaze when it was on the leftmost face ($F(1, 23) = 30.9$, $p < 0.01$), the same pattern was found for the nose ($F(1, 23) = 9.7$, $p < 0.01$). The opposite pattern was found for the leftmost eye, it received significantly more gaze when it was on the rightmost face ($F(1, 23) = 118.5$, $p < 0.01$). Planned comparisons for features on the leftmost face found the nose received more gaze than the mouth ($t(23) = 3.07$, $p < 0.01$) and there were no other significant differences in gaze to the features. Whereas for the rightmost face, the leftmost eye received more gaze than the rightmost eye ($t(23) = 4.27$, $p < 0.01$) and the mouth (t (4.27, $p < 0.01$), same pattern was also found for the nose.

A series of t-tests were performed to see the effect of inversion on features on the leftmost and rightmost faces, they revealed that the leftmost eye received more gaze in the upright orientation and this was significant for the leftmost face ($t(23) = 2.4$, $p < 0.05$) and marginally significant for the rightmost face ($t(23) = 1.99$, $p = 0.059$). A similar pattern was found for the rightmost eye and it received more gaze on upright face which was significant for the leftmost face ($t(23) = 6.84$, $p < 0.01$) and the rightmost face ($t(23) = 4.51$, $p < 0.01$). However the opposite pattern was found for the nose and it received more gaze when the faces were inverted and this was significant for the leftmost face ($t(23) = 5.05$, $p < 0.01$) and the rightmost face ($t(23) = 3.66$, $p < 0.01$). The mouth also received more gaze when the faces were inverted but this was only significant for the leftmost face ($t(23) = 2.53$, $p < 0.05$).

Unfamiliar Mismatched Faces

Results from the 3-factor ANOVA performed on the data for the familiar mismatched faces found a main effect of features ($F(3, 69) = 10.7$, $p < 0.01$), the leftmost eye (.21) received more gaze than the rightmost eye (.12), nose (.13) and all the features received more gaze than the mouth (.05). There were two significant 2-way interactions; orientation and features ($F(3, 69) = 28.3$, $p < 0.01$) and face and features ($F(3, 69) = 28.7$, $p < 0.01$).

Figure 2.25 shows the mean proportion of gaze to features on the upright and inverted faces. The orientation and features interaction found a similar pattern to that found for the familiar matched faces. A series of t-tests found the leftmost eye ($t(23) = 4.17$, $p < 0.01$) and rightmost eye ($t(23) = 6.60$, $p < 0.01$) received more gaze on upright faces. Whereas the nose received more gaze on inverted faces ($t(23) = 6.37$, $p < 0.01$). Two separate 1-factor ANOVAs were conducted, one for the upright faces and one for the inverted faces. The analyses for the upright faces found a main effect of features ($F(3, 69) = 22.2$, $p < 0.01$) and planned comparisons found the leftmost eye received more gaze than the rightmost eye ($t(69) = 2.69$, $p < 0.05$) and comparisons with other features produced higher t values. The rightmost eye received more gaze than the nose ($t(69) = 3.46$, $p < 0.01$) and the comparison with the mouth produced a higher t value.

The analyses for the inverted faces found a main effect of features ($F(3, 69) = 7.7$, $p < 0.01$) and planned comparison t-tests found the leftmost eye ($t(23) = 2.66$, $p < 0.05$), $p < 0.01$) and nose ($t(69) = 3.16$, $p < 0.01$) received more gaze than the rightmost eye and comparisons with the mouth produced higher t values.

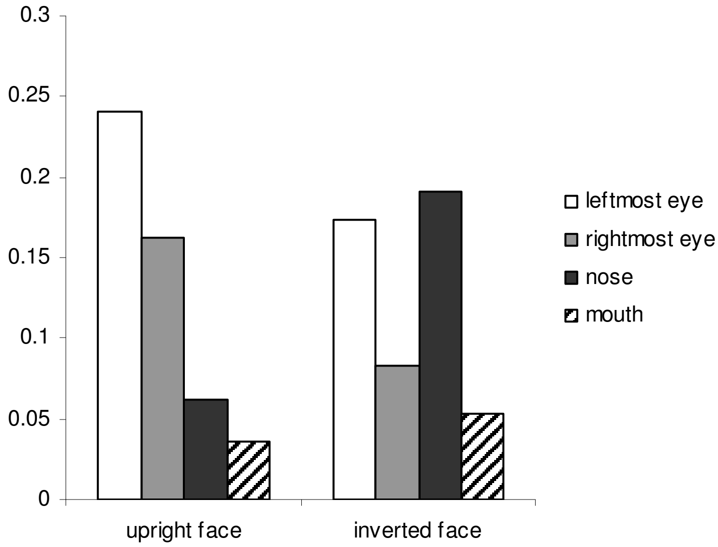
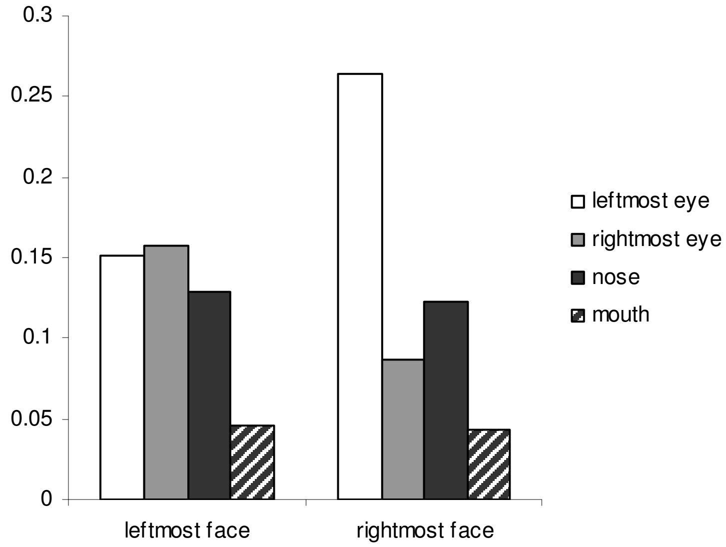


Figure 2.25 Mean proportion of gaze to features of upright and inverted unfamiliar mismatched faces.

Figure 2.26 shows the mean proportion of gaze to the features on the leftmost and rightmost faces. The face and features interaction for unfamiliar mismatched faces found some features received more gaze on the leftmost face, whereas others received more on the rightmost face. T-tests found the rightmost eye received more gaze on the leftmost face ($t(23) = 4.83$, $p < 0.01$), and the opposite pattern was found for the leftmost eye and it received more gaze on the rightmost face ($t(23) = 5.77$, $p < 0.01$).

Two ANOVAs were conducted, one for the leftmost faces and one for the rightmost faces. The analyses for the leftmost face found a main effect of features ($F(3, 69) = 5.8$, $p < 0.01$) and planned comparisons revealed the leftmost eye ($t(23) = 3.47$, $p < 0.01$), rightmost eye ($t(23) = 3.71$, $p < 0.01$) and the nose ($t(23) = 2.78$, $p < 0.01$) received more gaze than the mouth. The analyses for the rightmost face also found a main effect of features ($F(3, 69) = 19.4$, $p < 0.01$) and planned comparisons found the leftmost eye received more gaze than the nose ($t(23) = 3.71$, $p < 0.01$) and comparisons with the other features produced higher t values. The nose received more gaze than the mouth ($t(23) = 2.78$, $p < 0.01$).



2.26 Mean proportion of gaze to features of unfamiliar mismatched faces

Results summary

The first fixation analysis showed that there was a strong leftward bias for the location of the first fixation and the over 80 percent of the time viewers looked at the face on the left first. There was a main effect of features which found a bias for the leftmost eye and it received more gaze than the other features regardless of familiarity and match, whilst the eyes and nose were looked at more than the mouth.

Although there were some differences as a function of familiarity and match, overall the patterns were very similar. The familiar (matched and mismatched) and unfamiliar mismatched all showed significant 2-way interactions for orientation and features and face and features, and the familiar faces also had 2-way interactions for orientation and face. The main difference was that the unfamiliar matched faces had a significant 3-way interaction for orientation, face and features.

Effect of inversion

When the faces were inverted this increased gaze to the nose and mouth regions, whilst when the faces were upright this increased gaze to the eyes, this pattern was consistent regardless of familiarity, or match. For the upright familiar faces there was a bias for the leftmost eye and it received more gaze than the rightmost eye, and the eyes both received more gaze than the nose and mouth. For the upright unfamiliar matched faces; the leftmost eye received more gaze than the rest of the features on the rightmost face and the eyes received more gaze than the nose and mouth on the leftmost face. For the upright unfamiliar mismatched faces the eyes received more gaze than the nose and mouth.

When the familiar (matched and mismatched) faces were inverted, the leftmost eye and nose received more gaze than the mouth. When the unfamiliar mismatched faces were inverted, the leftmost eye and nose received more gaze than the rightmost eye and mouth. For the inverted unfamiliar matched faces, the nose received more gaze than the mouth for the leftmost face, and for the rightmost face the leftmost eye and nose received more gaze than the rightmost eye and mouth.

Effect of face side (left or right of the screen)

The rightmost eye received more gaze on the leftmost face, whereas the leftmost eye received more gaze on the rightmost face, and this pattern was consistent regardless of familiarity and match. For the leftmost face; the eyes received more gaze than the mouth for the familiar faces and unfamiliar mismatched faces. For the leftmost unfamiliar matched faces, when they were upright the eyes received more gaze than the nose and mouth, but when they were inverted the nose received more gaze than the mouth.

For the rightmost face; the leftmost eye received more gaze than the other features and this was consistent across familiarity and match. However the nose received more gaze than the mouth for familiar faces and unfamiliar mismatched faces.

There was also an effect of face and orientation which revealed that the when the leftmost face was upright it received more gaze per feature, whereas the rightmost face received more gaze per feature when it was inverted, this pattern was found for the familiar and unfamiliar mismatched faces.

Discussion

The main aim of this experiment was to establish if there are differences in how upright and inverted faces are examined for a matching task. The eye gaze data confirmed that there were different viewing patterns for upright and inverted faces. The eyes received more gaze when the faces were upright, whereas mouth and in many instances the nose received more gaze when the faces were inverted. This seems to show that there is an overall bias towards the top half of space and the features that reside in the top half will received more gaze. This bias towards the top half of faces and face-like objects has been found in previous research using eye movements (Barton et al., 2006) and other studies (Caldara, et al., 2006; Turati, 2004; Turati, et al., 2002).

Although previous research has reported some qualitative differences in how upright and inverted faces are viewed, results have not always been consistent. Findings from infants' exploration of faces showed the nose and mouth were looked at for longer on upright faces, as compared to inverted faces, but no significant differences were found for the eye region (Gallay et al., 2006). This is completely the opposite to my findings and could relate the participants used, as Gallay and colleagues used infants, whereas I used adults and there does seem to be some evidence that young children process faces differently from adults (Campbell & Tuck, 1995; Campbell, Walker, & Baron-Cohen, 1995; Diamond & Carey, 1977). Research that has used adults has reported results similar to those found here. Barton et al. (2006) reported that participants looked more at the eyes and forehead of upright faces and the chin and mouth of inverted faces.

However not all research has found differences in the way features are viewed on upright and inverted faces. Henderson et al., (2001) found no significant differences in fixation locations as a function of inversion and in both orientations the eyes were viewed more than any other features. Another study also found that the eyes appeared to be the most important feature regardless of inversion. In this study a face was presented embedding in noise, so that only certain areas of the face were visible. Then two high contrast faces were presented and then viewers had to decide which one had been previously presented. The results found that the eyes and eyebrow region appeared to be the most useful for the task in either orientation (Sekuler, Gaspar, Gold, & Bennet, 2004).

The eyes appeared to be the most important features for recognition and also for the matching task, and this confirms other research which has shown the importance of the eye region for recognition (Henderson et al., 2001; Janik et al., 1978) and also for face-matching (O'Donnell & Bruce, 2001). There was also a bias for the left eye which appeared to receive more gaze than the right eye for many of the conditions. The bias for the left eye has been found previously in studies using eye movements (Barton et al., 2006) and is thought to be due to the right hemisphere specialisation of faces (Schyns, Bonnar, & Gosselin, 2002; Vinette, Gosselin, & Schyns, 2004).

Another interesting finding came from the first fixation analysis, which might relate to the dominance of the right hemisphere for face processing. The results revealed a specific scanning pattern where the majority of participants looked firstly at the leftmost face and then at the rightmost face. The perceptual bias of first saccades to the left side of faces has been shown in a variety of other studies (Butler et al., 2005a; Mertens, Siegmund, & Grusser, 1993). There is still a debate whether this results from the right hemisphere bias for face processing (Rhodes, 1985b, 1993), or is a cultural bias as a consequence of scanning left to right for reading (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989). All of these studies used single faces, whilst our study found the leftward bias is persistent across pairs of faces.

The left to right scanning strategy that was found for face pairs helps to explain findings by Megreya & Burton (2006). They discovered that when two target faces were presented along with a 10-face line up, subjects performed more accurately using the left face, as compared to the right face. Although they suggested that this could reflect a left to right scanning strategy, they did not employ any eye tracking measures as confirmation.

Further analyses from the eye movement data revealed an intriguing viewing strategy where the leftmost and rightmost faces were explored in different ways. The leftmost face had gaze distributed evenly across both eyes and although this was more than the nose it was not statistically significant, whilst the rightmost face had the majority of gaze to the leftmost eye and the other features were viewed significantly less. This scanning strategy showed that participants did not make a feature-by-feature comparison as suggested by Walker-Smith, Gale & Findlay (1977), as they did not look at the same features on both faces. Viewers appeared to use more of a global strategy gaining a holistic impression of the faces. This suggests that when presented with face pairs, viewers looked initially at the leftmost face, built up an internal representation using the eyes and nose and held this in working memory to compare with the rightmost face. Once this representation had been created they did not have to view all the features on the right face as fixating on the left eye was sufficient to make a decision. Research using a scene comparison task suggested that when presented with two different images, viewers often maintain one object in working memory whilst making a 'same' or 'different' judgement (Gajewski & Henderson, 2005).

Other differences in viewing patterns between the left and right faces found the rightmost eye was viewed more on the leftmost face, and the leftmost eye was viewed more on the rightmost face. This showed that overall the eyes received more gaze when they where the 'inner' eyes, as compared to being the 'outer' eyes. However viewers were not using the inner eyes alone to make their matching decision as the nose and left eye of the left face was also used. Therefore viewers were not simply pairing the centremost eyes to make their decisions.

Other analyses for gaze to the left and right faces found the leftmost face received more gaze per feature when upright, whereas the rightmost face received more gaze per feature when inverted. The left faces receiving more gaze per feature when upright seems logical as there has been a left visual field bias for faces that has been well documented (Burt &

Perrett, 1997, Butler et al., 2005). However the right bias for the inverted faces is more difficult to explain.

Looking at the task performance, responses were more error prone when the faces were upside down, especially for the unfamiliar faces. This corroborates the face inversion effect found in previous studies, which showed that inverted faces were more difficult to recognise than upright faces (Scapinello & Yarmey, 1970; Yin, 1969). There was also an effect of familiarity, but only for familiar faces that had different identities, familiar pairs that were the same person received the same number of correct responses as the unfamiliar faces. This seems to show that there was an overall bias to say “same”, which was especially present for the unfamiliar faces.

General Discussion

Across all three experiments there were some similarities in how the upright and inverted faces were viewed. In Experiment 1; the eyes, forehead and hair received more gaze when the faces were upright, and when the faces were inverted the mouth received more gaze. This pattern was similar for Experiment 2; the eyes received more gaze when the faces were upright and the mouth received more gaze when the faces were inverted. For Experiment 3 the effect of inversion was the same, the eyes received more gaze when the faces were upright and the nose and mouth received more gaze when the faces were inverted. Taken together the findings from all three experiments appear to show that there was an overall bias for the top half of space and the features that resided in the top half were looked at for longer. The bias to look more at the features that reside in the top half of space has been found in previous research that used eye movements (Barton et al., 2006) and other studies have also found a bias for the top halves of faces and face-like objects (Caldara et al., 2006; Turati et al., 2006; Turati et al., 2002).

Inversion appeared to increase gaze to features that usually reside in the lower halves of faces, and it also had an effect on the distribution of gaze across the features. For Experiment 1 inversion decreased the bias for both eyes, but the bias for the left eye remained and the other internal features all received similar amounts of gaze. Experiment 2 found a similar pattern; the eyes received more gaze than the other features for upright faces, but when the faces were inverted all the internal features received similar amounts of gaze. For Experiment 3 there was a bias for the left eye in both orientations, however in upright faces the right eye received more gaze than the nose and mouth, but when the faces were inverted the gaze to the nose increased and for some conditions it was looked at for longer than the right eye and mouth.

Differences in viewing patterns for the upright and inverted faces could be due to different types of processing. When the faces are upright viewers are able to obtain a holistic impression of the face, however when the face are inverted the task becomes more difficult and viewers have to look at more of the internal features. For upright faces viewers are using holistic or configural processing by fixating on the eyes, whereas when the faces are inverted viewers use featural or piecemeal processing and have to look at all the internal features to make a matching or recognition decision. If this is the case then the different viewing patterns for upright and inverted faces support previous research on the FIE that has shown that faces are processed differently when inverted (Friere et al., 2000; Searcy & Bartlett, 1996).

The bias for the eyes that was found in all the experiments has been reported previously using eye movement studies (Henderson, et al., 2001; Janik, et al., 1978). For Experiments 1 and 3 there was also a bias for the left eye. Again this has been found in other studies using eye movements (Barton et al., 2006) and in studies that have employed the bubbles technique (Schyns, Bonnar, & Gosselin, 2002; Vinette, Gosselin, & Schyns, 2004). Along with the bias for the left eye, Experiment 3 found there was a bias for the left face and the majority of first fixations were made to the left face. The leftward bias for faces has been documented in a variety of other studies (Burt & Perret, 1997; Butler et al., 2005; Mertens et al., 1993). It is still being debated whether the leftward bias is due to a right hemisphere bias for faces processing (De Renzi & Spinnler, 1966; Rhodes, 1985b, 1993), or if the bias is related to directional scanning for reading left to right (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989). Whatever the explanation, it seems that the leftward bias for faces is also apparent when presented with pairs of faces, and this could have implications for presenting pairs of faces or even arrays containing several faces to witnesses of crimes. Megreya and Burton (2006) have already shown that when participants are presented with a pair of faces and a 10 face array, viewers are poorer to match the face on the right, as compared to the face on the left.

There are also other factors that can influence face-matching tasks which might help to explain the differences in performance and viewing patterns found for Experiments 2 & 3. For Experiment 2, there was a scanning strategy where the viewers looked mainly at the inner eyes (left eye on right faces & right eye on left face) and scanned between them and the outer eyes and other features received very little gaze. In Experiment 3 the pattern was similar but not as clear, although the inner eyes received more gaze than the outer eyes, the bias was not as strong as was found in Experiment 2. There was not as strong a bias for the right eye on the left face and both eyes received more gaze than the other features, although there was still a bias for the left eye on the right face. Differences between the experiments could be due to the same images for faces being used in Experiment 2, and different images for the same person being used in Experiment 3. Previous research has shown that using the same images of faces can lead to increased recognition rates (Bruce, 1982) and in Experiment 2 perhaps the task was so easy viewers did not have to look at all the features on each face to make a matching decision. Whereas for Experiment 3 the task was more difficult and viewers had to look at the eyes and nose on the left face first, build up an internal representation and then compare it to the right face.

The viewing patterns obtained across the two face-matching tasks appear to show that for the upright faces viewers did not use a feature by feature comparison as suggested by Walker-Smith, Gale and Findlay (1977), as they did not have to look at the same features on both faces. For Experiment 2 they mainly used the inner eyes and for Experiment 3 they used mainly the eyes and nose of the left face and then the left eye on the right face. If the viewers were not using a feature-by-feature comparison, then were they using more of a holistic or configural strategy? When the faces were upright fewer features were viewed therefore this might indicate holistic or global processing, whereas when the faces were inverted the gaze to the internal features was more evenly distributed and could therefore be interpreted as featural processing.

For all the experiments there was no clear pattern that familiar and unfamiliar faces were viewed in different ways. Other studies have found little differences in viewing patterns as a function of familiarity (Henderson et al., 2001; Henderson et al., 2005), although there is a study that did find differences in how familiar and unfamiliar faces were examined (Althoff & Cohen, 1999). In their study Althoff and Cohen asked participants to make fame and emotion judgements, and reported that less time was spent looking at the mouths of famous faces for the fame task and more time was spent looking at the left eye for the emotion task.

There was also no clear pattern that faces that matched or mismatched were viewed differently from one another. Stacey et al. (2005) found differences in how face pairs that matched and those that mismatched were viewed, however they used only two areas of interest, internal feature and external features. They found that there was more gaze to the internal features when faces matched (mean .95) than when they did not match (.92), although there was overall more gaze to the internal features regardless of match and familiarity.

Finally the task performance for Experiment 1 and 3 confirmed the expected inversion effect and participants performed less accurately when the faces were inverted. This pattern was not found in Experiment 2 as all the participants performed at ceiling levels, as the task was too easy. The inversion effect has been well documented and these results support those that have also found a considerable disadvantage for recognising inverted faces as compared to other inverted stimuli (Diamond & Carey, 1986; Scapinello & Yarmey, 1970; Yin, 1969).

Chapter Three

The influence of presentation layout on face matching and viewing patterns.

Introduction

As the preceding chapter has shown, inverting a face not only reduces matching performance, but also changes the viewing pattern to the features. The purpose of this chapter is to investigate whether changing the way face pairs are presented influences matching performance, and the way in which the faces are viewed.

Do multiple faces influence recognition and matching?

Deciding whether two face images are the same person is extremely important for forensic and security purposes, but little research has focused on whether presenting several faces influences recognition, or matching. Clifford and Hollin (1981) showed participants either a violent or a non-violent videotaped act, with a perpetrator who was either alone, or with two or four accomplices, and then an unexpected ten-person identification line up. They found that the number of perpetrators affected the identification of the main perpetrator and for the non-violent act recognition rates dropped from 40 % for the alone condition, to 30% when accompanied by two others, and to 20 % when accompanied by four others. Participants who viewed the violent act were also influenced by the number of perpetrators, identification dropped from 30 % for the alone condition to 20 % when accompanied by two others, and then 10 % when accompanied by four others. Therefore it appeared that as the number of perpetrators increased, accurate identification decreased.

Other research has also confirmed that viewing more than one person can adversely affect identification. Shepherd (1983) presented participants with a video of two men asking for directions and then after a delay of either one or four months, they were presented with a line up that either contained either one, both or neither targets. The results showed that although there was no significant effect of delay, only 1 out of 40 participants correctly identified both targets and accuracy was 20 % for identifying one of the targets from line-ups that contained either one or both targets.

The number of perpetrators not only affects whether they are later identified, but also appears to influence viewers' descriptions. Fashing, Ask and Granhag (2004) compared real life descriptions of witnesses of bank and post office robberies, with the actual video footage of the event. They found that witnessing two perpetrators commit a crime, led to less accurate descriptions, compared to only witnessing one person.

Being presented with two faces for a memory task also leads to poorer recognition than when only one is presented. Megreya and Burton (2006) presented participants with either one or two target faces and then after a 10 second delay they were shown a 10-face line up. In the single face condition participants accurately identified 59.5 % of the target faces, however in the two-face condition, participants were only able to identify one of the faces 34 % of the time. Participants incorrectly stated the target face was not present (misses) more often in the two-face condition (44 %), than the one face condition (31 %). Faces were also more likely to be misidentified in the two-face condition (22 %), as compared to the single face condition (9.5 %). This seems to show that the presentation of a face pair significantly influences whether either of those faces will be identified, but is this related to having to store two faces in memory, or do the two faces somehow interfere with each other when they are being encoded?

In a third experiment Megreya and Burton (2006) presented participants with either one or two target faces along with a 10-face line up, this places few demands on memory as the target faces do not need to be memorised. For the single face condition, participants made a correct match 70 % of the time, but for the two-face condition a correct match was made only 53.9 % of the time. In the two-face condition viewers were also more likely to misidentify a target face (24.5 %), than in the single face (12.3 %). This showed that the two-face disadvantage occurred at the encoding stage, and somehow the faces interfered with one another.

In a further experiment Megreya and Burton (2006) presented a face pair with a 10-face line up and the faces were either near to each other (1 cm apart) or far apart (8 cm apart). They proposed that when the faces were further apart the array may seem less cluttered and they may not interfere with one another as compared to being closer together. They reported there were significantly more correct matches for the far condition (57.8 %), as compared to the near condition (50.2 %). There were also fewer misses for the far condition (23.4 %) as compared to the near condition (30.4 %). This showed that there was an advantage for the matching task when the faces were further apart and they seemed to interfere with one another less. An additional finding was that responses for the face on the left were significantly more accurate than the right face, and this was present for both the near and far conditions. It was suggested that participants might be using a left to right scanning strategy, whereby the face on the left is viewed first and somehow interferes with encoding the face on the right, however they had no eye tracking measurements to confirm this.

Interference from faces.

The research described so far has shown that presenting more than one face can influence recognition rates, descriptions and also matching performance, this seems to show that faces can interfere with each other on the encoding level. There is research that has investigated whether faces can influence how we attend to other visual stimuli, such as non-face objects, names and even other faces. Studies of visual attention have shown us that faces can capture our attention and in a change blindness paradigm (where viewers are shown a scene and asked to notice whether there has been a change) there is an advantage for faces when they compete with other non-face objects (Ro, Russell, & Lavie, 2001).

When faces are presented along with names for a categorisation task, e.g. classifying faces or names as either pop stars or politicians, incongruent faces interfere more with the categorisation of printed names, than printed names interfere with the categorisation of faces (Young, Ellis, Flude, McWeeny, & Hay, 1986). Faces also slow down classification decisions when presented as flanker items on the periphery of a centrally presented name, if they are incongruent with the target word. Presentation of an upright face delays categorisation of a peripheral target more than the presentation of other object images, such as; fruit or flags, inverted faces and even names (Bindemann, Burton, Hooge, Jenkins, & de Haan, 2005). Although the distracter faces appeared to interfere with the processing of other non-face items, they did not interfere when the centrally presented item was a face, which seems to suggest that only one face could be processed at one time (Bindemann, Burton, & Jenkins, 2005). Another study which found that flanker faces slowed down name classification also found that the presence of an additional face diluted the interference, which seems to show that faces are stimuli that can compete with one another for attention (Jenkins, Lavie, & Driver, 2003).

There does seem to be some evidence that even when perceptual load or task demands are high, faces still can capture, or hold our attention. In a name searching task, participants were shown a series of letter strings along with a flanker face they were asked to ignore. It was found that increasing the perceptual load by increasing the number of letter strings did not reduce the interference from incongruent faces. However when the same task was carried out with objects (such as fruit, or musical instruments) increasing the perceptual load reduced the effect of incongruent distracter items (Lavie, Ro, & Russell, 2003; Ro, Russell, & Lavie, 2001). This showed that even when the perceptual load is high; faces can still capture or hold attention, whereas the distracter items that are other objects can be unattended.

One study investigating covert recognition used a priming task where letters were superimposed on a face, and the perceptual load was manipulated by asking subjects to either categorise the colour of the letters (red or blue), or look for specific letters (N or Z). When participants were later given a recognition test, they were faster and more accurate for recognising the old items in both the low and the high load conditions than they were to new faces (Jenkins, Burton, & Ellis, 2002). This showed that even in the high perceptual load condition, faces received the same amount of priming as those in the low condition. This suggests that even when other resources compete for our attention, faces are still processed on some level, whether they are explicitly remembered or not.

There is some evidence that faces processed under conditions where there is a high demand upon our attention, may not always be fully processed, or the presence of several faces may interfere with one another. In a study that examined divided attention and face recognition; a target face was presented either alone (full attention), in the middle of two flanking faces that participants were asked to ignore (full attention), or in the middle of the two faces that participants were asked to match (divided attention). The participants were then shown either whole faces, or isolated features and had to decide which face had been previously presented. In the full attention condition participants were better with the whole faces than the isolated parts, however for the divided attention there was no difference in performance for the whole faces, or isolated features. It was suggested that dividing attention eliminated holistic processing of the centrally presented face and that viewers were using more of a featural or piecemeal form of processing (Palermo & Rhodes, 2002). If presenting more than one face at a time influences how faces are processed, could this be reflected in other measures such as the eye movements produced when examining the faces? Also if changing the way faces are presented (e.g. close together or far apart) makes matching easier or more difficult, could this also be reflected in eye movements patterns?

Eye movements and face matching.

So far, there has been no research that has specifically examined whether the manipulation of face presentation for a matching task influences the way faces are viewed. Research that used eye movements measures to investigate face matching has found that when faces are presented side by side (one full face and one three-quarters view) that viewers look significantly more at the internal features than the external features, regardless of familiarity (Stacey, Walker, & Underwood, 2005). When faces are presented one on top of the other it appears that the top parts of the face are viewed first and that the majority of fixations are between the eyebrow and mouth region. It was concluded that participants have to look at the same features on each face to make a matching decision (Walker-Smith, Gale, & Findlay, 1977).

There are several studies that have used single faces to explore how they are viewed during recognition tasks. They have found that the majority of time spent viewing the eye region, followed by the nose and then mouth (Althoff & Cohen, 1999; Henderson et al., 2001; Henderson et al., 2005; Janik et al., 1978), also the most common scanning strategy was to fixate on the left eye, to right eye to left eye and vice versa (Groner, Walder, & Groner, 1984). There also appears to be a leftward bias for faces and the majority of first fixations are to the left side of the face (Butler et al., 2005; Mertens et al., 1993). However so far no one has confirmed whether this leftward bias for faces also generalises to pairs of faces for a matching task.

The aim of this chapter is to examine whether changing the layout i.e. the way the faces are presented, not only changes matching performance, but also affects how the faces are viewed. Two face matching experiments were conducted, the first was similar to the Megreya and Burton (2006) experiment 4, except only two faces were presented for the matching task and they were presented either close together, or far apart. The second experiment was similar to that by Walker-Smith, Gale and Findlay (1977) in that for one condition the faces were presented vertically one on top of the other, however the faces were also presented side by side, but misaligned so that either the left or the right face was higher.

Experiment 4

In this experiment the distance between the faces was manipulated so that they were either close together or further apart. Megreya and Burton (2006) found that when faces are presented further apart (8 cm) that performance for matching pairs of faces to a 10-face line up was more accurate than when faces were presented closer together (1cm apart).

They suggested that pairs of faces in close proximity influence each other, so a matching decision is impaired. If the distance between a pair of faces does influence a matching decision, then there may well be differences in viewing patterns between faces that are closer together or further apart.

Method

Participants

24 participants took part in the study (13 female). All were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 120 faces, half were celebrities and half were unfamiliar people from an in-house database. All the faces were male, and presented in pairs. Half of the pairs were presented with 10cm between each face and half with 2 cm. The pairs were either two faces of different identities, or they were two different images of the same person (see figure 3.1).

All the images were converted to grey scale and cropped around the faces, so they were presented on a white background. Each face was approximately 13.5 cm by 10 cm, subtending a visual angle of 7.7 and 5.7 degrees and a resolution of 72 pixels per inch. The stimuli were presented on 21 inch Belinea TFT flat screen monitor, 1 meter from the participant using E-Prime software.

Figure 3. 1 Examples of stimuli; unfamiliar mismatched near and unfamiliar matched far.

Apparatus

Eye tracking data were recorded using a non-invasive remote eye tracking device (RED) from Senso-Motor Instruments, which was placed on a table below the monitor. Eye movements were captured using Iview version 2.3 software and the participants were calibrated using a 9-point display screen, before stimuli presentation. Participants had Asden HS35s headphone/ microphone combination headsets, so that they were able to communicate with the experimenter in the other room.

Design & Procedure

The experiment employed a 5-factor within subjects design. The first variable was face (leftmost/rightmost), the second was familiarity (familiar/unfamiliar), the third was match (match/mismatch), the fourth was distance (near/far), and the fifth features viewed (leftmost eye, rightmost eye, nose and mouth). Participants were instructed that they would be presented with pairs of familiar and unfamiliar faces, and their task was verbally to indicate whether the faces were the ‘same’ person, or two ‘different’ people. Each pair was presented for 2 seconds.

Analysis

The preliminary analysis of eye gaze data began by ascertaining whether there was a sufficient capture rate of all eye gaze data for each participant. Using the Iview 2.3 software, the viewing time for each face was analysed to see how much of the data was undefined, (i.e. gaze not recorded within the areas of interest). If the undefined data was higher than 30 percent, then the subject’s data was discarded. The eye gaze data loss may occur through head movement, blinking, hand gesticulation obscuring the infrared beam, or untraceable eyes. 30 participants were tested, however 6 had to be discarded as the eye gaze data fell below the capture criteria of 70 percent. 24 participants were used in the final analysis.

The faces were divided into 4 areas of interest (AOI) created using Iview 2.3. They were the; leftmost eye, rightmost eye, nose and mouth. The AOI were from the perspective of the viewer, therefore the leftmost eye was always on the left from the viewer’s perceptive. Separate AOI were created for each individual face as the faces can vary in configuration. Eye gaze data with fixations shorter than 100 ms were discarded, in line with comparable studies (see Baron, 1980, Fischer et al., 1989). Only the data for faces that were correctly categorised as being the ‘same’ or ‘different’ were used in the analysis.

Eye gaze data were converted to proportions of gaze per feature for each face, as the gaze duration and the number of fixations could differ across subjects. The proportion of gaze to features was calculated across the two distance conditions (near/far) so that they could be directly compared, as preliminary analyses using the gaze duration found differences between the two distance conditions. Because the proportions were calculated across two trials, the sum of proportions for the four faces was equal to 1.

Results

Task performance

Figure 3.2a shows the mean correct responses for the familiar faces at both distances and figure 3.2b shows the mean correct responses for unfamiliar faces at both distances. A 3-factor ANOVA: Familiarity (familiar/unfamiliar) x Match (match/mismatch) x Distance (near/far) was performed on the response data. It revealed that there was a main effect of familiarity; familiar faces received more correct responses than unfamiliar faces (95 vs. 85 %, $F(1, 23) = 39.4$, $p < 0.01$). There was also a significant 3-way interaction for familiarity, match and distance, ($F(1, 23) = 13.5$, $p < 0.05$). The analysis of the simple simple main effects revealed that familiar faces received more correct responses than unfamiliar faces for all conditions, ($p < 0.05$), except for the matched far faces, ($F < 1$). Overall there was no significant effect of distance for the familiar faces, however it did seem to influence performance for the unfamiliar faces. The unfamiliar matched faces received significantly more correct responses when they were presented far apart, as compared to being near to one another ($F(1, 23) = 46.8$, $p < 0.01$), however when the faces mismatched, distance had no significant affect on responses.

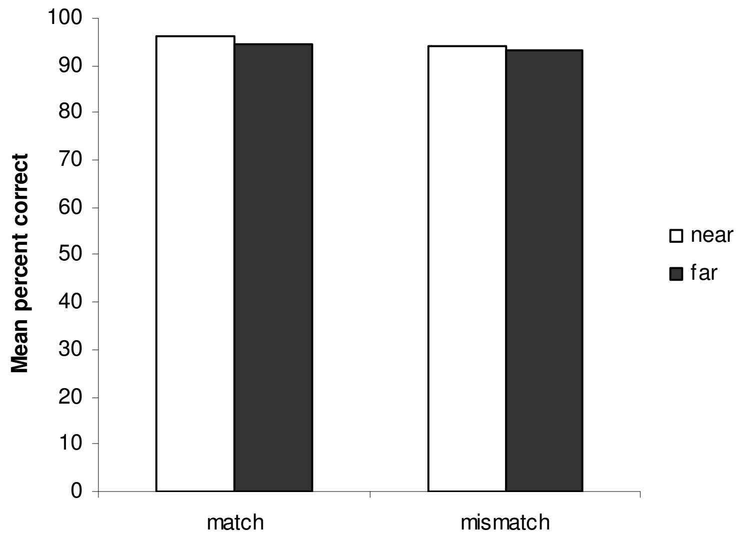


Figure 3.2a. Mean percentage correct for familiar matched and mismatched faces, near and far.

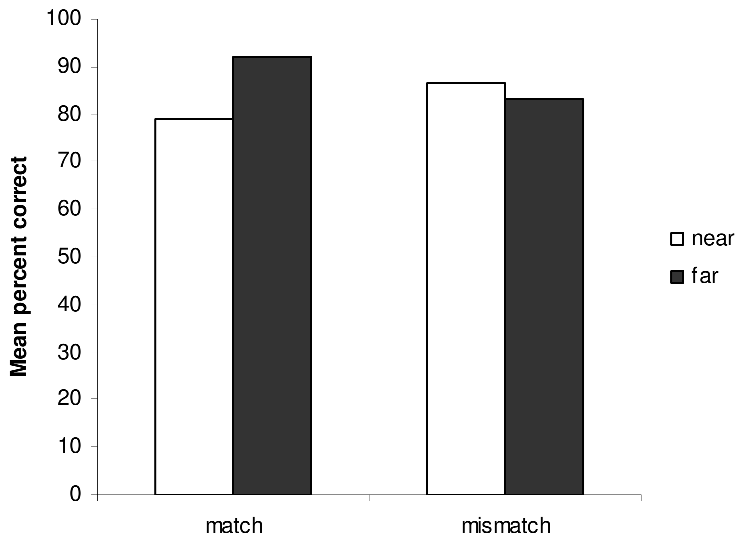


Figure 3.2b. Mean percentage correct for unfamiliar matched and mismatched faces, near and far.

Location of first fixation

The location of the first fixation for each trial was examined to see if viewers looked initially at the rightmost or leftmost face. A paired sample t-test found that viewers made significantly more first fixations to the leftmost face than the rightmost face (83.3 % vs. 16.7 %; $t\ (23) = 7.3$, $p < 0.01$). This was an extremely strong effect and will be explored further in chapter 5 where a full analysis will be carried out.

Proportion of gaze to features

Data were analysed by a 5-factor ANOVA: Familiarity (familiar/unfamiliar) x Match (same/different) x Distance (near/far) x Face (leftmost/rightmost) x Feature (leftmost eye, rightmost eye, nose, and mouth). There was a main effect of distance, the faces in the near condition received significantly more gaze per feature than those far apart (.08 vs. .05; $F(1, 23) = 75.1$, $p < 0.01$). There was a main effect of face, with the rightmost face receiving more gaze per feature than the leftmost face (.07 vs. .05; $F(1, 23) = 23.3$, $p < 0.01$). There was a main effect of features ($F(3, 69) = 30.4$, $p < 0.01$), the leftmost (.10) and rightmost (.10) eyes received proportionately more gaze than the nose (.04) and all these features received more gaze than the mouth (.003). There were also two significant 4-way interactions for; familiarity, distance, face and features ($F(3, 69) = 3.0$, $p < 0.05$), and match, distance, face and features ($F(3, 69) = 4.6$, $p < 0.01$). The data was therefore split into four sets and four separate 3-factor ANOVAs were performed for the familiar matched, familiar mismatched, unfamiliar matched and unfamiliar mismatched faces.

Familiar Matched Faces

Figure 3.3a shows the mean proportion of gaze to features for faces in the near condition, and figure 3.2b shows the mean proportion of gaze to features for faces far apart. Results from the 3-factor ANOVA performed for the familiar matched faces found a main effect of distance, the near faces received significantly more gaze per feature than those far apart, (.8 vs. .05; $F(1, 23) = 75.1$, $p < 0.01$). There was a main effect of face, the rightmost face received more gaze per feature than the leftmost face (.07 vs. .05; $F(1, 23) = 23.3$, $p < 0.01$). There was a main effect of features ($F(3, 69) = 30.4$, $p < 0.01$); the leftmost eye (.10) and rightmost eye (.10), received more gaze than the nose (.04) and mouth (.003).

There was also a significant 3-way interaction; for distance, face and features ($F(3, 69) = 11.9$, $p < 0.01$).

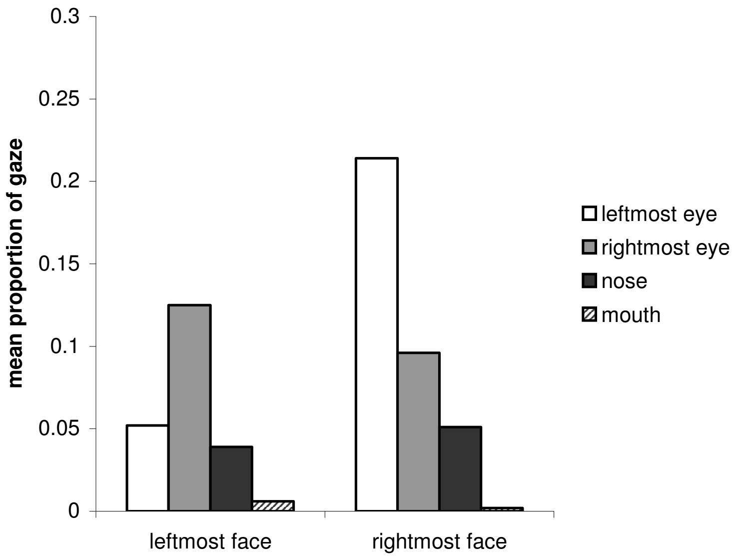


Figure 3.3a. Mean proportion of gaze to features for familiar matched near faces.

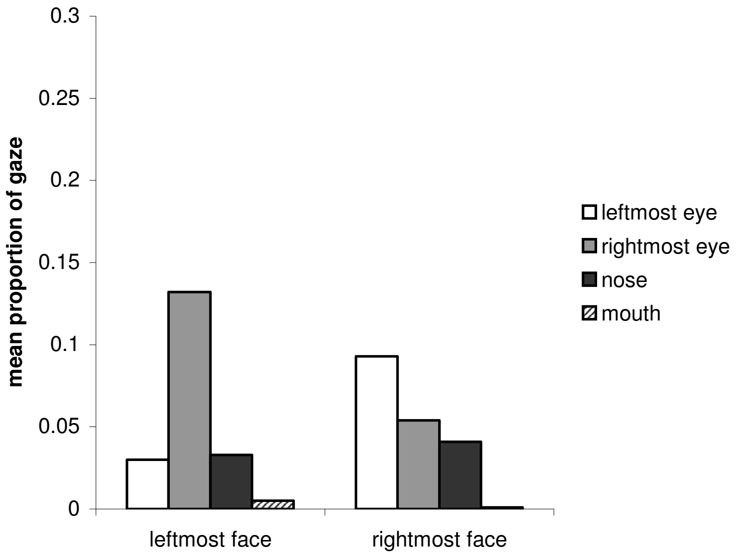


Figure 3.3b. Mean proportion of gaze to features for familiar matched far faces.

The analysis of the simple simple main effects for the distance, face and features interaction revealed when the faces were near one another, the leftmost eye on the leftmost face received significantly more gaze than when the faces were far apart ($F(1, 23) = 5.9$, p

< 0.05). A similar pattern was found for the leftmost eye ($F(1, 23) = 266.0$, $p < 0.0$) and rightmost eye ($F(1, 23) = 21.0$, $p < 0.01$) on the rightmost face, they received more gaze when the faces were near, than when they were far apart. Distance appeared to have no significant effect on gaze to the nose or mouth of either face, or the rightmost eye on the leftmost face ($F < 1$).

The gaze to features also varied in relation to the face side (rightmost/leftmost face) and the rightmost eye received significantly more gaze on the leftmost face and this was significant when the faces were near ($F(1, 23) = 6.5$, $p < 0.05$) and far apart ($F(1, 23) = 46.7$, $p < 0.01$). Whereas the opposite pattern was found for the leftmost eye, it received significantly more gaze on the rightmost face and this was significant when the faces were near ($F(1, 23) = 272.4$, $p < 0.01$) and far apart ($F(1, 23) = 46.7$, $p < 0.01$). Face side had no significant effect on gaze to the nose and mouth ($F < 1$).

Planned comparison t-tests were carried out on the gaze to individual features to see if there were significant differences in proportions of gaze for the leftmost and rightmost faces at both distances (near/far). The results for the leftmost face in the near condition found the rightmost eye received more gaze than the leftmost eye ($t(23) = 2.81$, $p < 0.01$), and comparisons with the other features produced higher t values. The same pattern was found in the far condition, with the rightmost eye receiving more gaze than the leftmost eye ($t(23) = 3.81$, $p < 0.01$) and comparisons with the other features produced higher t values. For the near rightmost face, the leftmost eye received significantly more gaze than the rightmost eye ($t(23) = 5.58$, $p < 0.01$) and comparisons with the other features produced even higher t values. For the far rightmost face, the leftmost eye received more gaze than the mouth ($t(23) = 3.46$, $p < 0.01$).

Familiar Mismatched Faces

Figure 3.4a shows the mean proportion of gaze to features on faces that were near one another and figure 3.4b shows the mean proportion of gaze to features on faces that were far apart. Results from the 3-factor ANOVA performed for the familiar mismatched faces found a main effect of distance, when the faces were near they received significantly more gaze per feature than when they were far apart, (.7 vs. .05; $F(1, 23) = 55.5$, $p < 0.01$). There was a main effect of face, the rightmost face received more gaze per feature than the leftmost face (.07 vs. .06; $F(1, 23) = 6.0$, $p < 0.05$). There was main effect of features ($F(3, 69) = 29.4$, $p < 0.01$); the leftmost eye (.10) and rightmost eye (.11), received more gaze than the nose (.05) and mouth (.003). There was also a significant 3-way interaction; for distance, face and features ($F(3, 69) = 7.5$, $p < 0.01$).

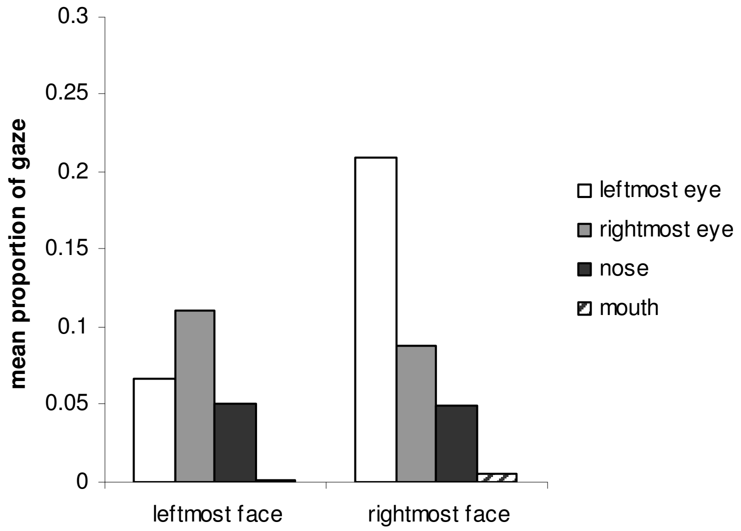


Figure 3.4a Mean proportion of gaze to features for familiar mismatched near faces.

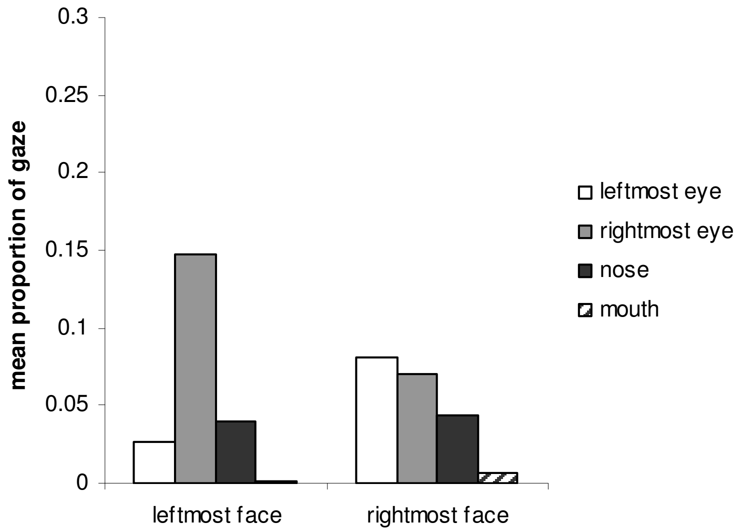


Figure 3.4b. Mean proportion of gaze to features for familiar mismatched far faces.

The analysis of the simple simple main effects for the distance, face and features interaction revealed for the near faces, the leftmost eye on the leftmost face received significantly more gaze than when the faces were far apart ($F(1, 23) = 26.9$, $p < 0.01$), the opposite pattern was found for the rightmost eye on the leftmost face ($F(1, 23) = 22.1$, $p < 0.01$), it received more gaze when the faces were far apart. For the rightmost face, the leftmost eye ($F(1, 23) = 264.8$, $p < 0.0$) and rightmost eye ($F(1, 23) = 4.4$, $p < 0.05$) received more gaze when the faces were near, than when they were far apart. Distance appeared to have no significant effects on gaze to the nose or mouth of either face ($F < 1$).

The face side (leftmost/rightmost) did have an influence on gaze to features, the rightmost eye received more gaze on the leftmost face and this was significant when the faces were far apart ($F(1, 23) = 23.6$, $p < 0.01$). However the opposite pattern was found for the leftmost eye, it received more gaze on the rightmost face and this was significant when the faces were near ($F(1, 23) = 80.5$, $p < 0.01$) and far apart ($F(1, 23) = 23.6$, $p < 0.01$). The face side had no significant effect on the nose or mouth or the rightmost eye when the faces were near ($F < 1$).

Planned comparisons were conducted to determine if differences in gaze to features for the faces at both distances were significant. The results for the near leftmost face revealed the rightmost eye received more gaze than the nose ($t(69) = 2.54$, $p < 0.01$ and mouth ($t(69) = 4.58$, $p < 0.01$) and the leftmost eye received more gaze than the mouth ($t(69) = 2.75$, $p < 0.01$). For the far leftmost faces, the rightmost eye received more gaze than the nose ($t(69) = 4.5$, $p < 0.01$) and comparisons with the other features produced higher t values. For the near rightmost face, the leftmost eye received more gaze than the rightmost eye ($t(69) = 5.04$, $p < 0.01$) and comparisons with other features produced higher t values, whereas the rightmost eye received more gaze than the mouth ($t(69) = 3.42$, $p < 0.01$). For the far rightmost face, the leftmost eye ($t(69) = 3.13$, $p < 0.01$) and rightmost eye ($t(69) = 2.71$, $p < 0.01$) received more gaze than the mouth.

Unfamiliar Matched Faces

Figure 3.5a shows the mean proportion of gaze to features for the near faces and figure 3.5b shows the mean proportion of gaze to features for the far faces. Results from the 3-factor ANOVA performed for the unfamiliar matched faces found a main effect of distance, the near faces received significantly more gaze per feature than the far faces, (.8 vs. .05; $F(1, 23) = 62.5$, $p < 0.01$). There was a main effect of face, the rightmost face received more gaze per feature than the leftmost face (.08 vs. .05; $F(1, 23) = 29.3$, $p < 0.01$). There was also a main effect of features ($F(3, 69) = 29.5$, $p < 0.01$); the leftmost eye (.11) and rightmost eye (.10), received more gaze than the nose (.05) and mouth (.003).

There was also a significant 3-way interaction; for distance, face and features ($F(3, 69) = 24.1, p < 0.01$).

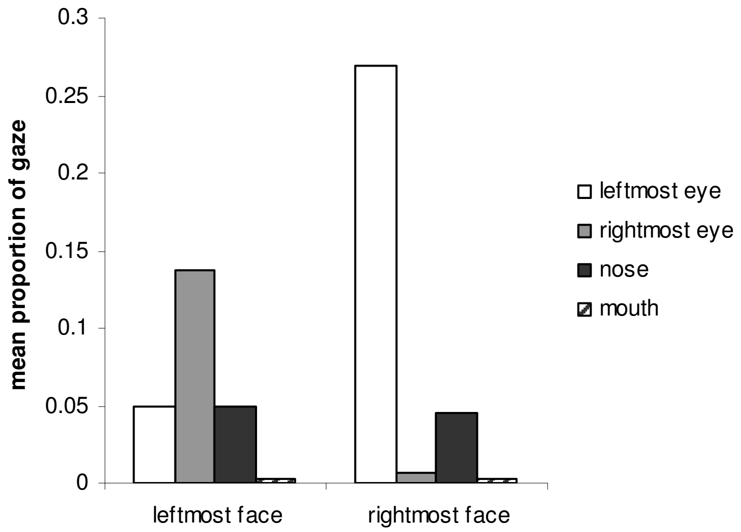


Figure 3.5a. Mean proportion of gaze to features for unfamiliar matched near faces.

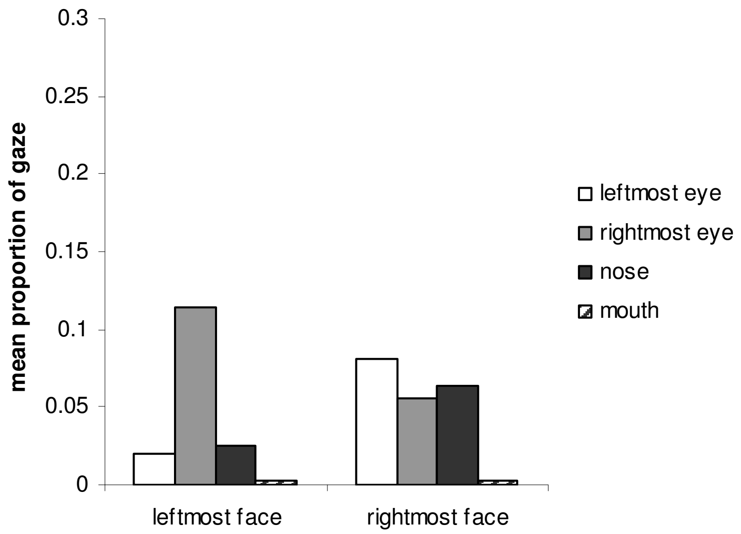


Figure 3.5b. Mean proportion of gaze to features for unfamiliar matched far faces.

The analysis of the simple simple main effects for the distance, face and features interaction revealed, the leftmost eye on the leftmost face received significantly more gaze for the near faces than the far faces ($F(1, 23) = 5.7, p < 0.05$). A similar pattern was found for the leftmost eye on the rightmost face, it received more gaze when the faces were near, than when they were far apart ($F(1, 23) = 248.6$, $p < 0.01$). The rightmost eye received marginally more gaze in the near condition on the leftmost face ($F(1, 23) = 3.4$, $p = 0.07$) and on the rightmost face ($F(1, 23) = 3.2$, $p = 0.09$). Whilst the nose received marginally more gaze in the near condition, but only for the leftmost face ($F(1, 23) = 4.2$, $p < 0.05$). Distance appeared to have no significant effects on gaze to the rightmost eye, nose or mouth of either face ($p > 0.05$).

The face side (leftmost/rightmost) did have an influence on gaze to features, the rightmost eye received more gaze on the leftmost face, and this was significant when the faces were near ($F(1, 23) = 21.4$, $p < 0.01$) and far ($F(1, 23) = 20.7$, $p < 0.01$). However the opposite pattern was found for the leftmost eye, it received more gaze on the rightmost face and this was significant when the faces were near ($F(1, 23) = 292.2$, $p < 0.01$) and far ($F(1, 23) = 22.1$, $p < 0.01$). The nose also received more gaze on the rightmost face, but this was only significant when the faces were far apart ($F(1, 23) = 9.0$, $p < 0.01$). The face side had no significant effect on the nose when the faces were near, or the mouth ($p > 0.05$).

Planned comparisons were conducted to determine if differences in gaze to the features of the leftmost and rightmost faces at both distances were significant. The results for the leftmost face revealed the rightmost eye received more gaze than the nose ($t(69) = 3.63$, $p < 0.01$) when the faces were near, and comparisons with the other features produced higher t values. A similar pattern was found when the faces were far apart, the rightmost eye received more gaze than the nose ($t(69) = 3.71$, $p < 0.01$) and comparisons with the other features produced higher t values. The results for the rightmost face found the leftmost eye received more gaze than the rightmost eye ($t(69) = 8.04$, $p < 0.01$) when the faces were near, and comparisons with the other features produced higher t values. The rightmost eye also received more gaze than the mouth ($t\ (69) = 3.08$, $p < 0.01$). When the rightmost face was in the far condition, the leftmost eye ($t\ (69) = 3.21$, $p < 0.01$), rightmost eye ($t\ (69) = 2.21$, $p < 0.05$) and nose ($t\ (69) = 2.54$, $p < 0.01$) all received more gaze than the mouth.

Unfamiliar Mismatched faces

Figure 3.6a shows the mean proportion of gaze to features on the near faces and figure 3.6b shows the mean proportion of gaze to features on the far faces. Results from the 3-factor ANOVA performed for the unfamiliar mismatched faces found a main effect of distance, when the faces were near they received significantly more gaze per feature than when they were far apart, (.7 vs. .05; $F\ (1, 23) = 43.2$, $p < 0.01$). There was a main effect of face, the rightmost face received more gaze per feature than the leftmost face (.08 vs. .05; $F\ (1, 23) = 23.5$, $p < 0.01$). There was also a main effect of features ($F\ (3, 69) = 33.7$, $p < 0.01$); the leftmost eye (.11) and rightmost eye (.10), received more gaze than the nose (.04) and mouth (.005). There was also a significant 3-way interaction; for distance, face and features ($F\ (3, 69) = 4.7$, $p < 0.01$).

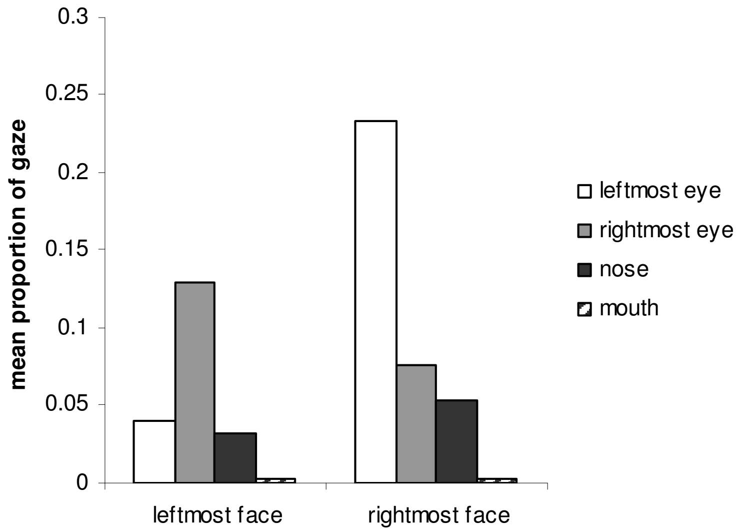


Figure 3.6a. Mean proportion of gaze to features for unfamiliar mismatched near faces.

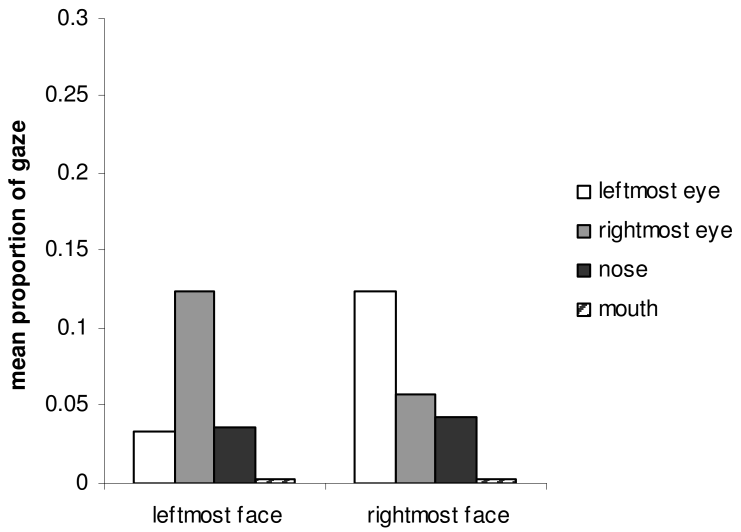


Figure 3.6b. Mean proportion of gaze to features for unfamiliar mismatched far faces.

The analysis of the simple simple main effects for the distance, face and features interaction revealed that distance did not have any significant effect on gaze to features on the leftmost face ($p > 0.05$ for all features), however it did affect gaze to features on the rightmost face. When the faces were near, the leftmost eye on the rightmost face received significantly more gaze than when the faces were far apart ($F (1, 23) = 175.0$, $p < 0.01$).

The same pattern was found for the rightmost eye on the rightmost face, and it received more gaze when the faces were near ($F(1, 23) = 5.3$, $p < 0.05$). Distance appeared to have no significant effects on gaze to the nose, or mouth ($p > 0.05$).

The face side (leftmost/rightmost) did have an influence on gaze to features, and the rightmost eye received more gaze on the leftmost face and this was significant when the faces were near ($F(1, 23) = 14.2$, $p < 0.01$) and far apart ($F(1, 23) = 23.0$, $p < 0.01$). However the opposite pattern was found for the leftmost eye, it received more gaze on the rightmost face and this was significant when the faces were near ($F(1, 23) = 189.3$, $p < 0.01$) and far apart ($F(1, 23) = 42.1$, $p < 0.01$). The face side had no significant effect on the nose or the mouth ($p > 0.05$).

Planned comparisons were conducted to determine if differences in gaze to the features of the leftmost and rightmost faces at both distances were statistically significant. For the leftmost face, the rightmost eye received more gaze than the leftmost eye and this was significant when the faces were near ($F(69) = 3.71$, $p < 0.01$), and comparisons with the other features produced higher t values. A similar pattern was found when the leftmost faces were far apart, the rightmost eye received more gaze than the nose ($t(69) = 3.67$, $p < 0.01$) and comparisons with the other features produced higher t values. The results for the rightmost face found the leftmost eye received more gaze than the rightmost eye ($t(69) = 3.71$, $p < 0.01$) when the faces were near, and comparisons with the other features produced higher t values. When the rightmost face was in the far condition, the leftmost eye received more gaze than the rightmost eye ($t(69) = 2.79$, $p < 0.01$), and comparisons with the other features produced higher t values, whilst the rightmost eye received more gaze than the mouth ($t(69) = 2.25$, $p < 0.05$).

Results summary

The analysis of the eye gaze data found that although there were two 4-way interactions for; familiarity, distance, face and features and match, distance, face and features the patterns across familiarity (familiar/unfamiliar) and match (match/mismatch) were very similar. There was a main effect of distance, face and features across all conditions. The main effect of features revealed that the eyes received more gaze than the nose and mouth for most of the conditions; more specific differences are explained below.

Effect of distance

The effect of distance found that overall when the faces were near one another, more gaze was received per feature than when they were far apart. Further analyses found the leftmost eye received more gaze for the near faces for all of the conditions, except for the unfamiliar mismatched leftmost face. When the faces were near one another there was also increased gaze to the rightmost eye, but only for the familiar mismatched and unfamiliar mismatched rightmost faces. For the familiar mismatched leftmost face, the rightmost eye received more gaze when the faces were far apart. Distance appeared to have no significant effect on gaze to the nose and mouth.

Effect of face side (left or right of the screen)

The main effect of face side was that the rightmost eye received more gaze on the leftmost face and this was statistically significant for all conditions, except for the familiar mismatched faces when they were near. The opposite pattern was found for the leftmost eye it received more gaze on the rightmost face and this was statistically significant for all conditions.

For the leftmost faces in the familiar matched and the unfamiliar (matched and mismatched) conditions, the rightmost eye received more gaze than all of the other features, and this was significant at both distances. For the leftmost faces in the familiar mismatched condition, the rightmost eye received more gaze than all the features when the faces were far apart, but only received more gaze than the nose and mouth when the faces were near.

For the rightmost faces, the leftmost eye received more gaze than all the other features, when the faces were near. When the faces were far apart, the leftmost eye received more gaze than the other features on the rightmost face, but this was only significant for the unfamiliar mismatched faces. When the faces were far apart, the rightmost eye received more gaze than the mouth for the familiar (matched & mismatched) and unfamiliar matched faces. The rightmost eye also received more gaze than the mouth for the all the familiar and unfamiliar faces when they were far apart, whilst the nose received more gaze than the mouth for the unfamiliar matched faces when the faces were far apart.

Discussion

The aim of this experiment was to see if the results from Megreya and Burton’s (2006) study could be replicated. They reported that when unfamiliar faces were closer together, matching was more error prone than when faces were further apart, and suggested when faces are in close proximity they can influence each other. Another main aim was to investigate whether manipulating the distance between the face would influence the viewing strategies whilst carrying out the task.

The eye gaze data for this experiment appears to show that although there were interactions involving familiarity and match, when these factors were separated and separate analyses performed, the overall patterns were very similar. Distance on the other hand did appear to influence how the faces were viewed and the majority of time the eyes received more gaze when the faces were close together than when they were further apart, especially the leftmost eye on the rightmost face. Overall, the eyes received more gaze than the other features which confirms the results of previous studies (Althoff & Cohen, 1999; Henderson et al., 2001; Henderson et al., 2005; Mertens et al., 1993).

One interesting finding was that the faces received different patterns of gaze when they were on the left of the screen as compared to being on the right of the screen. The rightmost eye received more gaze on the leftmost face than the rightmost face, and in many cases it received more gaze than the other features on the leftmost face. However the leftmost eye received more gaze on the rightmost face, than on the leftmost face and in many cases received more gaze than the other features on the rightmost face. These patterns were consistent when the faces were both near and far, although in the near condition the pattern appeared to be stronger as the eyes received more gaze. It appeared that viewers were looking more at the eyes in the centre of the screen and just scanning between these inner eyes to make a matching decision. This pattern is similar to that found by Groner et al. (1984) who found that when exploring single faces the most common triplet sequence of fixations was from the left eye to right eye and then left eye or vice versa. In the near condition it could be suggested that the viewers are pairing the inner eyes of the faces as they would as if viewing the eyes of a single face, however when the faces are far apart they could not be using this strategy as the eyes would be proportionally further apart than they would be on a single face.

The eye gaze data seems to suggest that when looking at the two faces in either the near or far condition, viewers are using the shortest viewing route possible by looking at the two centre eyes. It appears that viewers do not need to look at the same features on both faces as suggested by Walker-Smith et al. (1977) before making a matching decision as they look at a different eye on each face. However, Walker-Smith et al (1977) did not place the faces side by side; rather they positioned them one on top of the other and this might well influence how the faces are viewed.

The first fixation results found that the majority of first fixations were to the face on the left, this is one issue that Megreya and Burton (2006) suggested from the results of their study, but were unable to confirm due to not having any eye movement data. The leftward bias in single faces has been explored by a variety of studies that have found the majority of first fixations are made to the left sides of faces (Butler et al., 2005; Mertens, Siegmund, & Grusser, 1993; Phillips & David, 1997), however no research has focused on the leftward bias for pairs of faces. There is still a debate whether the leftward bias is a result of the right hemisphere dominance for face processing (Rhodes, 1985, 1993), or whether it results from a cultural bias to scan left to right for reading (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989).

When looking at task accuracy, overall performance was better for the famous faces, except when they were 10cm apart and belonged to the same person. Conversely it appeared to be more difficult to match the non-famous faces when they were closer together if they had the same identity. This confirms similar findings by Megreya and Burton (2006). They found that when unfamiliar faces were 8cm apart, performance was better than when the faces were 1cm apart, although their task was slightly different, as they had to match target faces with a 10-face array. They suggested that when the faces were closer together they influenced one another and could reduce performance. Additionally when the faces had the same identity, they were significantly harder to match when they were closer together, than when they were further apart. However when faces belong to two different people, it was easier to discriminate between them, no matter whether they were close together, or further apart.

Experiment 5

In this experiment the aim was to examine how pairs of faces were examined for a matching task when they were placed vertically one on top of the other and also side by side, but misaligned so that the left or right face was higher than the other face. In experiment 4 viewers used the inner or centre eyes (leftmost eye on the rightmost face and rightmost eye on the leftmost face) more than the other features to make a matching decision and seem to carry out this scanning strategy regardless of the distance between the faces. In Experiment 4 faces were presented side by side and therefore the scanning strategy they used was to use the shortest route possible across the eyes. If the faces are presented vertically one on top of the other then scanning from the rightmost eye on the leftmost face to the leftmost eye on the rightmost face will no longer be the shortest scanning route, therefore will viewers change how they view the faces?

Walker-Smith et al. (1977) presented pairs of faces one on top of the other for a matching task and found that the most of first fixations were to the top half of the faces and that the majority of gaze was to the eyes, nose and mouth. They also concluded that viewers would need to fixate on the same features on each face in order to make a matching decision, however they only used 3 participants and 8 pairs of faces. In this experiment a larger number of stimuli and participants will be used.

Method

Participants

24 participants took part in the study (12 female); all were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 168 faces, 120 from Experiment 4 plus an additional 48 faces; half were celebrities and half unfamiliar people from an in house database. All the faces were male, and presented in pairs. The pairs were either two faces of different identities, or they were two different images of the same person. They were presented so that the faces were placed either vertically, one on top of the other, misaligned so that the face on the left was higher or the face on the right was higher (see figure 3.7). The centre point between the eyes of each face was always 12 cm from the other face, in all the conditions.

All the images were converted to grey scale and cropped around the faces, so they were presented on a white background. Each face was approximately 12 cm by 8.5 cm subtending to a visual angle of 6.8 by 4.6 degrees and the resolution was 72 pixels per inch. The stimuli were presented on 17-inch screen monitor using Experiment Builder, SR Research.

Figure 3.7. Examples of stimuli; high right mismatched familiar, high left matched unfamiliar and vertical mismatched familiar faces.

Apparatus

The participants' eye movements were measured using the head-mounted SR Research EyeLink System; data was recorded from only the right eye. The stimuli were presented in four blocks, using Experiment Builder (SR Research). A nine-point calibration was carried out at the beginning of each block and a drift correction was performed at the beginning of each trial.

Design

The experiment employed a 5-factor within subjects design. The first variable was familiarity (familiar/unfamiliar), the second was match (match/mismatch), the third was stimuli layout (vertically/high left/ high right), the fourth was face location (top face/ bottom face) and the fifth was the features (leftmost eye, rightmost eye, nose and mouth).

Procedure

The participants were instructed that they would be presented with pairs of faces, and the task was to press one key if the pair of faces were the same person and another key if they were two different people, and each pair was presented for 2 seconds.

Analysis

The analysis was the same as for Experiment 4, except that Dataviewer Software (SR Research) was used to create the 4 AOI. The gaze duration was converted into percentage of gaze per feature, as fixations and gaze duration can vary across subjects. The percentages were calculated across the layout condition; so that they could be directly compared. This meant that the sum of percentages for the six faces (2 in each condition) was equal to 100 percent.

Results

Task performance

Figure 3.7a shows the mean correct responses for the familiar faces and figure 3.7b shows the mean correct responses for the unfamiliar faces. The correct responses for the matching task were analysed by a 3-factor ANOVA; Familiarity (familiar/unfamiliar), Match (match/mismatch) and Layout (vertical/ high left/high right). The results from the analysis found there was a main effect of familiarity; the familiar faces received significantly more correct responses than the unfamiliar faces (92 % vs. 82 %; $F(1, 23) = 33.3$, $p < 0.01$). There was a significant three-way interaction between familiarity, identity and layout ($F(2, 46) = 3.5$, $p < 0.05$).

The simple main effects for the familiarity, identity and layout interaction revealed the familiar mismatched faces received more correct responses than the unfamiliar mismatched faces in the high right condition ($F(1, 23) = 27.0$, $p < 0.01$) and the high left condition ($F(1, 23)$ 19.1, $p < 0.01$). The matched familiar faces received marginally more correct responses than the matched unfamiliar faces in the high left condition ($F(1, 23) = 3.9$, $p = 0.06$). The unfamiliar faces in the high right condition, received more correct responses when the faces were matched, as compared to being mismatched ($F(1, 23)$ 5.6, $p < 0.05$). Layout appeared to have no effect on performance for familiar faces ($p > 0.05$), but there were some differences for the unfamiliar matched ($F(2, 46) = 3.5$, $p < 0.05$) and mismatched ($F(2, 46) = 11.1$, $p < 0.01$).

Planned comparisons found that for unfamiliar matched faces, those in the high right layout received more correct responses than those in the high left layout ($t(46) = 2.63$, $p < 0.05$). Also unfamiliar mismatched faces received more correct responses in the vertical layout than the high right ($t(46) = 4.69$, $p < 0.01$) and high left layout ($t(46) = 2.74$, $p < 0.05$), and marginally more correct responses in the high left than the high right layout ($t(46) = 1.95$, $p = 0.057$).

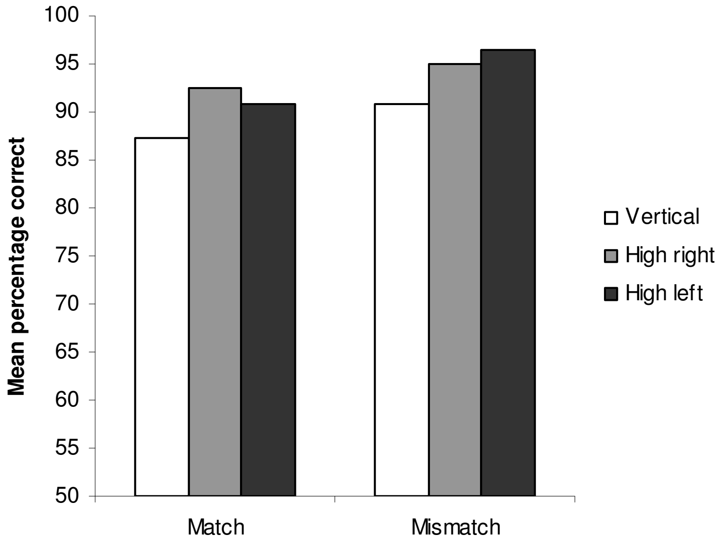


Figure 3.8a Mean accuracy for familiar faces for all layout conditions.

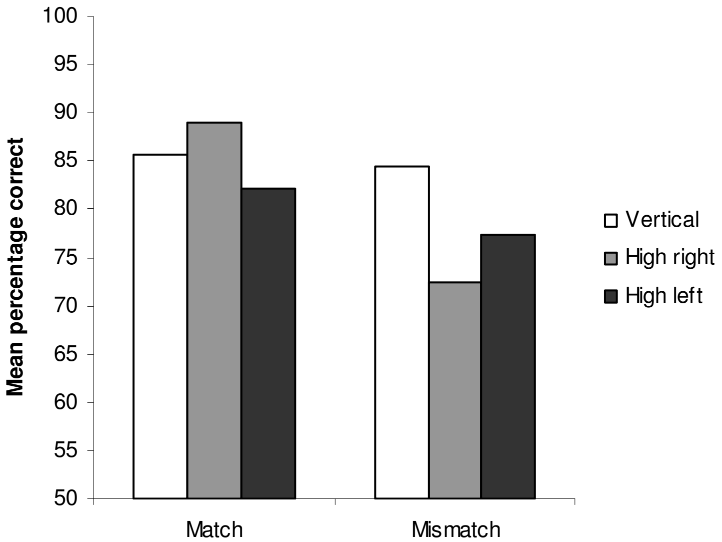


Figure 3.8b Mean accuracy for unfamiliar faces for all layout conditions.

Percentage of gaze to features

A 5-factor ANOVA; Familiarity (familiar/unfamiliar), Match (match/mismatch), Layout (vertically/high right/ high left), Face (top face/ bottom face) and Features (leftmost eye, rightmost eye, nose and mouth) was performed on the percentage of gaze data. The results from the analysis found a main effect of layout ($F (2, 46) = 4.9$, $p < 0.05$), face in the vertical condition (4.1) received more gaze per feature than the high right (3.8), but not more than the high left conditions (3.9). There was main effect of face, with the top face receiving more gaze per feature than the bottom face (4.1 vs. .3.7; $F(1, 23) = 8.9$, $p < 0.01$). There was a main effect of features ($F(3, 69) = 11.8$, $p < 0.01$); the leftmost eye (6.5) received the most amount of gaze, followed by the nose (6.0), then the rightmost eye (2.4) and the mouth (0.9). There was also a significant 4-way interaction for familiarity, match, layout and features, $F(3, 69) = 2.8$, $p < 0.05$). The data was split into four sets and four separate 3-factor ANOVAs were performed for the familiar matched, familiar mismatched, unfamiliar matched and unfamiliar mismatched faces.

Familiar matched faces

Figure 3.9 shows the mean percentage of gaze for the top and bottom faces for all the layout conditions and figure 3.10 shows the mean percentage of gaze to features for faces in the all the layout conditions. Results from the 3-factor ANOVA performed for the familiar matched faces found a main effect of layout ($F(2, 46) = 4.1$, $p < 0.05$), faces in the vertical condition (4.4) received significantly more gaze per feature than those in the high right condition (4.0), but not the high left condition (4.1). There was a main effect of features ($F(3, 69) = 11.1$, $p < 0.01$); the leftmost eye (7.0) and nose (6.1) received more gaze than the rightmost eye (2.5) and mouth (1.0). There was also a significant two-way interaction for layout and face ($F(2, 46) = 7.2$, $p < 0.01$) and for layout and features ($F(6, 138) = 20.5$, $p < 0.01$).

The analysis of the simple main effects for the layout and face interaction revealed the top face received significantly more gaze that the bottom face in the vertical layout ($F(1, 23) = 9.9$, $p < 0.01$). There were also significant differences in the amount of gaze to the top face as a function of layout (F ($F(2, 46) = 11.38$, $p < 0.01$), planned comparisons found the top face received significantly more gaze in the vertical layout than in the high left layout (t (46) = 2.27, p < 0.05). There were no significant differences in gaze to bottom face as a function of layout (F < 1).

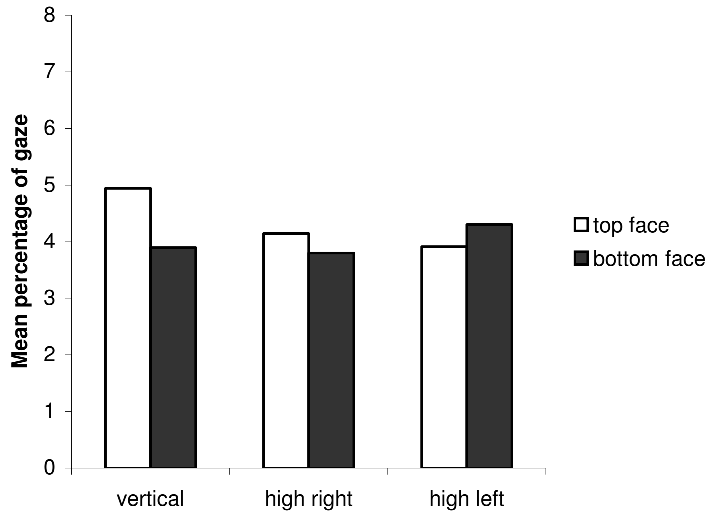


Figure 3.9 Mean percentage of gaze for the top and bottom familiar matched faces for the layout conditions.

The simple main effects for the layout and features interaction revealed there were some significant differences in gaze to the leftmost eye (F (2, 46) = 9.1, p < 0.01), and the nose (F (2, 46) = 21.8, p < 0.01) depending on the face layout. Planned comparisons revealed the leftmost eye received marginally more gaze in the high right than the high left layout (t (46) = 1.84, p = 0.07). The nose received significantly more gaze in the vertical (t (46) = 4.05, p < 0.01) and the high left layouts (t (46) = 4.04, p < 0.01) than the high right layout.

The simple main effects also revealed that there were some differences in the amount of gaze to the features in the vertical (F (3, 69) = 4.1, p < 0.01), high right (F (3, 69) = 3.5, p < 0.05) and high left layouts (F (3, 69) = 3.9, p < 0.05). Planned comparisons found, for the vertical faces the leftmost eye received more gaze than the mouth (t (69) = 2.09, p < 0.05), and the nose received marginally more gaze than the mouth (t (69) = 1.93, p = 0.057). For faces in the high right layout, the leftmost eye received more gaze than the mouth (t (46) = 2.22, p < 0.05) and there were no other significant differences between the features. For the high left layout, the leftmost eye (t (69) = 1.81, p = 0.07) and nose (t (69) = 1.89, p = 0.06) received marginally more gaze than the mouth.

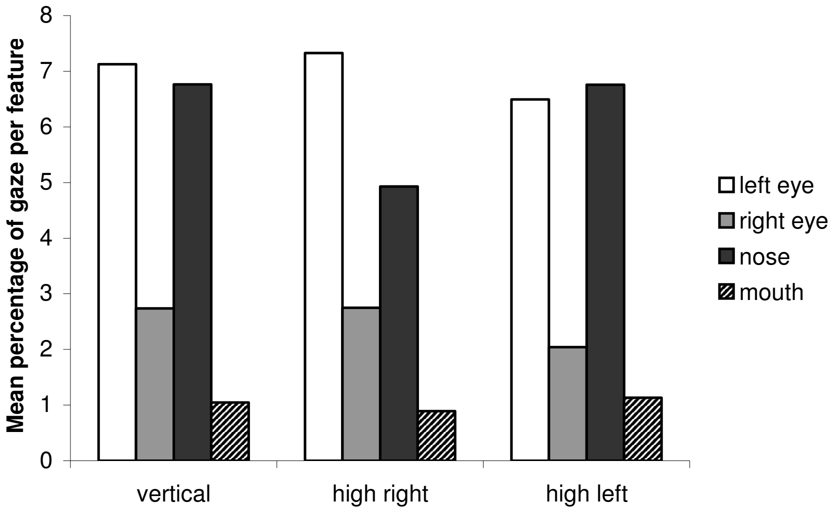


Figure 3.10 Mean percentage of gaze to features on the familiar matched faces for the layout conditions.

Familiar mismatched faces

Figure 3.11 shows the mean percentage of gaze for the top and bottom faces for the layout conditions and figure 3.12 shows the mean percentage of gaze to features for faces in all the layout conditions. Results from the 3-factor ANOVA performed for the familiar mismatched faces found a main effect of layout (F (2, 46) = 3.9, p < 0.05), faces in the vertical condition (4.1) received significantly more gaze per feature than those in the high right condition (3.7), but not the high left condition (3.9). There was a main effect of features (F (3, 69) = 11.3, p < 0.01); the leftmost eye (6.5) and nose (5.8) received more gaze than the rightmost eye (2.3) and mouth (0.97). There was also a significant two-way interaction for layout and face ($F(2, 46) = 6.78$, $p < 0.01$) and for layout and features ($F(6, 138) = 3.5$, $p < 0.01$).

The analysis of the simple main effects for the layout and face interaction revealed the top face in the vertical layout received more gaze than the bottom face ($F(1, 23) = 11.0$, $p < 0.01$). Also that there were some significant differences in gaze to the top faces as a function of layout ($F(2, 26) = 10.1$, $p < 0.01$) and planned comparisons revealed the top face received more gaze in the vertical layout, than the high left layout ($t(46) = 2.2$, $p < 0.05$).

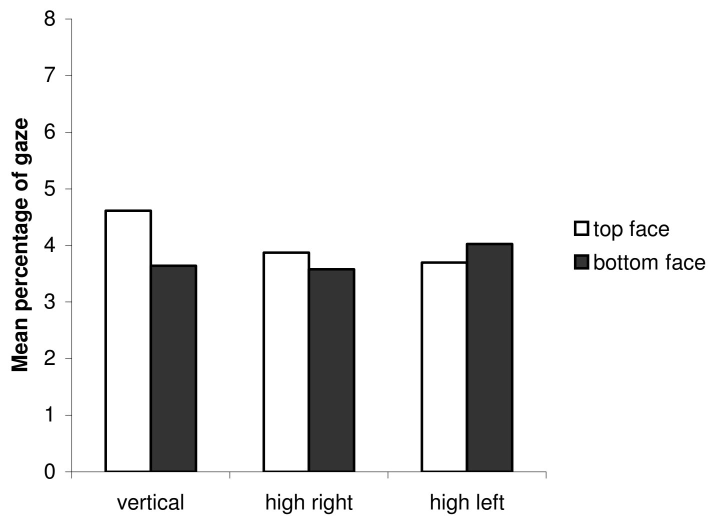


Figure 3.11 Mean percentage of gaze for the top and bottom familiar mismatched faces for the layout conditions.

The analysis of the simple main effects of the layout and features interaction revealed there were some significant differences in the amount of gaze to the rightmost eye ($F(2, 46) = 3.79$, $p < 0.05$) and nose ($F(2, 46) = 23.0$, $p < 0.01$) as a function of face layout. Planned comparisons found the rightmost eye received marginally more gaze in the high right layout, as compared to the high left layout ($t(46) = 1.73$, $p = 0.09$). Analyses for the nose found it received more gaze in the vertical (t (46) = 4.1, $p < 0.01$) and the high left layout (t (46) = 4.22, $p < 0.01$), than the high right layout.

The analyses from the simple main effects also found there were differences in the amount of gaze to features for the vertical (F (3, 69) = 4.2, $p < 0.01$), high right (F (3, 69) = 3.4, $p < 0.05$) and high left layouts (F (3, 69) = 4.1, $p < 0.01$). Planned comparisons for the vertical layout found the leftmost eye (t (63) = 2.20, $p < 0.05$) and nose (t (63) = 2.33, $p < 0.05$) received more gaze than the mouth. For the high right layout the leftmost eye received more gaze than the mouth (t (63) = 2.33, $p < 0.05$). In the high left layout, the leftmost eye (t (69) = 1.80, p = 0.76) and nose (t (69) = 1.96, p = 0.054) received marginally more gaze than the mouth.

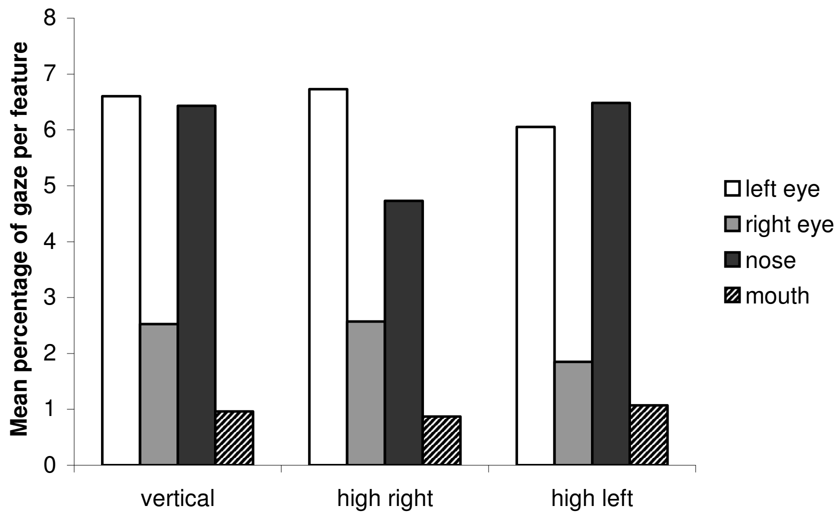


Figure 3.12 Mean percentage of gaze to features on the familiar mismatched faces for all lay out conditions.

Unfamiliar matched faces

Figure 3.13 shows the mean percentage of gaze for the top and bottom faces for all the layout conditions and figure 3.14 shows the mean percentage of gaze to features for faces in all the layout conditions. Results from the 3-factor ANOVA performed for the unfamiliar matched faces found a main effect of layout ($F\ (2, 46) = 5.1$, $p < 0.05$), faces in the vertical condition (4.5) received significantly more gaze per feature than those in the high right condition (3.9), but not the high left condition (4.1). There was a main effect of face, and the top face received more gaze than the bottom face (4.4 vs. 3.9; $F\ (1, 23) = 7.2$, $p < 0.05$). There was a main effect of features ($F\ (3, 69) = 12.8$, $p < 0.01$); the leftmost eye (6.8) and nose (6.6) received more gaze than the rightmost eye (2.4) and mouth (.8). There was also a significant two-way interaction for layout and face ($F\ (2, 46) = 8.4$, $p < 0.01$) and for layout and features ($F\ (6, 138) = 3.6$, $p < 0.01$).

The analysis of the simple main effects for the layout and face interaction revealed for vertical layout, the top face received more gaze than the bottom face ($F\ (1, 23) = 14.6$, $p < 0.01$). There were some significant differences in gaze to the top faces as a function of layout ($F\ (2, 46) = 12.6$, $p < 0.01$) and planned comparisons revealed the top face received more gaze in the vertical layout than the high right layout ($t\ (46) = 2.48$, $p < 0.05$).

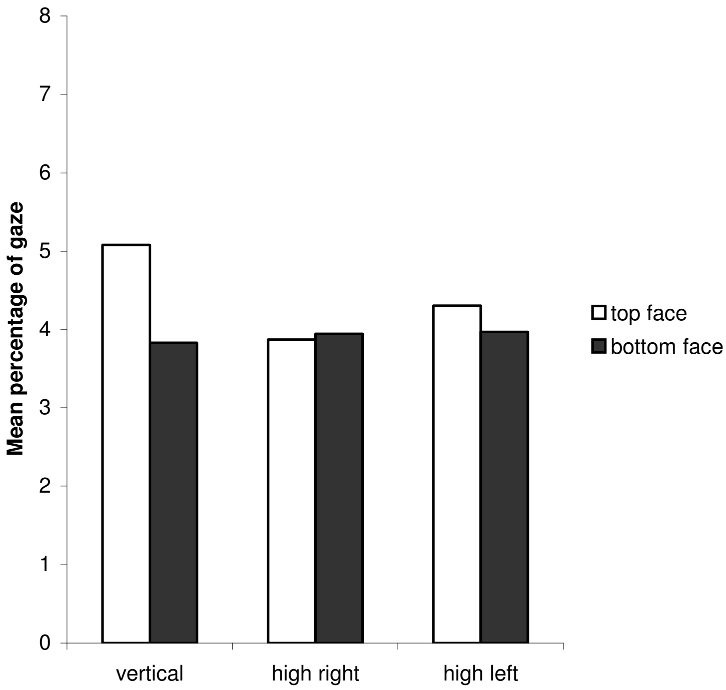


Figure 3.13 Mean percentage of gaze for the top and bottom unfamiliar matched faces for the layout conditions.

The analyses of the simple main effects for the layout and features interaction found there were differences in the amount of gaze to the leftmost eye ($F(2, 46) = 5.4$, $p < 0.01$), nose ($F(2, 46) = 14.9$, $p < 0.01$) and mouth ($F(2, 46) = 3.7$, $p < 0.05$) in the different layouts. The leftmost eye received more gaze in the vertical than the high left layout ($t(46) = 2.17$, $p < 0.05$), the nose received more gaze in the high right than the high left layout ($t(46) = 3.74$, $p < 0.01$) and the mouth received marginally more gaze in the vertical than the high right layout ($t(46) = 1.8$, $p = 0.078$).

The simple main effects also revealed differences between the amount of gaze the features received to each face as a function of layout this was significant for the vertical ($F(3, 69) = 4.3$, $p < 0.01$), high right ($F(3, 69) = 4.1$, $p < 0.01$) and high left layout ($F(3, 69) = 4.7$, $p < 0.01$). Planned comparisons found the leftmost eye received more gaze than the mouth and this was significant for the vertical ($t(63) = 2.10$, $p < 0.05$) and high right layouts ($t(63) =$

2.25, p < 0.05). Whilst the nose received more gaze than the mouth in the high left layout (t (63) = 2.31, p < 0.05).

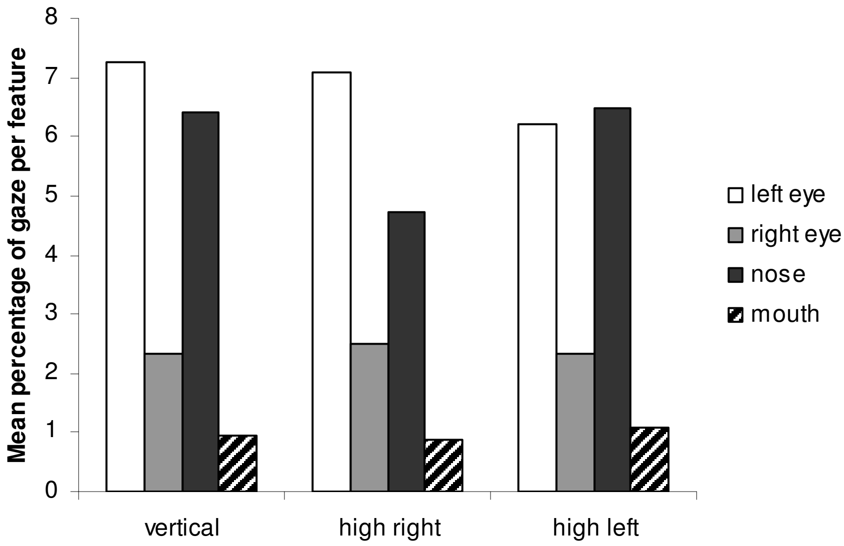


Figure 3.14 Mean percentage to features on the unfamiliar matched faces for the layout conditions.

Unfamiliar mismatched faces

Figure 3.15 shows the mean percentage of gaze to the top and bottom faces for the layout conditions and figure 3.16 shows the mean percentage of gaze to features for faces in all the layout conditions. Results from the 3-factor ANOVA performed for the familiar matched faces found a main effect of face, the top face received more gaze per feature than the bottom face (4.4 vs. 3.9; F (1, 23) = 7.8, p < 0.01). There was a main effect of features (F (3, 69) = 12.0, p < 0.01); the leftmost eye (6.9) and nose (6.5) received more gaze than the rightmost eye (2.6) and mouth (.8). There were also significant two-way interactions for layout and face (F (2, 46) = 5.4, p < 0.01) and for layout and features (F (6, 138) = 2.5, p < 0.05).

The analysis of the simple main effects for the layout and face interaction revealed the top face received more gaze than the bottom face and this was significant for the vertical ($F(1, 23) = 8.7$, $p < 0.01$) and the high right layout ($F(1, 23) = 5.1$, $p < 0.05$). Also there were some significant differences in gaze to the bottom faces as a function of layout ($F(2, 46) = 3.6$, $p < 0.05$), however planned comparisons for gaze to the bottom face revealed the differences were not significant ($p > 0.05$).

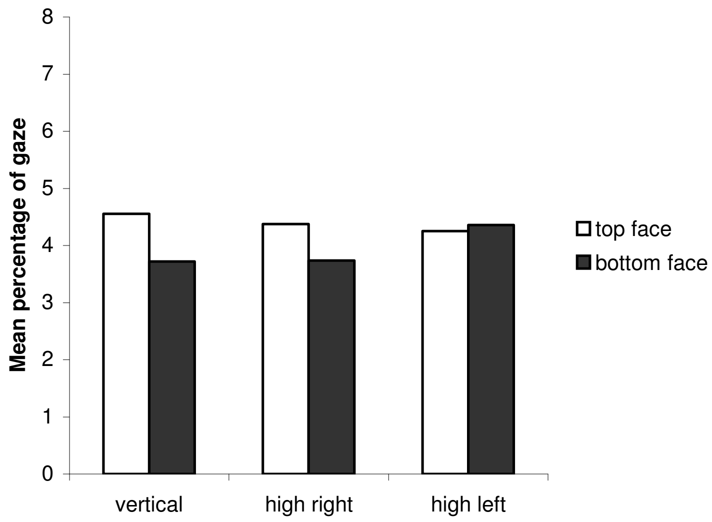


Figure 3.15 Mean percentage of gaze for the top and bottom unfamiliar mismatched faces for the layout conditions.

The analysis of the simple main effects for the layout and features interaction found there were differences in the amount of gaze to the leftmost eye ($F(2, 46) = 6.8$, $p < 0.01$) and the rightmost eye ($F(2, 46) = 4.6$, $p < 0.05$), as a function of the different layouts. The leftmost eye received more gaze in the high left ($t(46) = 2.47$, $p < 0.05$) and marginally more in the vertical layout ($t(46) = 1.95$, $p = 0.057$), than the high right layout. The rightmost eye received more gaze in the high right than the vertical layout ($t(46) = 2.11$, $p < 0.05$). There were no significant differences in gaze to the nose or mouth as a function of layout ($p > 0.05$).

The analysis of the simple main effects also revealed differences between the amount of gaze the features received to each face as a function of layout, this was significant for the vertical ($F(3, 69) = 4.5$, $p < 0.01$), high right ($F(3, 69) = 2.8$, $p < 0.05$) and high left layout ($F(3, 69) = 5.0$, $p < 0.01$). Planned comparisons found for the vertical layout found, the leftmost eye received more gaze than the mouth ($t(69) = 2.07$, $p < 0.05$). For the high right layout the nose received marginally more gaze than the mouth ($t(69) = 1.76$, $p = 0.08$). For the high left layout the left eye ($t(69) = 2.23$, $p < 0.05$) and nose ($t(69) = 2.11$, $p < 0.05$) received more gaze than the mouth.

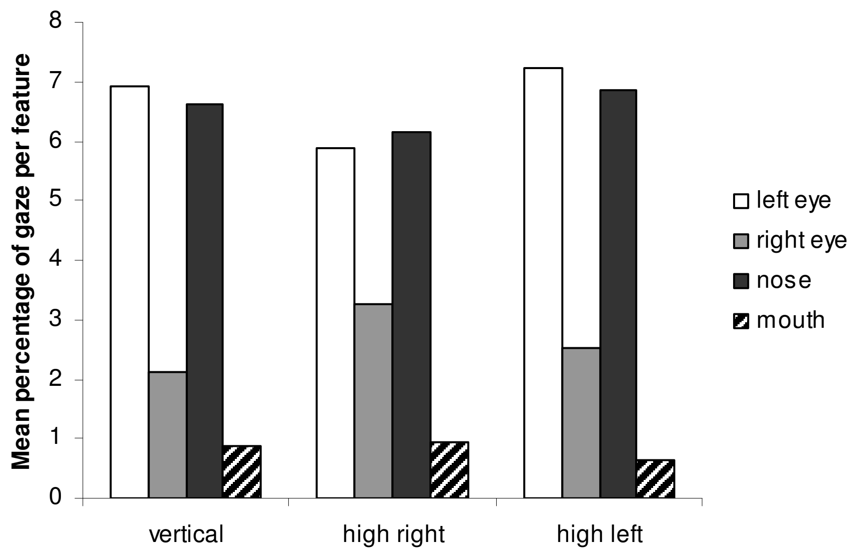


Figure 3.16 Mean percentage of gaze to features on the unfamiliar mismatched faces for the layout conditions.

Results Summary

The analysis of the eye gaze data found that although there was a 4-way interaction for; familiarity, match, layout and features, the patterns across familiarity (familiar/unfamiliar) and match (match/mismatch) conditions were very similar. There was a main effect of layout, which was significant for all conditions, except the unfamiliar mismatched faces.

The main effect of features was significant across all conditions, this found the leftmost eye received more gaze than the mouth for nearly all conditions and in some instances the nose also received more than the mouth; more specific differences are explained below.

Effect of Layout

The familiar (matched and mismatched) and unfamiliar matched faces all found a main effect of layout, whereas the unfamiliar mismatched faces did not. For the significant cases, faces in the vertical layout received more gaze per feature than those in the high right layout. The top face also received more gaze in the vertical than the high left layout for all conditions and more gaze in the vertical layout than the high right layout for the unfamiliar matched faces.

The amount of gaze to features was also influenced by layout. The leftmost eye received more gaze in the high right than the high left layout for the familiar matched faces, more in the vertical than the high left layout for the unfamiliar matched faces, and for the unfamiliar mismatched faces it received more gaze in the high left than the vertical layout. The rightmost eye received more gaze in the high right than the high left layout for the familiar mismatched faces, and more in the high right than the vertical layout for the unfamiliar mismatched faces. The nose received more gaze in the vertical and high left than the high right layout and this was significant for all conditions. The mouth received more gaze in the vertical condition than the high right condition, but only for the unfamiliar mismatched.

There were also differences in gaze to the individual features depending on the face layout. For faces in the vertical layout, the leftmost eye received more gaze than the mouth for all conditions and the nose received more gaze than the mouth for the unfamiliar faces (matched and mismatched). For faces in the high right layout, the leftmost eye received more gaze than the mouth for the familiar faces (matched and mismatched) and the unfamiliar matched faces, whilst the nose received more gaze than the mouth for the unfamiliar mismatched faces. For faces in the high left layout the leftmost eye and nose received more gaze than the mouth for the familiar faces and the unfamiliar mismatched faces, whilst the nose received more gaze than the mouth for the unfamiliar matched faces.

Effect of face

The main effect of face was only significant for the unfamiliar (matched and mismatched) faces, where the top face received more gaze than the bottom face. However there were significant interactions for face and layout across the conditions. The top face received more gaze than the bottom face when it was in the vertical layout and this was significant for all the conditions, the top face also received more gaze than the bottom for the high right layout, but this was only significant for the unfamiliar mismatched faces.

Discussion

The aim of this experiment was to determine if changing the way the faces are presented for a matching task, not only influences performance, but also the way that the faces are viewed. The eye gaze results found that overall the pattern of gaze to features across the different layouts was very similar, although those in the vertical layout appeared to receive more gaze per feature, than those in the high right or high left layouts. The increase in gaze to faces in the vertical layout seems to be specifically for the top faces and there appeared to be an overall bias towards the top face. The bias towards the top half of space has been found in previous research using faces and face- like objects (Caldara et al., 2006; Turati et al., 2006; Turati et al., 2002) and there was also a bias to look at the top half of space for Experiments 1, 2 and 3, described in Chapter 2.

Although there were some differences in the amount of gaze to features depending on the layout, there was no clear pattern where one or more features consistently received more gaze in one particular layout as compared to another. Overall there appeared to be a bias for the leftmost eye and that was consistent regardless of the layout, the bias for the left eye has been found in other studies using eye movements (Barton et al., 2006) and the bubbles technique (Schyns, Bonnar, & Gosselin, 2002; Vinette, Gosselin, & Schyns, 2004). There are other eye movement studies using faces that have found overall biases for the eye region (Henderson et al, 2001, Henderson et al., 2005, Janik et al., 1978).

In Experiment 5 the gaze to the leftmost eye was consistently more than to the mouth, and the layout did influence the amount of gaze it received, however the pattern was not consistent. The leftmost eye received more gaze in the high right, than the high left layout for the familiar matched faces, and more in the vertical, than in the high left layout for the unfamiliar matched faces. However for the unfamiliar mismatched faces, the leftmost eye received more gaze in the high left than the vertical layout. Face layout did seem to influence the amount of gaze to the rightmost eye and it received more gaze in the high right condition, for the mismatched faces (familiar and unfamiliar). The nose consistently received more gaze when it was in the vertical and high left layouts and this was for all conditions. Whilst the mouth received more gaze in the high right condition, but only for the unfamiliar mismatched faces. Overall the gaze to features varied little as a function of layout and the features viewed most were the leftmost eye and the nose regardless of layout, however in the separate analyses they did not received significantly more gaze than the rightmost eye.

In this experiment it appeared that viewers were using the leftmost eye and the nose on both the top and bottom face equally and the gaze to features did not seem to vary for the top or bottom faces. This seems to show that viewers were looking at the same features on both faces to make a matching decision, as was suggested by (Walker-Smith, Gale, & Findlay, 1977), namely the leftmost eye and nose and looked less at the rightmost eye and rarely at the mouth.

The face layout appeared to have little effect on the accuracy of matching two familiar faces, however there were some differences as a function of layout when the faces were unfamiliar. Responses for the unfamiliar matched faces were most error prone in the high left layout, whereas when they mismatched they were most error prone for faces in the high right layout and most accurate for faces in the vertical layout. Accuracy may have been reduced in the high right layout for the mismatched unfamiliar faces as a result of the left visual filed bias for faces, however there seems to be no plausible explanation as to why responses would be most error prone in the high left condition for the mismatched unfamiliar faces.

General Discussion

The aim of this chapter was to investigate whether manipulating the way faces are displayed can influence the viewing patterns and matching performance. In Experiment 4, the faces were presented side by side and were either near to one another or far apart, whereas in Experiment 5 the faces were placed either vertically one above the other or side by side, but misaligned with either the left or right face higher than the other one.

In Experiment 4 viewers used the two centre or inner eyes (rightmost eye on the left face and the leftmost eye on the rightmost face) more than the other features to make their matching decision. Whilst in Experiment 5 viewers used the leftmost eye and the nose equally for both faces to make a matching decision. In Experiment 4 the rightmost eye appeared to be more useful (when on the leftmost face) than it was in Experiment 5, whilst the nose was more useful in Experiment 5, than it was in Experiment 4. It appears that the way faces are presented can influence how they are viewed, as scanning strategies for Experiments 4 and 5 differed. In Experiment 4 viewers used the inner eyes and this was also a finding of Experiment 2 (in chapter 2), whilst for Experiment 3 viewers used mainly the eyes and nose of the left face and the leftmost eye on the right face. In Experiments 2, 3 and 4 the faces are presented side by side and viewers scanned horizontally across the eye region.

In Experiment 5 faces were presented vertically one on top of the other and viewers used the leftmost eye and nose, this seems to support Walker–Smith et al.'s (1977) research, where they suggested that the same features need to be fixated upon each face before a matching decision can be made. In Experiment 5 viewers appear to be scanning vertically up and down from the leftmost eye and nose from one face to another. This seems to show that viewers were using the shortest scanning route possible when carrying out the matching task, for Experiment 4 and in the vertical condition for Experiment 5, but not for the high right and high left conditions in Experiment 5, as again they would only need to scan between the inner eyes (see figures 3.17 for examples of scanning strategies when viewing the stimuli).

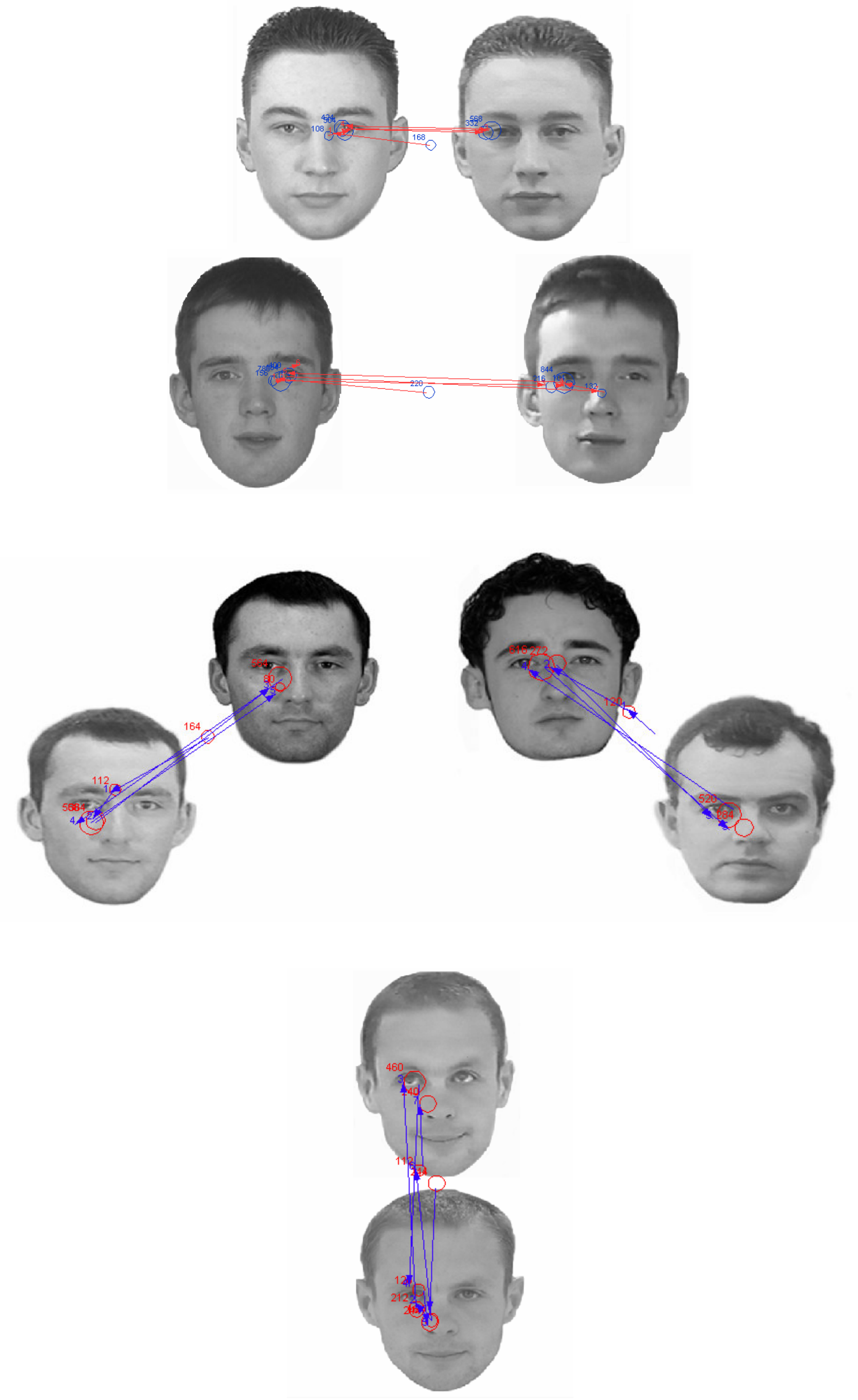


Figure 3.17 The viewing strategies used in Experiment 4 and 5.

For Experiments 4 and 5 the eye gaze data showed that overall the eyes are important for matching, this was also found for Experiments 2 and 3 and has been a finding in previous research using single faces (Althoff and Cohen, 1999; Henderson et al., 2001; Henderson et al., 2005; Janik et al., 1978). Another finding was that the leftmost eye was also particularly important for matching and this was also found for Experiment 3 and has been found by studies using eye movements (Barton et al., 2006) and the bubbles technique (Schyns et al., 2002; Vinette et al., 2004).

There were no clear differences in eye movement patterns for the familiar and unfamiliar faces for both Experiment 4 and 5, this was also an earlier finding from Experiments 1, 2 and 3 (in Chapter 2). Previous studies have also found little difference in eye gaze patterns for faces that are recognised as being previously presented, compared to those that are classed as new and unfamiliar (Henderson et al., 2001; Henderson et al., 2005). However there is some research that has found differences in the way famous and non-famous faces are viewed. Althoff and Cohen (1999) reported that participants spent less time looking at the nose of famous faces for a fame judgement, and more time looking at the left eye of famous faces for an emotion judgement.

There was also no clear differences in eye gaze patterns for faces that matched as compared to those that mismatched for Experiments 4 and 5, again this was also a finding of the earlier experiments in chapter 2. There has been research that has found differences in the amount of gaze to features depending on whether a pair of faces match. Stacey et al. (2005) found that viewers looked more at the internal features (eyes, nose and mouth) of matched faces (.95) as compared to when they mismatched (.92), however they also found that overall there was more gaze to the internal features regardless of familiarity. They did not separate out the internal features, therefore they were not able to investigate whether there were any differences in gaze to the specific features.

Experiment 4 and 5 both found more accurate matching performance for the familiar faces than the unfamiliar faces, although overall performance for the familiar faces was better in Experiment 4, as compared to Experiment 5. This might relate to fewer pairs of faces being used in Experiment 4 and therefore more faces might have been recognized. Whereas Experiment 5 used extra faces and perhaps the participants were not familiar with all of them and this influenced matching performance. Alternatively participants might have been better at matching faces presented side by side, instead of those presented either vertically one above the other or misaligned.

Both experiments found the way that a pair of faces was presented could influence the matching of unfamiliar faces, for Experiment 4 responses were more error prone when the faces were closer together, whereas for Experiment 5 responses were more error prone in the high right condition. This seems to suggest that the way unfamiliar faces are presented can influence a matching decision, and faces may affect each other if they are placed too close together, or if one if higher on the right side than the other one. This has implications for presenting pairs of faces or even arrays of faces to witnesses of crimes for identification. As the beginning of this chapter has shown, faces on the right might be more poorly identified than those on the left and when faces are close together, or one is placed higher on the right hand side this may reduce matching performance.

Chapter Four

The influence of spatial filtering and masking on face matching and viewing patterns.

Introduction

The previous chapter showed manipulating the presentation layout of face pairs can influence matching performance and the features that are viewed whilst making a matching decision. The faces used in all the preceding chapters have been high quality images, however in real life it might not always be possible to use high quality images when trying to identify a suspect and in some cases the images may be unclear or information may be missing, such as with CCTV footage. Additionally when a person is further away, their face appears not only smaller, but the fine details are less clear and it is difficult recognize. The focus of this chapter is to investigate how manipulating images of faces through either changing the spatial frequency, or masking the features, influences matching decisions and viewing patterns.

The influence of spatial frequency filtering on face recognition and matching.

Spatial frequency refers to how rapidly an image changes across space. Low spatial frequency (LSF) images represent large-scale variations and contain course scale information, such as face shape and the position of the features (see figures 4.1 & 4.2). High spatial frequency (HSF) images contain fine grain information, such as sharp edges and the details of facial features. When someone is near we can see all the spatial frequencies, or a full bandwidth (FB) image, however when someone is further away, such as 25 m, the only visual information available is in the LSF domain, then as the person gets closer the mid spatial frequency and HSF information also becomes available (Loftus & Harley, 2005).

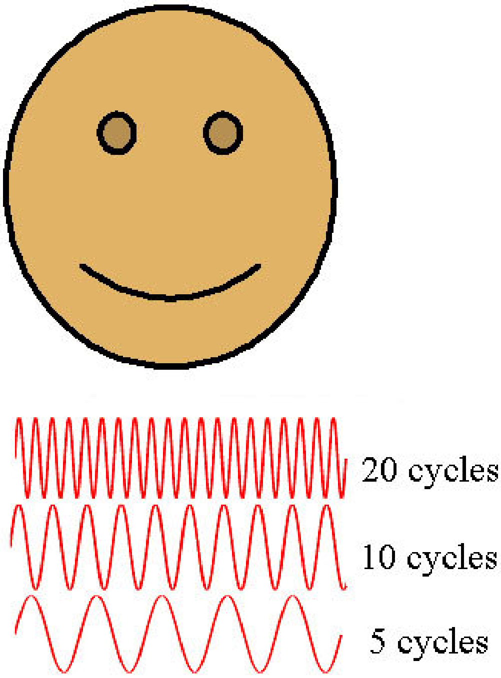


Figure 4.1 Illustrates the spatial frequency for filtering faces reported as cycles per face width.

For face processing and recognition studies spatial filtering is usually carried out according to the cycles per face width, rather than the number of cycles per degree of visual angle. The greater the number of cycles/face width the higher the spatial frequency. Research has found that the optimum bandwidths for face recognition are between 8-13 cycles/face width (Nasanen, 1999).

Figure 4.2 The first image an unfiltered image of Gordon Brown with all the spatial frequencies, the second is filtered so that it contains only low spatial frequencies (LSF) of less than 8 cycles/face width, and the third is filtered so that it contains only high spatial frequencies (HSF) over 24 cycles/face width.

There are a number of studies that have investigated how filtering images to display specific spatial frequencies affects face processing and recognition. Research has shown that full bandwidth (FB) or unfiltered photographs of faces are recognised more easily than outline drawings, or two tone intensity images, that preserve the HSF or LSF information (Bruce, Hanna, Dench, Healey, & Burton, 1992; Davies, Ellis, & Shepherd, 1978). Other studies have also shown that when faces contain only HSF or LSF information, they are more poorly recognised than when the images contain broader, or mid spatial frequency information (Costen, Parker, & Craw, 1994, 1996; Fiorentini, Maffei, & Sandini, 1983; Parker, Lishman, & Hughes, 1996). These studies seemed to suggest that the mid spatial frequencies are more important for face recognition than the LSF or HSF. However more recent studies have suggested that the mid spatial frequencies are not always advantageous when trying to determine if a face has been previously presented. Parker, Lishman, & Hughes (1996) found that responses when trying to match faces when one was a LSF image, were not significantly more error prone when both images were FB, but they were significantly longer.

Liu, Collin, Rainville and Chaudhuri (2000) noted that previous studies that investigated the affect of spatial frequency on face recognition had not examined the importance of images being spatially filtered in the same way from the study to test phase, they called this the spatial frequency overlap. In many cases these studies had compared the recognition of faces that had previously been presented as unfiltered images during a study phase and then filtered and presented again for a recognition test. Liu et al., (2000) presented faces during the study phase that were already filtered and then presented the faces again for a recognition test. They found there was no advantage for the mid spatial frequencies, but recognition responses were accurate for faces filtered into LSF or HSF images, but only if the study face had been filtered with similar spatial frequencies. This seemed to show that the spatial frequency overlap between study and test was more important than the spatial frequency of the images themselves.

One criticism of the Liu et al., (2000) study was that they used the same image from study to test phase and it could therefore be argued that participants were carrying out an image matching task, rather than a face recognition task. Collin, Liu, Troje, McMullen, and Chaudhuri (2004) addressed this issue with their study and, like Liu et al., (2000), found that participants recognised faces more accurately if they had been filtered in the same way from study to test. Kornowski and Petersik (2003) also found that accurate face recognition relied more on the degree of congruency between the spatial filtering of faces at study and test phases, rather than the range of spatial frequencies. They argued that the overlap in spatial frequencies between two images was more important than a particular range of spatial frequencies.

Collin, Therrien, Martin and Rainville (2006) used a slightly different paradigm to investigate the role of different spatial frequencies in face recognition. Participants were presented with a target face that was either filtered, or unfiltered and then four comparison faces. Participants could then adjust the spatial frequency of the target face until they felt it could just be recognised as one of the comparison faces. They found that when the comparison face was unfiltered, the target face was adjusted to the mid spatial frequencies, but if it was filtered to the LSF or HSF then participants would adjust the spatial frequency in accordance to the filtered faces. They suggested that when a face is unfiltered the mid spatial frequencies become more important, however when a face is filtered it is easier to match it to another with similar filtering. Their study reported that viewers were able to match filtered faces, but does filtering a face to either LSF or HSF convey different types of information to the person viewing the face?

Goffaux and colleagues investigated whether LSF and HSF images might relate to different types of processing, such as configural or featural. Goffaux, Hault, Michel, Vuong and Rossion (2005) presented faces that were transformed either configurally (moving the distance between the eyes), featurally (replacing the eyes), or both configurally and featurally. The faces were presented as LSF, HSF or unfiltered images. Participants had a target face and two probe faces and had to decide if one of the probes matched the target face, the target and probes were always presented in the same SF. They found that when faces differed featurally, there was an advantage for the HSF over the LSF images, but when the faces differed configurally, performance was better for the LSF than HSF faces. They suggested that LSF information is used to extract configural information resulting in a course description of a face, whereas featural processing is largely dependent on HSF information.

Goffaux et al. (2005) were not the first researchers to suggest that LSF may be useful for configural processing. Sergent (1986) suggested that holistic processing would be largely dependent on LSF and that the extraction of features would depend mostly on HSF. Collishaw and Hole (2000) also found that blurred or LSF faces can be recognized as long as they were not also inverted, which would prevent configural processing. Goffaux and colleagues have however provided a number of experiments that seem to support the view that LSF are used for holistic processing.

In a study similar to Young et al., (1987), Goffaux and Rossion (2006) presented participants with pairs of composite faces that were either aligned, or misaligned and were either FB, LSF or HSF images. They reported that when participants had to decide if the two top halves of the faces were the same person, spatial frequency only influenced the aligned faces and the LSF images had the lowest performance. They suggested that this provided evidence that the faces were being processing holistically in the LSF condition, as participants were not able to ignore the bottom halves of the face.

In another study participants were presented with either a whole face or a part face (pair of eyes), that were FB, HSF or LSF images. Then they were presented with two probe faces, and they had to decide which had been previously presented. They found that responses were more accurate for whole rather than part faces and responses were also more accurate for the FB and HSF images than the LSF images. The whole/part advantage was twice as large for the FB and LSF faces as compared to the HSF images, which led them to suggest that FB and LSF images were more useful for holistic processing, whereas the HSF images were useful for featural processing (Goffaux & Rossion, 2006).

Being presented with LSF images of faces when we are used to seeing FB images does seem to lead to overall poorer recognition of specific identities, however as the research described has shown, overall we are still able to recognize or match faces even if they are blurry, the same way we are able to recognize a friend from a distance. But how good is face recognition when specific features are masked or missing? Goffaux and Rossion (2006) found that when presented with a whole face or a pair of eyes, performance was significantly more accurate with the whole face, than with the eyes alone. The following section focuses on recognition and matching when important information, such as the eyes, is missing or masked.

How important are the eyes for recognition and matching?

Many face recognition studies using eye movements have found that the eyes are the features that are looked at more than any other features, indeed Henderson et al. (2001) found that 60 % of fixations were directed to this region, and a number of studies have found similar results (Althoff & Cohen, 1999; Barton et al., 2006; Janik et al, 1978). The most common triplet set of fixations when viewing a face was found to be scanning from the left eye to right eye to left eye and vice versa (Groner, Walder & Groner, 1984). The eye region appears to receive more gaze duration than any other feature when learning faces and during recognition (Henderson et al., 2005). In other studies using the bubbles technique (Gosselin & Schyns, 2001), which is a paradigm where only small areas of a stimuli are revealed at any one time, the eyes were found to be the most useful feature for recognition (Schyns, Bonnar, & Gosselin, 2002; Vinette, Gosselin, & Schyns, 2004).

Face recognition research using single faces has revealed that the eye region seems to be the most important feature of the face; however there has been some evidence that the eye region may also be important for face-matching, especially for familiar faces. O'Donnell & Bruce (2001) manipulated the eyes, mouth, chin and hair of familiar and unfamiliar faces and found that familiarity seemed to increase the sensitivity to detect changes to the eyes, but not the other internal features. They suggest that as we learn faces, we attend to and learn more about the eyes, as compared to the other internal facial features.

Developmental research, has also found that the eye region is extremely important for face perception and there is evidence that infants attend to the eyes of a face before they are able to recognise whole faces (Maurer, 1985; Taylor, Edmonds, McCarthy, & Allison, 2001). Other research has shown that infants prefer face-like stimuli with more elements in the top half (Turati et al., 2002; Turati et al. 2005) and this bias toward the top half of faces and face-like objects continues into adulthood (Caldara et al., 2006). One study using a person with prosopagnosia, who had an impairment in recognising familiar faces, found that unlike the controls, she did not use the information in the eye region to recognise faces, rather the information in the lower half of the face was used (Caldara et al., 2005). However there is some research that has investigated whether it is the eyes themselves that are important for face recognition, or the area including the eyebrows.

In one study, famous faces were presented with either the eyes removed or the eyebrows removed and participants were asked to name the faces (Sadr, Jarudi, & Sinha, 2003). They found that responses were more accurate for the faces with no eyes (55.8 %) than those without eyebrows (46.3 %) and concluded that the eyebrows were as important for face recognition as the eyes themselves. However this study has been criticized, because removing the eyebrows altered the configuration of the faces and another study tried to replicate these results using a slightly different paradigm. White (2004) presented famous faces that either had the eyebrows removed, masked with a simulated plaster or in the original format. Faces were presented with names underneath that were either congruent, or incongruent with the faces and participants had to make a match or mismatch response. Responses were faster for the original images, but not significantly different from the images with the masked eyebrows, however responses for faces where the eyebrows were removed, were significantly slower than those with the masked eyebrows. White (2004) concluded that removing the eyebrows altered the configuration of the faces leading to poorer recognition, but masking them did not.

There has been no research using eye movement measures to investigate what features are used to recognize, or match faces when the eyes/eye region is not present or masked. There has also been no research using eye movements to explore how faces may be viewed if the features, such as the eyes are blurred, as they are in LSF images. In this chapter three experiments are reported, two of which used eye movement measures. In the first experiment low spatial frequency images of faces were presented along with full bandwidth images for a face matching task and eye movements were recorded. The second experiment also employed eye movement measures and masked the inner eyes (right eye on left face and left eye on right face), as experiments in previous chapters (Experiments 2, 3 and 4) found, the inner eyes were the most viewed features when faces are presented side by side. The third experiment presented pairs of eyes along with the eyebrow region for matching, as this region has been found to be the most useful for the face matching tasks.

Experiment 6

In this experiment low spatial frequency (LSF) images of faces were used, as there is less fine detail for the eye region and this area is blurred with little definition between the eye outline, sclera and iris (see figure 4.2).This is the type of information that might be obtained through CCTV footage, or when a person is far away. As there is less fine grain information in the eye region, participants may not have enough visual information needed to make a matching decision by only scanning between the two central or inner eyes. If participants need more visual information from the LFS images, then they might fixate upon more areas of the face, than the FB images. However if the viewing pattern is merely a global scanning strategy for gaining a general or holistic impression of each face, then the pattern may persist even with the LSF images.

Research has shown that when trying to match faces where one of the faces is a LSF image, there were no significant differences in the number of errors as compared to FB images, although it took significantly longer when one of the faces was a LSF image (Parker, Lishman, & Hughes, 1996). Other research has found that faces are matched more accurately if they are filtered similarly (Collin et al., 2004) which seems to suggest that performance will be better when both faces are filtered to the same spatial frequencies. As it takes longer to match a LSF image to a FB image, than to match two FB images, do viewers gaze longer at a set of specific features (e.g. the central eyes) for the LSF image, or do they gaze at more features per se?

Method

Participants

24 participants took part in the study (12 female). All were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 84 pairs of male celebrity faces, presented in pairs. All the pairs were presented in the upright orientation, half were matched pairs (two different images the same person), the other half were mismatched pairs (different identities). 28 pairs were full bandwidth (FB) images, 28 pairs were low spatial frequency (LSF) images (less than 8 cycles per face width). The remaining 28 pairs consisted of one face that was a full bandwidth (FB) image and the other was a low spatial frequency (LSF) image, this was counterbalanced so that the LSF image appeared equally as the left or right face (see figure 4.2).

All the images were converted to grey scale and cropped around the faces, so they were presented on a white background. Each face was 13.5 cm by 10 cm, subtending to a visual angle of 8 degrees by 6 degrees. They were placed 5cm apart from each other and the resolution was 72 pixels per inch. The stimuli were presented on 21 inch Belinea TFT flat screen monitor, 1 meter from the participant using E-Prime software.

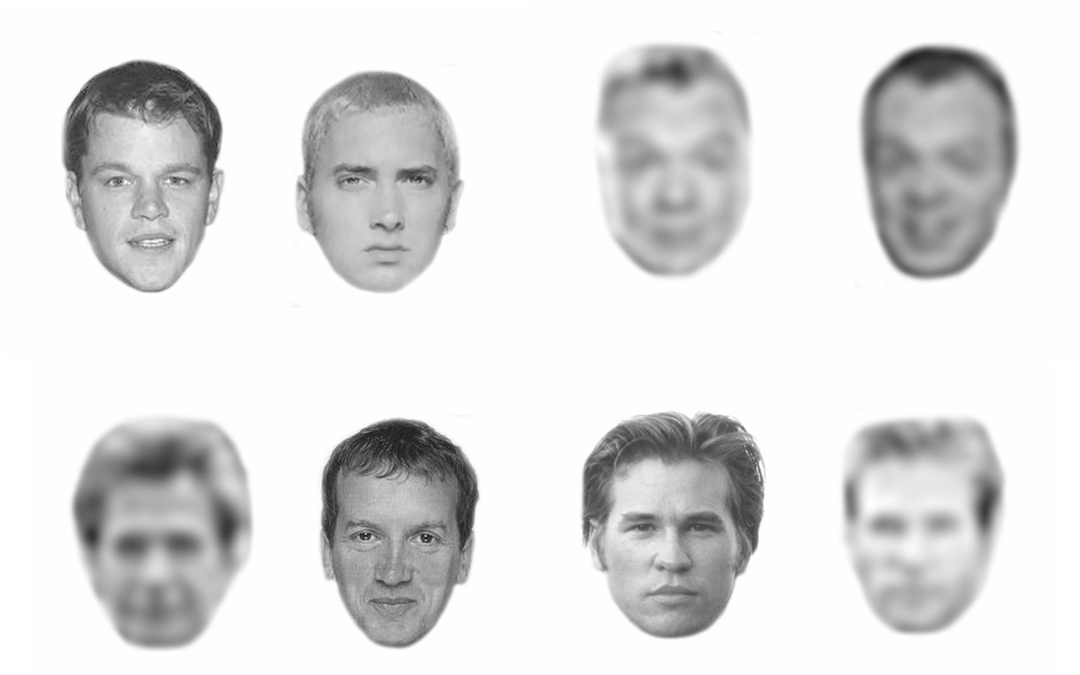


Figure 4.3 Examples of the types of stimuli used, clockwise from the top left; mismatched FB images, matched LSF images, matched right LSF, mismatched left LSF.

Apparatus

Eye tracking data were recorded using a non-invasive remote eye tracking device (RED) from Senso-Motor Instruments, which was placed on a table below the monitor. Eye movements were captured using Iview version 2.3 software and the participants were calibrated using a 9-point display screen, before stimuli presentation. Participants had Asden HS35s headphone/ microphone combination headsets, so that they were able to communicate with the experimenter in the other room.

Design & Procedure

The experiment employed a 4-factor within subjects design. The first variable was Match (match/ mismatched), the second was Spatial frequency (FB images, LSF images, LSF left face, LSF right face), the third was Face side (left/right) and the fourth was the Features (left eye, right eye, nose, mouth). The participants were instructed that they would be presented with pairs of familiar faces, some of which would be blurry and some normal images. The task was verbally to indicate whether the face pair was the same person or two different people. Each pair was presented for 2 seconds. The experimenter recorded the verbal responses.

Analysis

The preliminary analysis of eye gaze data began by ascertaining whether there was a sufficient capture rate of all eye gaze data for each participant. Using the Iview 2.3 software, the viewing time for each face was analysed to see how much of the data was undefined, (i.e. gaze not recorded within the areas of interest). If the undefined data was higher than 30 percent, then the subject's data was discarded. The eye gaze data loss may occur through head movement, blinking, hand gesticulation obscuring the infrared beam, or untraceable eyes. 29 participants were tested, however 5 had to be discarded, as the undefined data were above 30 percent. 24 participants were used in the final analysis.

The faces were divided into 4 areas of interest (AOI) created using Iview 2.3, they were; the left eye, right eye, nose and mouth. Separate AOI were created for each individual face, as the faces varied in regards to configuration. For the purpose of description here the AOI are given from the perspective of the viewer, therefore the left eye is always on the left from the viewer's perspective.

Eye gaze data with fixations shorter than 100 ms were discarded, in line with comparable studies (Baron, 1980; Fischer et al., 1989). Only the data for faces that were correctly categorised as being 'same' or 'different' were used in the analysis. Eye gaze data was converted to percentages of gaze per feature for each face, as gaze duration and number of fixations could differ across subjects. The percentage of gaze was split across all the spatial frequency conditions, so that they could be directly compared, as preliminary analyses using gaze duration had shown there were some differences in gaze as a function of spatial frequency.

Results

Task performance

Figure 4.4 shows the mean percentage correct for the matched and mismatched faces in all the spatial frequency conditions. A 2-factor ANOVA was performed on the response data;

Match (matched/mismatched), Spatial frequency (FB, LSF, left face LSF, right face LSF). There was a main effect of match, responses were more accurate for the mismatched faces than the matched faces (92 % vs. 84 %; $F(1, 23) = 15.9$, $p < 0.01$). There was a main effect of spatial frequency ($F(1, 23) = 23.1$, $p < 0.01$), responses were more accurate for faces that were FB images (94 %) than when they were both LSF images (88 %) or the left face was a LSF (78 %), but not when the right face was a LSF (92 %). There was a significant 2-way interaction for match and spatial frequency ($F(2, 46) = 9.1$, $p < 0.01$).

The analysis from the simple main effects for the interaction found there were significantly more correct responses for the mismatched faces in the LSF condition ($F(1, 23) = 10.1$, $p < 0.01$) and the left LSF condition ($F(1, 21) = 23.2$, $p < 0.01$). There were also some significant differences in responses to the matched faces, as a function of spatial frequency ($F(3, 63) = 32.3$, $p < 0.01$). Planned comparisons found that responses for the FB condition were marginally more accurate than the LSF right condition ($t(63) = 1.76$, $p = 0.08$) and comparisons with the other conditions produced higher t values. Responses for the right LSF condition were significantly more accurate than those for the LSF condition ($t(63) = 2.89$, $p < 0.01$) and the left LSF condition ($t(63) = 7.44$, $p < 0.01$). Responses for the LSF condition were also more accurate than those for the left LSF condition ($t(63) = 4.55$, $p < 0.01$).

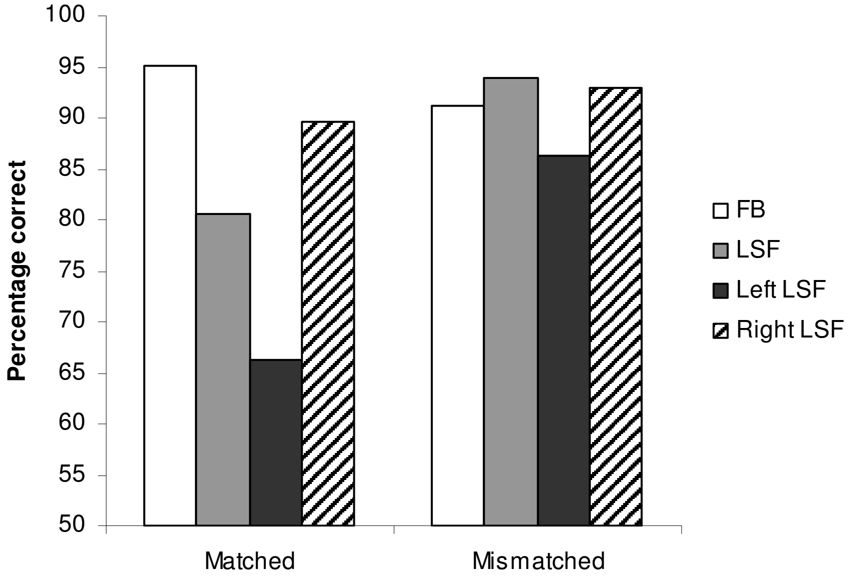


Figure 4.4 The mean percentage correct for the matched and mismatched faces for all the spatial frequency conditions.

Location of first fixation

The location of the first fixation for each trial was examined to see if viewers looked initially at the rightmost or leftmost face. A paired sample t-test found that viewers made significantly more first fixations to the leftmost face than the rightmost face (89.2 % vs. 10.8 %; $t (23) = 15.9$, $p < 0.01$). This was an extremely strong effect and will be explored further in chapter 5 where a full analysis will be carried out.

Percentage of gaze to features

Eye data were analysed by a 4-factor ANOVA: Match (match/mismatch) x Face (rightmost/leftmost) x Spatial frequency (FB, LSF, left LSF, right LSF) x Feature (left eye, right eye, nose, and mouth). There was a main effect of spatial frequency ($F (3, 69) = 9.9$, $p < 0.01$), the faces in the left LSF (3.3) and right LSF conditions (3.5), received more gaze per feature than faces in the FB (2.8) or LSF conditions (2.8). There was a main effect of face, with the left face receiving more gaze per feature than the right face (3.4 vs. .2.8: $F(1, 23) = 160.4$, $p < 0.01$). There was a main effect of features ($F(3, 69) = 23.4$, $p < 0.01$), the left eye (5.3) received more gaze than the nose (3.0), but not the right eye (4.0) and all the features received more gaze than the mouth (0.2). There was also a significant 4-way interaction for; match, spatial frequency, face and features ($F(3, 69) = 3.0$, $p < 0.05$). The data was therefore split into two sets and two separate 3-factor ANOVAs were performed for the matched, mismatched faces.

Matched faces

Figures 4.5a to 4.5d show the mean percentage of gaze to features on the right face for all the different spatial frequency conditions. Results from the 3-factor ANOVA performed for the matched faces found a main effect of spatial frequency ($F(3, 69) = 4.7$, $p < 0.01$), faces in the left LSF (3.4) and right LSF (3.4) conditions, received more gaze per feature than the FB images (2.8) and the LSF images (2.8). There was also a main effect of features ($F(3, 69) = 22.3$, $p < 0.01$), the left eye (5.6) received more gaze than the right eye (3.6) and the nose (3.0), and all the features received more gaze than the mouth (0.2). There was also a significant 3-way interaction for spatial frequency, face and features ($F(9, 207) = 2.8$, $p < 0.01$).

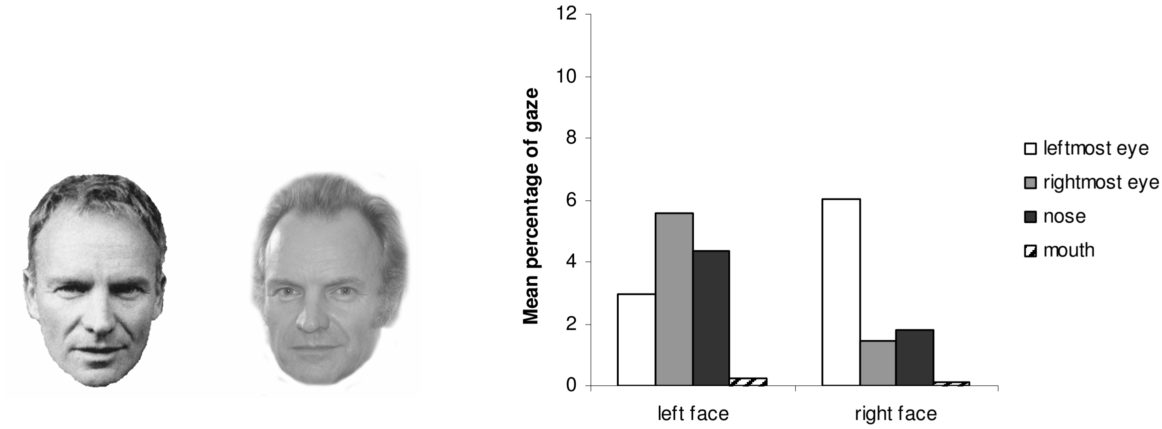


Figure 4.5a Mean percentage of gaze to features on the left and right faces for matched FB condition.

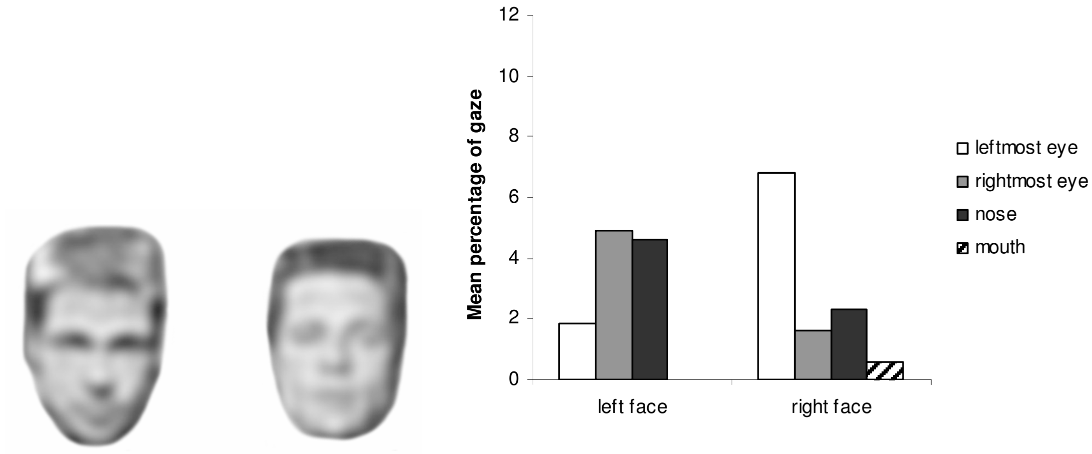


Figure 4.5b Mean percentage of gaze to features on the left and right faces for matched LSF condition.

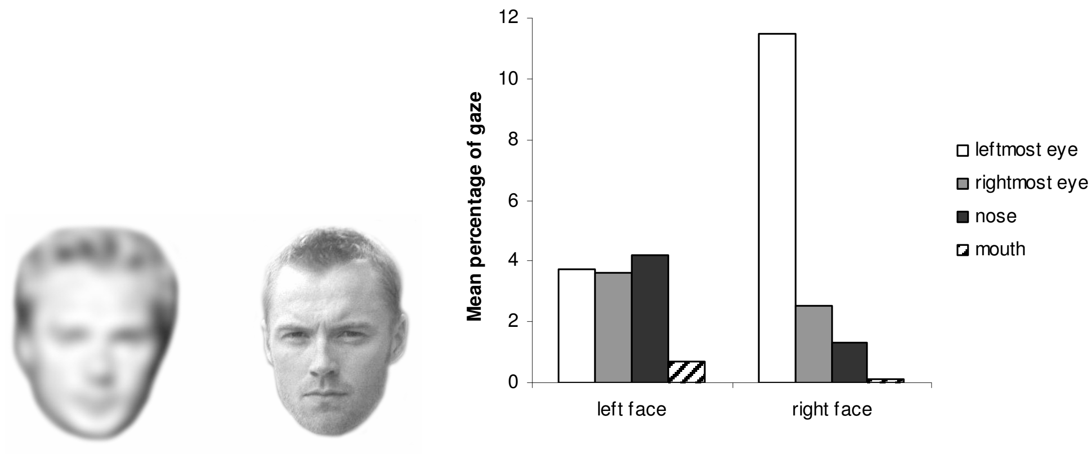


Figure 4.5c Mean percentage of gaze to features on the left and right faces for matched left LSF condition.

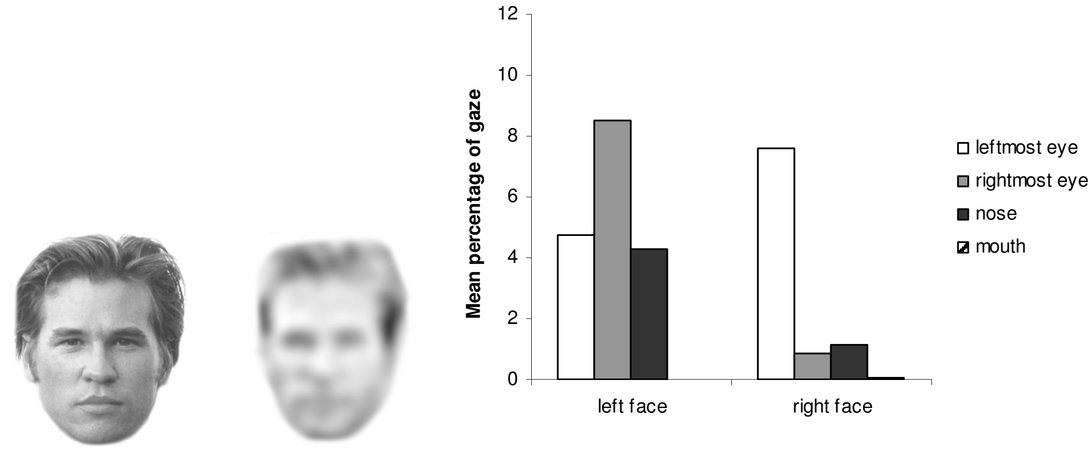


Figure 4.5d Mean percentage of gaze to features on the left and right faces for matched right LSF condition.

The analysis of the simple simple main effects for the interaction revealed that for some conditions the features received more gaze than in other conditions. There were significant differences in gaze to the left face (F (3, 69) 2.9, $p < 0.05$) and the right face in the FB condition (F (3, 69) 3.6, $p < 0.01$). Planned comparisons for the left face found the right eye (t (63) = 2.82, $p < 0.01$) and nose (t (63) = 2.17, $p < 0.05$) received more gaze than the mouth. Comparisons for the right face found that left eye received more gaze than the nose (t (63) = 2.21, $p < 0.05$) and comparisons with the other features produced even higher t values (see figure 4.5a).

There were also significant differences for features on the left face (F (3, 69) = 3.1, $p < 0.05$) and the right face in the LSF condition (F (3, 69) = 4.2, $p < 0.01$). Planned comparisons for the left face found the right eye (t (63) = 2.59, $p < 0.01$) and nose (t (63) = 2.43, = 0.05) received more gaze than the mouth. Comparisons for the right face found the left eye received more gaze that the nose (t (63) = 2.36, $p < 0.05$) and comparisons with the other features produced higher t values (see figure 4.5b).

Analyses for the left LSF condition found there were no significant differences in gaze to the features on the left face ($p > 1$), but there were significant differences for features on the right face ($F(3, 69) = 15.0$, $p < 0.01$). Planned comparisons for features on the right face found that the left eye received significantly more gaze than the right eye ($t(63) = 8.96$, $p < 0.01$) and comparisons with the other features produced higher t values (see figure 4.5c).

There were also significant differences in gaze to the left face ($F(3, 69) = 6.8$, $p < 0.01$) and right face ($F(3, 69) = 6.8$, $p < 0.01$) in the right LSF condition. Planned comparisons found the right eye received more gaze than the left eye ($t(63) = 1.98$, $p = 0.05$) and comparisons with the other features produced higher t values. The left eye ($t(63) = 2.51$, $p < 0.01$) and nose ($t(63) = 2.23$, $p < 0.05$) received more gaze than the mouth. Comparisons for the right face found the left eye received more gaze than the nose ($t(63) = 3.41$, $p < 0.01$) and comparisons with the other features produced higher t values (see figure 4.5d).

The analyses of the simple simple main effects also revealed that spatial frequency influenced the amount of gaze to the left eye ($F(3, 69) = 7.5$, $p < 0.01$) and the right eye ($F(3, 69) = 102.4$, $p < 0.01$) on the left face, and the left eye ($F(3, 69) = 140.4$, $p < 0.01$) on the right face. Planned comparisons for the left eye on the left face found it received more gaze in the right LSF condition and this was more than the FB condition ($t(69) = 2.83$, $p < 0.01$) or the LSF condition ($t(69) = 4.57$, $p < 0.01$). The left eye also received more gaze in the left LSF condition than in the LSF condition ($t(69) = 2.9$, $p < 0.01$). Planned comparisons for the right eye on the left face found that it received more gaze in the right LSF condition and this was more than when in the FB condition ($t(69)$ 4.58, $p < 0.01$) and comparisons with the other spatial frequency conditions produced higher t values.

Planned comparisons for the right face found the left eye received the most amount of gaze in the left LSF condition and this was significantly more than in the right LSF condition ($t (69) = 6.05$, $p < 0.01$) and comparisons with the other conditions produced higher t values.

Analyses from the simple simple main effects also revealed that some features received more gaze depending on whether they were on the left, or right face. The left eye received more gaze on the right face and this was significant for all the spatial frequency conditions ($p < 0.05$). The opposite pattern was found for the right eye, it received more gaze on the left face and this was also significant for all the spatial frequency conditions ($p < 0.05$), except when the left face was a LSF image ($p > 0.05$). The nose received more gaze on the left face and this was significant for all the spatial frequency conditions ($p < 0.05$). There appeared to be no significant effect of face side upon gaze to the mouth.

Mismatched faces

Figures 4.6a to 4.6d show the mean percentage of gaze to features on the left and right face for all the spatial frequency conditions. Results from the 3-factor ANOVA performed for the matched faces found a main effect of spatial frequency ($F (3, 69) = 5.4$, $p < 0.01$), faces in the right LSF condition (3.5) received more gaze per feature than the FB images (2.9) and the LSF images (2.8), but not more than faces in the LSF left condition (3.2). There was a main effect of face with the left face receiving more gaze per feature than the right face (3.5 vs. 2.7; $F (1, 23) = 17.4$, $p < 0.01$). There was also a main effect of features ($F (3, 69) = 20.2$, $p < 0.01$), the left eye (4.9) and the right eye (4.4) received more gaze than the nose (3.0), and all the features received more gaze than the mouth (0.14). There were also two significant 2-way interactions, for spatial frequency and features ($F (9, 207) = 3.6$, p <

0.01) and for face and features ($F(3, 69) = 19.2$, $p < 0.01$) and a 3 way interaction for spatial frequency, face and features that did not reach significance ($F(9, 207) = 1.2$, $p = 0.4$).

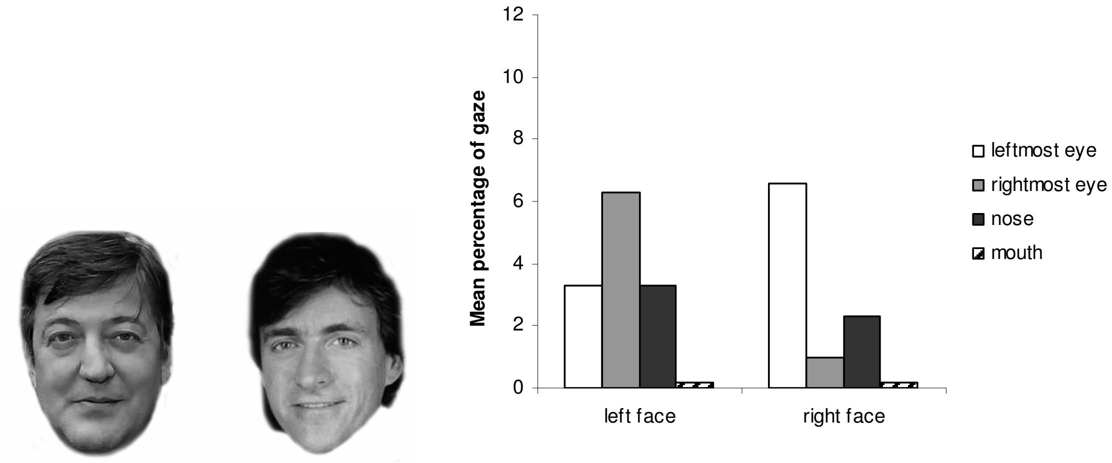


Figure 4.6a The mean percentage of gaze to features on the left and right faces for mismatched FB images.

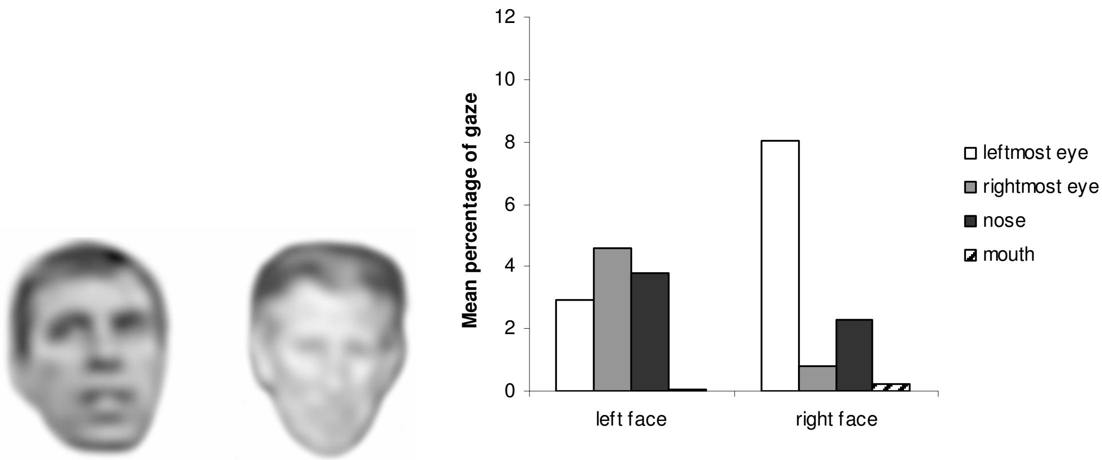


Figure 4.6b Mean percentage of gaze to features on the left and right faces for mismatched LSF condition.

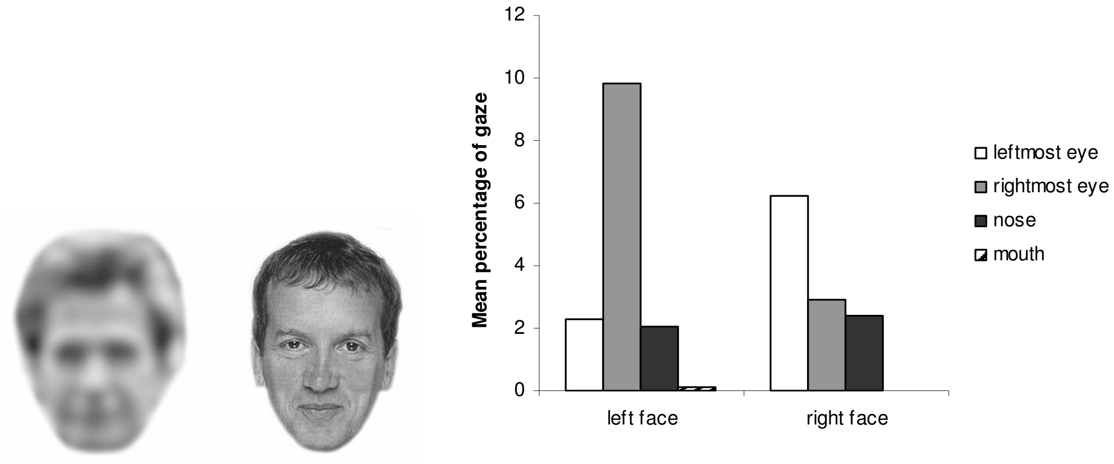


Figure 4.6c Mean percentage of gaze to features on the left and right faces for mismatched left LSF condition.

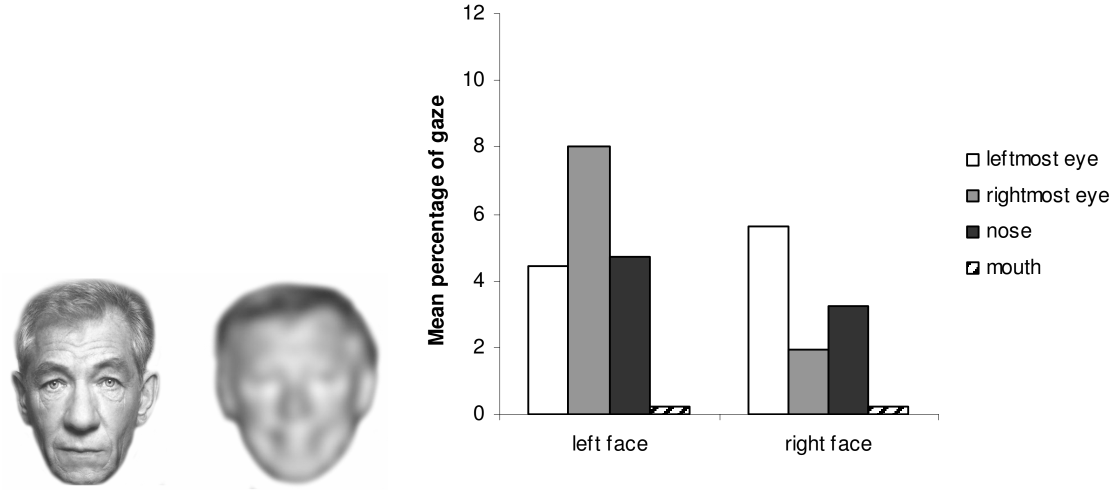


Figure 4.6d Mean percentage of gaze to features on the left and right faces for mismatched right LSF condition.

The analysis of the simple simple main effects for the 3-way interaction revealed for some conditions the features received more gaze than in other conditions. There were significant differences in gaze to the left face (F (3, 69) 3.4, $p < 0.05$) and the right face in the FB condition (F (3, 69) 4.4, $p < 0.01$) and planned comparisons for the left face found the right eye received more gaze than the mouth (t (63) = 3.2, $p < 0.01$). Planned comparisons for the right face found the left eye received more gaze than the nose (t (63) = 2.23, $p < 0.05$) and comparisons with the other features produced even higher t values (see figure 4.6a).

There were also significant differences for features on the left face in the LSF condition that nearly approached significance ($F (3, 69) = 2.2$, $p = 0.09$) and for the right face in the LSF condition ($F (3, 69) = 7.0$, $p < 0.01$). Planned comparisons for the left face found the right eye ($t (63) = 2.4$, $p < 0.05$) and nose ($t (63) = 1.98$, $= 0.05$) received more gaze than the mouth. Comparisons for the right face found the left eye received more gaze that the nose ($t (63) = 2.99$, $p < 0.01$) and comparisons with the other features produced even higher t values (see figure 4.6b).

There were significant differences in gaze to the features on the left face ($F (3, 63) = 10.1$, $p < 0.01$) and right face ($F (3, 69) = 3.6$, $p < 0.05$) in the left LSF condition. Planned comparisons for the left face found the right eye received more gaze than the left eye ($t (63) = 3.95$, $p < 0.01$) and comparisons with the other features produced even higher t values. Comparisons for features on the right face found that the left eye received marginally more gaze than the right eye ($t (63) = 1.74$, $p = 0.09$) and comparisons with the other feature produced higher t values (see figure 4.6c).

There were also significant differences in gaze to the left face ($F (3, 69) = 5.6$, $p < 0.01$) and right face ($F (3, 69) = 2.9$, $p < 0.05$) in the right LSF condition. Planned comparisons found the right eye received more gaze than the nose ($t (63) = 1.75$, $p < 0.09$) and comparisons with the other features produced higher t values. The nose ($t (63) = 2.34$, $p < 0.05$) and left eye ($t (63) = 2.0$, $p < 0.05$) received more gaze than the mouth. Comparisons for the right face found the left eye received more gaze than the right eye ($t (63) = 1.94$, $p = 0.06$) and the mouth ($t (63) = 2.83$, $p < 0.01$) see figure 4.6d.

The analyses of the simple simple main effects also revealed that spatial frequency influenced the amount of gaze to the left eye ($F(3, 69) = 4.6$, $p < 0.01$) and the right eye ($F(3, 69) = 30.2$, $p < 0.01$) and the nose ($F(3, 69) = 7.4$, $p < 0.01$) on the left face, and the left eye ($F(3, 69) = 140.4$, $p < 0.01$) and right eye ($F(3, 69) = 5.6$, $p < 0.01$) on the right face. Planned comparisons for the left eye on the left face found the there was more gaze in the right LSF condition than the FB condition ($t(69) = 2.02$, $p < 0.05$) and comparisons with the other SF conditions produced higher t values. The left eye also received marginally more gaze in the FB condition, than the left LSF condition ($t(69) = 1.74$, $p = 0.09$). Planned comparisons for the right eye on the left face found it received more gaze in the left LSF condition than the right LSF condition ($t(69) = 3.11$ $p< 0.01$) and the FB condition ($t(69) = 3.05$, $p < 0.01$), it also received more gaze in the FB condition than the LSF condition ($t(69) = 2.86$, $p < 0.01$). Planned comparisons for the nose found that it received more gaze in the right LSF condition than the FB condition ($t(69) = 2.44$, $p < 0.01$) and the left LSF condition ($t(69) = 4.6$, $p < 0.01$), it also received more gaze in the LSF ($t(69) = 3.05$, $p < 0.01$) and FB condition ($t(69) = 2.16$, $p < 0.05$) than the left LSF condition.

Planned comparisons for the left eye on the right face found there was more gaze in the LSF condition than the FB condition ($t(69) = 2.55$ $p < 0.01$) and comparisons with the other SF conditions produced higher t values. For the right eye on the right face there was more gaze in the left LSF condition than FB condition ($t(69) = 3.3$, $p < 0.01$), and the right LSF condition ($t(69) = 3.68$ $p < 0.01$). There was also marginally more gaze for the right eye in the right LSF condition than the LSF ($t(69) = 1.98$ $p = 0.05$).

The simple simple main effects also revealed a significant influence on face side with some features receiving more gaze on the left faces, whilst others received more on the right face. The left eye received more gaze on the right face and this was significant for all the SF conditions ($p < 0.01$) except the right LSF condition ($p > 0.1$). The right eye received more gaze on the left face and this was significant for all the SF conditions. The nose also received marginally more gaze on the left face for the LSF condition ($F(1, 23) = 4.3$, $p = 0.05$) and the right LSF condition ($F(1, 23) = 4.01$, $p = 0.06$).

Results Summary

Both the matched and mismatched faces had very similar viewing patterns (see figures 4.5a-d and 4.6a-d). The main difference was for the left LSF condition; for the matched faces the gaze to the features on the left face was evenly distributed (see figure 4.5c), however for the mismatched faces there was a bias for the right eye on the left face (see figure 4.6c), for both the matched and mismatched faces there was a bias for the left eye on the right face, however this bias appeared to be stronger for the matched faces. There were some other small differences, which are explained below in more detail.

Effect of spatial frequency

The main effects of spatial frequency revealed that for matched faces in the condition where only one face was a LSF image, the faces received more gaze per feature than when both faces were LSF images or FB images. For the mismatched faces when the right face was a LSF image the faces received more gaze per feature, than when the left face was a LSF image, or when both faces were FB images. Spatial frequency also interacted with the amount of gaze to features and face side. When the left face was a LSF image gaze was evenly distributed to the eyes and nose (apart from the mismatch condition), whereas when the right face was a LSF image there was an overall bias towards the left eye.

Many of the viewing patterns were the same for the matched and mismatched faces. The left eye on the left face received more gaze in the left LSF and right LSF conditions, than when both faces were FB, or LSF images. When the left eye was on the right face it received more gaze in the left LSF condition, as compared to the other spatial frequency conditions. When the left eye was on the right face, it received the most amount of gaze in the left LSF condition for the matched faces, but the LSF condition for the mismatched faces. The right eye on the left face received the most amount of gaze in the right LSF condition for matched faces, but for the mismatched faces it received more gaze in the left LSF condition. The right eye on the right face received the most amount of gaze in the right LSF condition, but this was only significant for the mismatched faces. The nose on the left faces received the most amount of gaze in the right LSF condition, but this was only significant for the mismatched faces. Spatial frequency also did not influence the amount of gaze to the mouth.

Effect of face side (left or right of the screen)

Overall the main effects of face side were that the right eye received more gaze on the left face and when on the left face it received more gaze than the other features. This pattern was found for both the matched and mismatched faces, for most of the spatial frequency conditions. Whereas the left eye received more gaze on the right face and when on the right face it was the feature that received the most amount of gaze. The nose also appeared to receive more gaze on the left face, but face side appeared to have no significant effect on gaze to the mouth and it received the least amount of gaze.

Discussion

Looking at the eye gaze data, the viewing patterns were very similar for the matched and mismatched faces, the one major difference was for the left LSF condition, where the left face was a LSF image and the right face was a FB image. For the matched faces viewers looked evenly at all the features on the left face, whereas for the mismatched faces viewers looked mainly at the right eye on the left face. When the faces were the same identity, viewers had to look at more features on the left face to make an accurate decision, whereas when the faces were different people, viewers only looked at the right eye on the left face and compared it to left eye on the right face. For the mismatched faces viewers performed the scanning strategy observed in previous experiments (Experiments 2, 3 & 4), where they look more at the inner eyes than the outer ones. There did however seem to be a very strong bias for the left eye on the right face in the matched faces, so it seems that once all the features on the left face had been viewed, only the right eye on the left face was viewed to make an accurate decision.

The eye gaze data showed that there was still an overall bias towards the eyes and they seemed to be the features that received more gaze than the other features, although in the LSF condition the nose also received a substantial amount of gaze, but only when on the left face. An explanation for why the nose might have received more gaze on the left face and also why gaze was evenly distributed across the features on the left face in the matched left LSF, is that viewers looked at the left face first, built up an internal representation that they compared to the face on the right. If the images were similar, or presented as LSF images, then viewers had to look at the right eye and the nose to build a holistic impression of the left face, whereas when the faces were different people and FB images, viewers only needed look at the inner eyes to make an accurate decision.

The eyes that were in the centre of the screen (the right eye on the left face and the left eye on the right face) did appear to receive more gaze than the outer eyes (left eye on left face and right eye on right face), and this was persistent regardless of spatial frequency filtering. The left eye consistently received more gaze on the right face, and the right eye consistently received more gaze on the left face. This pattern was also found for previous Experiments 2, 3 and 4. This seems to show that this viewing pattern is more for a global scanning strategy used to gain a holistic impression of the face, as it was present for the FB and LSF images. The Goffaux et al. (2005) and Goffaux and Rossion (2006) studies both found evidence that LSF images of faces are processed more holistically than HSF images, so the viewing patterns observed here might represent global strategies.

The first-fixation analysis found that viewers looked first at the face on the left significantly more than the face on the right. This was also a finding of Experiment 3 and 4 in previous chapters. Other research has also found a leftwards bias for faces (Butler et al., 2005; Mertens, Siegmund, & Grusser, 1993). There is still a debate whether this results from the right hemisphere dominance for face processing (Rhodes, 1985, 1993), or is a cultural bias as a consequence of scanning left to right for reading (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989). This issue will be explored further in chapter 5.

Looking at the task performance for the matched faces, it appears that converting the faces to LSF images did reduce the overall accuracy, but this was most profound when the left face was a LSF image and the right face was a FB image. It seems that viewers looked to the face on the left first and if it was a LSF image it interfered with matching a FB image on the right. However if both images were LSF, or the right image was a LSF image and the left face was a FB image, responses were less error prone, especially for the mismatched faces. When the right face was a LSF image, responses were more accurate than when both faces were LSF images.

Previous research has shown that presenting LSF images of faces appears to reduce recognition accuracy (Costen, et al., 1994, 1996; Fiorentini et al.,1983; Parker et al., 1996), these studies presented FB images and then used filtered faces as test items. However other research has shown that when faces are presented in similar spatial frequencies from study to test, LSF images can be easily recognised and responses are more error prone when faces differ in SF from study to test (Collins et al., 2004; Collins et al., 2006; Konowski & Petersik, 2003; Lui et al., 2000). These studies predict that face matching performance should be more error prone when viewers are presented with one FB image and one LSF image, however this was only the case for the left LSF condition, and for the right LSF condition accuracy was the same as if both face were FB images and greater than when both faces were LSF images.

This experiment has shown that when both faces are presented as LSF images, performance is not as greatly impaired as when only the left face is presented as a LSF image and the right face is a FB image. In the LSF images the information in the eye region was blurred so that it was difficult to make distinctions between the sclera, iris and pupil, however viewers still seemed to use this region more than the other regions. Viewers also used the inner eyes (left eye on right face and right eye on left face) more than the outer eyes regardless of SF; this suggests viewers were using a global or holistic scanning strategy. In the next experiment the aim is to investigate what features are used to make a matching decision when one or both of the inners eyes has been masked and therefore does not contain any useful information.

Experiment 7

Method

Participants

22 participants took part in the study (12 female), all were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 224 pairs of male faces, which were either two different images of the same person or two different people. The faces were approximately 12 cm by 8.5 cm, with a resolution of 72 pixels per inch, and presented side by side with 5cm between each face. An eye mask was created which was a white square approximately 1.7 cm by 1.5 cm and it was placed either over the right eye on the left face (left mask), the left eye on the right face (right mask), or on both of those locations simultaneously (both mask), or not presented at all (no mask) see figure 4.7. All the images were converted to grey scale and cropped around the face; they were presented on a white background. The stimuli were presented on a 17 inch screen monitor using Experiment Builder, SR Research.

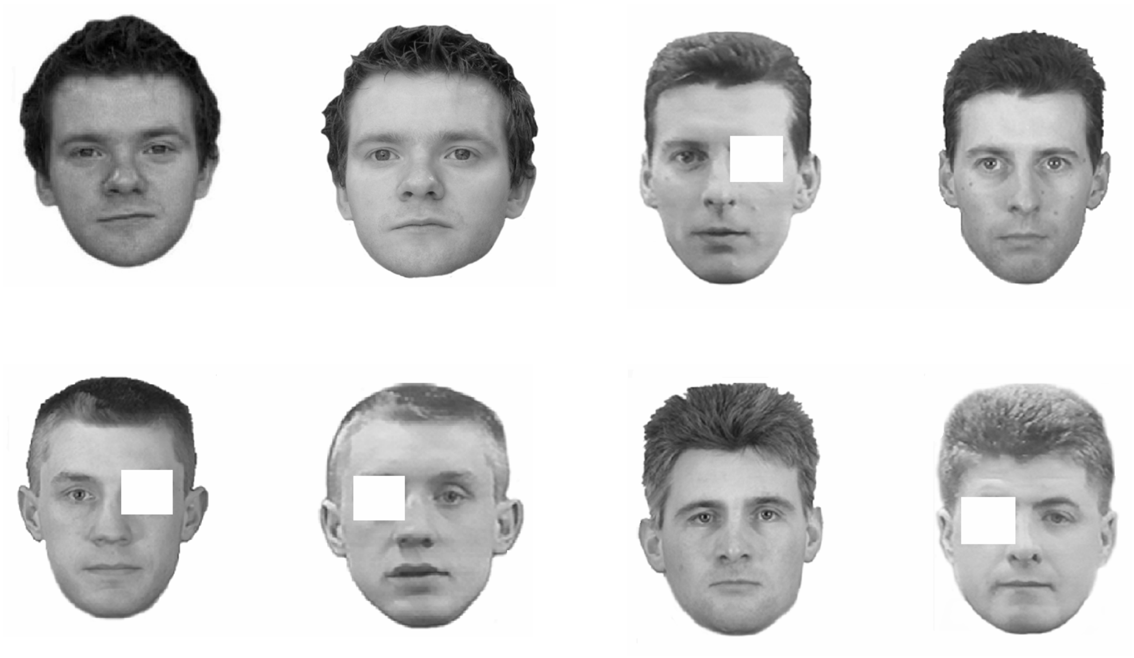


Figure 4.7. An example of stimuli used, going clockwise from the top left; unfamiliar matched no mask, unfamiliar matched left mask, unfamiliar mismatched right mask, unfamiliar matched both mask.

Apparatus

The participants' eye moments were measured using the head-mounted SR Research EyeLink System; data was recorded from only the right eye. The stimuli were presented in four blocks, using Experiment Builder (SR Research). A nine-point calibration was carried out at the beginning of each block and a drift correction was performed at the beginning of each trial.

Design and Procedure

The experiment employed a within subjects design. The first variable was Familiarity (familiar/unfamiliar), the second was Match (matched/mismatched), the third was Mask (no mask, right mask, left mask, both mask) and the fourth Face side (left face/right face) and the fifth were the Features (left eye, right eye, nose, mouth). Participants were told that they would be presented with pairs of faces and there task was to indicate via a keyboard response whether the faces were the same person or two different people.

Analysis

The analysis was carried out using Dataviewer Software (SR Research), where four areas of interest (AOI) were created for the facial features; the right eye, left eye, nose, mouth. Separate AOI were created for each face. Gaze duration was converted into percentage of gaze per feature, this was divided across the four mask conditions, so that the total gaze for four pairs of faces was equal to 100. 26 participants were tested, however the data from 4 were discarded due to high error rates in the unmasked condition and data loss, therefore 22 participants were used in the final analysis.

Results

Task performance

Figure 4.8 a shows the mean correct responses for familiar faces and figure 4.8 b shows the correct responses for unfamiliar faces. The task performance showed overall the familiar faces obtained more correct responses (mean = 91 %), than the unfamiliar faces (mean = 80 %). A 3-factor ANOVA; Familiarity (familiar/unfamiliar), Match (match/mismatch) and Mask (no mask, left mask, right mask, both mask) was conducted to examine the accuracy of responses. There were main effects of familiarity ($F (1, 21) = 6.2$, $p < 0.01$) and mask ($F (3, 63) = 5.4$, $p < 0.01$) and a 3-way interaction for familiarity, match and mask ($F (3, 63) = 6.6$, $p < 0.01$). Responses were significantly more accurate in the no mask (86 %) and the right mask conditions (88 %) than in the both mask condition (83 %), but not more than the left mask condition (85 %).

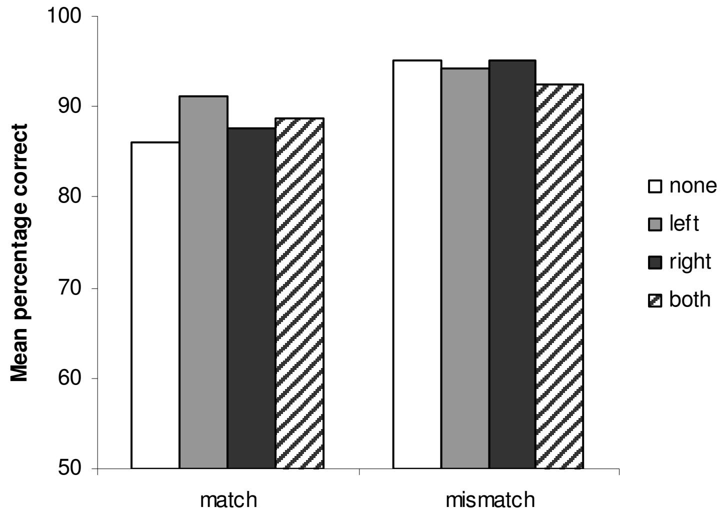


Figure 4.8a. The mean percentage correct responses for familiar faces.

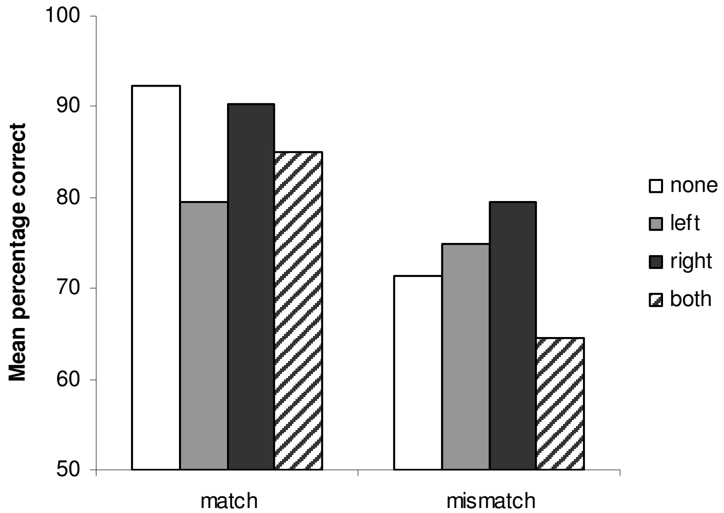


Figure 4.8b. The mean percentage correct responses for unfamiliar faces.

The analysis of the simple simple main effects for the 3-way interaction revealed when the faces were familiar they received more correct responses than when they were unfamiliar, this was significant for; matched faces with the left mask ($F(1, 21) = 7.7$, $p < 0.05$), also the mismatched faces with; no mask ($F(1, 21) = 31.8$, $p < 0.01$), left mask ($F(1, 21) =$

21.2, $p < 0.01$), right mask ($F(1, 21) = 13.7$, $p < 0.01$) and the both mask ($F(1, 21) = 44.1$, $p < 0.01$).

There was also an effect of match, but only for the unfamiliar faces. The unfamiliar faces with no mask received significantly more correct responses when they matched, than when they mismatched ($F(1, 21) = 7.6$, $p < 0.05$). The unfamiliar faces from the both mask condition also received more correct responses when the faces matched than when they mismatched ($F(1, 21) = 7.3$, $p < 0.05$).

The analysis of the simple simple main effects revealed an influence of mask, but only for the unfamiliar matched ($F(3, 63) = 8.5$, $p < 0.01$) and unfamiliar mismatched faces ($F(3, 63) = 10.4$, $p < 0.01$). Planned comparisons for the unfamiliar matched faces found there were significantly more correct responses for the no mask condition than the both mask ($t(63) = 2.59$, $p < 0.01$) or left mask conditions ($t(63) = 4.59$, $p < 0.01$). Faces in the right mask condition received more correct responses, than the left mask condition ($t(63) = 3.89$, $p < 0.01$). Planned comparisons for the unfamiliar mismatched faces found that all the mask conditions received more correct responses than the both mask conditions ($p < 0.01$) and the right mask condition received more correct responses than the no mask condition ($t(63) = 2.9$, $p < 0.01$).

Percentage of gaze to features

A 5-factor ANOVA; Familiarity (familiar/unfamiliar), Match (match/mismatch), Mask (none, left mask, right mask, both mask), Face (left/right) and Features (left eye, right eye, nose & mouth) was conducted on the percentage of gaze duration. Results from the analysis found a main effect of mask ($F(3, 63) = 2.8$, $p < 0.05$), faces in the left mask condition (3.2) received more gaze per feature, than those in the no mask (3.07) or right mask conditions (3.07), but not more than the both mask condition (3.11). There was also a main effect of features ($F(3, 63) = 9.8$, $p < 0.01$), the nose (4.6) received more gaze than the right eye (3.4), but not the left eye (3.8) and all features received more gaze than the mouth (0.6). There was a 4-way interaction for familiarity, match, face and features ($F(3, 63) = 2.9$, $p < 0.05$), the data was therefore split into two sets and separate ANOVAs were performed on the familiar and unfamiliar faces.

Familiar faces

Figures 4.9a to 4.9d show the mean percentage of gaze to features on the left and right familiar faces for all the mask conditions, the stimuli examples have used both matched and mismatched pairs. A 4-factor ANOVA; Match (match/mismatch), Mask (no mask, left mask, right mask, both mask), Face (left/right) and Features (left eye, right eye, nose, mouth) was conducted on the percentage of eye gaze to features on the familiar faces. Results from the analysis found a main effect of face, the right face received more gaze per feature than the left face (3.3 vs. 2.9; $F(1, 21) = 7.0$, $p < 0.05$). There was a main effect of features ($F(3, 63) = 8.5$, $p < 0.01$), the left eye (3.8), right eye (3.4) and nose (4.5) all received more gaze than the mouth (0.7). There was also a 3-way interaction for mask, face and features ($F(9, 189) = 20.6$, $p < 0.01$).

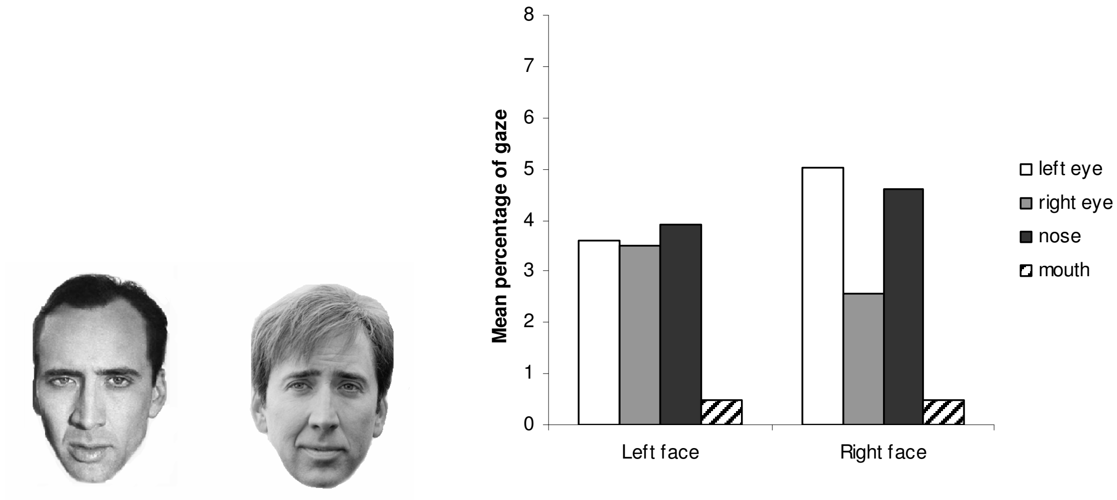


Figure 4.9a Mean percentage of gaze to the left and right familiar faces with no mask.

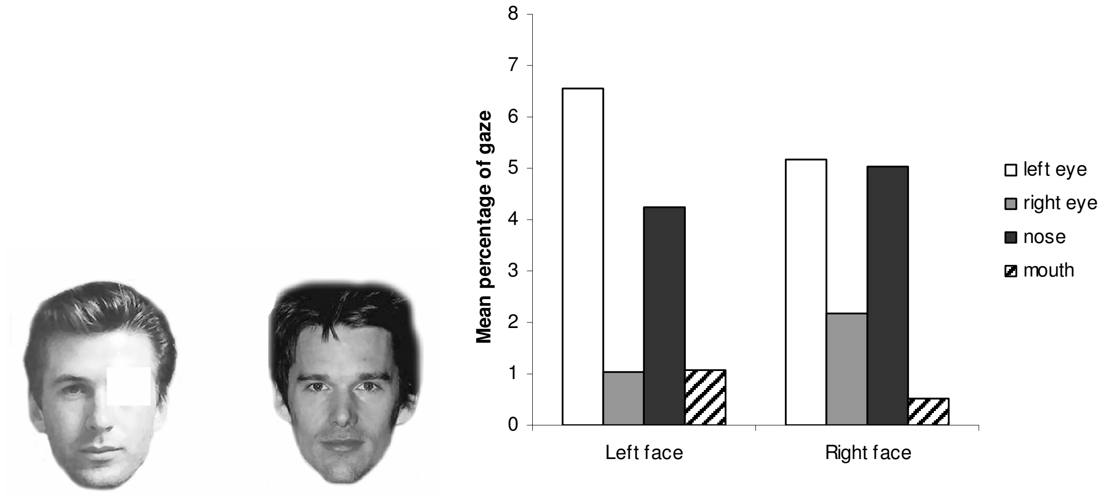


Figure 4.9b Mean percentage of gaze to the left and right familiar faces with the left mask.

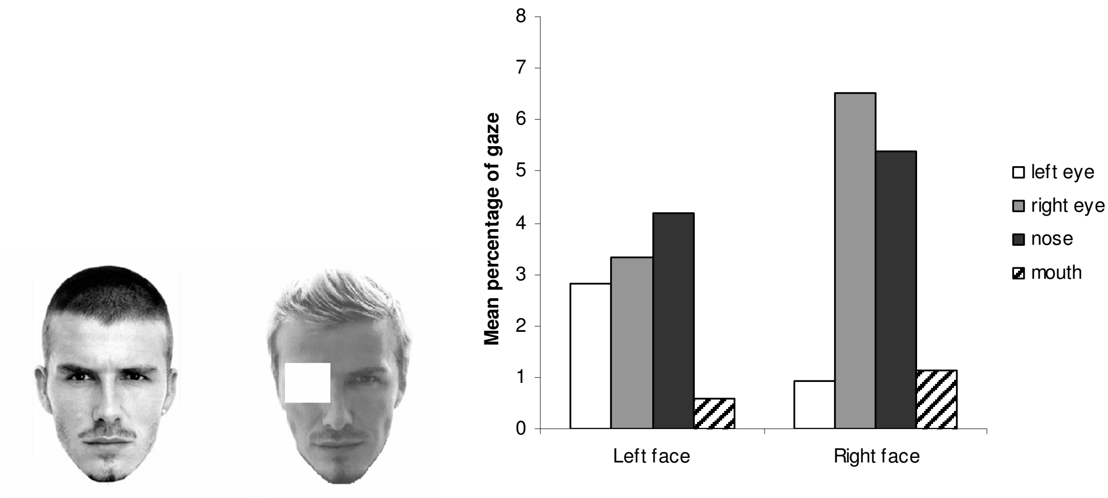


Figure 4.9c Mean percentage of gaze to the left and right familiar faces with the right mask.

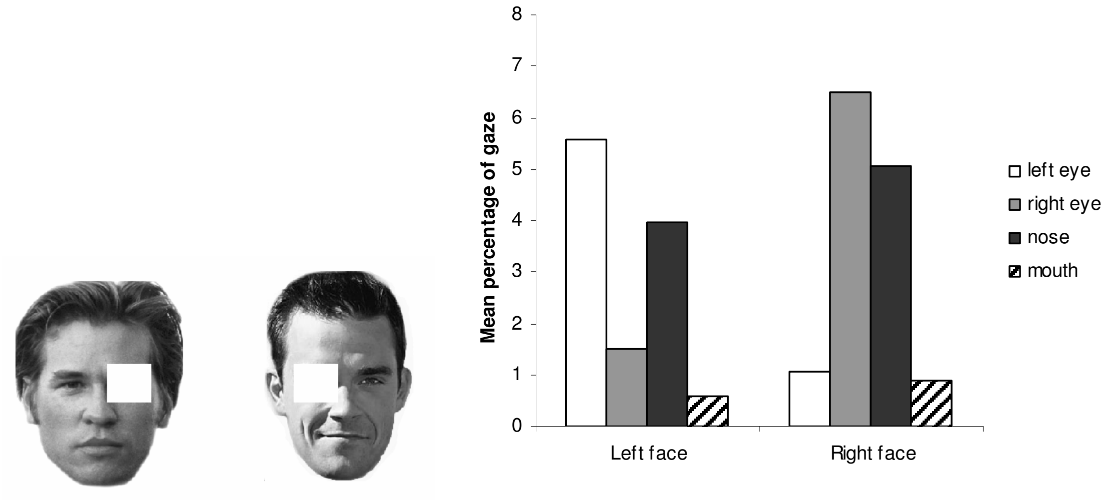


Figure 4.9d. Mean percentage of gaze to the left and right familiar faces with the both mask.

The analysis of the simple simple main effects found that some features received significantly more gaze than others, depending on face side and mask. There were no significant differences in gaze to features on the left and right face in the no mask condition ($p > .1$) see figure 4.8a. There were marginally significant differences in gaze between features on the left face in the left mask condition ($F\ (3, 63) = 2.7$, $p = 0.5$), but not the right face in the left mask condition ($p >.1$). Planned comparisons for features on the left face in the left mask condition found the left eye received marginally more gaze than the right eye ($t\ (63) = 1.70$, $p = 0.09$) and mouth ($t\ (63) = 1.68$, $p = 0.09$) see figure 4.9b.

The analysis for the simple simple main effects also revealed there were no differences in gaze to features on the left face in the right mask condition, however there were significant differences in gaze to the features on the right face in the right mask condition ($F\ (1, 21) = 3.2$, $p < 0.05$). Planned comparisons for the features on the right face in the right mask condition found the right eye received marginally more gaze than the left eye ($t\ (63) = 1.73$, $p = 0.09$) and the mouth ($t\ (63) = 1.73$, $p = 0.09$) see figure 4.9c.

There were no significant differences in gaze to features on the left face in the both mask condition ($p > 0.1$) but there were some significant differences in gaze to features on the right face in the both mask condition ($F (1, 21) = 3.1$, $p < 0.01$). Planned comparisons for the right face in the both mask condition found the right eye received marginally more gaze than the left eye ($t (63) = 1.67$, $p = 0.09$) and the mouth ($t (63) = 1.73$, $p = 0.09$) see figure 4.9d.

The simple simple main also revealed that the mask condition affected the amount of gaze that certain features received and there were some significant differences in gaze to the left eye on the left face ($F (3, 63) = 66.9$, $p < 0.01$), the right eye on the left face ($F (3, 63) = 36.2$), the left eye on the right face ($F (3, 63) = 126.7$, $p < 0.01$) and right eye on the left face ($F (3, 63) = 130.8$, $p < 0.01$). The masking appeared to have no significant affect on gaze to the nose or mouth ($p > 0.1$).

Planned comparisons for features on the left face found the left eye in the left mask condition received more gaze per feature than in the both condition ($t (63) = 2.34$, $p < 0.05$) and comparisons with the other conditions produced even higher t values. The left eye in the both mask condition received more gaze than the no mask condition ($t (63) = 4.68$, $p < 0.01$) and the right mask condition ($t (63) = 6.51$, $p < 0.01$). The left eye in the no mask condition received marginally more gaze than for the right mask condition ($t (63) = 1.83$, $p = 0.07$). Planned comparisons for the right eye on the left face found that it received more gaze in the no mask condition ($t (63) = 4.76$, $p < 0.01$) and the right mask condition ($t (63) = 4.38$, $p < 0.01$) than in the both mask condition, and comparisons with the left mask condition produced even higher t values.

Planned comparisons for features on the right face found the left eye received more gaze in the left mask ($t (63) = 9.75$, $p < 0.01$) and both condition ($t (63) = 9.35$, $p < 0.01$) than the no mask condition, and when left mask and both mask conditions were compared to the right mask condition they produced higher t values. The right eye on the right face received more gaze in the right mask condition than in the no mask ($t (63) = 9.47$, $p < 0.01$) and left mask conditions ($t (63) = 10.41$, $p < 0.01$), the right eye also received more gaze in the both mask condition than the no mask ($t (63) = 9.35$, $p < 0.01$) and the left mask condition ($t (63) = 10.29$, $p < 0.01$).

The analysis of the simple simple main effects showed a significant effect of face with some features receiving more gaze on the left face and others more on the right face. The left eye received more gaze on the left face for the left mask condition ($F (1, 21) = 5.7$, $p < 0.05$), the right mask condition ($F (1, 21) = 11.1$, $p < 0.01$) and the both mask condition ($F (1, 21) = 61.9$, $p < 0.01$), however the left eye received more gaze on the right face for the no mask condition ($F (1, 21) = 6.1$, $p < 0.05$). The right eye received more gaze on the right face in the right mask condition ($F (1, 21) = 31.3$, $p < 0.01$) and in the both mask condition ($F (1, 21) = 76.1$, $p < 0.01$) and marginally more in the left mask condition ($F (1, 21) = 4.0$, $p = 0.06$). The nose received more gaze on the right face in the right mask condition ($F (1, 21)$ 4.7, $p < 0.05$). Face side appeared to have no significant effect on gaze to the mouth ($p > 0.1$).

Unfamiliar faces

Figures 4.10a to 4.10d show the mean percentage of gaze to features on the left and right unfamiliar faces for all the mask conditions. The stimuli examples have used both matched and mismatched pairs. Figure 4.11a and 4.11b show the mean percentage of gaze to features on the left and right matched and mismatched faces. A 4-factor ANOVA: Match (match/mismatch), Mask (no mask, left mask, right mask, both), Face (left/right) and Features (left eye, right eye, nose and mouth) was conducted on the percentage of eye gaze to features on the unfamiliar faces. Results from the analysis found a main effect of mask ($F (3, 63) = 2.8$, $p < 0.05$), faces in the left mask condition (3.3) received more gaze per feature than faces in the right mask condition (2.9) and the both mask condition (2.9), but not more than the no mask condition (3.1) . There was a main effect of features ($F (3, 63) = 10.2$, $p < 0.01$), the left eye (3.8), right eye (3.4) and nose (4.7) all received more gaze than the mouth (0.6). There was also a 3-way interaction for mask, face and features ($F (9, 189) = 22.0$, $p < 0.01$) and a 3-way interaction for match, face and features ($F (3, 63) = 4.6$, $p < 0.01$).

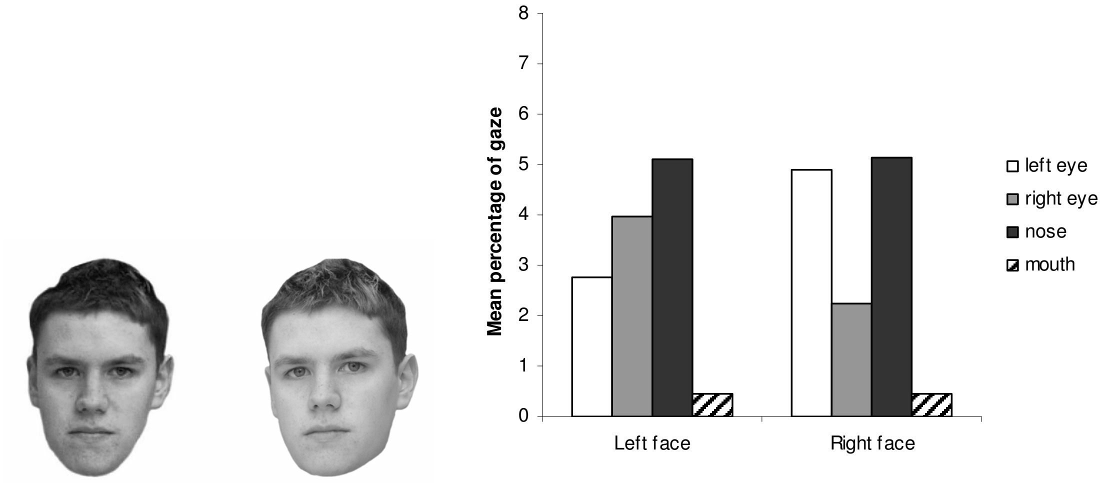


Figure 4.10a Mean percentage of gaze to the left and right unfamiliar face with no mask.

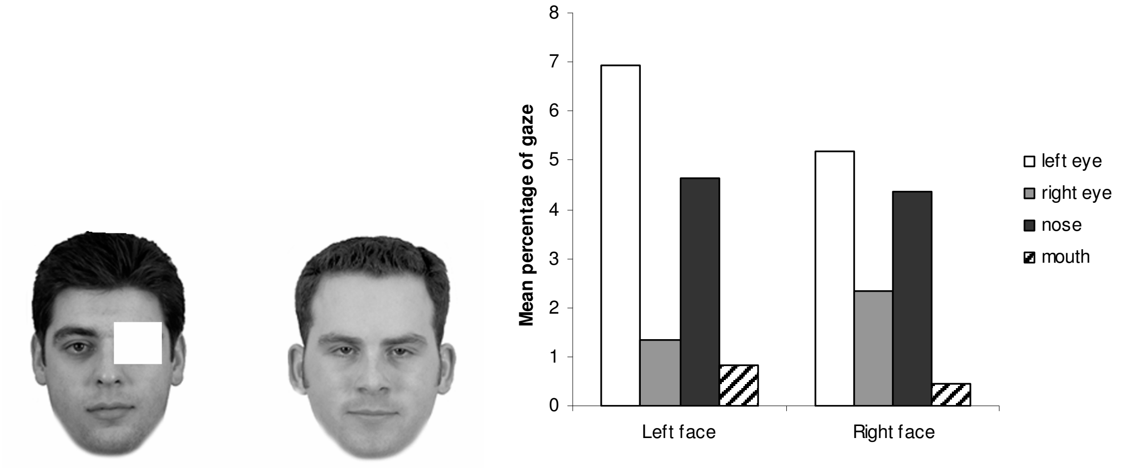


Figure 4.10b Mean percentage of gaze to the left and right unfamiliar faces with the left mask.

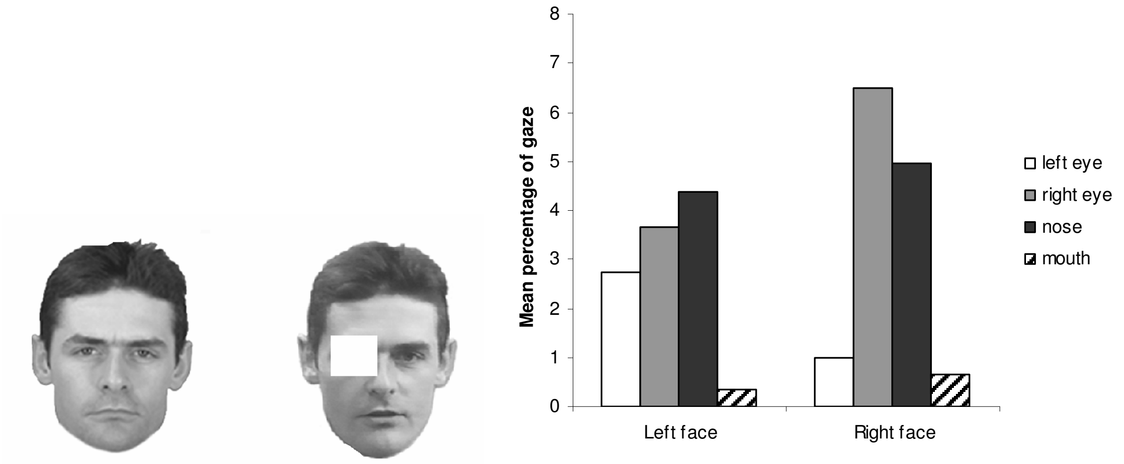


Figure 4.10c Mean percentage of gaze to the left and right unfamiliar faces with the right mask.

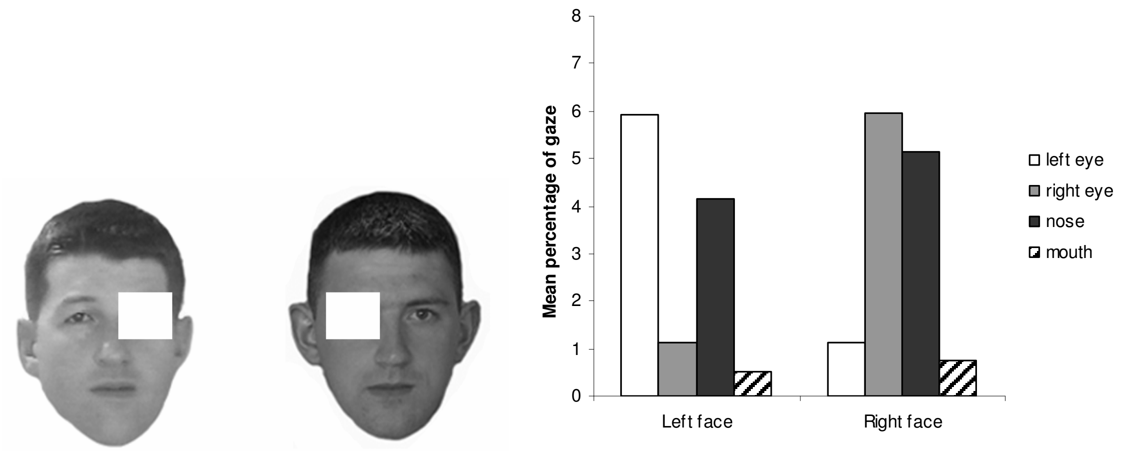


Figure 4.10d Mean percentage of gaze to the left and right unfamiliar faces with the both mask.

The analysis of the simple simple main effects found that some features received significantly more gaze than others, depending on face side and mask. There were no significant differences in gaze to features on the left and right face in the no mask condition ($p > .1$) see figure 4.10a. There were significant differences in the gaze to features for the left face in the left mask condition ($F (3, 63) = 3.3$, $p < 0.05$), but not the right face in the left mask condition ($p >.1$) Planned comparisons for features on the left face in the left mask condition found the left eye received marginally more gaze than the right eye ($t (63) = 1.76$, $p = 0.08$) and the mouth ($t (63) = 1.91$, $p = 0.06$) see figure 4.10b.

The analysis of the simple simple main effects found there were no significant differences in gaze to the left face in the right mask condition ($p > .1$), however there were some significant differences in gaze to features on the right face in the right mask condition ($F (3, 63) = 3.3$, $p < 0.05$). Planned comparisons for features on the right face in the right mask condition, found the right eye received marginally more gaze than the left eye ($t (63) = 1.72$, $p = 0.09$) and mouth ($t (63) = 1.83$, $p = 0.07$) see figure 4.10c.

There were marginally significant differences in gaze to the left face in the both mask condition ($F (3, 63) = 2.6$, $p =0.06$) and for the right face in the both mask condition ($F (3, 63) = 2.8$, $p < 0.05$). Planned comparisons for the features on the left face in the both mask condition found the left eye received marginally more gaze than the mouth ($t (63) = 1.70$, $p = 0.09$). Comparisons for features on the right face for the both mask condition found that the right eye received marginally more gaze than the mouth ($t (63) = 1.70$, $p = 0.09$) see figure 10.d.

The analysis of the simple simple main effects from the mask, face and features interaction revealed that there was a significant effect of the mask condition; the left eye ($F (3, 63) =$

171.5, $p < 0.01$), right eye ($F(3, 63) = 81.9$, $p < 0.01$) and the nose ($F(3, 63) = 6.0$, $p < 0.01$) on the left face received more gaze in some conditions than others, as did the left eye ($F(3, 63) = 192.9$, $p < 0.01$), right eye ($F(3, 63) = 190.9$, $p < 0.01$) and nose ($F(3, 63) = 4.7$, $p < 0.01$) on the right face.

Planned comparisons for features on the left face found the left eye received more gaze in the left mask condition, than the both mask condition ($t(63) = 3.03$, $p < 0.01$) and comparisons with other conditions produced even higher t vales. The left eye also received more gaze in the both mask condition than in the no mask condition ($t(63) = 9.54$, $p < 0.01$) and the right mask condition ($t(63) = 9.67$, $p < 0.01$). The right eye received more gaze on the left face when it was in the no mask condition, than the left mask ($t(63) = 7.99$, $p < 0.01$) and both mask conditions ($t(63) = 8.58$, $p < 0.01$). The right eye also received more gaze in the right mask condition, than the left mask ($t(63) = 6.98$, $p < 0.01$) and the both mask conditions ($t(63) = 7.58$, $p < 0.01$). The nose on the left face received more gaze in the no mask condition than in the both mask condition ($F(63) = 2.85$, $p < 0.01$) and the right mask condition ($t(63) = 2.16$, $p < 0.01$).

Planned comparisons for features on the right face found the left eye received more gaze in the no mask condition than the right mask ($t(63) = 12.5$, $p < 0.01$) and the both mask condition ($t(63) = 12.1$, $p < 0.01$), it also received more in the left mask condition than the right mask ($t(63) = 13.39$, $p < 0.01$) and no mask condition ($t(63) = 13.03$, $p < 0.01$). The right eye showed the opposite pattern, it received more gaze in the right mask condition than the no mask ($t(63) = 11.96$, $p < 0.01$) and the left mask condition ($t(63) = 12.59$, $p < 0.01$), it also received more gaze in the both mask condition than the no mask ($t(63) = 11.0$, $p < 0.01$), and left mask condition ($t(63) = 11.65$, $p < 0.01$). The nose received more gaze in the no mask condition (t (63) = 2.27, p < 0.05) and the both mask condition (t (63) = 2.27, p < 0.01) than the left mask condition.

There was also a significant effect of face with some features receiving more gaze on the left face, whereas others received more on the right face. The left eye received more gaze on the left face for the left mask condition (F (1, 21) = 10.4, p < 0.01), the right mask (F (1, 21) = 15.0, p < 0.01) and the both mask condition (F (1, 21) = 77.4, p < 0.01), however for the no mask condition (F (1, 21) = 15.0, p < 0.01), it received more gaze the on the right face. The right eye received more gaze on the left face for the no mask condition (F (1, 21) = 9.9, p < 0.01) and received more gaze on the right face for the right mask condition (F (1, 21) = 179.3, p < 0.01) and the both mask condition (F (1, 21) = 77.8, p < 0.01). Face side appeared to have no significant effect on gaze to the nose and mouth (F < 1).

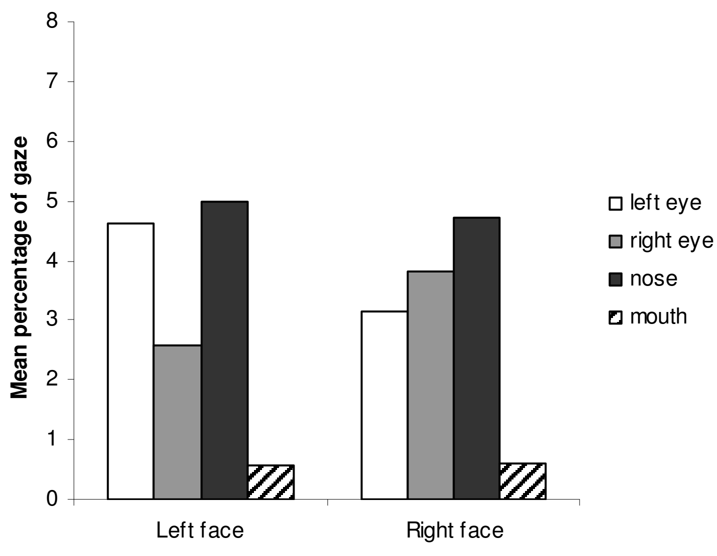


Figure 4.11a The mean percentage of gaze to features on the left and right matched faces.

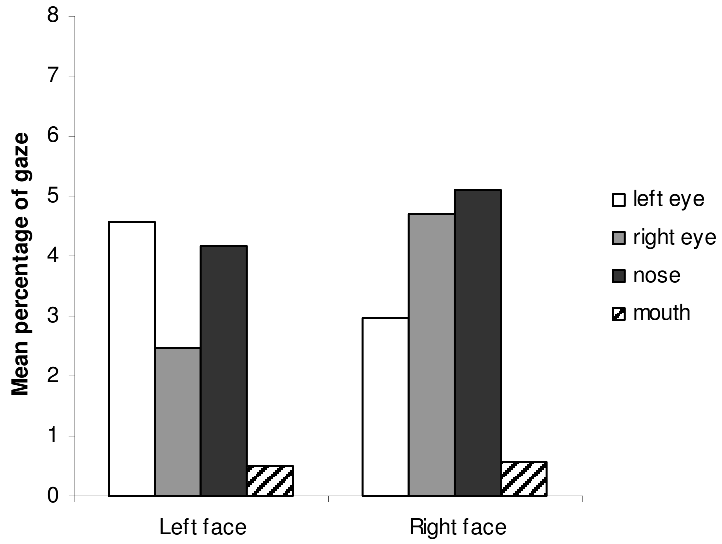


Figure 4.11b The mean percentage of gaze to features on the left and right mismatched faces.

The analysis of the simple simple main effects for the match, face and features interaction (see figures 4.11a and 4.11b) revealed that some features received more gaze in the matched condition, whereas others received more in the mismatched condition, however when planned comparisons were conducted these differences were found to not be statistically significant ($p > .1$). There were some differences in gaze to features as a function of face side, the left eye received more gaze on the left face and this was significant for the matched ($F(1, 21) = 14.5$, $p < 0.01$) and mismatched faces ($F(1, 21) = 17.5$, $p < 0.01$). Whereas the right eye received more gaze on the right face and this was significant for the matched ($F(1, 21) = 10.3$, $p < 0.01$) and mismatched faces ($F(1, 21) = 33.5$, $p < 0.01$). The nose also received more gaze on the right face, but this was only significant for the mismatched faces ($F(1, 21) = 5.9$, $p < 0.05$).

There were also some significant differences in the amount of gaze to features. This was significant for the left matched faces ($F(3, 63) = 3.3$, $p < 0.05$) and the right mismatched faces ($F(3, 63) = 3.3$, $p < 0.05$). However when planned comparisons were performed upon the differences between gaze to features they were found to not be statistically significant ($p > .1$).

Results summary

There were more correct responses for the familiar than unfamiliar faces and the mask appeared to influence responses only for the unfamiliar faces. Both the familiar and unfamiliar faces had main effects of features with the eyes and nose receiving more gaze than the mouth. The familiar faces received more gaze to the right than left face and the unfamiliar faces found that faces in the left mask condition received more gaze per feature than those in the other masked conditions. Overall the eye gaze data revealed that the viewing patterns for the familiar and unfamiliar faces were very similar (see figures 4.8a-d and 4.9a-d). There were however some differences that are explained in more detail below.

Effect of Mask

When there was no mask, all the features received equal amounts of gaze and this was the case for the familiar and the unfamiliar faces. When one or both of the inner eyes were masked, this increased gaze to the other unmasked eye on that face. For the familiar and unfamiliar faces the unmasked eye received more gaze when it was the left eye on the left face in the left mask condition, and the right eye on the right face in the right mask and both mask condition.

The eye gaze patterns for the left and right mask conditions were the same for the familiar and unfamiliar faces. In the left face left mask condition, the left eye received more gaze than the right eye (masked eye) and there were no differences in gaze to features on the right face. In the right face right mask condition, the right eye received more gaze than the left eye (masked eye) and there were no differences in gaze to the left face. In the both mask condition there were some differences between the familiar and unfamiliar faces. For the familiar faces, the right eye on the right face received more gaze than the left eye (the masked eye) and there were no significant differences in gaze to features on the left face. For the unfamiliar faces, the left eye on the left face received more gaze than the right eye (masked eye) and there were no differences in gaze to features on the right face.

Effect of Match

Whether the faces matched, or mismatched appeared to have no influence on viewing patterns for the familiar faces. However there were some differences for the unfamiliar faces. There was an interaction with match, face and features, however when planned comparisons were conducted the differences as a function of match were not found to be statistically significant, and the overall pattern for the matched and mismatched faces was very similar (see figures 4.10a and 4.10b).

Effect of Face

The familiar faces had a main effect of face, with the right face receiving more gaze per feature than the left face, this main effect was not statistically significant for the unfamiliar faces. Face did interact with mask and features for both the familiar and unfamiliar faces. The left eye received more gaze on the right face for the no mask condition, but for all the other masked conditions it received more gaze on the left face and this was the same for the familiar and unfamiliar faces. The right eye received more gaze on the left face for the no mask condition, but this was only significant for the unfamiliar faces. In the other mask conditions the right eye received more gaze on the right face and this was significant for both the familiar and unfamiliar faces. The nose received more gaze on the right face for the right mask condition, but this was only statistically significant for the unfamiliar faces.

Discussion

The eye gaze data showed that masking one or more of the inner eyes did affect gaze to the other unmasked eyes and the pattern was very similar for the familiar and unfamiliar faces (see figures 4.8a-d to 4.9a-d). When the right eye was masked on the left face, it increased gaze to the left eye on the left face, and when the left eye was masked on the right face, it increased gaze to the right eye on the right face, when both the inner eyes were masked it increased gaze to the outer eyes. This pattern was found for both the familiar and unfamiliar faces and seems to show that when the information is missing to make a matching decision, viewers will look elsewhere to obtain the information they need to make an accurate decision. There was an overall shift in strategy due to masking from viewing only the eyes to all the other features.

By masking the inner eyes the scanning strategy observed in Experiments 2, 3 and 4, where the inner eyes are looked at more than the outer eyes, was disrupted and viewers had to look more at the outer eyes of the faces. Even in the no mask condition, there appeared to be little evidence of this scanning strategy observed in previous experiments. However, the left eye did receive more gaze on the right face for the no mask condition, for both the familiar and unfamiliar faces and the right eye received more gaze on the left face for the unfamiliar faces in the no mask condition. When the faces were not masked all the features appeared to receive similar amounts of gaze and there was no bias for the eyes. It is possible that masking the eyes changed the way that the unmasked faces were viewed, with the gaze was being distributed more evenly for the unmasked faces. This seems to show that manipulating some faces changed the overall viewing strategy too all faces, even those that were not manipulated.

Although there initially appeared to be an effect of match, when planned comparisons were performed these differences were found to not be statistically significant. The viewing patterns for the matched and mismatched faces are very similar and neither condition appears to show a bias for particular features (see figures 4.10a and 4.10b). Whether the faces matched or mismatched did influence task performance, this was only the case for the unfamiliar faces.

Looking at the task performance it appeared that the presence of a mask over the inner eyes only affected accuracy for the unfamiliar faces and the familiar faces were unaffected by masking the eyes. Responses for unfamiliar faces were more error prone for the both mask condition than the no mask and right mask condition. Responses for the unfamiliar faces were more accurate when the faces matched, but only for the no mask and both mask conditions.

When the unfamiliar faces matched, there were more correct responses for the no mask condition than the both mask and left mask condition. This seems to show that even when only the right eye is masked on the left face and the faces are the same person, this can impair matching. However when the left eye was masked on the right face this did not impair performance and for the mismatched faces accuracy was greater than the no mask condition. Although first fixation data was not collected for this experiment, it could be suggested that viewers looked initially at the face on the left as results from previous experiments have found (Experiments 3, 4 and 6) and use this face as a comparison face to compare/contrast with the face on the right. If the right eye is masked on the left face, then the internal representation will be lacking in featural information to compare to the right face and this could impede matching more than masking the left eye on the right face.

The results have shown that when a pair of faces is unfamiliar then masking the inner eyes and in some cases the left eye on the right face, can impair matching performance. These findings support previous research that has shown that recognition can be impaired by masking the eyes and eyebrow region (Sadr et al., 2003; White, 2004). When the eyes were unmasked, they received more gaze than the other features for many conditions, this has been found by previous studies using eye movements (Althoff & Cohen, 1999; Barton et al., 2006; Henderson et al., 2001, Henderson et al., 2005; Janik et al., 1978). If the eyes are looked at more than other features because of their importance for face recognition and matching, and masking them impairs recognition and matching, how well are people able to recognise pairs of eyes without the other facial features?

Experiment 8

In this experiment the aim was to investigate how well participants could perform a matching task when only presented with the eye regions of two faces, as all previous studies have found that the eyes were the most important features for carrying out a matching task. Goffaux and Rossion (2006) presented a target that was either a whole face, or a pair of eyes. This was followed by probe items that were either a pair of faces or two pairs of eyes and participants had to decide which had been previously displayed (whole faces were always followed by whole faces and eyes by eyes). In the test phase one of the probe items was always identical to the previously presented target item.

They found that performance was more accurate (approx 87 %) for the whole faces, as compared to the eyes alone (approx 78 %), responses were also faster for the whole faces than the eyes alone. However they did not present the faces simultaneously and therefore recognition was reliant on memory for the previously presented image, rather than matching.

Method

Participants

26 participants took part in the study (18 female); all were students or members of staff at the Department of Psychology, Glasgow University. All were able to recognise faces displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 160 pairs of male eyes, half were famous faces and half were from unfamiliar faces. They were presented two pairs at a time, half were the same identity (different images) and half were two different identities. The eye region was approximately 2cm by 6cm and included the eyebrows. The eyebrows were included, as previous research has shown that the eyebrows are also important for face recognition, so this area was left to maximise performance (Sadr et al., 2003; White, 2004). The image resolution of 72 pixels per inch, and the pairs of eyes were presented side by side at a distance of 5cm. (see figure 4.11). All the images were converted to grey scale and cropped around the eyes, so they were presented on a white background. The stimuli were presented on 17 inch monitor using Experiment Builder, SR Research.

Figure 4.12. Unfamiliar matched eyes, unfamiliar mismatched eyes.

Design & Procedure

The experiment employed a 2-factr within subjects design. The first variable was familiarity (familiar/unfamiliar) and the second variable was match (match/mismatch). The participants were instructed that they would be presented with two pairs of eyes and the task was to press one key if the eyes were the same person and another key if they were two different people. Each pair was presented for 2 seconds. The accuracy was recorded and analysed using Dataviewer 3.1, SR Research.

Results

Figure 4.13 shows the mean accuracy for matching the familiar and unfamiliar eyes. A 2-factor ANOVA; Familiarity (familiar/unfamiliar) and Match (match/mismatch) was carried out of on the response data. The results found a main effect of match; eyes that matched received more correct responses than eyes that mismatched (72 % vs. 64 %, $F(1, 25) = 6.712$, $p > 0.05$). There was also a significant interaction for familiarity and match ($F(1, 25) = 18.924$, $p > 0.01$) which revealed unfamiliar eyes received significantly more correct responses when they matched, than when they mismatched ($F(1, 25) = 19.961$, $p > 0.01$). Furthermore, when the eyes matched, the unfamiliar eyes received more correct responses than the familiar eyes ($F(1, 25) = 15.892$, $p > 0.01$), however when they mismatched the familiar eyes received more correct responses than the unfamiliar eyes ($F(1, 25) = 10.590$, $p > 0.01$).

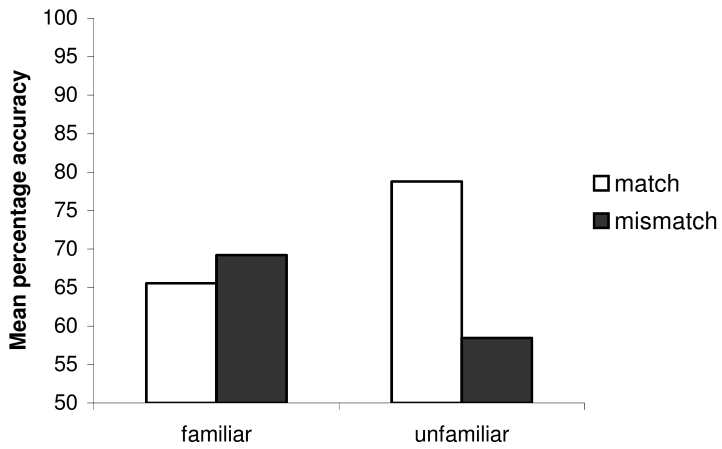


Figure 4.13. The mean correct responses for familiar and unfamiliar matched and mismatched eyes.

Discussion

The results found that when trying to match two pairs of eyes, the familiar eyes received more correct responses when they were two different people, whereas the unfamiliar eyes received more correct responses when they were the same person. The unfamiliar eyes in the matched condition may have received more correct responses because they were obtained from a database of face images that were taken by two different cameras, but on the same day with the same lighting. Therefore the images for the unfamiliar eyes would have less variation than those of the famous eyes, as they were from images obtained through internet searches and could have been taken under different lighting conditions and also with large time separations between them.

The accuracy results are comparable to those found in another study that presented eyes for a recognition task, especially the unfamiliar mismatched eyes. Gauffaux and Rossion (2006) found that when eyes were presented as FB images, accuracy was approximately 78 %. However their task was slightly different, as participants presented with a target pair of eyes, and then two probe sets of eyes and the task was to decide if one set was the same as those that had previously been presented. One of the probe eyes was always identical to the target eyes and therefore they did not have to make a mismatch decision. Also because the images were identical rather than two different images of the same person, participants could have been making an image match, rather than a recognition match, this could lead to higher accuracy rates.

The matching accuracy for the eyes alone was less than that for whole faces, if compared to the whole unmasked faces presented in Experiment 7 (see table 4.1). As the table below shows, for all conditions the whole faces have an advantage over the eyes alone, this was also a finding by Gauffaux and Rossion (2006). The pattern of results between the whole faces and eyes are similar as responses for the familiar items are more accurate when the items are mismatched, whereas for unfamiliar items the responses are more accurate when the items match. Again this could be due to the image properties as the unfamiliar items are more homogenous than the familiar ones.

Condition	Whole face	Eyes
Familiar matched	86.0 %	65.6 %
Familiar mismatched	95.1 %	69.2 %
Unfamiliar matched	92.2 %	78.8 %
Unfamiliar mismatched	71.4 %	58. 5 %

Table 4.1 Mean percentage accuracy for whole unmasked faces (Experiment 7) and eyes alone.

This experiment unsurprisingly has shown that although participants can perform above chance, when trying to determine if two pairs of eyes are the same person, being presented with only the eye regions leads to a much poorer performance than being presented with whole faces.

General Discussion

The aim of this chapter was to investigate whether manipulating the image properties of faces, by either filtering them to the low spatial frequencies, or masking the inner eyes influenced matching performance and viewing patterns. Previous research has found that the eyes are the most viewed features when carrying out a recognition task (Althoff & Cohen, 1999; Barton et al., 2006; Henderson et al., 2001, Henderson et al., 2005; Janik et al, 1978) and the eyes are also important when carrying out face matching tasks (O'Donnell & Bruce, 2001). Another aim was also to discover how well participants can perform a matching task when only presented with the eye region, as previous research has found that recognition performance is less accurate when only this area is presented, compared to whole faces (Gauffaux and Rossion, 2006).

The viewing patterns for Experiment 6 did vary from the LSF images to those that were FB images. Although there was an overall bias for the eyes, the nose seemed to receive more gaze on the left face if it was a LSF image. For Experiment 7, masking one or both of the inner eyes increased gaze to the other unmasked eyes. This seems to show that by manipulating the image properties, through SF filtering or masking features, the usual viewing patterns can be disrupted. Even when faces are not manipulated, when they are presented with faces that are manipulated there is a shift in the way the faces are viewed, therefore manipulating one face can alter the way another face (that is not manipulated) is viewed.

For both Experiment 6 and 7 however, there still seemed to be a bias for the inner eyes (right eye on left face and left eye on right face), and they received more gaze than the outer eyes (left eye on left face and right eye on right face) when they were unmasked. This viewing strategy of scanning between the inner eyes has also been found in Experiments 2, 3 and 4 and seems to suggest that viewers are using a global strategy to obtain a holistic impression of the face and by scanning the inner eyes viewers, are using the shortest route possible to look at one eye on each face.

Looking at task performance for the experiments, the results for Experiment 6 found that responses for the matched faces were more error prone when the left face was a LSF image and the right face was a FB image, as compared to the right face being a LSF image or when both images were LSF images. Whilst Experiment 7 found responses for the unfamiliar matched faces were more error prone when the right eye on the left face was masked, as compared to the left eye on the right face being masked. These results seem to show that manipulating the image of the left face seems to adversely affect matching more than manipulating the image of the right face. This could be because viewers look at the face on the left first and use it as a comparison to compare/contrast with the face on the right, if the left image has been manipulated so that some of the information is missing or unclear, then it makes the matching process more difficult and error prone.

There were however some differences in performance between the Experiments 6 and 7. For Experiment 6 responses for matched faces were more error prone when the left face was a LSF image, than when both images were LSF images. However for Experiment 7 responses for unfamiliar mismatched were more error prone when both faces were masked, as compared to all the other masked conditions. This seems to show that manipulating the spatial frequency of the left face impairs matching more than masking the right eye of the left face.

Finally, although Experiments 6 and 7 have shown the importance of the eyes for face matching, as have previous studies (O’Donnell & Bruce, 2001), Experiment 8 found the eye regions alone are not sufficient for accurate matching performance. The results from this experiment and findings from previous research (Gauffaux and Rossion, 2006) which has found that being presented with whole faces will lead to more accurate matching decisions, than being presented with only the eye regions.

Chapter Five

An investigation of scanning biases for face and object matching.

Introduction

The previous chapters have investigated how manipulating the way face pairs are presented influences matching accuracy and viewing patterns. Although the main focus of the earlier chapters was looking at differences in the amount of gaze to specific features, for three experiments there was a consistent finding. The first fixation analysis for Experiments 3, 4 and 6 reported that for three-quarters of the trials, the face on the left was viewed before the face on the right. The left perceptual bias has been found in numerous studies using individual faces, but to date this has not been reported using face pairs. The aim of this chapter is to investigate the leftward bias for face pairs by re-analysing the first fixation data for Experiments 3, 4 and 6, whilst including the additional variables of familiarity, face match, inversion, distance between the faces and low spatial frequency images to see if they influence the bias to look initially at the left face. Another aim is to investigate whether presenting pairs of similar objects produces a viewing bias when carrying out a matching task.

Early research by Wolf (1933) found when viewers were presented with a target face and a face that was a combination of either both left sides of the face, or right sides of the face, participants consistently reported the face made from the left halves looked more like the original image than the face made from the right halves. There has since been a wealth of research investigating the perceptual bias when looking at faces and this has used three main paradigms. The first is the use of chimeric face stimuli, where the two halves of a face are combined to make a new image and participants are asked to make a decision such as age, gender, expression or attractiveness and it can be determined which half of the face they used to make their decision. The second are visual field studies, where participants are asked to fixate on a central point and stimuli are presented briefly (200ms or less) to one or both visual fields, minimising the chance that viewers can make an eye movement. Response times and accuracy measures are used to determine how well the corresponding hemisphere can process the information; e.g. the right hemisphere (RH) processes stimuli in the left visual field (LVF). The third and the least reported method, uses eye movement measures to examine the bias in gaze towards either the left or right side of the face.

Perceptual asymmetries using chimeric faces

Early studies using chimeric faces suggested that the left visual field bias related to the properties of the face, rather than the viewer (Wolf, 1933). Then Gilbert and Bakan (1973) found that when the original target face was mirror reversed, viewers still chose faces made from the left half (right side of the original image) as looking more like the target face. They concluded that the left bias was due to the viewers' perceptual asymmetries and a right hemisphere specialisation for face processing, rather than the physical properties of the faces themselves. This was in accordance with neuropsychological research reporting that damage to the right hemisphere led to impaired facial recognition (De Renzi & Spinnler, 1966).

More recent research using chimeric faces has shown that the left perceptual bias can be found for a variety of tasks such as: judgements of emotion, attractiveness, gender and age (Burt & Perrett, 1997; David, 1989; Levine & Levy, 1986). However when asked to lip read from a chimeric face, a right bias emerged (Burt & Perrett, 1997). This seemed to show that the right hemisphere was involved in most face processing tasks, however when viewers were asked to make a decision involving language, the left hemisphere was activated, leading to a right visual bias. There are other factors that are thought to influence the degree of perceptual bias that viewers elicit when viewing faces.

Age is one factor that can influence the degree of perceptual bias. Research using chimeric faces has shown that the left bias emerges from about 5 years of age, however it seems to decline after the age of 60 years (Failla, Sheppard, & Bradshaw, 2003), the same finding has been found with visual field research (Levine & Levy, 1986). Another factor that seems to influence perceptual bias is familiarity. Brady and colleagues found when the target face is someone very familiar, viewers will consistently choose chimeric faces made from the left halves, even if the target face is mirror reversed, (i.e. on the right side of space). However, viewers unfamiliar with the target faces will choose the faces made from the halves on the left side of space regardless of the mirror reversed target face. This seemed to provide some evidence that facial asymmetries are stored in memory. However when viewers were shown their own face, they were more likely to choose a face made from the right halves as they look in a mirror (Brady, Campbell, & Flaherty, 2004, 2005). They suggest the reason for the disparity between viewing a familiar face and ones own face, is that face processing is a predominately a right hemisphere process, whereas self recognition and self concept are thought to be left hemisphere processes (Brady, Campbell, & Flaherty, 2005).

Other factors thought to influence the perceptual bias are handedness and reading direction. In a study by David (1989) viewers had to judge the emotion of a chimeric face. The results showed there was a consistent left bias for the right-handers, but not the left-handers. However, Vaid and Singh (1989) found no reliable difference in relation to handedness, but an influence of reading direction. They presented chimeric faces to Hindi readers (left to right), Arabic readers (right to left), Hindi/Urdu readers (bidirectional) and illiterates. They found that the Hindi readers had the strongest leftwards bias (83.3 %), whilst the Arabic readers had a rightward bias that did not reach significance (53 %) and the bidirectional and illiterate group showed no overall bias.

Heath, Rouhana and Ghanem (2005) tried to replicate Vaid and Singh's (1989) findings using larger samples for each group, they used; English/French (Roman script) only readers, Arabic only readers, participants that used a mixture of Roman and Arabic scripts and illiterates. They found handedness influenced the Roman only and Arabic only groups, and right-handers in the Roman only group showed the greatest leftwards bias and right-handed Arabic only group showed no bias. The left-handed Roman only group and Arabic only group who were ambidextrous showed the greatest rightward bias. They also found half of the bidirectional readers had a left bias, whilst the other half had a right bias, and the illiterates showed a slight left bias. They concluded that although face perception was a right hemisphere task for right-handers, handedness and reading direction could also influence scanning biases.

Not all studies have found a perceptual bias, one early study found no significant differences in the perceptual bias for readers of English or Hebrew (right to left), or for left or right-handed participants, and all were found to have an overall left bias (Gilbert & Bakan, 1973). However this study could be criticised as many of the Hebrew subjects had learnt English from 13 years of age, which might influence scanning biases. Also Vaid and Singh (1989) noted that Hebrew arithmetic and music reads from left to right and therefore a weakened left bias might still be present.

Perceptual asymmetries using the visual field paradigm

The research described so far has used chimeric faces to determine whether a decision about a face based on either the left or right side, however other research has used the visual field paradigm, of briefly presenting stimuli to one or both visual fields (VF). There are several studies that have found that recognition of faces is superior when shown to the left visual field (LVF), whereas word recognition or lexical decisions have higher performance when presented to the right visual field (RVF) (Dutta & Mandal, 2002; Hagenbeek & Van Strien, 2002). However there are some inconsistencies and in some cases the LVF bias is not always present (Rhodes, 1985b).

It has been suggested that responding verbally, as opposed to using manual responses, may activate the left hemisphere (LH), as it is the dominant hemisphere for language, and this could result in a right visual field bias. However, the LH cannot be attributed exclusively to naming, as Sergent (1982) found LH superiority in the judgement of occupational categories. Other studies have also found RH superiority for tasks that require naming (Glass, Bradshaw, Day, & Umilta, 1985; Levine & Koch-Weser, 1982). According to Rhodes (1985) names and semantic information activate the left hemisphere, and the visual information about a face activates the RH.

One reason that RH might be dominant for face processing, is that the RH is associated with holistic or global processing and is activated for other classes of homogenous stimuli that can be individuated using configural cues (Rhodes, 1993). Anderson and Parkin (1985) found a LVF advantage for matching pairs of hands, but not aeroplanes. It has also been suggested that the RH is activated when presented with low spatial frequency (LSF) images, whereas the LH is involved more with high spatial frequency (HSF) processing (Sergent, 1982). However there is research that has shown that VF biases are not confined to only the left and right VFs.

Hagenbeek and Van Strien (2002) examined visual half-field asymmetries and reported there was a lower left and upper right visual field advantage for a face-matching task, whereas for a letter naming task there was an upper right visual field bias. They argue that they may have obtained an upper right visual field advantage for face processing, as the faces presented were cartoon faces and not real images, which may have been processed in a local/featural fashion, and use different cortical areas than photographs. Whereas if they had used real images of faces they may have been processed in a global/holistic fashion, which would have produced a left visual field advantage that has been found in so many previous studies.

Although many studies have found some kind of asymmetry in face processing tasks, there have been some studies that have found no asymmetry for face recognition (Kampf, Nachson, & Babkoff, 2002; Rhodes & Wooding, 1989). Kampf et al., (2002) presented faces to the left, centre and right visual fields and asked participants to make various judgements; such as whether the object was a face, familiarity, occupation and name. Participants either pressed a response button, gave a verbal response, or both together. The results reported that presentation to the central visual field produced the shortest response times and there were no significant differences for the left and right visual fields, this was found for all the different judgement tasks and for the different types of responses. They concluded that familiar face recognition was not lateralised, as they found no visual superiority.

Although not all the studies described have found a LVF bias for faces the majority do seem to find this pattern. This left perceptual bias is thought to be due to RH dominance for face processing, and may also be influenced by reading direction, however there is some evidence that this is reflected in eye movement patterns and scanning biases when viewing faces.

Eye movement studies investigating the left visual field bias for faces.

Early research by Yarbus (1967) suggested that the left side appeared to be looked at more than the right side, however the stimuli were line drawings and not very realistic. Since then a number of eye movement studies have found a leftwards bias is reflected in eye movements when viewing faces. Phillips and David (1997) found that healthy subjects showed an overall bias to look at the left side of a face first, whereas schizophrenic subjects showed the reverse and made more first saccades to the right sides. They suggest that the right bias for the schizophrenic group could reflect a right hemisphere dysfunction.

There is research that compared the viewing patterns for faces and other types of stimuli. Mertens, Siegmund and Grusser (1993) presented faces and vases and found a left bias for the faces, but not the vases. They mirror reversed the faces in case any of the stimuli had more salient details on the left side, however they still found an overall bias towards the left side of space, regardless of the mirror reversal. Another study that presented faces, landscapes and fractals also found that there were significantly more first saccades to the left side of faces as compared to the other stimuli. When the faces were presented so that they were inverted there was a reduction in the number of first saccades to the left, however there was still a slight leftwards bias (Leonards & Scott-Samuel, 2005). In another study using chimeric faces and a gender decision, it was reported that inversion did reduce the bias as compared to upright faces, however there was still a leftwards bias (Butler & Harvey, 2005).

In another study, Butler et al., (2005) presented chimeric faces for a gender decision and found that 75 percent of first fixations were made to the left of the face. Additionally when participants initially made a saccade to the left side they produced more left saccades and fixated for longer on the left side. Even when gender decisions were based on the right side of the face, participants still looked initially to the left on 71 percent of trials. However Butler and Harvey (2006) argue that eye movement studies cannot fully explain the left perceptual bias. They conducted a gender task using chimeric faces that were presented for only 100ms, so that the viewers were not able to saccade to either the left or right and still found a reduced, but significant left perceptual bias for responses. They suggest that allowing eye movements enhances the left perceptual bias, but does not necessarily cause it.

All of the studies described so far have found a left perceptual bias for faces, however the majority have used individual faces. There is no research to date that has examined whether the left perceptual bias is present when presented with pairs of faces for a matching task. It has also not been examined whether inverted a pairs of faces will decrease the bias towards the left as has been found in previous studies (Leonards & Scott-Samuel, 2005).

Experiment 3 re-analysis

The aim of this experiment reported in chapter 2, was to investigate whether inverting faces, so that they are upside down influences the bias to look at the face on the left before the face on the right. When faces are upright they are believed to be processed more in a configural or holistic manner, however when they are inverted this leads to more featural processing, and faces are thought to be processed more like other objects (Gauthier et al., 1999; Haxby et al., 1999a; Rossion & Gauthier, 2002). If the faces are processed featurally when they are inverted this may weaken the left perceptual bias, as the process might not be dominated by the right hemisphere.

Previous research investigating the perceptual bias for single faces has found inconsistent results; Rhodes (1993) found a left bias for upright faces, but not inverted faces. Whilst Butler and Harvey (2005) found the left bias was reduced for the inverted faces, but still above chance. They argued that the inversion of face-like stimuli does not abolish the right superiority effect for face processing. There is however no research that has investigated the perceptual bias for pairs of faces and whether it is influenced by face inversion.

In Experiment 3 (chapter 2) the eye gaze data reported there was a left perceptual bias and the left face received significantly more first fixations than the right face, however only a t-test was performed on this data and the other factors such as inversion, familiarity and face match, were not included in the analysis. The first fixation data will now be re-analysed including the factors; familiarity, face orientation and face match, for the methodology see chapter 2.

Location of first fixation

Figure 5.1a shows the mean percentage of first fixations to the left face for the familiar faces and figure 5.1b shows the mean percentage of first fixations to the left face for the unfamiliar faces. A 3-factor ANOVA was performed on the percentage of first fixations to the left face Familiarity (familiar/unfamiliar), Match (match/mismatch), Orientation (upright/inverted). The results from the analysis found no significant main effects, but there was a significant 3-way interaction between all the factors ($F (1, 23) = 7.1$, $p < 0.05$).

The simple simple main effects from the interaction revealed inversion significantly decreased the number of first fixations to the left faces, but only for the familiar matched faces ($F (1, 23) = 6.8$, $p < 0.05$). There were some significant effects of match, the familiar upright faces ($F (1, 23) = 5.7$, $p < 0.05$) and unfamiliar inverted faces ($F (1, 23) =4.9$, $p < 0.05$) received more fixations to the left face when the faces matched, however the familiar inverted faces ($F (1, 23) = 15.4$, $p < 0.05$) and the unfamiliar upright faces ($F (1, 23) = 4.2$, $p = 0.05$) received more first fixations to the left face when the faces mismatched. There was also an effect of familiarity, the matched inverted faces received more first fixations to the left face when the faces were unfamiliar as compared to being familiar ($F (1, 23) = 6.4$, $p < 0.05$).

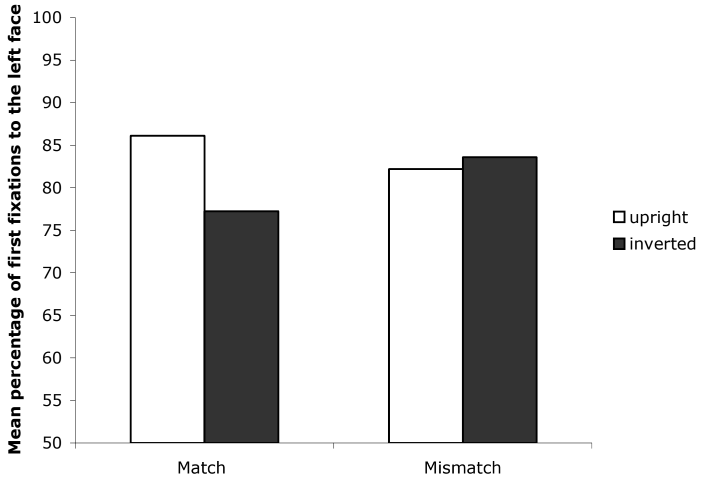


Figure 5.3a Mean percentage of first fixations to the left face for the familiar matched and mismatched faces.

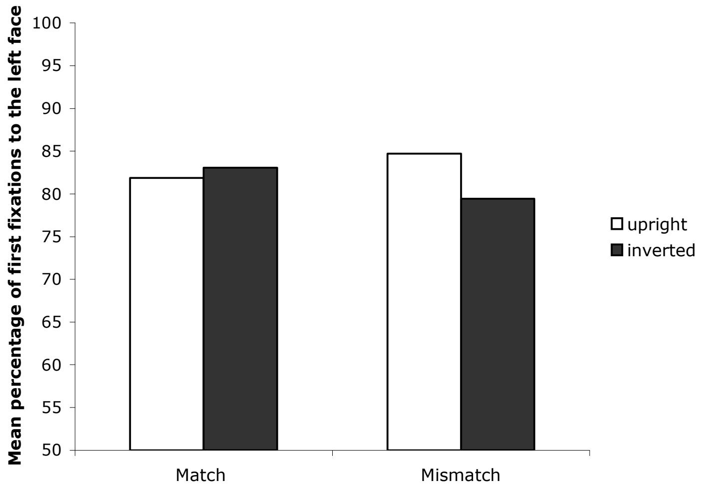


Figure 5.1b Mean percentage of first fixations to the left face for the unfamiliar matched and mismatched faces.

Discussion

The overall pattern for the familiar and unfamiliar and matched and mismatched faces was very similar, there was a very strong bias to look at the left face first regardless of the other factors. Face inversion only reduced the number of first fixations to the left face for the familiar matched faces.

As there have been no other studies investigating the perceptual bias for pairs of faces, all comparisons to previous research rely on studies using individual faces. Previous research by Butler & Harvey (2005) found that when viewing upright and inverted chimeric faces there was still an overall bias for the left side of the face in both conditions, however it was significantly reduced when the faces were inverted. They argue that face inversion does not destroy the left superiority for face processing, as there was still an overall bias for the left face in the inverted faces condition. However other research by Rhodes (1993) found that there was no perceptual bias for inverted faces. Both of these studies used slightly different paradigms as Butler & Harvey (2005) used chimeric faces and Rhodes (1993) used the visual field paradigm, this might help to explain why they found different results.

There were some differences due to inversion for Experiment 3 and it could be argued that the reason there were fewer first fixations to the left face for the inverted familiar matched condition is because viewers were using more of a featural processing strategy, than holistic or configural processing. However there was still overall bias for the left face, regardless of all the other factors and the results are congruent with Butler and Harvey's (2005) finding that inversion does not abolish the right hemisphere superiority for faces processing.

Experiment 4 re-analysis

The aim of this experiment reported in chapter 3, was to investigate how manipulating the distance between a pair of faces influences the leftwards bias for face matching. Megreya and Burton (2006) reported that when a face pair was presented along with a 10-face array, matching the left face with a face from the array was more accurate than matching the right face. They suggested that this might reflect a left to right scanning strategy, however they had no eye movement data to confirm this. In Experiment 4 it was reported that the majority of first fixations were made to the left face; now a re-analysis will be carried out including familiarity, face match and distance between the faces. For the methodology see chapter 3.

Location of first fixation

A 3-factor ANOVA was conducted on the percentage of first fixations to the left face; Familiarity (familiar/unfamiliar), Match (match/mismatch) and Distance (near/far). The results found a significant effect of distance, with more first fixations to the left face in the far condition than the near condition (84.9 % vs. 81.6 %; $F(1, 23) = 5.4$, $p < 0.05$). There were no other significant main effects or interactions.

Discussion

Again there appeared to be an overall bias for the left face regardless of familiarity and match, however this bias was slightly reduced when the faces were placed close together. Megreya and Burton (2006) found that when faces were close together and compared to a ten-face array, performance was worse than when the faces were further apart. They suggest when faces are close together performance is impaired because the faces interfere with one another. The response data from Experiment 3 (see chapter 2) also found that when unfamiliar faces were matched and close together, responses were more error prone than when they were further a part. This might also be reflected in the decrease of the leftwards bias for the first fixation. Perhaps when the faces are closer together there is more interference from the right face and this hinders matching performance.

Experiment 6 re-analysis

The aim of this experiment reported in chapter 4, was to investigate how filtering the spatial frequency (SF) of face images would affect the initial leftwards bias for face matching. Research has shown that when faces are presented as LSF images this promotes more holistic or global processing, whereas if they are HSF images this promotes featural processing (Goffaux, et al., 2005; Goffaux & Rossion, 2006; Sergent, 1986). It has been suggested that holistic processing is predominantly a RH process and featural processing occurs more in the LH. A number of studies have reported a left perceptual bias for LSF images (Grabowska & Nowicka, 1996; Keenan, Whitman, & Pepe, 1989).

The accuracy data for Experiment 6 reported that matching was more error prone when the left face was a LSF image and the right face was a FB image. There was also another finding, there were more first fixations to the left face than the right face; however this was only analysed using a t–test and the other factors were not taken into consideration. The first fixation data will now be re-analysed including the factors of face match and spatial frequency (SF) of the image (for the methodology see chapter 4). If processing LSF images of faces is a RH task then this might produce a stronger bias for first fixations to the left face than the FB images.

Location of first fixation

Figure 5.2 shows the mean percentage of first fixations to the left matched and mismatched faces. A 2-factor ANOVA was conducted; Match (match/mismatch) and SF (FB, LSF, LSF left, LSF right). There was a main effect of match, the matched faces received more first fixations to the left face, than the mismatched faces (91.7 % vs. 87 %; $F(1, 23) = 8.6$, $p < 0.01$). There was a main effect of SF ($F(1, 23) = 10.0$, $p < 0.01$), the FB (92 %), LSF (91.1 %) and LSF right (92 %) conditions all received more first fixations to the left face than the LSF left condition (82.4%). There was also a significant 2-way interaction between match and SF ($F(3, 69) = 5.9$, $p < 0.01$).

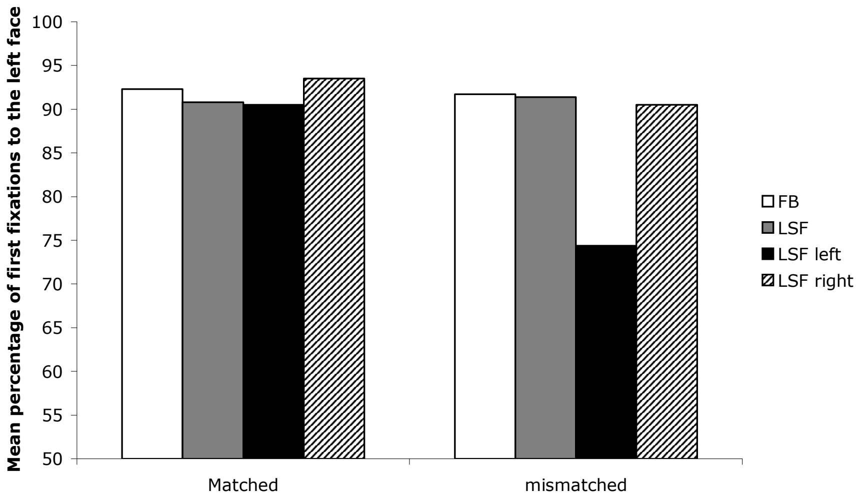


Figure 5.2 Mean percentage of first fixations to the left face for the matched and mismatched faces.

The simple main effects for the interaction revealed the LSF left condition received significantly more first fixations to the left face when the faces matched, than when they mismatched ($F(1, 23) = 24.5$, $p < 0.01$). Planned comparisons for the mismatched faces found there were significantly less first fixations to the left face for the LSF left condition, as compared to all the other SF conditions ($p < 0.01$).

Discussion

The results from the first fixation analysis have revealed that as with Experiments 3 and 4 there was an overall bias to look at the left face first. However when faces were two different people and the left face was a LSF image and the right face was a FB image the number of first fixations to the left face decreased as compared to the `other SF conditions. The LSF left condition was also found to be the most error prone for responses (see chapter 4), however responses were more error prone for the LSF left condition when the faces matched, rather than mismatched.

There does not seem to be any evidence to support the theory that LSF images activate the RH more than the FB images, as the LSF images did not received significantly more first saccades to the left than the FB images. However there was an overall strong bias to look initially at the left face first regardless of SF, perhaps as the bias for the left face was already almost at ceiling, filtering the faces to the LSF could not increase the leftward bias any further.

These data appear to show that when the face on the left is a LSF image and the right face is a FB image the overall leftwards bias is reduced, but only if the faces are two different people. This could be because viewers are drawn to the more detailed FB image on the right, however not enough to look there initially for the majority of trials, as there is still a strong bias to look at the left face first.

All of the experiments described so far have used pairs of faces for a matching task and reported that although some factors can slightly reduce the initial leftwards bias, there is still a strong bias to look at the left face before the face on the right. There are two main explanations for this bias; the right hemisphere dominance for face processing, and the cultural bias to scan left to right due to reading direction. The following experiment will investigate whether the bias of looking at one specific item first can also be found for matching pairs of objects.

Experiment 9

This experiment used pairs of line drawn images from the Matching Familiar Figures Test (MFFT), used to measure impulsivity, reflectivity, attentional and cognitive processes (Kagan, 1965). This test usually consists of one target item and then an array of 6 similar items, one of which is identical to the target item. Viewers then have to decide which item from the array is identical to the target. However in Experiment 9 only pairs of items were used to complement the face-matching task. Items from the MFFT were used as previous research has shown performance on this task correlates with matching a target face to an array (Megreya & Burton, 2006).

The images are HSF images (see figure 5.3) as they only depict the outlines and edges of objects with little shading or LSF information. The images are also very similar and only differ on one particular feature, for example for the pair of bicycles only the handlebars differ. As the items are very similar, and viewers have to look for one difference between the features, it could be suggested that a featural scanning strategy is used rather than a holistic scanning strategy. If participants use more featural processing and the images only contain HSF information, the matching process may activate the LH and might lead to more of a RVF bias. However there could still be an influence of cultural scanning biases from reading and handedness, which might still produce a left bias.

Previous research presenting objects has found inconsistent results. Mertens et al. (1993) found a left bias for faces, but no bias when viewing vases. Levine, Banich and Koch-Weser (1988) found that there was a left bias for faces and houses, but not for chairs. Some research has reported there can sometimes be a left bias for objects, under some circumstances. When categorising an object at the basic level (e.g. car) there is usually a RVF superiority, however when an object is identified as a specific exemplar (e.g. Volkswagen Golf) it is more quickly matched to a label when presented in the LVF (Laeng, Zarrinpar, & Kosslyn, 2003). This shows that the RH is also involved in processing objects, but only when discriminating or categorising specific exemplars, and not at the basic level for object categorisation. All of these studies have used individual items for either a categorisation or recognition task. However when similar pairs of objects are presented for a discrimination task, will this then reflect a RH or LH process?

Method

Participants

24 right-handed participants took part in the study (14 female); all were students or members of staff at the Department of Psychology, Glasgow University. All were native readers of left to right scripts and were able to recognise objects displayed via a monitor without glasses. The participants were paid for their time.

Stimuli

The stimuli consisted of 36 pairs of objects from the Matching Familiar Figures Test (MFFT) (Kaplan, 1965). Although the pairs had similar appearance, half were identical and half were slightly different (see figure 5.3). The image resolution was 72 pixels per inch, and the figures were presented side by side with 5cm between them. The images were grey scale and presented on a white background. The stimuli were presented on 17 inch screen monitor using Experiment Builder, SR Research.

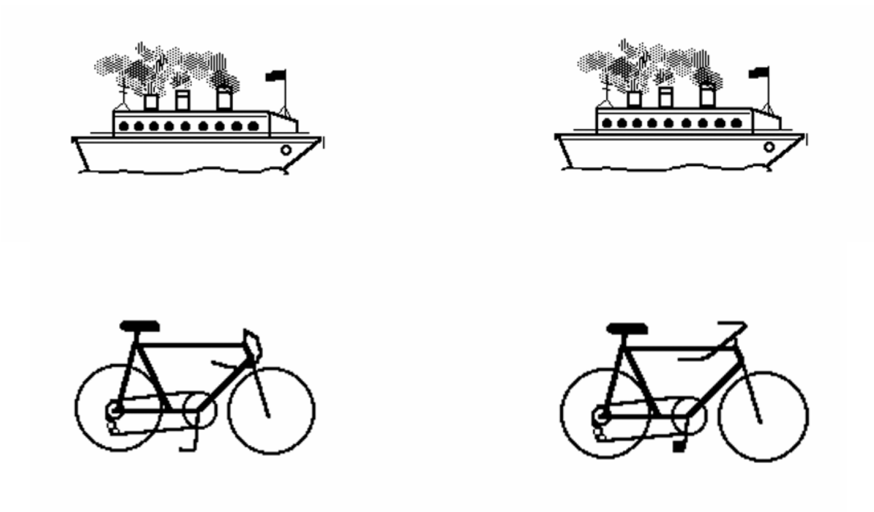


Figure 5.3 Examples of matched objects and mismatched objects.

Apparatus

The participants' eye movements were measured using the head-mounted SR Research EyeLink System; data was recorded from only the right eye. The stimuli were presented in two blocks. A nine-point calibration was carried out at the beginning of each block and a drift correction was performed at the beginning of each trial.

Design & Procedure

The experiment employed a within subjects design, all the participants saw all the pairs and the objects either matched, or mismatched. The participants were instructed that they would be presented with pairs of very similar objects and they had to determine if they were identical, or slightly different. The participant's task was to press one key if the pair was the same and another key if they were different, and each pair was presented for 2 seconds.

Results

Task performance

A within subjects t test was performed on the correct response data. The analysis found that there were significantly more correct responses when the objects matched, than when they mismatched (93.8 % vs. 62.3 %; $t(23) = 7.49$, $p < 0.01$).

Location of first fixation

The location of the first fixation (left object/right object) was determined using Dataviewer (SR Research). A 2-factor within subjects ANOVA was conducted on the location of the first fixation data; Match (match/mismatch) and First fixation location (left object/right object). The analysis found there was a main effect of fixation, with significantly more first fixations to the left object than the right object (82.4 % vs. 17.5 %; $F(1, 23) = 42.2$, $p < 0.01$). There was no other significant main effect, or interaction.

Discussion

The results from the first fixation analysis revealed that there was a very strong bias to look at the object on the left before looking at the object on the right. This shows that the leftwards bias is not only found for face stimuli, but can also be present when presented with pairs of similar objects.

As the task required the viewers to look for small differences between the two objects it is doubtful that they were carrying out a global or holistic scanning strategy and it seems more plausible that they were using some kind of featural processing. However there was still a very strong leftward bias, which indicates that they were using the right hemisphere for the task. The viewers however did not have to categorise objects at the basic level, so perhaps they were using a strategy more akin to categorising objects at the exemplar level (Laeng et al. 2003).

All the participants were right handed and also had a left to right reading direction; therefore this might strengthen the leftwards bias. For future research it would be interesting to carry out the same task with a group of left-handed participants to see if this weakens the bias. It would also be interesting to replicate the study using a group of participants who use a right to left reading direction, and see if this influences leftwards bias.

General Discussion

The first three experiments described in this chapter showed a very strong bias to look initially at the face on the left of the screen and this was regardless of familiarity, face match, inversion, distance between the faces, or whether the face was a LSF image. In Experiment 9 the data reported a strong bias to look initially at the object on the left. Overall the bias for face-matching and the object-matching were comparable, for over 70 percent of trials the object on the left was viewed first. This seems to provide some evidence that the right hemisphere was dominant in all the matching tasks, regardless of whether the items were faces or objects.

One criticism of Experiments 3, 4 & 5 is that handedness data were not collected and therefore there is no way of knowing if any variations in perceptual bias were due to subjects being right or left handed. However as the majority of the population is right handed, it can be assumed that the majority of participants in these studies were also right handed. Another criticism of the face matching experiments is that reading direction details were also not obtained from the subjects, which may have influenced perceptual bias as other studies have shown (Health et al., 2000). However as the majority of participants were from European countries it can again be assumed that the majority used a left to right reading strategy. Both handedness and reading direction will be taken into consideration in all future research investigating perceptual bias.

For all the experiments in this chapter there was a bias to look at the item that was on the left side of the screen before looking at the item on the right side and this was consistently found for face and non-face items. This seems to show that the left perceptual bias is not only found for faces, but also found for matching pairs of similar objects. Other research has found mixed results when viewing objects, in some cases there were no perceptual biases for objects (Mertens et al., 1993), whilst other research found a left bias for houses but not for chairs (Levine et al., 1988).

However the task in Experiment 9 is quite different to all the other studies using faces and objects, as it involved viewing two objects simultaneously and deciding if they were the same or different. Could being presented with a pair of items rather than one item automatically produce a stronger bias, as viewers will have to look at one item first? It is possible that in a paradigm that presents two items simultaneously, there is a stronger influence of reading direction and handedness, so it would be interesting to try and replicate the results of Experiment 9 using left handed individuals and also those that read right to left.

Using a matching paradigm did seem to increase the number of leftward first fixations as compared to other previous studies. Again these differences could be down to different methodologies and tasks. For example Butler et al., (2005) and Butler and Harvey (2005) used chimeric faces and the task was gender decision and therefore the faces may have been viewed differently to those in a matching task. Whilst Mertens at al., (1993) used a recognition task with individual face and vases, and these items might have been viewed differently to those presented simultaneously for a matching task.

Another interesting finding was that the leftward bias for Experiment 4 appeared to be larger than that observed for the other experiments. The average first fixation to the left face for Experiment 4 was over 90 %, except when the left face was LSF image and the right face was a FB image. This seems to suggest that being presented with LSF images increases the bias to look left first, as Experiments 3 and 6 showed average first fixations to the left between 77 and 86 percent of trials. It would be interesting to explore further the influence of filtering the spatial frequency of images and whether it affects the left perceptual bias. To do this an additional face matching task could be conducted where the faces are filtered to show only HSF information to investigate if this weakens the bias to look the left face first, as it has been suggested that the LH is dominant for HSF information.

Finally, all the experiments described in this chapter have shown a very strong bias to look at the item on the left before looking on the item on the right. This seems to reflect a RH dominance for carrying out the matching task, however reading styles and handedness may also have had an additive affect and increase the probability that first fixations were to the left.

Chapter Six

Summary and Conclusions.

This thesis has investigated how pairs of faces are viewed simultaneously for a matching task, where participants have to decide whether two faces are the same person. Deciding whether two face images are the same person is extremely important for a variety of security and forensic tasks, such as matching robbers caught on CCTV footage to live suspects, matching a person to a passport photograph and proof of identity when opening a bank account, or picking up a parcel. As chapter 1 reported, when people try to match unfamiliar faces their responses can be extremely error prone (Bruce et al., 1999, Henderson et al., 2001, Megreya & Burton, 2006). However when the faces are familiar, recognition and matching can be extremely accurate, even with poor quality images (Bruce et al., 2001, Burton et al., 1999).

Very little research has investigated how pairs of faces are viewed for a face matching task, and two studies to date have been published on this issue. One study found that the majority of gaze was to the region between the brow and mouth, and suggested that participants have to view the same features on both faces before making an accurate matching decision (Walker-Smith, Gale, & Findlay, 1977). The other study found that the majority of gaze was to the internal features (eyes, nose and mouth) and the external features (forehead, chin, ears) received very little gaze, regardless of familiarity (Stacey, Walker, & Underwood, 2005). Although these studies highlighted the importance of the internal features for face matching they still left various questions answered. This thesis attempted to answer these questions including; which internal features are important when trying to match faces simultaneously, do participants use a specific viewing strategy when carrying out a matching decision and if so does this viewing pattern change if the face pair presentation is manipulated?

The majority of experiments reported in this thesis seem to suggest that the most important features for carrying out a matching task (when faces are presented side by side) are the eyes, and across all the experiments the eyes were looked at for longer than the other internal features. For a number of experiments there was a scanning strategy whereby the eyes that were in the middle of the screen (the right eye on the left face and the left eye on the right face) received more gaze than the outer eyes (left eye on the left face and the right eye on the right face). This seemed to show that the participants were not viewing exactly the same features on each face as was suggested by Walker-Smith et al. (1977), as the viewers were able to make a correct matching decision by fixating on a single eye on each face. This scanning strategy was found for Experiment 2 which used the same images for the matched condition, for Experiment 4 when the faces were close together and for Experiment 6 when the faces mismatched. For Experiments 3, 4 (far condition) and 6 (mismatched condition) the scanning strategy of looking only at the inner eyes was not as clear, although the inner eyes did seem to receive more gaze than the outer eyes. Participants looked more at features on the left face (eyes and nose) and only looked at the left eye on the right face, this suggests they were using the left face to build up a representation to compare to the right face.

The experiments described in the second chapter investigated the face inversion effect and reported that matching accuracy for Experiments 1 and 3 was more error prone for inverted faces, as compared to upright faces, this confirmed the face inversion effect that has been found in other studies (Scapinello & Yarmey, 1970; Yin, 1969). It also reported that there were different viewing patterns for faces that were inverted, as compared to being upright. Overall there was a bias to look at the top half of space, so the eyes (Experiments 1, 2 and 3) and forehead (Experiment 1) received more gaze when the faces were upright, whereas the mouth (Experiments 1, 2 and 3) and nose (Experiment 3) received more gaze when the faces were inverted. Previous research using inverted faces has also reported a bias to look for longer at features that reside in the top half of space (Barton et al., (2006).

However not all research has found differences in the viewing patterns for upright and inverted faces, Henderson et al. (2001) reported little difference in viewing patterns as a function of inversion and stated their data did not support the transition from holistic processing for upright faces to featural processing for inverted faces. This thesis supports the view that viewing patterns vary due to face inversion for matching and familiarity decisions. When the faces were upright the eyes received the most amount of gaze, and this could be interpreted as a global scanning strategy, where participants use the eyes to build up a holistic impression of the face. Then when the faces were inverted the gaze was distributed more evenly to the eyes, nose and mouth, as if the participants were having to view more features at a time, and this could be interpreted as more of a featural, or local scanning strategy.

The different viewing strategies reported for the upright and inverted faces helps to confirm findings from previous research, which reported that inverting faces disrupts configural, rather than featural processing (Farah et al., 1995; Freire et al., 2000; Leder and Bruce, 2000; Rhodes et al., 1993; Searcy and Bartlett, 1996; Tanaka and Farah, 1993; Young et al., 1987). This also supports Rossion and Gauthier's (2002) conclusion that the face inversion effect occurs during face encoding, as differences reported here were for matching tasks, when faces are presented simultaneously. Future research could try to investigate the differences in viewing upright and inverted faces and give further evidence to support a shift from global to local processing by using additional eye movement measures, such as those employed by Groner, Walder and Groner (1984). They made the distinction between local scan paths, looking at a consistent pattern of fixations (e.g. left eye, right eye, left eye) and global scan paths, the distribution of fixations over a larger time scale (e.g. start, middle and end of total viewing time). By using these types of measures along with number of fixations it may be possible to make a clear distinction between local and global processing.

As previously described when faces were upright and side by side there was an overall bias to look more at the inner eyes (left eye on the right face and the right eye on the left face), as compared to the outer eyes (left eye on the left faces and the right eye on the right face) and the other features. However when the faces were presented vertically one on top of the other, the viewing strategy changed and the left eye and the nose became the dominant features for the face matching task (Experiment 7). The findings from Experiment 7 support previous research that suggested that the same features on both faces need to be fixated upon when performing a matching task, but only when faces are presented vertically one above the other, as they were for Experiment 7 and for Walker-Smith et al., (1977) study. When comparing the viewing patterns from the experiments that presented faces side by side to those that presented faces vertically one above the other, it appears that the way face pairs are presented can influence the way they are viewed and different features are important depending on the layout.

The way faces are presented for a matching task has huge implications for the area of eye witness identification and matching criminals caught on CCTV footage. If presenting faces in a particular way influences matching performance, then this should be taken into consideration so as to maximise the chance of an accurate match being made. The experiments reported here found that presenting unfamiliar face pairs close together can impair performance, especially if they are the same identity (Experiment 4). This was also found in when trying to match a face from a pair to a 10-face array (Megreya & Burton, 2006). Presenting the faces misaligned, so that the right face is higher can also hinder matching performance (Experiment 5).

Another interesting finding was that if the faces were filtered to display only low spatial frequency (LSF) information, matching was especially error prone if the left face was a LSF image, than when only the right face was a LSF image, or when both faces were LSF images. Previous research has suggested that presenting faces as LSF images should reduce recognition performance (Costen, et al., 1994, 1996; Fiorentini et al., 1983; Parker et al., 1996), however if this were the case then performance should have been worse for the condition where both faces were LSF images. Alternatively, other research has suggested that it is the spatial frequency overlap between images that is important and performance is more error prone if faces are filtered differently from one another (Collin, et al., 2004; Collin et al., 2006; Kornowski & Petersik, 2003; Liu et al., 2000), however if this were the case then performance for the condition where the right face was a LSF image should have been as error prone as when the left face was a LSF image. Whereas when the right face was a LSF image, performance was the same as when both faces were unfiltered. The reason that the performance may have been more error prone when the left face was a LSF image, is that the majority of the time participants looked at this face first and used it as a comparison face to match to the face on the right and if it was a LSF image there was less featural details and therefore more of a discrepancy between the two images. When the left face was LSF image it also influenced viewing patterns and the left face received more gaze to the nose, although overall there was still a bias for the eyes.

Presenting faces as LSF images not only influenced performance, but also the viewing patterns of the participants. When one of the faces was a LSF image, the faces received more gaze to the eyes than when both faces were LSF images, or both were unfiltered. There was also a bias for the inner eyes (right eye on the left face and left eye on the right face) and they received more gaze than the outer eyes. The bias to scan between the two central eyes was especially seen when the faces mismatched, but was not as strong when the faces were matched. The bias for the inner eyes seems to give more support for a global scanning strategy, as only holistic or global information can be conveyed for the LSF images, as they lack fine detailed featural information. There were some other differences when the faces matched, as participants had to look at more features on the left face, but only at the left eye on the right face. This scanning strategy of looking at the internal features on the left face more equally, but only viewing the left eye on the right face is similar to the strategy found for upright faces in Experiment 3. It appears that participants look at the features on the left face to build up a representation that they compare to the right face.

As previously described there was a scanning strategy across a number of experiments (2, 4 and 6) of scanning across the central or inner eyes, and in many cases the other facial features received very little gaze. When the faces were placed vertically one above the other this changed the viewing strategy and there was also another way of disrupting the scanning strategy. In Experiment 7, when one or both of the inner eyes were masked viewers had to look more at the adjacent eye to make an accurate decision. This showed that the eyes were still the most important features, as there was little increase in gaze to the nose and mouth as a result of masking the eyes. It also revealed that masking the right eye on the left face was more detrimental than masking the left eye on the right face. The impairment from masking the eye on the left face may relate to viewers looking at this face first (although first fixation data for this experiment was not collected) and if the information is missing it impairs matching with the right face. This helps to confirm results from Experiment 6 that found that filtering the left face to convey only LSF information was more detrimental to matching than when both or the right face were LSF images.

A number of experiments within this thesis have shown the importance of the eyes for face matching and previous research has also shown that the eyes are important for matching familiar faces (O'Donnell & Bruce, 2001). Studies that have masked the eyes and eye brows argue that it is not the eyes alone that are important, but also the eyebrows (Sadr et al., 2003, White, 2004). However having the eyes and eyebrows alone for a matching task significantly reduced task performance (Experiment 8) and therefore it appears that it is the eyes and eyebrows within the context of a face, which are important for accurate matching performance. Further research could explore the importance of the eyes for accurate matching by using faces with both eyes masked to complement Experiment 8, or use a more ecological approach by using faces wearing sunglasses.

One interesting finding that was consistent across three experiments was that over 80 percent of the time participants looked at the face on the left, before looking at the face on the right. The bias to look towards the left side of faces has been found in previous studies (Butler et al., 2005, Butler & Harvey, 2005, Heath et al., 2005, Leonards & Scott-Samuel, 2005, Mertens et al., 2003, Phillips & David, 1997), but this is the first time this has been reported using pairs of faces. The bias to look at the face on the left helps to explain findings from previous research using face pairs to match to a 10-face array. Megreya and Burton (2006) found that matching was more accurate for the face on the left, than the face on the right and suggested that viewers might be looking at the left face first which could interfere with processing the right face, however they had no eye movement data to confirm this.

The bias to look initially at the left face was persistent and not significantly reduced by face inversion (Experiment 3), manipulating the distance between the two faces (Experiment 4), or filtering the images to show only low spatial frequency information (Experiment 6). This seems to suggest that for many of the experiments participants looked at the left face first and used it as a comparison face to compare/contrast with the right face. There are various explanations for the left perceptual bias found in faces, including the right hemisphere dominance for face processing (Rhodes, 1985, 1993), however reading direction and handedness also may effect the perceptual bias (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989). Future research could use participants who read right to left scripts, or left handed individuals to see if this influences the bias to look a the left face first.

The leftwards bias reported in the experiments in this thesis was stronger than that found in previous studies using eye movement measures (Butler et al., 2005, Butler & Harvey, 2005, Leonards & Scott-Samuel, 2005, Mertens et al., 2003, Phillips & David, 1997). This may relate to the task, as previous studies have all used individual faces for recognition, gender or emotion judgements, whereas the experiments in this thesis present pairs of faces for a matching task. The nature of a matching task may itself promote a stronger bias to look at one item first, as the participants have to compare the two items to make an accurate decision. Early eye movement research reported that the task given may influence the viewing strategies elicited (Yarbus, 1967). The bias to look first at the item on the left was also found when participants were shown object pairs that had similar appearance

(Experiment 9), this shows that the bias is not specifically related to faces and may be related to carrying out a matching task with pairs of stimuli.

There was not only a bias for looking at the left face first, but also a bias to look at the left eye for longer (Experiments 1, 3, 7). The bias for the left eye has been found in previous studies using eye movement measures (Barton et al., 2006) and also in studies using the bubbles technique (Schyns et al., 2002, Vinette et al., 2004). This might also be linked to the bias to look at the left face first, and could be due to the right hemisphere dominance for face processing (De Renzi & Spinnler, 1966; Rhodes, 1985, 1993), or could relate to cultural biases due to reading left to right (Heath, Rouhana, & Ghanem, 2005; Vaid & Singh, 1989).

Although the majority of experiments reported matching performance was more accurate for the familiar faces, as compared to the unfamiliar faces, there was no clear differences in scanning strategies for faces that were familiar, compared to those that were unfamiliar. Other studies have also found very little differences in viewing patterns for familiar and unfamiliar faces (Henderson et al, 2001, Henderson et al., 2005). However some studies have found differences in how familiar and unfamiliar faces are viewed. Althoff and Cohen (1999) found that famous faces received fewer fixations and with less symmetry than non famous faces, additionally for a fame judgment, less time was spent looking at the nose of famous faces, and for an emotion judgement more time was spent looking at the left eye of the famous faces. Barton et al. (2006) also found that famous faces received fewer fixations than unfamiliar faces, and there were more fixations to the eyes and nose. Differences between these findings could again relate to carrying out different tasks, as the task given can influence viewing patterns (Yarbus, 1967). The previous studies (Althoff &

Cohen, 1999, Barton et al., 2006) used individual faces for a fame and emotion tasks, whereas the majority of experiments reported in this thesis used pairs of faces for a matching task.

An alternative explanation for there being no differences as a function of familiarity for viewing patterns reported in this thesis and previous research (Henderson et al., 2001, Henderson et al., 2005), whereas other research has found differences (Althoff & Cohen, 1999, Barton et al., 2006) could relate to different eye movement measures. The experiments reported here used proportion of gaze, whereas other studies have used number of fixations and also Markov analyses. Using these different types of measures may influence how the viewing patterns are interpreted, as previous research has shown that scanning effects can be derived from analysing the number of fixations, when the total duration of fixations are very similar (Barton et al., 2006). However some research has found no difference in the pattern of fixations and gaze duration for face processing tasks (Stacey et al., 2005). In all future research eye movement measures should include proportion of fixations as well as gaze duration, to determine whether the viewing patterns are the same for these different measures.

There were also no differences in viewing strategies for faces that matched, as compared to those that mismatched. There are only two studies to date have used eye movement measures to investigate face matching and one of those did not analyse the differences in viewing patterns for faces that matched or mismatched (Walker-Smith, Gale, & Findlay, 1977). The other study did find some differences as a function of face match, with more gaze to the internal features for matched faces as compared to mismatched faces (Stacey, Walker, & Underwood, 2005). However the matching experiments reported in this thesis only analysed the data for the internal features, as previous studies have found that the internal features receive on average over 90 percent of the gaze (Stacey, Walker, & Underwood, 2005). The experiments in this thesis reported that overall there were no clear differences in viewing the internal features for the matched and mismatched faces were viewed and both were viewed using similar strategies.

A number of conclusions can be drawn from the studies in this thesis. Firstly the eyes appear to be the most important features for face matching when faces are side by side, however when the faces are placed vertically one above the other the left eye and nose appear to be the most important features. This shows that not only does a given task influence eye movement patterns (Yarbus, 1967), but also the way that stimuli are presented. When faces are presented side by side viewers scan horizontally across the eye regions and in some cases only need to fixate upon one eye on each face, as if using the shortest route possible (Experiments 2, 4 and 6). However in some circumstances viewers need to look at more features on the left face to compare to the right face. There was a bias that emerged whereby viewers looked at the face on the left first and used this to compare to the face on the right, further research could be carried out in this area to try and determine whether this bias is due to a right hemisphere dominance for face processing, related to reading direction, handedness or an artefact of presenting pairs of items for a matching task.

The way face pairs are presented can also influence performance, and matching can be more error prone if faces are presented closer together, or misaligned so that the right face is higher than the left face. Matching can also be more error prone when the two face images are of different qualities (e.g. LSF) or have information missing (masked eyes) and if faced with this situation matching may be more accurate if the better quality image is placed on the right hand side. This has implications for presentation of line ups and arrays to eye witnesses and hopefully through additional research face matching can be made more accurate.

References

Althoff, R. R., & Cohen, N. J. (1999). Eye-Movement-Based Memory Effect: A Reprocessing Effect in Face Perception. *Journal of Experimental Psychology: Learning Memory and Cognition, 25*, 997-1010.

Althoff, R. R., Cohen, N. J., McConkie, G., Wasserman, S., Maciukenas, M., Azen, R. (1999). Eye Movement-Based memory Assessment. In W. Becker, H. Deubel & T. Merger (Eds.), *Current Occulomotor Research: Physiological & Psychological Aspects* (pp. 293-302). New York: Plenum.

Althoff, R. R., Maciukenas, M., & Cohen, N. J. (1993). Indirect Assessment of Memory using Eye Movement Monitoring. *Society of Neuroscience Abstracts, 19*, 439.

Anderson, E., & Parkin, A. J. (1985). On the Nature of the Left Visual-Field Advantage for Faces. *Cortex, 21*, 453-459.

Baron, L. (1980). Interaction between Television and Child related Characteristics as Demonstrated by Eye Movement Research, Education, Communication and Technology. *A Journal of Theory, Research and Development, 24*, 267-281.

Bartlett, J. C., Searcy, J. H., & Abdi, H. (2003). What are the routes to face recognition? In M. A. Peterson & G. Rhodes (Eds.), *Perception of faces, objects, and scenes: Analytic and holistic processes* (pp. 21-47). New York, NY: Oxford University Press.

Barton, J. J., Radcliffe, N., Cherkasova, M. V., Edelman, J., & Intriligator, J. M. (2006). Information processing during face recognition: the effects of familiarity, inversion, and morphing on scanning fixations. *Perception, 35*, 1089-1105.

Begleiter, H., Porjesz, B., & Wang, W. (1995). Event-related brain potentials differentiate priming and recognition to familiar and unfamiliar faces. *Electroencephalography Clinical Neurophysiology, 94*, 41-49.

Behrmann, M., Avidan, G., Margotta, J. J., & Kimchi, R. (2005). Detailed exploration of Face -related Processing in Congenital Prosopagnosia. *Journal of Cognitive Neuroscience, 17*, 1130-1149.

Benton, A. L. (1980). The Neuropsychology of Facial Recognition. *American Psychologist, 35*, 176-186.

Bindemann, M., Burton, A. M., Hooge, I. T., Jenkins, R., & de Haan, E. H. (2005). Faces retain attention. *Psychononic Bulletin Review, 12*, 1048-1053.

Bindemann, M., Burton, A. M., & Jenkins, R. (2005). Capacity limits for face processing. *Cognition, 98*, 177-197.

Bonner, L., Burton, A. M., & Bruce, V. (2003). Getting to know you: How we learn new faces. *Visual Cognition, 10*, 527-536.

Boutsen, L., & Humphreys, G. W. (2002). Face context interferes with local part processing in prosopagnosic patient. *Neuropsychologia, 40*, 2305-2313.

Brady, N., Campbell, M., & Flaherty, M. (2004). My left brain and me: a dissociation in the perception of self and others. *Neuropsychologia, 42*, 1156-1161.

Brady, N., Campbell, M., & Flaherty, M. (2005). Perceptual asymmetries are preserved in memory for highly familiar faces of self and friend. *Brain and Cognition, 58*, 334-342.

Bruce, V. (1982). Changing faces: Visual and non-visual coding processes in face recognition. *British Journal of Psychology, 73*, 105-116.

Bruce, V., Hanna, E., Dench, N., Healey, P., & Burton, A. M. (1992). The importance of "mass" in line drawings of faces. *Applied Cognitive Psychology, 6*, 619-628.

Bruce, V., Henderson, Z., Greenwood, K., Hancock, P. J. B., Burton, A. M., & Miller, P. (1999). Verification of face identities from images captured on video. *Journal of Experimental Psychology-Applied, 5*, 339-360.

Bruce, V., Henderson, Z., Newman, C., & Burton, A. M. (2001). Matching identities of familiar and unfamiliar faces caught on CCTV images. *Journal Experimental Psychology: Applied, 7*, 207-218.

Bruce, V., & Humphreys. (1994). Recognizing Objects and Faces. *Visual Cognition, 1*, 141-180.

Bruce, V., & Langton, S. (1994). The Use of Pigmentation and Shading Information in Recognizing the Sex and Identities of Faces. *Perception, 23*, 803-822.

Burt, D. M., & Perrett, D. I. (1997). Perceptual asymmetries in judgements of facial attractiveness, age, gender, speech and expression. *Neuropsychologia, 35*, 685-693.

Burton, A. M., Wilson, S., Cowan, M., & Bruce, V. (1999). Face recognition in poor quality video: Evidnce from Security Surveillance. *Psychological Science, 10*, 243-248.

Butler, S., Gilchrist, I. D., Burt, D. M., Perrett, D. I., Jones, E., & Harvey, M. (2005). Are the perceptual biases found in chimeric face processing reflected in eye-movement patterns? *Neuropsychologia, 43*, 52-59.

Butler, S. H., & Harvey, M. (2005). Does inversion abolish the left chimeric face processing advantage? *Neuroreport, 16*, 1991-1993.

Butler, S. H., & Harvey, M. (2006). Perceptual biases in chimeric face processing: eye-movement patterns cannot explain it all. *Brain Research, 1124*, 96-99.

Caldara, R., Schyns, P., Mayer, E., Smith, M. L., Gosselin, F., & Rossion, B. (2005). Does prosopagnosia take the eyes out of face representations? Evidence for a defect in representing diagnostic facial information following brain damage. *Journal of Cognitive Neuroscience, 17*, 1652-1666.

Caldara, R., Seghier, M. L., Rossion, B., Lazeyras, F., Michel, C., & Hauert, C. A. (2006). The fusiform face area is tuned for curvilinear patterns with more high-contrasted elements in the upper part. *Neuroimage, 31*, 313-319.

Campbell, R., & Tuck, M. (1995). Recognition of Pairs of Famous-Face Photographs by Children - an Experimental Note. *Perception, 24*, 451-456.

Campbell, R., Walker, J., & Baron- Cohen, S. (1995). The Development of Differential Use of Inner and Outer Face Features in Familiar Face Identification. *Journal of Experimental Child Psychology, 59*, 196-210.

Christie, F., & Bruce, V. (1998). The role of dynamic information in the recognition of unfamiliar faces. *Memory & Cognition, 26*, 780-790.

Clifford, B. R., & Hollin, C. R. (1981). Effects of the type of incident and the number of perpetrators on eye witness memory. *Journal of Applied Psychology, 66*, 364-370.

Clutterbuck, R., & Johnston, R. A. (2002). Exploring levels of face familiarity by using an indirect face-matching measure. *Perception, 31*, 985-994.

Clutterbuck, R., & Johnston, R. A. (2004). Demonstrating the acquired familiarity of faces by using a gender-decision task. *Perception, 33*, 159-168.

Clutterbuck, R., & Johnston, R. A. (2005). Demonstrating how unfamiliar faces become familiar using a face matching task. *European Journal of Cognitive Psychology, 17*, 97 - 116.

Collin, C. A., Liu, C. H., Troje, N. F., McMullen, P. A., & Chaudhuri, A. (2004). Face recognition is affected by similarity in spatial frequency range to a greater degree than within-category object recognition. *Journal of Experimental Psychology: Human Perception and Performance, 30*, 975-987.

Collin, C. A., Therrien, M., Martin, C., & Rainville, S. (2006). Spatial frequency thresholds for face recognition when comparison faces are filtered and unfiltered. *Perception and Psychophysics, 68*, 879-889.

Collishaw, S. M., & Hole, G. J. (2000). Featural and configurational processes in the recognition of faces of different familiarity. *Perception, 29*, 893-909.

Costen, N. P., Parker, D. M., & Craw, I. (1994). Spatial content and spatial quantisation effects in face recognition. *Perception, 23*, 129-146.

Costen, N. P., Parker, D. M., & Craw, I. (1996). Effects of high-pass and low-pass spatial filtering on face identification. *Perception and Psychophysics, 58*(4), 602-612.

Crundall, D., Chapman, P., Phelps, N., & Underwood, G. (2003). Eye movements and hazard perception in police pursuit and emergency response driving. *Journal Experimental Psychology: Applied, 9*, 163-174.

Crundall, D., Underwood, G., & Chapman, P. (1999). Driving experience and the functional field of view. *Perception, 28*, 1075-1087.

David, A. S. (1989). Perceptual Asymmetry for Happy Sad Chimeric Faces - Effects of Mood. *Neuropsychologia, 27*, 1289-1300.

Davies, G., Ellis, H., & Shepherd, J. (1978). Face Recognition Accuracy as a Function of Mode of Representation. *Journal of Applied Psychology, 63*, 180-187.

De Gelder, B., Bachoud-Levi, A. C., & Degos, J. D. (1998). Inversion superiority in visual agnosia many be common to a variety of orientation polarised objects besides faces. *Vision Research, 38*, 2855-2861.

De Gelder, B., & Rouw, R. (2000). Paradoxical configuration effects for faces and objects in prosopagnosia. *Neuropsychologia, 38*, 1271-1279.

De Renzi, E., & Spinnler, H. (1966). Facial recognition in brain-damaged patients. *Neurology, 16*, 145-152.

Delvenne, J. F., Seron, X., Coyette, F., & Rossion, B. (2004). Evidence for perceptual deficits in associative visual (prosop)agnosia:a single care study. *Neuropsychologia, 42*, 597-612.

Diamond, R., & Carey, S. (1977). Developmental-Changes in Representation of Faces. *Journal of Experimental Child Psychology, 23*, 1-22.

Diamond, R., & Carey, S. (1986). Why faces, Are and Are Not Special: An Effect of Expertise. *Journal of Experimental psychology: General, 115*, 107-117.

Dubois, S., Rossion, B., Schiltz, C., Bodart, J. M., Michel, C., Bruyer, R., et al. (1999). Effect of familiarity on the processing of human faces. *Neuroimage, 9*, 278-289.

Duchowski, A. T. (2002). A breadth-first survey of eye-tracking applications. *Behavior Research Methods Instruments & Computers, 34*, 455-470.

Dutta, T., & Mandal, M. K. (2002). Visual-field superiority as a function of stimulus type and content. *International Journal of Neuroscience, 112*, 945-952.

Ellis, H. D., Shepherd, J. W., & Davies, G. M. (1979). Identification of Familiar and Unfamiliar Faces from Internal and External Features - Some Implications for Theories of Face Recognition. *Perception, 8*, 431-439.

Failla, C. V., Sheppard, D. M., & Bradshaw, J. L. (2003). Age and responding-hand related changes in performance of neurologically normal subjects on the line-bisection and chimeric-faces tasks. *Brain and Cognition, 52*, 353-363.

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance, 21*, 628-634.

Farah, M. J., Wilson, K. D., Drain, H. M., & Tanaka, J. R. (1995). The inverted face inversion effect in prosopagnosia: evidence for mandatory, face-specific perceptual mechanisms. *Vision Research, 35*, 2089-2093.

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is "special" about face perception? *Psychological Review, 105*, 482-498.

Fashing, I. V., Ask, K., & Granhag, P. A. (2004). The Man Behind the Mask: Accuracy and Predictors of Eyewitness Offender Descriptions. *Journal of Applied Psychology, 89,* 722-729.

Findlay, J. M. (1997). Saccade target selection During Visual Search. *Vision Research, 37*, 617-631.

Findlay, J. M., & Gilchrist, I. D. (2003). *Active Vision: The Psychology of Looking and Seeing*. New York: Oxford Press.

Fiorentini, A., Maffei, L., & Sandini, G. (1983). The Role of High Spatial-Frequencies in Face Perception. *Perception, 12*, 195-201.

Fischer, P. M., Richards, J. W., Berman, E. F., & Krugman, D. M. (1989). Recall and Eye Tracking Study of Adolescents Viewing Tobacco Ads. *Journal of American Medical Association, 261*, 90-94.

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology, 80*, 347-371.

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: direct evidence. *Perception, 29*, 159-170.

Gajewski, D. A., & Henderson, J. M. (2005). The role of saccade targeting in the transsaccadic integration of object types and tokens. *Journal Experimental Psychology: Human Perception and Performance, 31*, 820-830.

Gallay, M., Baudouin, J. Y., Durand, K., Lemoine, C., & Lecuyer, R. (2006). Qualitative differences in the exploration of upright and upside-down faces in four-month-old infants: an eye-movement study. *Child Development, 77*, 984-996.

Gauthier, I., Tarr, M. J., Anderson, A. W., Skudlarski, P., & Gore, J. C. (1999). Activation of the middle fusiform 'face area' increases with expertise in recognizing novel objects. *Nature Neuroscience, 2*, 568-573.

Gilbert, C., & Bakan, P. (1973). Visual Asymmetry in Perception of Faces. *Neuropsychologia, 11*, 355-362.

Glass, C., Bradshaw, J. L., Day, R. H., & Umilta, C. (1985). Familiarity, spatial frequency and task determinants in processing laterally presented representations of faces. *Cortex, 21*, 513-531.

Goffaux, V., Hault, B., Michel, C., Vuong, Q. C., & Rossion, B. (2005). The respective role of low and high spatial frequencies in supporting configural and featural processing of faces. *Perception, 34*, 77-86.

Goffaux, V., & Rossion, B. (2006). Faces are "spatial"--holistic face perception is supported by low spatial frequencies. *Journal Experimental Psychology: Human Perception and Performance, 32*, 1023-1039.

Gosselin, F., & Schyns, P. G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Research, 41*, 2261-2271.

Grabowska, A., & Nowicka, A. (1996). Visual-spatial-frequency model of cerebral asymmetry: a critical survey of behavioral and electrophysiological studies. *Psychological Bulletin, 120*, 434-449.

Groner, R., Walder, F., & Groner, M. (1984). Looking at Faces:Local and Global Aspects of Scanpaths. In A. G. gale & F. Johnson (Eds.), *Theoretical and Applied Aspects of Eye Movements Research*. Amsterdam: Elsevier.

Hagenbeek, R. E., & Van Strien, J. W. L. (2002). Left-Right and upper-Lower Visual field Assymmetries for Face Matching, Letter Naming and lexical Decision. *Brain and Cognition 49,* 34- 44.

Hancock, P. J. B., Bruce, V., & Burton, A. M. (2000). Recognition of Unfamiliar Faces. *Trends in Cognitive Sciences, 4*, 330-337.

Haxby, J. V., Ungerleider, L. G., Clark, V. P., Schouten, J. L., Hoffman, E. A., & Martin, A. (1999). The effect of Face Inversion on Activity in Human Neural Systems for Face and Object Perception. *Neuron, 22*, 189-199.

Heath, R. L., Rouhana, A., & Ghanem, D. A. (2005). Asymmetric bias in perception of facial affect among Roman and Arabic script readers. *Laterality, 10*, 51-64.

Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in Cognitive Sciences, 7*, 498-504.

Henderson, J. M., Falk, R., Minut, S., Dyer, F. C., & Mahadevan, S. (2001). Gaze control for face learning and recognition by humans and machines. In T. F. Shipley & P. J. Kellman (Eds.), *From fragments to objects: Segmentation and grouping in vision. Advances in psychology, 130* (pp. 463-481). New York, NY, US: Elsevier Science.

Henderson, J. M., & Hollingworth, A. (1999). High-level scene perception. *Annual Review Psychology, 50*, 243-271.

Henderson, J. M., & Hollingworth, A. (1999). The role of fixation position in detecting scene changes across saccades. *Psychological Science, 10*, 438-443.

Henderson, J. M., Williams, C. C., & Falk, R. J. (2005). Eye movements are Functional During Face Learning. *Memory and Cognition, 33*, 98-106.

Henderson, Z., Bruce, V., & Burton, A. M. (2001). Matching the faces of robbers captured on video. *Applied Cognitive Psychology, 15*, 445-464.

Hollingworth, A., & Henderson, J. M. (1998). Does consistent scene context facilitate object perception? *Journal Experimental Psychology: General, 127*, 398-415.

Hummel. (2003). The complementary properties of Holistic and Analytical Representations of Shape. In M. A. Peterson & G. Rhodes (Eds.), *Perception of faces, objects, and scenes: Analytic and holistic processes* (pp. 212-235). New York, NY: Oxford University Press.

Janik, S. W., Wellens, A. R., Goldberg, M. L., & Dell'Osso, L. F. (1978). Eyes as the centre of focus in the visual examination of faces. *Perceptual and Motor Skills, 47,* 857-858.

Jenkins, R., Burton, A. M., & Ellis, A. W. (2002). Long-term effects of covert face recognition. *Cognition, 86*, B43-B52.

Jenkins, R., Lavie, N., & Driver, J. (2003). Ignoring famous faces: category-specific dilution of distractor interference. *Perception Psychophysics, 65*, 298-309.

Kagan, J. (1965). Reflection-Impulsivity and Reading-Ability in Primary Grade Children. *Child Development, 36*, 609-628.

Kampf, M., Nachson, I., & Babkoff, H. (2002). A serial test of the laterality of familiar face recognition. *Brain and Cognition, 50*(1), 35-50.

Keenan, P. A., Whitman, R. D., & Pepe, J. (1989). Hemispheric asymmetry in the processing of high and low spatial frequencies: a facial recognition task. *Brain and Cognition, 11*, 229-237.

Kemp, R., Towell, N., & Pike, G. (1997). When seeing should not be believing: Photographs, credit cards and fraud. *Applied Cognitive Psychology, 11*, 211-222.

Klatzky, R. L., & Forrest, F. H. (1984). Recognizing Familiar and Unfamiliar Faces. *Memory & Cognition, 12*, 60-70.

Kornowski, J. A., & Petersik, J. T. (2003). Effects on face recognition of spatial-frequency information contained in inspection and test stimuli. *Journal of General Psychology, 130*, 229-244.

Laeng, B., Zarrinpar, A., & Kosslyn, S. M. (2003). Do separate processes identify objects as exemplars versus members of basic-level categories? Evidence from hemispheric specialization. *Brain and Cognition, 53*, 15-27.

Land, M. F., & Hayhoe, M. (2001). In what ways do eye movements contribute to everyday activities? *Vision Research, 41*, 3559-3565.

Lander, K., & Bruce, V. (2000). Recognizing famous faces: Exploring the benefits of facial motion. *Ecological Psychology, 12*, 259-272.

Lander, K., & Bruce, V. (2004). Repetition priming from moving faces. *Memory & Cognition, 32*, 640-647.

Lander, K., Bruce, V., & Hill, H. (2001). Evaluating the effectiveness of pixelation and blurring on masking the identity of familiar faces. *Applied Cognitive Psychology, 15*, 101-116.

Lavie, N., Ro, T., & Russell, C. (2003). The role of perceptual load in processing distractor faces. *Psychological Science, 14*, 510-515.

Le, S., Raufaste, E., & Dermonet, J.-F. (2003). Processing of normal, inverted and scrampled faces in a patient with prosopagnosia: Behavioural and eye tracking data. *Cognitive Brain Research, 17*, 26-35.

Leder, H., & Bruce, V. (2000). When inverted faces are recognized: the role of configural information in face recognition. *Quarterly Journal of Experimental Psychology, 53*, 513-536.

Leonards, U., & Scott-Samuel, N. E. (2005). Idiosyncratic initiation of saccadic face exploration in humans. *Vision Research, 45*, 2677-2684.

Levine, S. C., Banich, M. T., & Koch-Weser, M. P. (1988). Face recognition: a general or specific right hemisphere capacity. *Brain and Cognition, 8*, 303-325.

Levine, S. C., & Koch-Weser, M. P. (1982). Right hemisphere superiority in the recognition of famous faces. *Brain and Cognition, 1*, 10-22.

Levine, S. C., & Levy, J. (1986). Perceptual asymmetry for chimeric faces across the life span. *Brain and Cognition, 5*, 291-306.

Liu, C. H., Collin, C. A., Rainville, S. J., & Chaudhuri, A. (2000). The effects of spatial frequency overlap on face recognition. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 956-979.

Liu, C. H., Seetzen, H., Burton, A. M., & Chaudhuri, A. (2003). Face recognition is robust with incongruent image resolution: Relationship to security video images. *Journal of Experimental Psychology-Applied, 9*, 33-41.

Loftus, G. R., & Harley, E. M. (2005). Why is it easier to identify someone close than far away? *Psychonomic Bulletin and Review, 12*, 43-65.

Loftus, G. R., & Mackworth, N. H. (1978). Cognitive Determinants of Fixation Location During Picture Viewing. *Journal Experimental Psychology: Human Perception and Performance, 4*, 565-572.

Luria, S. M., & Strauss, M. S. (1978). Comparison of eye movements over faces in photographic positives and negatives. *Perception, 7*, 349-358.

Malone, D. R., Morris, H. H., Kay, M. C., & Levin, H. S. (1982). Prosopagnosia - a Double Dissociation between the Recognition of Familiar and Unfamiliar Faces. *Journal of Neurology Neurosurgery and Psychiatry, 45*, 820-822.

Maurer, D. (1985). Infants' perception of facedness. In T. Field & N. Fox (Eds.), *Social Perception in Infants* (pp. 73-100). Norwood, New Jersey: Ablex.

Megreya, A. M., & Burton, A. M. (2006). Recognising faces seen alone or with others: when two heads are worse than one. *Applied Cognitive Psychology, 20*, 957-972.

Megreya, A. M., & Burton, A. M. (2006). Unfamiliar faces are not faces: evidence from a matching task. *Memory Cognition, 34*, 865-876.

Mertens, I., Siegmund, H., & Grusser, O. J. (1993). Gaze motor asymmetries in the perception of faces during a memory task. *Neuropsychologia, 31*, 989-998.

Mohr, B., Landgrebe, A., & Schweinberger, S. R. (2002). Interhemispheric cooperation for familiar but not unfamiliar face processing. *Neuropsychologia, 40*, 1841-1848.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31*, 553-566.

Moscovitch, M., Winocur, G., & Behrmann, M. (1997). What is special about Face Recognition? Ninteen Experiments on a Person with Visual Object Agnosia and Dylexia, but Normal Face Recognition. *Journal of Cognitive Neuroscience, 9*, 555-604.

Murray, J. E., Yong, E., & Rhodes, G. (2000). Revisiting the perception of upside-down faces. *Psychological Science, 11*, 492-496.

Nasanen, R. (1999). Spatial frequency bandwidth used in the recognition of facial images. *Vision Research, 39*, 3824-3833.

Norton, & Stark. (1971). Eye movements and visual perception. *Scientific American, 224*, 34-43.

O'Donnell, C., & Bruce, V. (2001). Familiarisation with faces selectively enhances sensitivity to changes made to the eyes. *Perception, 30*, 755-764.

O'Regan, J. K., Deubel, H., Clark, J. J., & Rensink, R. (2000). Picture Changes During Blinks: Looking Without Seeing and Seeing Without Looking *Visual Cognition, 7*, 191-211.

Palermo, R., & Rhodes, G. (2002). The influence of divided attention on holistic face perception. *Cognition, 82*, 225-257.

Parker, D. M., Lishman, J. R., & Hughes, J. (1996). Role of coarse and fine spatial information in face and object processing. *Journal of Experimental Psychology-Human Perception and Performance, 22*, 1448-1466.

Phillips, M. L., & David, A. S. (1997). Viewing strategies for simple and chimeric faces: an investigation of perceptual bias in normals and schizophrenic patients using visual scan paths. *Brain and Cognition, 35*, 225-238.

Pike, G. E., Kemp, R. I., Towell, N. A., & Phillips, K. C. (1997). Recognizing moving faces: The relative contribution of motion and perspective view information. *Visual Cognition, 4*, 409-437.

Posner, M. I. (1980). Orienting of Attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Rayner, K. (1998). Eye Movements in Reading and Information Processing: 20 Years of Research. *Psychological Bulletin, 124*, 372-422.

Rhodes, G. (1985). Lateralized processes in face recognition. *British Journal of Psychology, 76 (Pt 2)*, 249-271.

Rhodes, G. (1985). Perceptual asymmetries in face recognition. *Brain and Cognition, 4*, 197-218.

Rhodes, G. (1993). Configural coding, expertise, and the right hemisphere advantage for face recognition. *Brain and Cognition, 22*, 19-41.

Rhodes, G., & Wooding, R. (1989). Laterality Effects in Identification of Caricatures and Photographs of Famous Faces. *Brain and Cognition*, 201-209.

Rizzo, M., Hurtig, R., & Damasio, A. R. (1987). The Role of Scanpaths in Facial Recognition and Learning. *Annals of Neurology, 22*, 41-45.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: a detection advantage in the flicker paradigm. *Psychological Science, 12*, 94-99.

Robbins, R., & McKone, E. (2007). No face-like processing for objects-of-expertise in three behavioural tasks. *Cognition, 103*, 34-79.

Rock, I. (1974). The perception of disoriented figures. *Scientific American, 230*, 78-85.

Rossion, B., & Gauthier, I. (2002). How Does the Brain Process Upright and Inverted Faces. *Behavioral and Cognitive Neuroscience Reviews, 1*, 62-74.

Sadr, J., Jarudi, I., & Sinha, P. (2003). The role of eyebrows in face recognition. *Perception, 32*, 285-293.

Scapinello, K., & Yarmey, A. (1970). The role of familiarity and orientation in immediate and delayed recognition or pictorial stimuli. *Psychonomic Science, 21*, 329-331.

Schyns, P. G., Bonnar, L., & Gosselin, F. (2002). Show me the features! Understanding recognition from the use of visual information. *Psychological Science, 13*, 402-409.

Searcy, & Bartlett. (1996). Inversion and processing of component and spatial-relational information in faces. *Journal Experimental Psychology: Human Perception and Performance, 22*, 904-915.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennet, P. J. (2004). Inversion leads to Quantitative, Not Qualitative, Changes in Face Processing. *Current Biology, 14*, 391-396.

Sergent, J. (1982). About face: left-hemisphere involvement in processing physiognomies. *Journal of Experimental Psychology: Human Perception & Performance, 8*, 1-14.

Sergent, J. (1986). Microgenesis of face perception. In H.D. Ellis, M. A. Jeeves, F. Newcombe & A. M. Young (Eds.), *Aspects of face processing* (pp. 17-33). Dordrecht: Martinus Nijhoff.

Shepherd, J. W. (1983). Identification after long delays. In S. M. A. Lloyd-Bostock & B. R. Clifford (Eds.), *Evaluating witness evidence* (pp. 173-187). Chichester: Wiley.

Stacey, P., Walker, S., & Underwood, J. (2005). Face processing and familiarity: Evidence from eye-movement data. *British Journal of Psychology, 96*, 407-422.

Sturzel, F., & Spillman, L. (2000). Thatcher illusion: Dependence on angle of rotation. *Perception, 29*, 937-942.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology A, 46*, 225-245.

Tanaka, J. W., & Farah, M. J. (2003). The Holistic Representation of Faces. In M. A. Peterson & G. Rhodes (Eds.), *Perception of faces, objects, and scenes: Analytic and holistic processes* (pp. 21-47). New York, NY: Oxford University Press.

Taylor, M. J., Edmonds, G. E., McCarthy, G., & Allison, T. (2001). Eyes first! Eye processing develops before face processing in children. *Neuroreport, 12*, 1671-1676.

Turati, C., Macchi Cassia, V., Simion, F., & Leo, I. (2006). Newborns' face recognition: role of inner and outer facial features. *Child Development, 77*, 297-311.

Turati, C., Simion, F., Milani, I., & Umilta, C. (2002). Newborns' preference for faces: what is crucial? *Developmental Psychology, 38*, 875-882.

Turati, C., Valenza, E., Leo, I., & Simion, F. (2005). Three-month-olds' visual preference for faces and its underlying visual processing mechanisms. *Journal Experimental Child Psychology, 90*(3), 255-273.

Underwood, G., Chapman, P., Bowden, K., & Crundall, D. (2002). Visual search while driving: Skill and awareness during inspection of the scene. *Transportation Research Part F*, 5, 87-97.

Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., & Crundall, D. (2003). Visual attention while driving: Sequences of eye fixations made by experienced and novice drivers. *Ergonomics, 46*, 629-646.

Vaid, J., & Singh, M. (1989). Asymmetries in the perception of facial affect: is there an influence of reading habits? *Neuropsychologia, 27*, 1277-1287.

Valentine, T. (1988). Upside down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79*, 471-491.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 43A*, 161-204.

Vinette, C., Gosselin, F., & Schyns, P. G. (2004). Spatio-temporal dynamics of face recognition in a flash: it's in the eyes. *Cognitive Science, 28*, 289-301.

Walker-Smith, G. J., Gale, A. G., & Findlay, J. M. (1977). Eye movement strategies involved in face perception. *Perception, 6*, 313-326.

White, M. (2004). Removing eyebrows impairs recognition of famous faces, or doesn't, depending on how the eyebrows are removed. *Perception, 33*, 1215-1220.

Wolf, W. (1933). The experimental study of forms of expression. *Character & Personality, 2*, 168-176.

Yarbus, A. L. (1967). *Eye Movements and Vision*. New York: Plenum Press.

Yin, R. K. (1969). Looking at Upside Down Faces. *Journal of Experimental Psychology, 81*, 141-145.

Yin, R. K. (1970). Face recognition by brain-injured patients: a dissociable ability? *Neuropsychologia, 8*, 395-402.

Young, A. W., Ellis, A. W., Flude, B. M., McWeeny, K. H., & Hay, D. C. (1986). Face-name interference. *Journal Experimental Psychology: Human Perception and Performance, 12*, 466-475.

Young, A. W., Hay, D. C., McWeeny, K. H., Flude, B. M., & Ellis, A. W. (1985). Matching familiar and unfamiliar faces on internal and external features. *Perception, 14*, 737-746.

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception, 16*, 747-759.