Lateral Biases of Attention and Perception During Face Processing: What is the Impact of Ageing?

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Author's Declaration

This thesis is the results of the author's original research. It has been composed by the author and has not previously been submitted for examination which has led to the award of a degree.

Signed:

Date:

This is dedicated to my Dad who

died just weeks before I submitted this thesis.

Acknowledgments

Working on this Ph.D. has been an experience that I will never forget and I feel very fortunate to have had it. I have been able to pursue a project in a research area that I am passionate about, funded by the University of Strathclyde and for this I am extremely grateful.

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Previously Published Work

Findings reported in study 1 have been previously presented and submitted as follows:

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Abstract

Although faces are processed bilaterally it is widely accepted that the right hemisphere (RH) dominates for processing attributes such as gender and identity and the left hemisphere (LH) dominates for processing lip-reading. The processing of emotional expressions is somewhat more equivocal, but depending on the emotion being expressed is dominated by either the RH or LH. This hemispheric laterality results in perceptual judgements being biased to the contralateral side when facial decisions are made, and for eye movements to be biased to the contralateral side of the face too. In older adulthood, however, lateralized hemispheric dominance is predicted to reduce as additional recruitment of the non-dominant hemisphere is also required to maintain performance, and this may impact on a reduction in lateralization of perception and eye movements. Consequently, it would be anticipated that in older adulthood a reduction in hemispheric lateralization would impact on the lateralization of perceptual judgements and eye movements during face processing tasks. To test this, a series of experiments were devised to investigate differences in the perceptual and eye movement lateralization of younger and older adults when facial decisions are made. Four studies are reported; studies one and two investigated the RH dominant face processing tasks of gender and identity, study three investigated the LH dominant task of lip-reading and study four investigated emotion processing which, depending on the emotion expressed, is dominated by either the LH or RH. Studies three and four also used the Landmark task to assess whether lateral response biases are face specific. The results of these studies provide empirical evidence quantifying the impact of ageing on lateralized judgements and eye movements using tasks associated with predominantly unilateral processing in

younger adulthood. Differences according to age are discussed in relation to cortical changes and the predictions of theories of ageing.

Chapter 1

Literature Review

1.1 Hemispheric Lateralisation

Hemispheric lateralisation is a term used to describe the dominance of one hemisphere over the other when conducting particular tasks. For example, it is well noted that the left hemisphere (LH) specializes for language, whereas an advantage for processing faces is found in the right hemisphere (RH). Prior to the advent of scanning technology behavioural tasks were designed to enable investigation of hemispheric specialization using clinical and non-clinical groups. These experiments assessed asymmetries in perception via the sensory modalities of touch, hearing and vision. Typically verbal information has a right hand, ear and visual field advantage (inferred to reflect LH specialization) whereas non-verbal and facial information has a left (RH) advantage (e.g. Burt & Perrett, 1997; Chiarello, Dronkers & Hardyck, 1984; Jewell & McCourt, 2000, Hiscock, Inch & Kinsbourne, 1999).

1.2 The Asymmetry of Face Processing

The initial observation that faces are judged according to the left side (from the viewer's perspective) was first revealed by Wolff (1933). Participants judged left and mirror left composite faces to bear a closer resemblance to the original face than right and mirror right composites. Similar studies supported these findings (McCurdy, 1949; Lindzey, Prince & Wright, 1952), and this leftward bias was originally believed to be due to the left side of the face expressing more of the true character of the face than the right side.

Subsequently, the notion that the asymmetry of faces determined this leftward bias was tested. As with Wolff's (1933) study, Gilbert and Bakan's (1973) participants saw left/left and right/right mirrored composites presented with the original (left/right) face. However, crucially, they also saw these composites with a flipped (right/left) face. In accordance with Wolff's findings, participants judged the left/left composites to more closely resemble the original left/right face. However, participants persisted to base their decisions on the side of the face seen to the left by judging the right/right composites as more closely resembling the flipped right/left face. Consequently, for the first time it was revealed that the bias to judge faces according to the left side was not due to the asymmetries of the faces, but to a bias to judge from the side seen to the left. This is now known as the left perceptual bias 'LPB' and is considered to reflect RH specialization for face processing.

These early studies were influential for understanding perceptual asymmetries during face processing. However, the information that can be gathered and the type of analysis that can be used on these composite images is somewhat limited and it is for these reasons that for some time now researchers have been employing chimeric stimuli.

In common with composite images chimeric faces are split, usually down the vertical midline; in contrast with composite faces, however, the left and right sides of a chimeric face differ on a particular dimension such as emotional expression. An early example is that of Levy, Heller, Banich and Burton (1983) who created chimeric faces by taking photographs of nine actors with a smiling and neutral expression. By cutting along the mid-sagittal axis of one photograph (for example neutral) and re-combining it with the other half face expressing a smile two chimeric images, happy/left – neutral/right and neutral/left – happy/right were created for each identity. They presented each image alongside its mirror image and positioned one above the other in a booklet. In this free viewing task (i.e. no time limits were imposed) participants were required to state which image looked happier, with an ‘undecided’ option also included. Their results revealed that participants selected the chimeric image with the left side expressing a smile as looking happier than its mirror image and consequently revealed an LPB for judgements of happiness. The authors inferred from this that the LPB was due to selective activation of the right hemisphere.

Similarly, Luh, Rueckert and Levy (1991) found that when university students and staff were presented with photographic and schematic chimeric images they judged the gender chimerics as looking “more feminine” when the female half face was to the left. They also judged happy/neutral and happy/sad chimeric faces as looking happier when the expression of happiness was presented to the left rather than the right side. However, when using shapes rather than faces the results were somewhat more ambiguous. When judging between one asymmetric dot pattern and its mirror image, participants continued to demonstrate a LPB (albeit weaker than for the face stimuli), and no LPB was revealed for judgements of shape roundness. Consequently, the LPB was more reliably demonstrated with face rather than shape images.

These initial studies employed somewhat crude stimuli where the two half faces were clearly different and the vertical point where they joined was not concealed, this may have affected typical face processing strategies. Using newer technology enabled the production of stimuli where the left and right sides were matched for texture, light and colour and the vertical mid-line was merged to create more realistic, natural images (for details see Burt & Perrett, 1997).

Consistent with the earlier studies, Burt and Perrett (1997) found that a LPB was evident for judgements of attractiveness, age and gender, although a right perceptual bias was revealed for identification of phonemes assessed through lip-reading. A leftward bias has also been demonstrated for judgements of anger, disgust, fear, happiness, sadness and surprise when paired with a neutral half face in chimeric stimuli (Bourne, 2011) and for health and attractiveness (Reiss & Zaidel, 2001; Zaidel, Chen & German, 1995). To a lesser extent this bias is also evident when faces are inverted (Butler & Harvey, 2005; Parente & Tommasi, 2008), although this finding has not consistently been revealed (see Bourne 2011; Coolican, Eskes, McMullen & Lecky, 2008).

The asymmetric leftward bias for attention when judging gender has also been revealed (Hu, Hu, Xu & Qin, 2013) using the Bubbles technique developed by Gosselin and Schyns (2001) and Focus windows method, both of which obscure the stimulus (face) with the exception of isolated viewing regions. So, the bias to judge and look at facial attributes, particularly gender, on the left side is not dependent on the type of methodological paradigm used.

The strength of LPB, however, does differ according to the facial attribute being judged. Burt and Perrett (1997) recorded 77% of responses to the left side of chimeric faces for age judgements, compared with 67% for gender and 58% for emotional expression judgements. A greater number of leftward judgements have also been noted for emotion compared with identity decisions (Coolican et al., 2008).

These perceptual bias differences may reflect task difficulty, as Carbary, Almerigi and Harris (2002) observed that their most ambiguous happy/neutral chimerics received fewer leftward judgements than the least ambiguous. The authors suggested that this may be due to different processing strategies, specifically, that a configural RH processing style was used for the easy facial judgements, whereas the most difficult emotional faces relied on more bilateral featural processing (Lobmaier, Klaver, Loenneker, Martin & Mast, 2008). Individual differences may also be a contributory factor as a lack of a LPB to gender chimerics was found to reflect the "non-negligible" number of participants with either a RPB or no lateral perceptual bias (Samson, Fiori-Duharcourt, Doré-Mazars, Lemoine & Vergilino-Perez, 2014).

1.3 Face Processing Structures

So what causes the LPB? Using scanning technology it has been firmly established that the human brain relies on a distributed cortical network involving several regions across both hemispheres (Haxby, Hoffman & Gobbini, 2000; Ishai, 2008; Ishai, Schmidt & Boesiger, 2005). These are the fusiform face area (FFA; Kanwisher, McDermott & Chun, 1997; McCarthy, Puce, Gore & Allison, 1997), inferior occipital gyrus (IOG) also known as the occipital face area (OFA; Gauthier et al., 2000; Rossion et al., 2003), and superior temporal sulcus (STS; Hoffman & Haxby, 2000; Puce, Allison, Bentin, Gore & McCarthy, 1998). These key structures have been found to become active when different facial attributes are processed. The FFA becomes active during face processing in general and specifically during identity and gender tasks (Haxby et al., 2000). The OFA is noted to process the physical outline and structure of the face (Nichols, Betts & Wilson, 2010) and the STS processes facial movements such as direction of gaze, expressions of emotion and speech movements (Puce et al., 1998; Hoffman & Haxby, 2000). Although these structures are bilaterally positioned, they are all larger and more active in the RH compared with the LH, and as such face processing is RH dominant (Kanwisher et al., 1997; McCarthy et al., 1997; Pitcher, Walsh & Duchaine, 2011).

Importantly, Yovel, Tambini and Brandman (2008) identified the volume of the FFA as being larger in the RH compared with the LH and this structural asymmetry correlated strongly with the magnitude of the LPB during a chimeric identity judgement task. The asymmetrical RH activity of the FFA, which is apparent through Yovel and colleagues' fMRI (functional magnetic resonance imaging) work, links the results of behavioural research with brain functioning and offers assurance to the interpretations of purely behavioural tasks.

1.4 The Asymmetry of Face Processing in Younger Adulthood – Clinical Studies

Clinical studies also provide evidence for hemispheric asymmetry during face processing. Split-brain patients, who have had their left and right hemispheres surgically disconnected, are perhaps uniquely placed to reveal functional lateralization and the way this impacts on perception. In split-brain patients only the stimulated hemisphere can use information for perceptual analysis and consequently presenting stimuli laterally to the left or right offers an insight into hemispheric specialisation. Employing a divided visual field task, Gazzaniga and Smylie (1983) demonstrated that all three of their split brain patients PS, JW and VP (aged 21, 29 and 30 years) were faster and more accurate at identifying faces which were presented to the left compared with the right visual field.

A further divided visual field experiment using split-brain patients JW and VP (Miller, Kingstone and Gazzaniga, 2002), manipulated the level of encoding for faces (gender (shallow) vs likability/trustworthiness (deep)) also found a LVF advantage. As information from the left visual field projects to the RH in these patients and the left and right hemispheres have been sectioned, this clearly shows the superiority of the RH for facial identification and encoding.

Perhaps unsurprisingly, damage to the RH has been found to reduce or even reverse the LPB when faces are processed. The most extreme cases of RH damage (Sarri, Greenwood, Kalra & Driver, 2011) can lead to hemispatial neglect and deficits such as a loss of awareness, orientation to, or exploration of the contralesional side. The impact this has on face processing was evident when a group of unilateral left neglect participants judged the emotion and identity of chimeric images. Rather than basing judgements on the left side, as the control group did, their decisions were based on information seen to the right side (Mattingley, Bradshaw, Phillips & Bradshaw, 1993). Consequently, damage to the RH reversed the LPB demonstrated by the controls. Hemispatial neglect is more common and severe following damage to the RH of right handed people, affecting attention to their left side (Bisiach & Vallar, 1988; Vallar, 1993). For this reason and due to the fact that left brain damaged people are less likely to be able to follow task instructions because of language impairments there has been comparatively little research conducted on right neglect after left brain damage. However, using a battery of non-verbal spatial orientation tasks it has been revealed that patients with right neglect following LH brain injury demonstrate significant deficits to their contralesional side (Kerkhoff & Zoelch, 1998). This mirrors the behaviour of RH brain damaged patients with left neglect and reveals the importance of each hemisphere's contralateral perceptions of space.

A more recent study which recruited children with unilateral hemispheric damage acquired through stroke found that children with the severest RH lesions did not demonstrate a typical LPB, but instead had an ipsilesional RPB to gender and happy/neutral chimeric faces (Bava, Ballentyne, May & Trauner, 2005). Smaller RH lesions resulted in a reduced LPB whereas lesions to the LH did not impact on the LPB compared with controls. This study again shows that the RH drives the LPB as damage to the RH reduces or even reverses this bias.

Neuropsychological studies of patients with prosopagnosia offer an alternative way of assessing the asymmetries of face perception. Prosopagnosia is a condition which results in patients being unable to recognize other people's faces, even when they encounter these faces on a regular basis, but does not affect their identification of other objects. Typically prosopagnosia is acquired following bilateral damage to the temporal lobes (Damasio, Damasio & Van Hoesen, 1982); however, it is also evident following unilateral RH damage (De Renzi, 1986; De Renzi, Perani, Carlesimo, Silveri & Fazio, 1994; Kolb, Milner & Taylor, 1983) and as such is further evidence of this hemisphere's dominance for face processing.

1.5 Left Gaze Bias and Left Perceptual Bias – Younger Adults

The RH dominance for face processing may not only impact on perceptual judgements to the left side of faces, but may also impact on eye movements to the left side. So far, only a few studies have investigated the link between leftward biases of attention and perception during face processing and so it is unclear whether the left gaze bias (LGB) is face specific. It is also unclear whether the LPB and LGB are linked or independent.

Leonards and Scott-Samuel (2005) suggest that because initial saccades are generated to the left side when analysing faces but not landscapes or fractals, this reflects a natural response for faces. However, these authors report that a third of their participants consistently generated initial saccades to the right. Mertens Siegmund and Grüsser (1993) also argued that a LGB was an internally driven response as it was only observed when faces, but not other symmetrical objects were assessed. The angle of the face also impacts on eye movements as more initial saccades are generated to the left side for directly orientated faces than for full or part profile faces (Bindemann, Scheepers & Burton, 2009).

Additionally, it has been noted that when judgements are based on the left side of faces, fixations to the left side are also greater in number and duration (Butler et al., 2005) potentially indicating an association between perception and attention to the left side of faces. In a subsequent study using the same stimuli (Butler & Harvey, 2006) the authors infer that eye movements reinforce the LPB as the 100ms exposure time condition received a weaker LPB than the 2000ms time condition in Butler and colleagues' 2005 study (55% vs 63% of left judgements).

However, the association between the LPB and LGB is not clearly understood. The LPB may be due to the LGB and, therefore, judgements are based on the left side because more frequent, longer fixations are also made to the left side. Alternatively, as Butler et al. (2005) suggest, the bias to generate eye movements to the left may be due to this side projecting to the RH which specializes in face processing. It is also possible that there is no direct relationship between eye movements and perceptual bias, both are independently orientated to the left due to RH bias in visuo-spatial processing. Butler et al. (2005) found a bias to generate first eye movements to the left with 75% being made to the left side. However, no overall LGB was found for the number or duration of fixations to the left side, even though a LPB was found. Consequently, the overall LPB was only reflected in a leftward bias for initial saccades and not frequency or duration of fixations. In an earlier study, when judging similarity of composite faces with whole faces a LPB was evident, but no accompanying LGB for first saccades or fixation duration was revealed (Grega, Sackeim, Sanchez, Cohen & Hough, 1988). Contrastingly, a LGB for first saccades and fixation duration was found by Phillips and David (1997) when control participants (rather than schizophrenic patients) viewed neutral expressions. A trend for these participants to look first and for longer to the left side was also revealed for judgements of happy/sad chimeric faces, however no LPB was revealed.

Recently, an experiment was conducted to determine the relationship between perceptual and attentional biases during judgements of whole and chimeric faces which were presented individually to the left, right, top or bottom of the screen (Samson et al., 2014). When no eye movements were generated (fixation remained stable on a centre cross) no perceptual bias was noted for any of the four face locations, and when one saccade was generated, a LPB was only apparent for the face presented at the top of the screen. However, when gaze bias was examined, there was a significant bias to the right side of the face when it was placed on the left of the screen and a significant bias to the left side of the face when it was presented to the right. Therefore, not only was gaze biased to the side of the face closest to the centre of the screen, but no direct link between perceptual and attentional biases was established. Like Butler et al. (2005), Samson and colleagues examined eye movements when the decision was based on the left and right face, however, no eye movement/perception link was revealed as a similar number of saccades were generated to the left and right sides irrespective of the side used for a decision. Consequently, the results of these studies do not consistently demonstrate an association between lateral biases of perception and attention in younger adults during face processing and as such one aim of this current thesis is was to investigate this.

1.6 Is the LPB the Result of Scanning Preference?

Some researchers argue that the bias to base judgements on the left side of faces is due, in part, to the well-practised directional scanning strategy used for reading, writing and music. Directional scanning becomes a habit even before a child can read. Parents and carers point to pictures and words as they progress through story books in the same direction that the language is noted. Consequently, directional scanning may become an instinctive way of analysing other objects such as faces too. Vaid and Singh (1989) investigated this using happy/neutral chimeric faces and found that left-right Hindu readers had the strongest LPB and the Arabic readers had the weakest LPB. They argue that this indicates that directional scanning style does impact on perceptual biases in face processing.

A more recent study (Megreya & Havard, 2011) used the 2 in 10 face matching paradigm developed by Megreya and Burton (2006a) to determine whether accuracy in matching the left or right target face with an identity from a 10 face line up was affected by directional reading style. The Arabic readers were significantly better at matching the right target face than the English readers, however, as both Arabic and English readers were better at matching the left than the right target this indicates that habituated scanning style impacts on LPB, but is superseded by RH dominance.

1.7 The Effect of Ageing on Face Processing

The LPB has also been noted to be weaker in older compared with younger adults, particularly when simuli are presented so briefly that eye movements may not be generated (Butler & Harvey, 2008). This is thought to reflect structural and functional changes of the brain with the onset of older age, as well as a decline in processing speed in older adulthood (for a review see Salthouse, 1996). In healthy ageing, changes to the brain include an overall loss of volume, white matter hyperintensities and grey matter atrophy, reduced cerebral blood flow, synaptic degeneration and neurochemical alterations (Uylings & de Brabander, 2002). Although it would be anticipated that these structural changes would be reflected in cognitive decline, this is not always evident (e.g. Salat, Kaye & Janowsky, 2002) and the reasons for continued cognitive ability in later life is unsurprisingly the focus of much current research.

The United Kingdom has an ageing population, and this demographic shift is affecting countries at different rates globally. With life expectancy increasing and the fertility rate below replacement level, the number of people aged 65 and over has risen from 15% of the population in 1985, to 17% in 2010 and this is projected to continue rising to over 23% by 2035 (Office for National Statistics, 2013). This is good news for many, as it enables them to continue to pursue hobbies and engage in social activities into their 80s and beyond. However, this trend also invites questions particularly regarding cognitive decline, a concern for many people entering older age.

Fortunately, in tandem with an increase in the ageing population has come a growth in research into the ageing brain. By comparing healthy and clinical samples and in utilising various scanning techniques (e.g. electroencephalogram ‘EEG’, positron emission tomography ‘PET’ and fMRI), an understanding of the changes that arise both structurally and functionally with increased age is advancing. PET evidence suggests that the brain’s response to age related structural changes is through functional reorganization and by engaging more symmetrical processing across the left and right hemispheres (Reuter-Lorenz et al., 2000). If this is the case then tasks which are processed predominantly in one hemisphere in younger adulthood may require additional recruitment of the contralateral hemisphere in older adulthood. Several models have been put forward to explain the effects of ageing on hemispheric laterality and these will now be discussed.

1.8 The Right Hemi-Aging Model

The Right Hemi-Aging model (Albert & Moss, 1988; Brown & Jaffe, 1975) predicts that the RH declines faster than the left in healthy ageing. Support for this model was demonstrated by Goldstein and Shelly (1981) who argued that in healthy ageing neuropathological changes to the brain occur in both hemispheres, but that deterioration of the RH is faster than the LH and consequently the RH “ages” sooner. This hypothesis was based on the results of 1,247 neuropsychiatric and general medical patients (aged between 20 and 80) who completed a battery of tests including the Halstead-Reitan neuropsychological test battery, the WAIS and other unreported procedures. Participants’ test scores were evaluated using Russell, Neuringer and Goldstein’s (1970) method of keys which place patients’ performance on verbal and spatial tasks into categories of brain damage. Using this method the effects of hemispheric damage on specific tasks was calculated according to a point scoring system with a higher number of points indicating poorer performance. Goldstein and Shelly's expectation that increased age would be associated with greater deterioration of the right, but not left hemisphere, was supported in the findings of their clinical and healthy (non-brain damaged) participants. No group differences were demonstrated for the LH function, but a significant difference for the RH was reported with a greater decline in the older group's RH function.

1.9 The HAROLD Model

More recently Cabeza (2002) proposed that more symmetrical processing occurs in older adulthood by way of compensating for functional decline. His HAROLD (Hemispheric Asymmetry in OLDer adulthood) model is one of the most widely accepted accounts of cognitive ageing and its central tenet is that progression into older age is accompanied by neural functioning becoming less lateralized, specifically within the prefrontal cortex (PFC). According to the HERA model (Hemispheric Encoding/Retrieval Asymmetry; Tulving, Kapur, Craik, Moscovitch & Houle, 1994) the left and right prefrontal cortices respectively encode and retrieve long-term episodic memory. Testing the HERA model using PET, Cabeza et al. (1997) found that the left encoding/right lateralized retrieval pattern predicted by this model was consistent in younger but not older participants during an episodic memory task, potentially indicating neural changes for the older group. Reuter-Lorenz and colleagues (2000) also noted that PFC activity was unilateral in younger adults, and an overall bilateral pattern was revealed in older adults using a working memory task. Interestingly, however, the older adults with bilateral activity were also higher performing (measured using RT). This finding was further investigated by categorizing older participants according to their performance in a battery of memory tests (Cabeza, Anderson, Locantore & McIntosh, 2002). Then, in two memory tasks; source memory of word lists (auditory or visual) and recall of word-pairings, PET recordings revealed that a systematic reduction in activity to the LH was evident across the groups in the source memory task, with LH activity being greatest for the younger adults and weakest for the high performing older adults. Additionally, only the high performing older adults revealed a reduction in lateralization for the recall tasks, whereas the activity for both low performing and younger adults was lateralized to the RH. Based on this converging evidence, the interpretation offered by Cabeza and colleagues (2002) was that high performance in older age depended on the brain working harder and enlisting a more distributed, compensatory processing system across both hemispheres.

Although Cabeza (2002) based the HAROLD model on age related asymmetry within the PFC, he notes that it is extendable to other brain regions, such as the temporal and parietal lobes which are used during face processing. Support for this has been found through PET scanning during tasks manipulating shallow (left/right orientation) and deep (pleasantness judgements) encoding of faces. Positive correlations between temporal activity and face recognition were found in the LH for younger adults and bilaterally for the older group faces (Grady, Bernstein, Beig and Siegenthaler, 2002).

Behavioural studies also offer some support for the HAROLD model (Cabeza, 2002) as older adults have demonstrated a weaker LPB than younger adults during gender judgements of chimeric faces (Butler & Harvey, 2008). Failla, Sheppard and Bradshaw (2003) assessed differences in LPB across the lifespan using happy/neutral chimerics and an LPB was evident in 5-7 year olds, 10-12 year olds and 20-30 year olds, but not in the oldest group (60-70 year olds). A non-significant trend was also revealed by Cherry, Hellige and McDowd's (1995) study assessing 20-70 year olds as their oldest participants revealed a weaker LPB to happy/neutral chimeric faces than the younger adults.

However, asymmetry differences, resultant of age, are not consistently revealed. Levine and Levy (1986) found no differences in LPB when they tested across the lifespan from children (mean age 5 years) through to elderly adults (mean age 78 years) in a chimeric happy/neutral task. Similarly Moreno, Borod, Welkowitz and Alpert (1990) found no LPB differences for older compared with younger adults. In a more recent study (Coolican et al., 2008) both younger adults and senior citizens revealed a LPB to happy/neutral chimeric faces with no group differences. However, when assessing perceptual asymmetry using left/left and right/right composites of neutral facial expressions the younger group persisted to demonstrate a LPB, but the older group did not. It is not clear from the HAROLD model why these inconsistencies have occurred, but the more recent STAC model could provide insight.

1.10 The STAC Model

The STAC (Scaffolding Theory of Aging and Cognition; Park & Reuter-Lorenz, 2009) model, suggests that by continually recruiting compensatory scaffolding systems, the brain adapts to various challenges. These challenges could be learning a new skill or adapting to changes in the brain due to injury or ageing. Scaffolding is described by the authors as "circuits that provide supplementary, complementary, and, in some cases, alternative ways to achieve a particular behavioural output or cognitive goal" (Park & Reuter-Lorenz, 2009:185). This occurs when the brain's circuitry is unable to perform task requirements and new pathways are created. For example, increased task complexity has been revealed to lead to more symmetrical processing in younger adults (Banich, 1998) which indicates that bilateral structures are recruited to improve task performance. This same bilateral processing is apparent in older adults but at lower levels of task complexity (Reuter-Lorenz, Stanczak & Miller, 1999). So both age groups recruit additional compensatory scaffolding when tasks are difficult, but the additional impact of older age prompts this recruitment when tasks are relatively simpler. For example Reuter-Lorenz & Cappell (2008) report that older adults activate the dorsolateral prefrontal cortex during verbal working memory tasks; younger adults activate this same area but at higher loads. Reuter-Lorenz and Cappell also explicitly state that performance differences between the groups are negligible at the lower level of task demand, but as task demand increases compensatory recruitment in older adults decreases and performance becomes impaired. Consequently, scaffolding compensates for structural and functional decline in older adulthood to improve task performance; however, above a certain level of task demand performance is impaired as activation in the older brain is insufficient. It should be noted that although the STAC model explains the brain's response to challenges such as age, it is not a model of ageing per se as these challenges are not necessarily age related.

As has been described, the HAROLD (Cabeza, 2002), like the STAC model, predicts greater inter-hemispheric interaction in older adulthood because scaffolding is most likely to be received from a homologous contralateral structure such as, for example, the FFA (Putnam, Wig, Grafton, Kelley & Gazzaniga, 2008). That being said, the site used for scaffolding in older adults may vary depending on the healthiness of the structure and so compensation may be recruited from a heterogeneous contralateral structure or even an ipsilateral structure. So there may be individual differences in older adults' bilateral processing due to the site used for scaffolding, the hemisphere used for scaffolding and the level of scaffolding required. This may help explain why perceptual differences are not always revealed when comparing older and younger adults (e.g. Levine and Levy, 1986; Moreno et al., 1990).

Both the HAROLD and STAC models were based on empirical evidence which predominantly assessed functioning of the prefrontal areas of the brain such as verbal working memory (Reuter-Lorenz et al., 2000), verbal long term memory (Cabeza et al., 1997 & Grady, McIntosh, Rajah, Beig & Craik, 1999), picture and word encoding tasks(Gutchess et al., 2005; Morcom et al., 2003). These studies showed age related differences in these tasks suggesting a requirement for greater recruitment of the frontal lobes, which, as has been comprehensively documented (see Cabeza & Dennis, 2013) deteriorates in older adulthood. For example using fMRI and PET scanning techniques studies have revealed increased bilateral activation across the frontal regions of older compared with younger adults which may reflect structural and functional changes in this region in older adulthood. Morcom et al. found greater bilateral activity in the frontal regions of older compared with younger adults in their word encoding and retrieval task. This was further supported in a series of tasks assessing working memory, long term memory and attention (Cabeza, et al., 2004).

Further research has utilized repetitive transcranial magnetic stimulation (rTMS) to younger and older adults. This technique is particularly advantageous in identifying key brain regions which are active for particular tasks as it disrupts neural activity, simulating temporary lesions to specific brain areas. Rossi et al. (2004) applied rTMS to the right and left dorsolateral prefrontal coretex as their younger and older participants made recognition judgements about pictures. They found that when rTMS was applied to younger adults'dorsolateral prefrontal cortex their memory retrieval was more significantly affected by left compared with right hemispheric activation suggesting the left hemisphere is more active in younger adults for this task. The memory retrieval of older adults was equally affected by application of rTMS to both the left and right hemispheres which indicates that both hemispheres are active for this task in older adulthood. Following on from this study, rTMS has been used to stimulate and therefore increase prefrontal activity in older adults performing a memory task (Solé-Padullés et al., 2006). The older adults with the greatest prefrontal activation after rTMS had the biggest memory improvements. Consequently, strong, converging evidence points to better performance in older adulthood being associated with greater bilateral and greater anterior activity.

What is less clear is whether the more posterior regions associated with face processing are subject to the impact of ageing in the same way as those associated with working memory, long term memory and attention. Face processing and line bisection tasks, as have been previously noted, are typically processed unilaterally in younger adulthood. They are therefore ideally suited to test the theories of ageing detailed above to determine whether perceptual asymmetries persist in older adulthood.

1.11 The Effect of Ageing on the LPB During Line-Bisection

In the line bisection task participants are presented with straight, horizontal lines of varying lengths shown individually on pieces of paper and are asked to mark through the centre of the line using a pen. An alternative to the line bisection task is the Landmark task. In this task a series of individually horizontal lines are presented on a computer screen. Each line is bisected through the centre, or slightly to the left or right of centre, and in a forced choice response participants state whether the line is “left shorter/right longer” or “right shorter/left longer”. Both the line bisection and Landmark tasks assess lateral perceptual biases when judging space. When bisecting lines, young, healthy participants, in general, bisect lines slightly to the left of centre, which Bowers and Heilman (1980) first termed pseudoneglect because it mirrors the chronic rightward bias and leftward neglect which is apparent following right parietal damage (Mattingley, Bradshaw, Nettleton & Bradshaw, 1994).

This leftward bias, however, has been found to become abolished or even reversed with age. For example Fujii, Fukatsu, Yamadori and Kimura (1995) found in their study of right handed participants that irrespective of the hand used, older adults (aged between 61-82 years) demonstrated a significant rightward bias and therefore bisected lines to the right of true centre, but middle aged adults (aged 42-60) and younger adults (aged 21-40) did not. Failla, et al. (2003) also report an effect of age on the line bisection task and further suggest an interaction with the hand used as the only group to demonstrate a rightward bias was older participants (aged 60-70) when they used their right hand. However, in Beste, Hamm and Hausmann’s (2006) gender, age and hand use analysis, they failed to replicate the effect of age and hand use. Instead, they found that when required to bisect using their left hand, participants of all ages (age range 20-79 years) demonstrated a leftward bias – with the exception of women aged 50-59 who demonstrated no bias. A non-significant trend of a rightward bias was noted for older women using their right hand (p = 0.08). The only condition where a rightward bias was revealed was for the oldest group of women (aged 70 years and over) when responding with their right hand. Although the results of these studies vary, it is clearly demonstrated throughout the literature (for a review see Jewell & McCourt, 2000) that the left bias demonstrated by younger adults is less pronounced in older adults. This could be interpreted as a deterioration of the RH supporting the Right Hemi-Aging Model (Albert & Moss, 1988; Brown & Jaffe, 1975), or as greater compensation from the LH supporting the HAROLD and STAC models (Cabeza, 2002; Park & Reuter-Lorenz, 2009).

1.12 Handedness

As is clear from Failla et al.'s (2003) work, handedness must be considered when conducting laterality tasks. Both the line bisection and Landmark tasks of spatial attention are lateralized to the RH and right handers have been reported to demonstrate a stronger leftward bias compared with left handers who do not significantly deviate from the midpoint (Brodie & Dunn, 2005).

Supporting these studies, functional transcranial doppler ultrasonography (fTCD) revealed that for a line-bisection task right handers' RH dominated in 95% of cases compared to 81% for left handers, and in a verbal fluency task right handers' LH dominated in 97% of cases compared to 74% for left handers (Flöel, Buyx, Breitenstein, Lohmann & Knecht, 2005). Fagard and Corroyer (2003) found that handedness in children aged between 3 – 8 years related to inter-hemispheric transfer such that the less right handed the child was, the better their performance on a bimanual co-ordination task. This again indicates that left handers process more bilaterally.

Other studies assessing laterality of language processing also indicate that right handers demonstrate greater laterality as they have a stronger right ear advantage in dichotic listening tasks (Bryden Brown, Roy & Rohr, 2006), and right perceptual bias for visually presented stimuli compared with left handers (Krach, Chen & Hartje, 2006). There is clearly consistency across these studies indicating that right handers are typically more lateralized to the RH for spatial tasks and the LH for language tasks indicating greater transference across hemispheres for left handers. Consequently, participants recruited for tasks which are dominated by either the LH or RH should be assessed as right handed, because the lateralization of left handers is less distinct.

1.13 Limitations of Current Literature

In tasks such as face processing and the line bisection task the LPB is a robust phenomenon in right handed, young adults (e.g. Bourne, 2011; Jewell & McCourt, 2000) and is considered to reflect the dominance of the RH for these tasks. Some researchers also suggest that a leftward bias for eye movements is related to the LPB, also due to the dominance of the RH. However, the relationship between perception and eye movements during face processing is not fully understood as an association between the two is not always evident (Grega et al., 1988; Samson et al., 2014).

Theories of ageing (Cabeza, 2002; Goldstein & Shelly, 1981; Park & Reuter-Lorenz, 2009) predict that the RH will have less dominance in older adulthood resulting in a reduced LPB and potentially a reduced LGB in older compared with younger adults. However, the majority of previous face processing studies have only used one type of experimental paradigm, and none have used eye-tracking to directly compare older and younger adults' eye movement patterns.

Typically, researchers have assessed differences in perceptual asymmetry using chimeric images showing happy/neutral expressions and the results of these studies have been inconsistent as age related differences have been revealed by some (Failla et al., 2003), but not all researchers (Levine & Levy, 1986, Moreno et al., 1990). However, as this may reflect cohort differences in perception of emotion they should be interpreted with caution. For a more thorough understanding of perceptual and eye movement asymmetry differences in younger and older adults, not only should a variety of different experimental paradigms be conducted, but these should also focus on different facial attributes.

1.14 Aims and Structure of Thesis

The overall aim of this thesis was to test the theories of ageing discussed above (Cabeza, 2002; Goldstein & Shelly, 1981; Park & Reuter-Lorenz, 2009) using a series of face processing tasks to determine whether older and younger adults differ in their lateralization of perception and eye movements and to investigate whether perception and eye movements are related. Using chimeric images and divided visual field tasks, the experiments detailed in this work were designed to investigate the effect of ageing on perceptual judgements to a variety of different facial attributes. Differences in the lateralization of older and younger adults' eye movements were also investigated and the direction of initial saccades along with the number of fixations and duration of fixations to the left and right side was used to assess this.

Chapter 2 provides details of the general method used for the experimental processes in this thesis. In Chapter 3 previous research is extended through the addition of eye-tracking technology to directly measure older and younger adults' eye movements to the left and right sides of a chimeric face when gender judgements are made. The aims of this study were to determine whether lateral biases of perception and eye movements differ between the two age groups and to determine the effects of stimulus presentation time on these lateral biases.

In Chapter 4 older and younger adults examined two target faces positioned to the left and right side of the screen and judged whether one of these faces was also present in the ten face line-up below. The aims of this study were to determine group differences in RT, in left/right face matching accuracy and also to investigate lateralized eye movement biases for these age groups.

Chapter 5 is the second study in this thesis to use chimeric faces and the aim was to determine differences in the lateralization of eye movements and perceptual judgements when speech sounds, assessed through lip-reading, are determined. To date the majority of face processing experiments test laterality using RH tasks such as identity or gender judgements. Language, however, is predominantly processed in the LH. Consequently, this study extends previous research and tests the theories of ageing by using a left rather than right hemisphere task. The Landmark task was conducted to assess whether lateral perceptual biases were face specific or more generally reflect perceptions of space.

The general aim of Chapter 6 was to determine whether older and younger adults differed when analysing emotional expressions. Specifically, the first aim was to determine whether there were group differences for valence and intensity judgements of emotional expression, and the second aim was to determine the impact of visual hemi-field on the groups' judgements. The Landmark task enabled comparisons between perceptions of emotion and space to be made. Following on, Chapter 7 provides a discussion of the findings of this thesis.

Chapter 2

General Method

2.1 Ethics

In accordance with the British Psychological Society's Code of Ethical Conduct, ethical approval for this programme of studies was granted by the School of Psychological Sciences and Health at the University of Strathclyde. Participants gave written, informed consent under the assurance that their data would be treated confidentially.

2.2 Participants

Convenience samples of participants were recruited on the basis that they had no neurological impairments and no visual deficits such as cataracts, macular degeneration or any other visual impairment requiring medical intervention or of a chronic nature. In addition, only Caucasian participants were recruited for study 2 and only participants who were native English speakers were recruited for study 3. Visual acuity was normal or corrected to normal and participants had a visual acuity of at least 25/20 as assessed on the day of testing using a pocket Snellen chart at a distance of 6ft. Recruitment was conducted via poster advertisements which were placed around the University and the Centre for Lifelong Learning - also situated on the University campus. Posters were distributed to households and businesses in and around Glasgow city centre, sent to day care centres for elderly adults in Glasgow and handed out to shoppers in the city centre. Different cohorts of participants were recruited for each of the studies detailed. Undergraduate psychology students received course credit in return for participation. Other participants received a nominal sum, the specifics of which are detailed in each study.

2.3 Design

In the chimeric studies (study 1(gender) and study 3 (lip-reading)) the dependent variables and a brief description of each is provided below. Details for study 2 (identity) are included where appropriate.

Perceptual bias. In study 1 the mean proportion of responses made according to the left side of the chimeric face was calculated per condition and per participant. In study 3 the mean proportion of responses made according to the right side of the chimeric face were calculated per condition and participant.

First saccades. Due to the removal of some trials (see Section 2.9 for details) the number of first saccades differed between participants. Consequently, to avoid distorted data the mean proportion of participants' initial saccades were calculated. For study 1 the number of left initial saccades was divided by the total initial saccades so that a mean proportion of > .5 revealed a bias to generate saccades to the left and < .5 a bias to the right. For study 3 the mean proportion of initial saccades to the right was calculated, that is a mean of >.5 revealed a bias to generate saccades to the right and < .5 a bias to the left. In study 2 the mean proportion of initial saccades to the left target face was calculated. This was determined by dividing the number of initial saccades to the area of interest surrounding the left target face by the total number of initial saccades to the areas of interest around the left and right target faces combined. This resulted in a mean proportion of initial leftward saccades with >.5 reflecting a leftward bias and <.5 a rightward bias.

Total number of fixations. The number of fixations varied between participants and across different trials and this variance could lead to distorted data if the number of overall fixations were analysed. To prevent this data were expressed as proportions, with proportions of > .5 indicating a leftward bias in studies 1 and 2 and proportions > .5 indicating a rightward bias in fixations in study 3.

Fixation duration. Running totals of fixation duration to the left and right sides of the face were totalled per trial and participant in all conditions for studies 1, 2 and 3. These were then averaged per participant for each face side and in each time condition.

2.4 Apparatus for Eye-Tracking Studies

Studies 1, 2 and 3 were conducted on a desktop computer attached to a 19 inch Viewsonic monitor with resolutions set at 1280 x 1024 pixels and a refresh rate of 85hz. In study 1 (gender bias) a response pad was situated on the participant's mid-sagittal axis with two response keys (m/f) aligned vertically. The response keys were counterbalanced between participants and responses were only made with the right hand. In studies 2 (identity) and 3 (lip-reading) participants pressed one key with their dominant right hand to stop eye movements being recorded, after which their responses were made verbally. The displays were controlled by Experiment Builder software version 1.1.1 (SR Research Ltd., Ontario, Canada). Eye movements were recorded using an Eyelink II eye-tracker (SR Research Ltd., Ontario, Canada) at 500Hz sample rate and at a spatial resolution, typically of .01°. Saccade onset was defined as a change of eye position with a minimum velocity of 22°/s or minimal acceleration threshold of $8000°/s^2$. Fixations were defined as eye behaviour which was neither a saccade nor a blink.

2.5 Measurement of Laterality

All participants were right handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). This inventory consists of ten items which are used to assess hand preference for performing everyday tasks such as writing and using a toothbrush. Handedness laterality was calculated according to the following formula (R-L)/(R+L) x 100. Scores higher than 40 indicate right handedness and scores below -40, left handedness. Laterality scores for the older and younger adults are detailed in the appropriate method section of each study.

2.6 Tests of Verbal Intelligence

In studies 1 (gender) and 2 (identity), participants performed The National Adult Reading Test (NART; Nelson, 1982) which correlates with full and verbal IQ (Crawford, Parker, Allan, Jack & Morrison, 1991). The NART consists of fifty single words, each of which is read aloud by participants. The words are non-phonetic and therefore require the participant to know them in order to pronounce them correctly. Accuracy is determined according to whether each word is pronounced correctly and in accordance with a pronunciation guide. The highest achievable score is 50 and the lowest 0.

Participants in studies 3 (lip-reading) and 4 (emotion) performed the Test of Premorbid Function (TOPF; Wechsler, 2009) which predicts full scale IQ and memory function. The TOPF consists of seventy words which participants read aloud and the pronunciation guidelines supplied with the pack determine accuracy. Similarly to the NART (Nelson, 1982), the TOPF has irregular grapheme to phoneme translations and therefore pronunciation of these words is atypical, for example “lascivious” and “plethora”. In accordance with TOPF instructions, participants were required to stop if five consecutive words are read inaccurately, otherwise participants completed the list and their sum was totalled. The highest achievable score on the TOPF is 70 and the lowest is 0.

2.7 General Procedure

Participants were tested individually in a quiet, darkened laboratory with a computer screen positioned centrally 57cm in front of them. A chin-rest maintained a stable head position and a blackout blind secured to the window ensured that ambient light was equalised throughout the lab. For consistent luminance across the computer screen, the computer was switched on prior to the start of the experiment in order for it to 'warm up' while participants completed the forms required for each experiment.

2.8 Procedure for Eye-Tracking in Studies 1, 2 and 3

After being given verbal instructions participants were fitted with the SR Eyelink II (SR Research Ltd., Ontario, Canada) eye-tracker which used the centre of the pupil to determine pupil location. When this had been fitted the room lights were switched off. Then, in order to allow time for participants' eyes to adapt to the change in light (while also confirming the requirements of each task) the instructions were re-stated.

At the start of each experiment and between each of the subsequent trial blocks, a nine-point 3 x 3 grid calibration and validation was conducted. During calibration and validation, participants were asked to remain still and focus on the black circle (.3°) which was presented on the grey computer screen until it had disappeared. The circle then randomly appeared in one of the other grid locations and participants were asked to fixate on it at this, and each subsequent location, until the sequence was complete. Participants were specifically requested not to generate anticipatory saccades when each fixation spot had been located, but to stare directly at each spot until it had gone. Although participants viewed the black circle used for calibration and validation along with the stimuli binocularly, the validation process ascertained the eye with the best spatial accuracy and therefore only one eye was tracked during the experiment. Following calibration and validation, each experiment started.

2.9 Eye Movement Errors

If the participant's pupil was moving or more than 1° away from the central fixation point following the calibration and validation procedures, an alarm sounded on the eye tracker and commencement to the following trial was disallowed. As a time lag of a few milliseconds occurs following acceptance of the validation procedure and commencement of the following trial, some eye movements were generated. Therefore, in accordance with previous literature (Wenban-Smith & Findlay, 1991) trials were removed if participants generated an anticipatory first saccade commencing within the first 80ms after stimulus presentation. Additionally, in order to maintain a consistent starting point across trials and participants, trials were also removed if participants fixated more than 1° away from the central fixation point prior to stimulus onset.

Chapter 3

Does Age Impact on Lateral Perceptions and Eye Movements When Gender is Judged?

3.1 Abstract

When deciding the gender of faces, young adults typically generate an initial leftward saccade and base their judgements on the left side of the face. This left perceptual bias (LPB) indicates that the right hemisphere dominates for face processing. With increased age hemispheric asymmetries are thought to reduce and a weaker LPB has been shown in older adults, particularly in restricted viewing times. However, it is not known whether the left gaze bias (LGB) also weakens with age. This study measured the eye movements of older and younger adults who judged the gender of chimeric faces under two time conditions. Both groups demonstrated an LPB when viewing time was unlimited, but the data were less supportive of a bias for the older adults in the time restricted condition. There were no age related differences for initial saccades, these were biased to the left for both groups. In the freeview condition both groups generated more fixations to the left when they also based their gender decision on the left side and looked for longer to the right side of the face when their response was also to the right side. Additionally, approximately 25% of the participants from both age groups based their judgement on the right side of the face, indicating a right perceptual bias (RPB). These RPB participants demonstrated no eye movement biases for their initial saccades or proportion of fixations, whereas participants with an LPB made initial saccades to the left and also looked more frequently to the left side. No differences between these groups was revealed for fixation duration, in the freeview condition they both looked for longer

to the right side when their response was also to the right. Consequently, increased age is not clearly associated with weakened eye movement biases. Instead initial saccades and proportion of fixations accompany an LPB but not an RPB.

3.2 Introduction

In general, faces appear approximately symmetrical along the vertical axis with the left and right sides typically revealing no discernible differences. However, research has consistently demonstrated that judgements of facial attributes such as similarity, gender, age and attractiveness are based on cues seen to the viewer's left (Burt & Perrett, 1997; Butler et al., 2005; Gilbert & Bakan, 1973). For example, when asked to judge the gender of a chimeric face, a LPB is revealed as judgements are typically based on information presented in the left visual field, even when faces are inverted (Parente & Tommasi, 2008). The LPB, as has been revealed through eye-tracking, is often accompanied by a left gaze bias (LGB; e.g. Butler et al., 2005) and the magnitude of the LGB for initial saccades and subsequent fixations has been found to remain constant across different task instructions suggesting that it is not responsive for selecting or processing particular facial attributes (Guo, Smith, Powell & Nicolls, 2012).

Some researchers argue that the LGB and the LPB are associated as it has been noted that when eye movements are not possible due to viewing time being restricted, only 55% of gender judgements were based on the left side (Butler & Harvey, 2006), however, when no limits to eye movements were imposed in a freeview condition 63% are based on the left side (Butler et al., 2005).

The bias to base facial decisions on the left side is considered to reflect a RH superiority for face processing (Kanwisher et al., 1997; McCarthy et al., 1997), support for which has been found through clinical studies (Bava et al., 2005; Kolb et al., 1983). However, as has been detailed in Cabeza's HAROLD model (2002) and Park and Reuter-Lorenz's STAC model (2009), ageing impacts on lateralized hemispheric specialties such as face processing. Consequently, as these two models are aligned in predicting greater symmetrical processing across both hemispheres in healthy older adults, such adults may also demonstrate more symmetrical eye movement patterns and perceptual judgements than young adults when completing gender judgement tasks, particularly if these two processes rely on the same neural circuits.

To date no studies have assessed the impact of ageing on lateral eye movement biases and the few studies that have examined the effect of ageing on perceptual biases have produced somewhat mixed evidence. For example Levine and Levy (1986), Moreno et al. (1990) and Coolican and colleagues (2008) found that both younger and older adults demonstrated an LPB to happy/neutral chimeric images with no significant difference in the strength of bias between the groups. However, Cherry et al.'s (1995) participants aged 20 to 70 years judged the emotional intensity of happy/neutral chimerics, it was the oldest adults who demonstrated the weakest LPB, although non-significantly so. This trend was more recently echoed in Failla et al.'s (2003) study. They found that from a group of participants aged 5-70 years, only those in the oldest group did not demonstrate an LPB. The same effect has also been revealed in a study employing gender chimerics, particularly when task difficulty was increased through limiting the viewing time (Butler & Harvey, 2008).

The aim of this study was to shed light on these inconsistencies by using eye-tracking to provide a more detailed analysis of face processing differences in older and younger adults. Using chimeric faces, participants judged each image's gender either in a limited or unlimited time condition. In addition to analysing participants' perceptual biases, the direction of their initial saccade was measured and the proportion and duration of fixations to each face side were calculated. Due to the older group's increased practice effects of reading, it is possible that the bias to generate initial saccades to the left will not change with age. Overall, i.e. not based on the side used for a response, it was anticipated the younger group would not demonstrate a LGB as no overall LGB was revealed by younger adults using these stimuli previously (Butler et al., 2005) and consequently no group differences were expected. However, it was anticipated that age would impact on the strength of the LPB and the association between the LPB and the number and duration of leftward fixations would differ between the groups. Additionally, based on Butler and Harvey's (2008) findings, it was anticipated that the greater demand imposed by limiting the viewing time would have a bigger impact on the older group, as speed of processing reduces in later life (Habekost et al., 2013). Consequently, when viewing time was limited, older adults were expected to reveal a further weakening of their left perceptual and eye movement biases compared with younger adults.

3.3 Method

Participants

Freeview condition. Sixty three right handed adults participated in this condition, 31 older adults (7 males) with a mean age of 65.10 (*SD* = 4.28, range 60-84 years) and 32 younger adults (9 males) with a mean age of 19.47 (*SD* = 2.30, range 18-28 years). Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed group differences with older adults demonstrating higher right laterality (*M* = 93.45, *SD* = 10.27) than younger adults (*M* = 86.63, *SD* = 13.33, $t(61) = -2.27$, $p = .027$). National Adult Reading Test (NART;

Nelson, 1982) results also indicated significant group differences with older adults scoring higher (*M* = 37.87, *SD* = 8.90) than younger adults (*M* = 26.88, *SD* = 5.60, $t(50.25) = -5.85$, $p < .001$), although no group differences were revealed for years spent in full time education for older (*M* = 15.26, *SD* = 3.47) or younger adults (*M* = 14.22, *SD* = 1.64), $t(42.45) = -1.51$, $p = .138$).

Time limited condition. Fifty two participants were initially recruited for this viewing condition; however, data from three older adults were removed due to difficulties in calibrating their eye movements. Data for three younger adults were also removed due to poor accuracy in judgements of single gender images (20% correct), being left-handed and failing to complete the task. Consequently, the data of forty six right-handed adults were included; 22 older (7 males) with a mean age of 66.50 (*SD* = 4.02, range 60-74 years) and 24 younger adults (3 males), mean age 20.46 (*SD* = 2.15, range 18-26 years). Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) did not significantly differ between the older (*M* = 85.45, *SD* = 15.17) and younger adults (*M* = 85.50, *SD* = 17.53, $t(44) = -.01$, $p = .993$). Analysis of the National Adult Reading Test (NART: Nelson, 1982) did not reveal age group differences (older; *M* = 34.82, *SD* = 6.78, younger; *M* = 35.75, *SD* = 3.61, $t(31.42) = -.57$, $p = .570$). Group differences were, however, revealed for education with older adults having spent less time in full time education than younger adults (older; *M* = 12.55, *SD* = 2.61 years, younger; *M* = 15.79, *SD* = 1.38 years, $t(31.28) = -5.20$, $p < .001$).

Design

To minimise the effects of fatigue and learning, separate cohorts of younger and older adults were recruited for the freeview and 1000ms time conditions. The between groups independent variables were age (younger and older), and time condition (1000ms and freeview) and the within groups independent variable was side of face (left and right). The dependent variables were perceptual bias, proportion of initial leftward saccades, proportion of leftward fixations and fixation duration. See Section 2.3 for full details.

Stimuli

The stimuli consisted of those used previously by Butler et al. (2005) and comprised 40 faces: ten male, ten female, ten left female/right male chimeric faces and ten left male/right female chimeric faces. See Burt and Perrett (1997) and Butler et al. (2005) for details of image composition and construction.

Procedure

A total of five blocks of trials were completed. In each block all forty images were presented once in a random sequence, with each face individually positioned in the centre of the screen at a visual angle of 20° x 20°. Following calibration and validation procedures at the start of each trial block, a forced choice task required participants to judge the gender of each image. The presentation of each face was preceded by a central fixation point (0.3° diameter) which was located at the centre of each face, mid sagitally at the centre of the nose and below the eyes. When fixation was stable, stimulus onset was activated and using the index finger and thumb of their right hand, participants made either a male or female response choice. In the freeview condition the image remained on the screen until a response was made, in the time limited condition each image remained for 1000ms after which participants responded. Eye movement data were collected binocularly, however, analysis was only conducted on the eye with the best spatial accuracy as assessed through validation for each block.

3.4 Results

The procedures noted in Section 2.9 led to 960 (7.62%) trials being removed from the freeview condition and 1,336 (10.6%) trials being removed from the time restricted condition.

Accuracy

As has been noted (Butler & Harvey, 2008) accuracy for the single gender faces in this task is less than perfect due to the somewhat androgynous appearance of some of the stimuli. However, one-sample *t*-tests against .5 (chance), revealed accuracy was significantly higher than chance for the younger adults in the freeview (M = .87, SD =.04; $t(31) = 55.78$, $p < .001$, $r = 1.00$) and limited time conditions (M = .84, SD =.05; $t(23) = 36.39$, $p < .001$, $r = .99$). Accuracy was also significantly higher than chance for older adults in the freeview and time limited conditions; M = .85, SD =.04; $t(30) = 43.98$, $p < .001$, $r = .99$ and M = .78, SD =.09; $t(21) = 15.01$, $p < .001$, $r = .96$ respectively. Therefore, as participants were easily able to detect the gender of the single gender images, their judgements of the male-female and female-male chimeric faces were taken as indicators as to the side they used to make their decision. As the primary aim of this experiment was to examine eye movement patterns and judgements to chimeric stimuli, no further analysis of the single gender images are detailed.

Perceptual Bias

As detailed in Section 2.3 the mean proportion of responses made according to the left side of the chimeric face was calculated for each participant. One sample *t*-

tests against chance (.5) were then conducted for each age group in each time condition (see Table 3.1).

Table 3.1.

Mean Proportion (SD) of LPB to Chimeric Images. Conducted through One-Sample t-tests Against Chance (.5).

		Perceptual Bias		
Group	*n*	Freeview	*n*	1000ms view
Younger adults	32	.55 (.10)**	24	.56 (.10)**
Older adults	31	.53 (.06)**	22	.53 (.07)

Note: *Proportions >.5 indicate a leftward bias.* **p<.01, *p<.05.

As can be seen, the means for the older adults in the freeview and time limited conditions were the same, but the levels of significance were p = .005 and p = .062 respectively. Confidence intervals (95%) were therefore calculated to determine where the population means fell for the younger and older adults in each viewing time condition. Throughout the results for this study confidence intervals for the difference between the means have also been reported for results which are significant, or approaching the level of significance.

A significant LPB, where the left side of the face was used to make the gender decision, was evident for the younger adults in both freeview (t(31) = 2.95, p = .006, r = .47, 95% CI [.02, .09]) and time limited conditions (t(23) = 2.91, p = .008, r = .52, 95% CI [.02, .10]). The older adults showed an LPB under the freeview condition ($t(30) = 3.02$, $p = .005$, $r = .48$, 95% CI [.01, .06]), but did not show a statistically significant effect when stimulus exposure time was limited ($t(21) = 1.97$, $p = 0.062$, $r = .39$, 95% CI [-.002, .06]).

To assess whether age or viewing time influenced the extent of the leftward judgement bias a two way independent ANOVA (Age x Time Condition) was then conducted. This revealed no significant main effects of age ($F(1,105) = 1.68$, $p = .197$, $\eta_p^2 = .02$, 95% CI [-.05, .01]), time condition ($F(1,105) = .002$, $p = .965$, $\eta_p^2 = .00$, 95% CI [-.03, .03]) or interaction ($F(1,105) = .06$, $p = .803$, $\eta_p^2 < .001$).

Initial Saccades

The mean proportion of initial saccades generated to the left side of the chimeric face was calculated as detailed in Section 2.3. One-sample *t* statistics against .5 (chance) were conducted for each time condition overall and for the side of the face used for a gender judgement (Table 3.2).

Table 3.2.

Mean Proportion (SD) of Left Initial Saccades Overall and for Left and Right Responses. Conducted Through One-Sample t-tests Against Chance (.5).

Proportion of Initial Saccades			
		Freeview	
Group	Overall	Left Judgements	Right Judgements
Younger	.62 (.31)*	.63 (.30)*	.61 (.32)
Older	.65 (.30)*	.65 (.30)**	.64 (.30)*
		1000ms	
Group	Overall	Left Judgements	Right Judgements
Younger	.65(.27)*	.66 (.26)**	.63 (.28)*
Older	.63 (.28)*	.64 (.28)*	.62 (.30)

Note: *Proportions >.5 indicate a leftward bias.* **p<.01, *p<.05.

A significant overall bias to generate initial saccades to the left was revealed in the freeview condition for the older ($t(30) = 2.69$, $p = .012$, $r = .44$, 95% CI [.03, .26]) and younger adults ($t(31) = 2.23$, $p = .033$, $r = .37$, 95% CI [.01, .23]). A significant leftward saccade bias was also revealed in the time limited condition for older ($t(21) = 2.11$, $p = .047$, $r = .42$, 95% CI [.002, .25]) and younger adults ($t(23) = 2.77$, $p = .011$, $r = .50$, 95% CI [.04, .26]). An independent ANOVA assessing the effect of age and time condition on the overall mean proportion of initial saccades generated to the left side of the chimeric faces revealed no significant main effects for age ($F(1,105) < .000$, $p = .998$, $\eta_p^2 = .00$, 95% CI [-.11, .11]), or time condition

($F(1,105) = .01$, $p = .910$, $\eta_p^2 = .00$, 95% CI [-.11, .12]) and the interaction was non-significant ($F(1,105) = .18$, $p = .669$, $\eta_p^2 = .00$).

When judgements were based on the left side of the face a significant left bias for initial saccades was demonstrated for younger ($t(23) = 3.06$, $p = .006$, $r = .54$, 95% CI [.05, .27]) and older ($t(21) = 2.24$, $p = .036$, $r = .44$, 95% CI [.01, .26]) participants in the 1000ms condition. It was also significant for the younger and older participants in the freeview condition ($t(31) = 2.43$, $p = .021$, $r = .40$, 95% CI [.02, .24] and $t(30) = 2.78$, $p = .009$, $r = .45$, 95% CI [.04, .26]). When judgements were based on the right side of the face older, but not younger, adults demonstrated a significant bias to initially saccade to the left side in the freeview condition (older; t $(30) = 2.62$, $p = .014$, $r = .46$, 95% CI [.03, .25]younger; $t(31) = 1.88$, $p = .070$, $r = .32$, 95% CI [-.01, .22]); whereas in the 1000ms time condition younger, but not older adults revealed a significant bias to initially saccade leftwards (younger; $t(23) = 2.26$, $p = .033$, $r = .48$, 95% CI [.01, .25], older; $t(21) = 1.89$, $p = .073$, $r = .38$, 95% CI [-.01, .25]) see Table 3.2.

A mixed ANOVA was conducted to assess the effect of age, time condition and side of response on the proportion of initial leftward saccades when judgements were based on the left and right side. The main effect of side of response was significant (F $(1,105) = 5.41$, $p = .022$, $\eta_p^2 = .05$, 95% CI [.003, .04]) with a higher proportion of initial saccades being generated to the left when the response was made to the left side of the face. The main effects of age group ($F(1,105) = .01$, $p = .933$, $\eta_p^2 < .001$, 95% CI [-.12, .11]) and time condition ($F(1, 105) = .01$, $p = .925$, $\eta_p^2 < .001$, 95% CI [-.12, .11]) were non-significant as were the interactions (all $p > .1$).

Proportion of Fixations

The average proportions of leftward fixations were calculated and separate averages were calculated for all trials combined and trials where the gender judgement was based on the left side of the face and for the right side of the face. Descriptive statistics are displayed in Table 3.3.

Table 3.3.

Proportion of Leftward Fixations Overall and for Left and Right Judgement Responses.

	Proportion of Fixations		
		Freeview	
Group	Overall	Left Response	Right Response
Younger	.53 (.11)	.54 (.10)*	.50 (.11)
Older	.50 (.13)	.51 (.13)	.48 (.14)
		1000ms view	
	Overall	Left Response	Right Response
Younger	.51 (.10)	.51 (.11)	.52 (.12)
Older	.52 (.16)	.53 (.16)	.50 (.20)

Note: *Proportions >.5 indicate a leftward bias. *p* < .05 *for one sample t-tests against chance (.5).*

For the overall combined data, the results of one-sample *t*-tests against chance (.5) revealed no significant lateral biases for either the younger or older group in the freeview ($t(31) = 1.40$, $p = .173$, $r = 24$. and $t(30) = -.19$, $p = .854$, $r = 03$.) or 1000ms time conditions ($t(23) = .53$, $p = .601$, $r = 11$. and $t(21) = .47$, $p = .644$, $r = 11$.). An independent (Age x Time Condition) ANOVA revealed no significant main effects of age ($F(1,105) = .28$, $p = .596$, $\eta_p^2 = .003$), or time condition ($F(1,105) = .02$, $p = .909$, $\eta_p^2 < .001$) and the interaction was also non-significant ($F(1,105) = .52$, $p = .474$, $\eta_p^2 = .01$).

To determine whether the side of the chimeric face used to make the perceptual judgements was accompanied by more fixations to that side of the face one-sample *t*-tests were conducted against chance (.5). These revealed that when judgements were based on the left side in the freeview condition, younger adults made proportionally more fixations to the left side ($t(31) = 2.42$, $p = .022$, $r = .16$, 95% CI [.01, .08]). No other significant lateral biases were revealed, all $p >.380$. A mixed ANOVA (Age x Side x Time Condition) revealed a significant main effect of face judgement side with there being proportionally more leftward fixations when the decision was based on the left side, than the right side of the face ($F(1,105) = 7.27$, $p = .008$, $\eta_p^2 = .07$, 95% CI [.01, .04]). The main effects of age ($F(1, 105) = .30$, $p = .586$, $\eta_p^2 = .003$, 95% CI [-.06, .04]). and time condition were non-significant ($F(1, 105) = .05$, $p = .823$, $\eta_p^2 < .001$, 95% CI [-.04, .06]). However, a significant response side x time condition interaction was revealed ($F(1, 105) = 4.28$, $p = .041$, $\eta_p^2 = .04$). As it was hypothesized that the proportion of leftward fixations may be affected by side of response and time condition a priori comparisons were conducted on this interaction. With only two comparisons to make, which were planned in advance, *t* – tests were conducted as recommended by Howell (2013) and were left uncorrected. This analysis revealed that significantly more leftward fixations were made with a left compared with right response in the freeview condition (*M* = 53, *SD* = .49 and *M* = .49, *t*(124) = 1.70, *p* = .046, *r* = .15, 95% CI [-.01, .08]). But not the 1000ms condition (*M* = .52, *SD* = .14 and *M* = .51, *SD* = .16, *t*(90) = .13, *p* = .898, *r* = .01, 95% CI [-.06, .07]). see Figure 3.1.

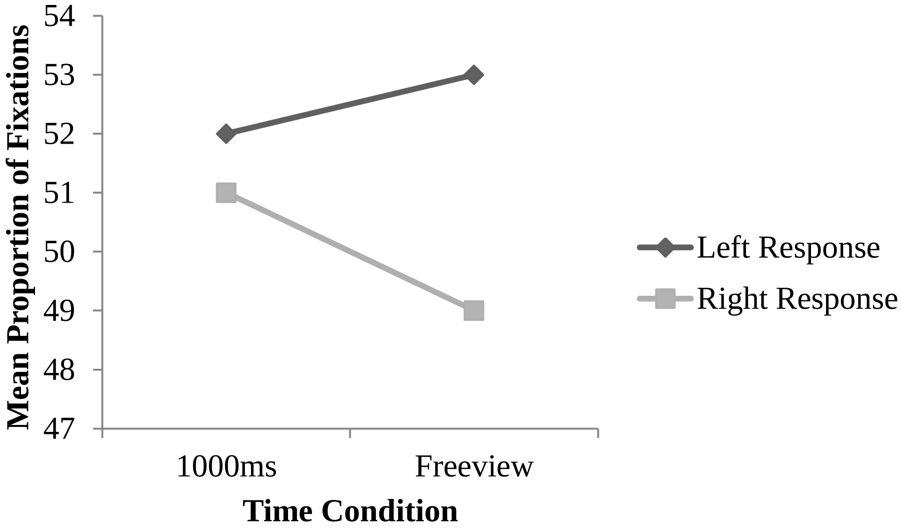

Figure 3.1. Response side x time condition interaction for proportion of leftward fixations.

Durations of Fixations

Table 3.4 shows the mean fixation times, overall (i.e. not dependent on the side used for a response) and Table 3.5 shows the mean fixation times when gender judgements were made to the left and right sides of the face.

Table 3.4.

Means (SD) for the Fixation Duration (ms) Overall to Left and Right Face Sides.

	Fixation Duration Overall Freeview Condition	
	Left Face	Right Face
Younger	910 (387)	868 (411)
Older	1180 (772)	1297 (854)
	Fixation Duration Overall 1000ms Condition	
	Left Face	Right Face
Younger	336 (72)	312 (81)
Older	340.07 (90)	323.98 (114)

Table 3.5.

Means (SD) for the Fixation Duration (ms) to Left and Right Face Sides According to Side of Response.

	Freeview Condition			
	Left Face Side Response		Right Face Side Response	
	Left Face	Right Face	Left Face	Right Face
Younger	937	881	832	928
	(390)	(388)	(409)	(423)
Older	1175	1193	1217	1322
	(732)	(846)	(862)	(863)

	1000ms Condition			
	Left Face Side Response		Right Face Side Response	
	Left Face	Right Face	Left Face	Right Face
Younger	341	333	311	314
	(74)	(71)	(85)	(81)
Older	341	339	318	329
	(87)	(100)	(113)	(120)

A mixed 2 x 2 x 2 x 2 ANOVA was conducted to determine whether age, time condition, face side or side of response impacted on fixation duration. This revealed a significant main effect of time condition ($F(1, 105) = 71.12$, $p < .001$, $\eta_p^2 = .40$, 95% CI [557.05, 899.97]). with a longer mean fixation duration (ms) in the freeview compared with 1000ms condition ($M = 1061$, $SE = 56$, 95% CI [197.92, 458.72] vs $M = 328$, $SE = 66$ CI [945.49, 1168.16]) and a main effect of age approaching the level of significance ($F(1, 105) = 3.81$, $p = .054$, $\eta_p^2 = .04$, 95% CI [-.48, 342.44]) with a trend for older adults to have a longer mean fixation duration (ms) than the younger adults ($M = 779$, $SE = 62$, 95% CI [654.91, 901.22] vs $M = 610$, $SE = 60$, 95% CI [487.79, 726.38]). No other main effects were significant ps > .061. A significant fixation side x response side interaction was revealed ($F(1, 105) = 24.41$, $p < .001$, $\eta_p^2 = .19$). Post hoc analysis was calculated using Tukey HSD by hand using the following equation $T = q_k\ (MSerror/n)$ as it is noted to have good power and control over type 1 errors (Field, 2009). Due to the different group sizes a harmonic mean was calculated 2/[(1/63)+(1/46)] = 53.18. This analysis revealed that mean fixation duration (ms) to the left side of the face was not significantly different for left or right responses ($M = 698$, $SE = 43$, 95% CI [612.57, 785.03] and $M = 687$, $SE = 48$, 95% CI [590.37, 783.72] $p > .05$). However, mean fixation duration (ms) to the right side of the face was significantly longer with a right ($M = 723$, $SE = 50$, 95% CI [623.85, 823.96]) than left response ($M = 670$, $SE = 50$, 95% CI [570.84, 769.30] $p < .01$; see Figure 3.2).

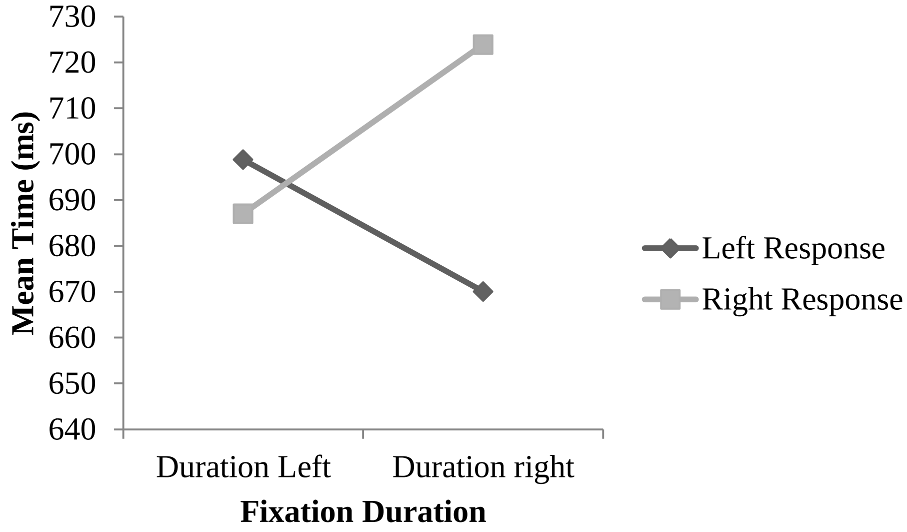

Figure 3.2. Fixation duration side x response side interaction

A significant fixation side x response side x time condition interaction was also revealed ($F(1, 105) = 16.18$, $p < .001$, $\eta_p^2 = .13$). Tukey HSD post hoc analysis revealed that in the 1000ms time condition fixation duration (ms) to the left side of the face did not differ significantly for responses made to the left and right sides (*M* = 341, *SE* = 66 , 95% CI [210.18, 472.48] and *M* = 336, *SE* = 74, 95% CI [189.35, 483.45]) and fixation duration (ms) to the right side of the face did not differ significantly for responses made to the left or right sides (*M* = 315, *SE* = 76, 95% CI [164.15, 466.01] and *M* = 322, *SE* = 76, 95% CI [170.16, 474.52]). In the freeview condition fixation duration (ms) to the left side of the face did not differ for left and right responses (*M* = 1056, *SE* = 56 , 95% CI [944.30, 1168.25] and *M* = 1037, *SE* = 63, 95% CI [912.14, 1163.24]), but fixation duration (ms) to the right side was significantly longer when the response was made to the right compared with the left side (*M* = 1125, *SE* = 65 , 95% CI [995.54, 1255.40] and *M* = 1025, *SE* = 64, 95% CI [896.19, 1153.92], $p < .01$) see Figure 3.3.

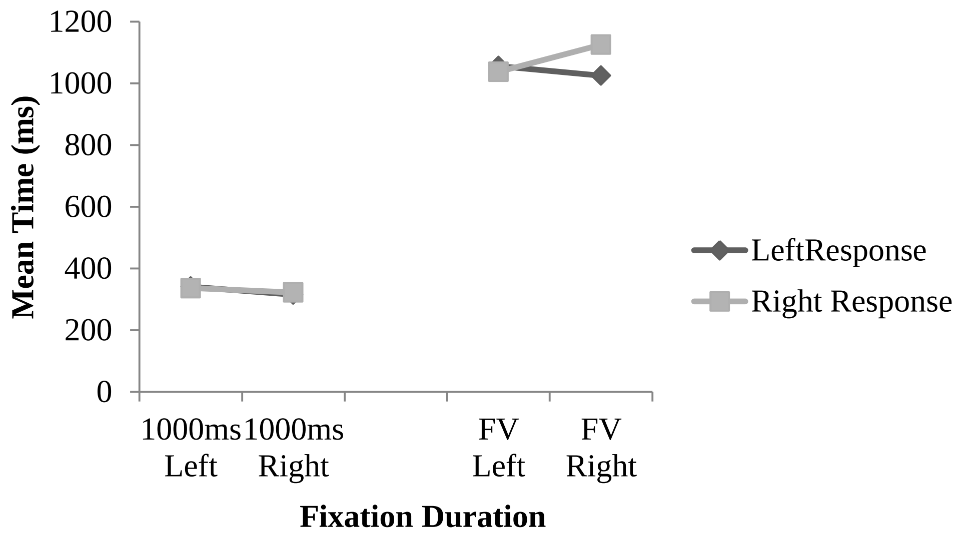

Figure 3.3. Fixation side x response side x time condition interaction for fixation duration.

Right Perceptual Bias

From inspecting the data it became clear that whilst a significant overall left perceptual bias was seen in all conditions, except for the older adults in the time restricted condition, there was a substantial number of participants who demonstrated a right perceptual bias; over 20% of participants across both age groups (22% freeview and 27% 1000ms). A right initial saccade has infrequently been noted in face processing research (e.g. Leonards & Scott-Samuel, 2005), but the impact of a right perceptual bias on initial saccades and other eye movement behaviour during face processing has not been documented. In the following analyses the eye movement patterns of participants with right and left perceptual biases were compared to identify scanning differences during this face processing task.

The full cohort of older and younger participants across both time conditions (n = 109) demonstrated a range in perceptual judgement bias of .30 to .77. Twelve participants had mean scores ranging from .49 to .51 demonstrating negligible, or no bias. These participants were not included in the following analyses. Based on the remaining 97 participants three bias groups were created. Participants with a strong left bias, demonstrated by their perceptual bias mean of ≥.61, participants with a weak left bias, revealed through a range of .52 - .60 and participants with a right perceptual bias ≤ .48.

The strong left perceptual bias group contained 22 adults; 4 older and 8 younger from the freeview condition (*M* = .67, *SD* = .04, range .62 - .75), 4 older and 6 younger from the time restricted condition (*M* = .66, *SD* = .05, range .61 - .77). Forty nine participants were included in the weak left perceptual bias group 15 older and 15 younger in the freeview condition (*M* = .55, *SD* = .02, range .52 - .60) and 7 older and 12 younger in the limited viewing (*M* = .56, *SD* = .02, range .52 - .59). The right perceptual bias group comprised of 24 participants, 6 older and 6 younger from the freeview condition (*M* = .43, *SD* = .05, range .29 - .48) and 6 older and 6 younger from the limited time condition (*M* = .43, *SD* = .05, range .30 - .48). Confirmatory one-sample *t*-tests against chance were conducted and confirmed that each group were significantly biased in their judgements.

To establish if the initial saccade was made in the direction of the judgement bias, additional one sample *t*-tests were conducted against .5 (chance). As Table 3.6 illustrates the strong left bias group in the freeview condition ($t(11) = 2.44$, $p = .033$, $r = .59$) and time restricted condition ($t(9) = 2.58$, $p = .030$, $r = .65$) generated a significantly greater proportion of initial saccades to the left compared to chance.

The weak left perceptual bias group showed the same pattern in both time conditions; freeview ($t(29) = 2.34$, $p = .026$, $r = .40$) and limited ($t(18) = 2.89$, $p = .010$, $r = .56$). However, the initial saccades of the right perceptual bias group approximated an equal 50/50 distribution to the left and right sides of the face in both the freeview ($t(11) = -.08$, $p = .941$, $r = .02$) and limited time conditions ($t(11) = .18$, $p = .859$, $r = .05$). Consequently, whilst all three groups demonstrated lateralized perceptual biases, only participants who biased their gender judgements to the left side also generated their initial saccades to the left. The right perceptual bias group was equally likely to generate their initial saccades to either face side.

Table 3.6.

Mean Proportion (SD) of Leftward Initial Saccades per Bias Group.

		Initial Saccades		
Group	*n*	Freeview	*n*	1000ms View
Strong Left	12	.73 (.32)*	10	.71 (.25)*
Weak Left	30	.63 (.30)*	19	.68 (.26)*
Right	12	.49 (.24)	12	.52 (.29)

Note: *Proportions >.5 indicate a leftward bias.*p* < .05 *one-sample t-tests against chance (.5).*

Based on the side of the face used to make the gender decision, a running total of the proportion of leftward fixations (Table 3.7) was also examined and one-sample *t*-tests against .5 (chance) were conducted.

Table 3.7

Proportion of Leftward Fixations According to Left and Right Side of Face Responses.

	Proportion of fixations	
	Freeview	
Group	Left Judgement	Right Judgement
Strong Left	.56 (.13)	.53 (.13)
Weak Left	.52 (.11)	.50 (.11)
Right	.48 (.13)	.42 (.15)
	1000ms view	
	Left judgement	Right judgement
Strong Left	.59 (.10)*	.58 (.14)
Weak Left	.53 (.09)	.53 (.10)
Right	.46 (.15)	.46 (.15)

Note: *Proportions >.5 indicate a leftward bias.***p* < .05 *one-sample t-tests against chance (.5).*

As shown in Table 3.7 the strong LBP group had a greater proportion of leftward fixations when they based their decision on the left side of the face ($t(9) = 2.68$, $p = .025$, $r = .44$, 95% CI [.01, .16]), all other results were non-significant ($ps > .104$). Running totals of the fixations made to each side of the face for responses to the left and right sides in the freeview and 1000ms are presented in Table 3.8 and Table 3.9 respectively. To determine whether group, fixation side, response side or time condition had a significant effect on fixation duration a mixed (3 x 2 x 2 x 2) ANOVA was conducted.

Table 3.8.

Mean (SD) Fixation Duration (ms) to the Left and Right Face Sides According to Side Used for a Response in the Freeview Condition.

	Duration of Fixations Freeview			
	Left Response		Right Response	
	Left Side	Right Side	Left Side	Right Side
Strong Left	855	700	839	807
	(505)	(238)	(238)	(272)
Weak Left	1158	1058	1182	1261
	(717)	(615)	(816)	(883)
Right	935	954	861	1010
	(410)	(416)	(467)	(438)

Table 3.9.

Mean (SD) Fixation Duration (ms) to the Left and Right Face Sides According to Side Used for a Response in the 1000 Condition.

	Duration of Fixations 1000ms			
	Left Response		Right Response	
	Left Side	Right Side	Left Side	Right Side
Strong Left	405	263	406	277
	(55)	(78)	(61)	(79)
Weak Left	337	323	335	327
	(66)	(97)	(59)	(100)
Right	299	352	290	350
	(96)	(116)	(106)	(112)

Not surprisingly a main effect of time condition was revealed with fixation duration being greater in the freeview (*M* = 962, *SE* = 62) than 1000ms time condition (*M* = 330, *SE* = 67; *F*(1, 89) = 37.98, *p* > .001, η_p^2 = .30, 95% CI[437.17, 853.21]). No significant main effects of response side (*F*(1, 89) = 1.47, *p* = .223, η_p^2 = .02, 95% CI[-47.75, 11.56]) fixation duration side (*F*(1, 89) = .06, *p* = .809, η_p^2 = .001, 95% CI[-77.26, 98.70]) or group were revealed (*F*(2, 89) = 1.35, *p* = .263, η_p^2 = .03, 95% CI strong left – weak left, weak left – right & strong left – right respectively[-437.97, 55.50; -110.11, 364.95; -341.90, 217.27]). However, a significant fixation duration side x response side interaction was revealed ($F(1, 89) = 15.26$, $p < .001$, $\eta_p^2 = .15$). Tukey HSD post hoc analysis using a harmonic mean [6/(1/12+1/12+1/12+1/10+1/30+1/19) = 14.29] revealed a significantly shorter mean fixation duration (ms) to the right side of the face with a left compared with a right response ($M = 623$, $SE = 59$ and $M = 672$, $SE = 59$; $p < .01$) but when looking at the left side of the face fixation duration did not differ significantly for left or right responses ($M = 665$, $SE = 51$ and $M = 652$. $SE = 58$; $p > .05$) see Figure 3.4.

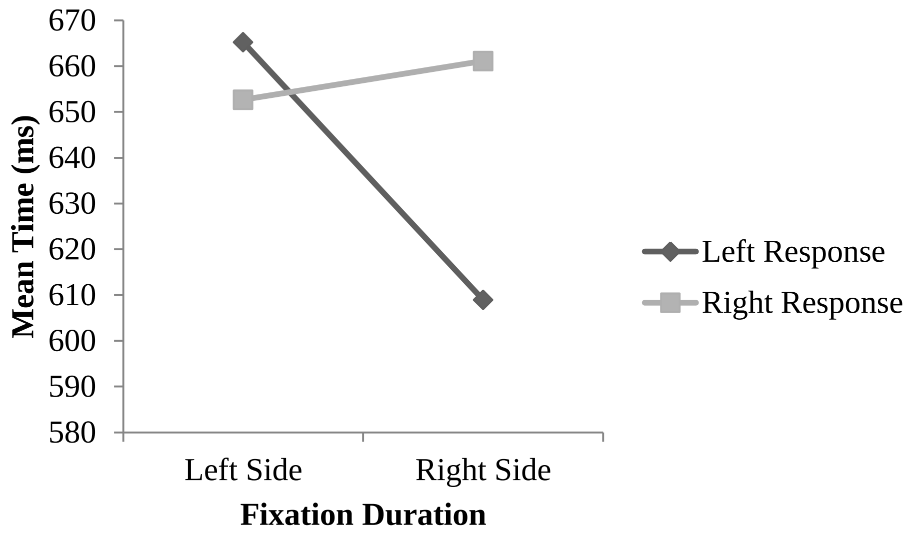

Figure 3.4. Fixation side x response side interaction for fixation duration.

A significant fixation duration side x response side x time condition interaction was revealed ($F(1, 89) = 11.45$, $p = .001$, $\eta_p^2 = .12$) . Tukey HSD post hoc analysis revealed that in the 1000ms time condition fixation duration (ms) to the left side of the face did not differ significantly for responses made to the left and right sides ($M = 347$, $SE = 76$ and $M = 344$, $SE = 86$) and fixation duration (ms) to the right side of the face did not differ significantly for responses made to the left or right sides ($M =$

313, *SE* = 87 and *M* = 318, *SE* = 87). In the freeview condition fixation duration (ms) to the left side of the face did not differ for left and right responses (*M* = 982, *SE* = 70 and *M* = 960, *SE* = 79), but fixation duration (ms) to the right side was significantly longer when the response was made to the right compared with the left side (*M* = 1026, *SE* = 80 and *M* = 934, *SE* = 80, $p < .01$) see Figure 3.5. These two interactions echo those in the age group analysis detailed previously (see Figures 3.2 and 3.3).

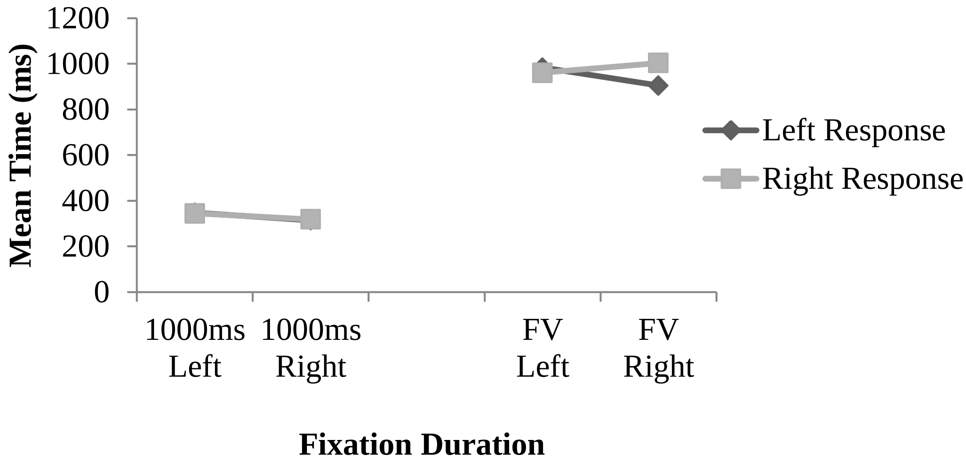

Figure 3.5. Fixation side x response side x time condition interaction for fixation duration.

3.5 Discussion

The aims of this study were twofold; the first objective was to determine whether the strength of the LPB reduces with age and increased task demand, the second was to determine whether the perceptual bias of older and younger adults is reflected in their eye movement strategies. It was found that overall both age groups based their judgements on the left side of the face when viewing time was unlimited.

This provides further evidence for an LPB, an effect which has consistently been demonstrated in face processing studies (e.g. Burt & Perrett, 1997). It also supports previous studies showing no effect of age on the LPB when faces are viewed for an unlimited time (Levine & Levy, 1986; Moreno et al., 1990; Coolican et al., 2008).

In the time limited condition the younger adults persisted to bias their perceptions of gender to the left, whereas the older adults were not significantly different from chance. This is a similar finding to Butler and Harvey (2008) who reported a significant effect of age and time condition on LPB. However, Butler and Harvey reported the presence of an LPB in their older cohort when viewing time was restricted to 300ms, but not when it was reduced to 100ms, whereas the older adults in the current study showed a lack of bias at 1000ms. This is despite the mean proportion of LPB at .53 being the same in both the time restricted condition in the current study and Butler and Harvey's 300ms condition. There was, however, greater variability in leftward judgements for the current group compared with Butler and Harvey's (*SD* = .07 vs .05) which may account for this disparity. Even though a larger sample was recruited in the current study; 22 older and 24 younger participants in this study for the limited time condition, versus 14 older (mean age = 72, SD = 3.9) and 22 younger adults (22.1 SD = 2.3) in Butler and Harvey's experiment, it is possible that the samples contained different proportions of participants with either no bias or a right bias. It is also worth noting that the older participants recruited by Butler and Harvey had a higher mean age (*M* = 72, *SD* = 3.9) than those in this current study (*M* = 66.50, *SD* = 4.02), which could have a bearing on their LPB. Additionally, Butler and Harvey adopted a within groups design. This is arguably a more powerful design as any differences found between the time conditions cannot be attributed to group differences as may be the case with a between groups design. However, it could also be argued that as they adopted a within groups design, their older group's LPB was an effect of cohort rather than age.

Findings from the eye movement analysis revealed an overall bias to generate first saccades to the left for both age groups. This leftward bias has frequently been noted in the face processing literature (Guo, Tunnicliffe & Roebuck, 2010; Mertens et al., 1993; Philips & David, 1997) and supports other studies showing such an effect for younger adults when judging gender (Butler et al., 2005), familiarity and emotional expressions (Guo et al., 2012). Additionally, as it is not necessarily related to perceptual judgements (Butler et al., 2005) an initial leftward bias is argued to be a reflexive action at the commencement of facial analysis (Leonards & Scott-Samuel, 2005). Consequently, for this reason and due to older adults having a more highly practiced left to right reading style, it was accurately anticipated that increased age would not result in fewer initial saccades being generated to the left overall.

When initial saccades were separated according to the side used for a response, in each time condition both older and younger adults demonstrated a leftward saccade bias when the left side of the face was subsequently used to make the gender judgement. Consequently an association between initial saccades to the left and left judgements is evident. This association was less consistently demonstrated when decisions were based on the right side as no lateral bias for initial saccades was evident for younger adults in the freeview condition or older adults in the 1000ms condition. Although it has previously been postulated that an initial leftward saccade is an automatic response when viewing faces (Leonards & Scott-Samuel, 2005) this was based on the results of participants who were asked to assess and retain information about faces, and the side used for a decision was not investigated. Nine out of the 37 participants in Leonards and Scott-Samuel's study made first saccades to the right and in a more recent study (Guo et al., 2012) 44% of initial saccades were also made to the right and potentially these participants' judgements were based on the right side too. Not only do the current findings contradict Leonards and Scott-Samuel's assertion, but they also indicate more bilateral processing when judgements are based on the right side. The use of scanning technology would be useful to assess lateral hemispheric activity and biases of perception and attention to investigate why a link between first saccades and perceptual bias is not evident for rightward judgements.

Lateral biases were calculated against chance for proportion of fixations and each side of the face was directly compared for fixation duration. Overall, i.e. not based on side of response, no lateral eye movement biases were revealed for the younger or older participants in either of the time conditions. These results were expected based on previous research (Butler et al., 2005) which notes that an overall left eye movement bias could be reflective of habituated scanning style as left-right readers may prioritise their eye movements to the left compared to right side of the face. The lack of overall lateral eye movement biases to the left side of the faces therefore indicates that participants did not engage in directional scanning when conducting this task. Additionally, as no lateral biases were anticipated for the younger group, no differences between the groups were expected and this hypothesis was supported.

When the left side of the face was used in making the gender response, a greater number of fixations were recorded on the left side of the face indicating RH dominance for this task and supporting Butler et al.’s (2005) findings. This effect was particularly apparent in the freeview time condition offering partial support for Butler and Harvey’s (2006) assertion that longer viewing times enhance left lateralised biased eye movements. However, full support for this argument is not revealed by the fixation duration data. This data revealed that both groups’ mean fixation duration was greater to the right side of the face when responses were also based on the right side in the freeview, but not the time limited condition.

Potentially, this eye movement behaviour reflects atypical scanning as participants ‘weigh up’ the two sides of the chimeric face before reaching a decision, however, as left lateral eye movement biases have been revealed for both the proportion and duration of fixations using chimeric images (Butler et al., 2005) this interpretation should be treated with caution. Alternatively, biases of eye movements and perception may not be related as it has been noted that no differences in eye movement lateralisation are evident irrespective of the side used for a response (Samson et al., 2014). Further research should therefore be conducted using chimeric and non-chimeric images to investigate the association between eye movements and perception.

The data also showed that the older group did not demonstrate a lateral bias for proportion of fixations. At first glance this appears to support the theories of ageing (Cabeza, 2002; Park & Reuter-Lorenz, 2009), as such symmetrical eye movements for the older group were anticipated, but the data revealed no significant differences according to age. Thus, age did impact on perceptual bias as has been noted previously (Butler & Harvey, 2008; Coolican et al., 2008; Failla et al., 2003), but the lateral eye movement behaviour shown by both age groups was not significantly different. This is the first study to track older adults' eye movements while they conducted a chimeric gender judgement task and the results suggest a link between first saccades and perception to the left side which supports previous literature on younger adults' perception and eye movements (Grega et al., 1988; Samson et al., 2014). They also indicate a link between perception and fixation duration to the right when time is not limited which suggests that scanning behaviour remains unaffected by advancing age.

The results did show, however, that approximately a quarter of participants (6 older and 6 younger adults in each of the time conditions) demonstrated a bias to judge faces from the right side. Given that face processing is considered a right hemisphere dominant task, this rightward bias of perception seems counterintuitive. Some individual differences, such as left handedness, have been found to impact on the LPB (Bourne, 2008), but all participants in this study were right handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971).

It has also been revealed that individual differences in state, trait and social anxiety affect lateralisation of emotion processing with high trait anxiety more strongly lateralising to the RH, and high social anxiety weakly RH or even LH lateralised (Bourne & Vladeanu, 2011). The participants in this current study were recruited randomly and therefore there is no reason to believe that they were high in any of these types of anxiety. However, as research into individual differences for lateralisation of facial processing is in its infancy, the causes of lateral processing differences have only just started to be explored. While it would be reasonable to expect participants to vary slightly in their degree of leftward bias, it was not expected that a reversed right perceptual bias would be apparent in this current study and particularly not for such a large number of participants.

However, studies using a line bisection task; where participants determine the midpoint of a horizontal line have shown right and left biases to exist (Braun & Kirk, 1999; Cowie & Hamill, 1998; Manning, Halligan & Marshall, 1990). It is therefore possible that the left hemisphere has greater input for spatial representation for some individuals than is noted in the literature. This interpretation has received support from a recent study (Varnava, Dervinis & Chambers, 2013) in which continuous Theta Burst Stimulation (cTBS) was applied to the left and right angular gyrus (AG) during a line bisection task. Participants who demonstrated an RPB, by bisecting the line to the right of the midline, revealed an exaggerated rightward bias (leftward neglect) when their right AG was stimulated. Contrastingly though, when cTBS was applied to either the left or right AG of LPB participants it had no effect on bias, which suggests that the LPB, and potentially neglect of the right side, is not controlled by the AG. Instead, as has been demonstrated using a series of tasks on stroke patients (Suchan & Karnath, 2011), lesions to cortical areas typically associated with serving language (the left superior and middle temporal gyri, inferior parietal lobule and insula) result in neglect to the right, and therefore a bias to the left side. This shows that areas in the LH may contribute to spatial orienting to the left, whereas the AG in the RH contributes to spatial orienting to the right. Research is now required to ascertain whether these same areas in the LH and RH impact on right and left biases of perception during face processing.

The eye movements of participants expressing an RPB have not been investigated previously. The analysis revealed that people who typically judged the gender of the chimeric from the right side did not demonstrate an initial saccade or proportion of fixations eye movement bias to the right in either time condition. Only participants classified as having either a weak or strong LPB made their first saccade to the left. Furthermore (with the exception of the strong left bias group when basing their judgement on the left side in the limited time condition), the side of the face used for a gender judgement had no bearing on the proportion of fixations made to that side. An examination of Tables 3.8 and 3.9 shows a trend in both time conditions for the strong left group to look for longer at the left than the right side of the face when their decision was based on the left side and when their decision was based on the right side. The right biased group showed the opposite pattern, a trend was revealed for this group to look for longer at the right side than the left whichever side of the face their decision was based on. Although no significant impact of group was revealed for fixation duration, in the freeview condition both groups looked for longer at the right than left side when their judgement was based on the right side. Consequently, both the assertion that perception accompanies attention (Butler et al., 2005), along with the general assumption that an initial eye movement to the left is a natural response when analysing faces (Leonards & Scott-Samuel, 2005) appear too simplistic since the association between gaze and perception is only consistently evident in those with an LPB.

It is unclear why the participants in this current study did not always demonstrate a left lateral bias eye movement bias when they also judged from the left side of the face, as Butler et al.'s (2005) participants clearly did. The same experiment was conducted, using the same stimuli and apparatus, and the younger adults were of the same age as Butler et al.'s. Potentially the current cohort contained an unusually high number of participants with an RPB and this acted to reduce the leftward eye movements typical during face processing. However, this is unlikely as a cross sectional design was used and a similar number of these right bias participants were recruited in both samples. Alternatively, it is possible that the majority of the young participants recruited by Butler et al. (2005) had a strong LPB since the movement patterns they reported are similar to those in the strong left bias group. Further research is therefore required to enable a better understanding of perception and gaze associations and to identify which individual differences drive such biases to the left or right.

In conclusion the results of this present study show that a LPB was revealed by younger adults in both viewing conditions. The older adults also demonstrated a LPB in the freeviewing condition, but the data were less supporting of this bias when time was restricted to 1000ms. Age, however, did not impact on initial saccades as these were biased to the left for both groups. Younger adults made proportionally more leftward fixations when their gender judgement was also based on the left side and time was not limited. Both groups' mean fixation duration was greater to the right side when they based their judgements on the right and time was not limited; however, no other biases were revealed for either age group's proportion or duration of fixations. While the majority of the population were biased to the left when judging the gender of faces, approximately a quarter judged from the right and this did not appear to be age dependent. Additionally, an LPB is accompanied by an initial saccade to the left and a strong LPB is also accompanied by proportionally more fixations to the left side. An RPB though, is not accompanied by these eye movements suggesting that different neural mechanisms may underlie right and left perceptual and gaze biases.

Chapter 4

What is the Impact of Age on Lateral Judgements and Eye Movements During a Face Matching Task?

4.1 Abstract

Accuracy in matching photographs of faces is important for verifying a person's identity in a variety of security and forensic settings. However, even people who are experienced in face matching are prone to error and this error rate appears to increase from younger to older adulthood. Using a 2-in-10 face matching paradigm which presents a target face and a foil face above a ten face line-up, previous research has shown that a target face placed on the left is matched more accurately with its line-up face than when the target face is on the right. This LPB has previously been noted in face processing studies, however, whether the LPB is associated with a LGB during face matching is not known. Study 1 reported an association between lateral biases of perception and gaze for gender judgements. However, although theories of ageing predict a reduction in lateral bias in older adulthood, this was not consistently demonstrated in study 1 when gender was judged. In order to determine whether these results were an effect of task the following study used a 2-in-10 face matching task while older and younger adults' eye movements were tracked. The findings revealed a trend towards a greater level of accuracy (hits) for the right compared with left target face, but no significant difference according to age. Analysis of correct face matches (hits) revealed that more initial saccades were generated to the left than right target face and the side used for a subsequent hit did not impact on this. Overall more fixations were also made to the left target face, and when a hit was based on the left target face proportionally more fixations were made to the left than right target

face. Overall, fixation duration was longer to the left compared with the right target face and older adults' fixation duration was longer than younger adults'. When a hit was based on the left target face a longer time was spent looking at the left than right target face, and when a hit was based on the right target face a longer time was spent looking at the right compared with left face. Response time (RT) for hits was significantly faster for younger compared with older adults, and the RT to the left target face significantly faster than the right. These results indicate that accuracy is biased to the right target face side and eye movements are biased to the left target face side. No group differences were demonstrated for lateral biases of accuracy or eye movements suggesting similar processing strategies were adopted by both age groups.

4.2 Introduction

Just a few decades ago the only requirement for a photograph to be used for identification was in a passport. Now personal photographs are required on various documentation such as full and provisional driving licences, rail, bus and subway season tickets, student registration cards, for gaining entry to work places and on discount cards such as Young Scot. With the increase in photographic identification cards to provide proof of identity comes the growing requirement to accurately match the bearer with their photograph. However, it has been well documented that face matching is prone to error. For example, cashiers have demonstrated a high error rate in face-matching accuracy when photo ID (using recent photographs) is used to verify identity in supermarkets (Kemp, Towell & Pike, 1997). Passport officers have also been found to falsely accept 14% of fraudulent passports (White, Kemp, Jenkins, Matheson & Burton, 2014), which indicates that even people who are experienced and required to match faces regularly are not reliably accurate.

As inaccuracies in face matching may lead to security risks and legal infringements, research is now focussing on factors which both help and hinder accurate identification using a variety of different paradigms. One task investigating face matching accuracy (Bruce et al., 1999) presented an unfamiliar face with a neutral expression looking directly at the camera positioned centrally above with a line-up of 10 faces (numbered for each position). In this 'one-in-ten' task participants were asked to state whether the target face (face at the top) was also present in the line-up and if so to state its location. The target face was a still from video footage and was filmed on the same day that the photograph for the line-up face was taken, so although the identity of the target and line-up face were the same, they looked slightly different. The images used were high quality to aid identification and were photographed in good light. However, participants only accurately matched the target face with the line-up face in approximately 70% of trials. Additionally, when the target face was not present in the line-up participants incorrectly matched it with a line-up face in approximately 30% of trials, even though they knew that the target face was not always present in the line-up. Using colour target and line-up faces reduces accuracy further (Bruce et al., 1999) as the colour of the skin can appear different in the two images increasing error rate as surface based information is particularly important for processing facial identity (Harris, Young & Andrews, 2014).

It has also been revealed that when the 'one-in-ten task' is made more difficult by presenting a target face which was photographed months apart from the line-up face, accuracy in matching is lower than when the images are photographed on the same day (78% vs 59%) and response times are slower too (Megreya, Sandford & Burton, 2013). Even when the task is simplified by always having the target face in the line-up accurate identification is still only at 76% for grey scale images (Bruce et al,. 1999).

The addition of an extra target face, the 'two-in-ten' task also reduces accuracy compared with the one-in-ten task. Accuracy with two target faces has been noted to be 66% compared with 82% with one target face (Bindemann, Sandford, Gillatt, Avetisyan & Megreya, 2012). Megreya and Burton (2006a) also found a reduction in accuracy for the two-in-ten task compared with the one-in-ten task (54% vs 70%). This, they suggested, may be due to difficulties in encoding unfamiliar faces which could be alleviated by reducing the perceptual interference of the target images by presenting them further apart rather than in close proximity. In separating the target faces by 8cm, the authors found that accuracy was higher than when presented at 1cm apart (58% vs 50%) supporting their view. They also found that the side the target face was presented on affects accuracy as participants matched the left target face more accurately than the right target face in both spacing conditions.

This left face advantage may be symptomatic of the left-right scanning strategy which is habituated in Western society. Some evidence (Megreya & Havard, 2011) supports this as right-left reading Egyptian participants are noted to be significantly better at matching the right target face than British left-right readers (63% vs 54%). However, as both Egyptian and British participants matched left target faces more accurately than right target faces scanning strategy cannot fully account for this leftward bias. Instead, the left face advantage may reflect the dominance of the RH for face processing tasks (Kanwisher et al., 1997; McCarthy et al., 1997; Pitcher et al., 2011) which theories of ageing predict will reduce in older adulthood (Cabeza, 2002; Park & Reuter-Lorenz, 2009).

Recently studies have reported that older adults' performance across a range of face perception tasks is slower and less accurate than younger adults' (Hildebrandt, Wilhelm, Herzmann & Sommer, 2013; Hildebrandt, Wilhelm, Schmiedek, Herzmann & Sommer, 2011) and more specifically, older adults have demonstrated reduced recognition and perception of both familiar and unfamiliar faces compared with younger adults. For example using grey scale, directly facing synthetic faces, which do not contain fine details such as skin texture, older and younger adults' ability to match one of two faces with a previously viewed face did not differ. However, older adults were less able to match faces which were presented at different viewing angles than younger adults (Habak, Wilkinson & Wilson, 2008). Older adults have been reported to be poorer at discriminating whether faces are identical or different when the face pairs presented were morphed to the same or a different extent (Lee, Smith, Grady, Hoang & Moscovitch, 2014). Younger adults have also demonstrated superiority in the recognition of upright and inverted faces compared with older adults, although no age group differences were revealed for object recognition (Boutet & Faubert, 2006). This potentially indicates age related changes to cortical structures specialized for processing facial identity, but not objects.

As was detailed in Section 1.3, three core regions have been noted to process faces; the occipital face area (OFA), superior temporal sulcus (STS) and fusiform face area (FFA) of the fusiform gyrus. Of these three regions the FFA is considered to be important for processing invariant facial characteristics which are necessary for face recognition. One way researchers have assessed this is through functional magnetic resonance image adaptation (fMRA), which is a phenomenon characterized by reduced blood-oxygen-level dependent (BOLD) responses to repeated stimuli. Using fMRA Andrews and Ewbank (2004) noted a reduction in activity (adaptation) in the FFA for repeated images of the same face, but this reduction was not apparent in the OFA or STS. As viewing the same face resulted in adaptation reduction only in the FFA, their study revealed this area to be particularly important when processing face identity. The STS increased in adaptation when the same face was presented with different emotional expressions and head/gaze directions indicating that the FFA dominates for processing identity whereas the STS dominates for processing emotional expressions and gaze direction supporting previous research (Hasselmo, Rolls, Baylis & Nalwa, 1989; Perrett & Mistlin, 1990).

Recently, an fMRI face and object matching study found that while younger adults showed activity in the core face processing regions when matching faces, these same regions were activated by faces and objects in the older adults (Burianová, Lee, Grady & Moscovitch, 2013). So a reduction in neural specificity to faces was demonstrated by the older group. Additionally, while the younger group showed activity in the right and left fusiform gyrus (FG) for the face task, the older group's functional connectivity was not between the right and left FG, but between the right FG and the left orbitofrontal cortex. Consequently, compensatory processing in older adulthood may not rely on greater activity in bilateral homologous structures, but instead on activity in other, more frontal regions.

The impact of ageing on identity matching has also been investigated by presenting the same synthetic faces used by Habak et al. (2008) to assess behavioural and adaptation differences for older and younger adults (Lee, Grady, Habak, Wilson & Moscovitch, 2011). Their in-scanner task required participants to detect a change in the size of a face while identity and/or viewpoint were manipulated and activity was measured in the left and right FFA and OFA. An additional out of scanner task required participants to decide whether a face presented on screen matched a previously presented face and again identity and/or viewpoint were manipulated. In the right FFA, the fMRA analysis showed that when the same identity was repeatedly presented in the same viewpoint younger adults had the most adaptation but older adults failed to show any adaptation. Despite this difference older adults had 97% accuracy when matching faces of the same viewpoint which indicates that other cortical regions compensate the FFA during face matching. These authors also assessed whole brain activity and found that older adults activated more regions in the LH than younger adults and that these same regions were activated to a greater extent by faster older adults. Interestingly, the opposite activation pattern was revealed for younger adults as slower performance was associated with activation in these LH regions. Consequently, the right FFA appears to be a key region for processing identity in younger adulthood; however more bilateral processing benefits face matching performance in older adulthood.

Right hemisphere dominance in face processing has been linked to a contralateral bias to base facial judgements and generate more eye movements to the left side of a face when judging gender (e.g. Butler et al., 2005). As has been detailed above, a reduction in RH dominance has been revealed in older compared with younger adults during face matching tasks (Lee et al., 2011), however, no tasks have assessed whether this is reflected in a reduction of leftward biases of perception and eye movements when face matching. The aims of this experiment were to investigate lateral differences in older and younger adults' face matching judgements, eye movements and reaction times using the 'two-in-ten' paradigm. It was anticipated that the RH dominance for this task in younger adulthood would be reflected in greater face matching accuracy for the left compared with the right target face, that an eye movement bias to the left target face would also be evident for the younger group, and that younger adults' RT would also be faster to the left target face. A reduction in leftward biases for accuracy, eye movements and RT was anticipated for the older group.

4.3 Method

Participants

A convenience sample of 30 older adults aged between 60 and 78 (15 male, 15 female; mean age = 65.70, *SD* = 4.32) and 30 younger adults aged between 18 and 30 (8 male, 22 female; mean age = 23.10, *SD* = 3.18) took part in this experiment. Participants received course credit, £5 expenses or a £10 High Street gift voucher in return for taking part. Laterality quotient as assessed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed group differences with older adults having significantly higher right laterality (M = 94.00, SD = 10.68) than younger adults (M = 83.13, SD = 16.97, $t(58)$ = -2.97, p = .004, r = .36). National Adult Reading Test (NART: Nelson, 1982) scores also showed significant differences between the groups with older adults scoring higher (M = 38.80, SD = 6.07) than younger adults (M = 28.80, SD = 6.58, $t(58)$ = -6.12, p < .001, r = .63). No significant group differences were revealed for years spent in full time education (older M = 15.23, SD = 10.85, younger M = 17.33, SD = 2.52), $t(58)$ = 1.03, p = .306, r = .13).

Stimuli and Task

The faces used for generating the stimuli for this study were previously used by Megreya and Havard (2011) and consisted of black and white photographs of male faces holding neutral expressions and looking directly towards the camera. Due to the previous use of these images a pilot of them was not necessary. A total of eighty stimuli were used, each of which comprised two different faces positioned to the top left and top right side of the screen (one target face and a foil face) with a line-up of ten different faces positioned underneath. Forty stimuli were used for the target present condition in which twenty left target faces and twenty right target faces were also present in the line-up below. Forty stimuli were used for the target absent condition in which neither of the top two faces was present in the line-up. The task required participants to determine which, if either, of the top two faces was also present in the line-up below. Each target face and its matching line-up face were photographs of the same person taken at different times of the same day, rather than being two identical photographs to enable facial identity rather than image matching.

The target, foil and line-up faces were scaled using GIMP software to ensure their sizes were standardised across images and trials. A grid was then created to enable the position of the top two faces and the line-up below to remain constant across trials. The grid was used as guidance and was not visible on the finished stimuli. Consistent with Megreya and Havard (2011) the target and foil faces were separated by 9°, and were 4.5° to the left/right of screen centre. The far left and far right faces in the line-up were also separated by 9° and line-up faces were positioned equidistance apart. Each target and foil face was approximately 3° x 4° and each line up face approximately 2° x 3° visual angle. In the target present condition each target face was only presented once. Target faces were positioned to the top left twenty times and to the top right twenty times, a foil was positioned on the opposite side of the screen.

Each target face matched a corresponding face in each of the ten line-up positions an equal number of times. The target absent condition was created by reversing the position of the target and foil face and by replacing the matching line-up face with a non-matching identity (see Figure 4.1 for example stimuli).

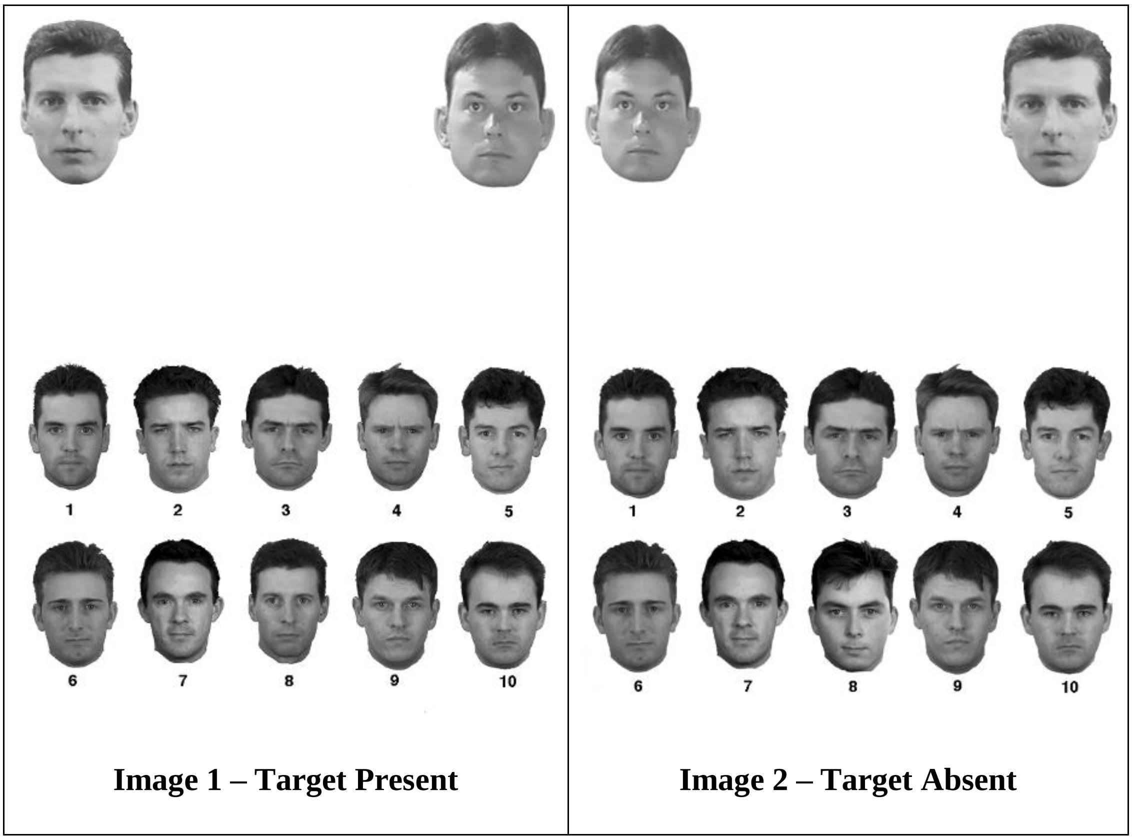

Figure 4.1. Example stimuli for target present and target absent conditions. Image 1 shows the left target face present at location 8 in the line-up, in Image 2 the top two faces have been counterbalanced and no matching face is in the line-up.

Procedure

To prepare participants for the task, they were shown an illustration which acted as an example stimulus while the task was explained to them. Participants were informed that they would be required to inspect each image and to judge whether either of the top two target faces was also present in the line-up below. It was explicitly stated to participants that the target face and its matching line-up face would not be identical photographs as the two photographs that were taken of the same person at different times of the day. Consequently, each participant was aware that when the target was present there would be slight differences between the target face and its corresponding line-up face. Participants were also informed that the target was present in the line-up in 50% of the trials and was absent in 50% of the trials. They were also made aware that the stimulus presentation order was randomised.

The experiment started following calibration and validation procedures (see Section 2.8). Each trial commenced with a central fixation circle (0.3°) to correct for drift due to head movements. Participants conducted eighty trials, broken down into four blocks of twenty trials. In every trial the stimulus remained on screen until the participant pressed a response key which stopped eye movements being recorded. Verbal responses were then given by participants. They stated "absent" if they believed the target was absent from the line-up. If a face was identified in the line-up, the position of the target face followed by its location in the line-up was given, for example "left present at number 8". Participants then pressed a different response key to commence the following trial. The experiment took approximately 1 hour to complete.

Data Analysis

The following analysis investigated the impact of age (older vs younger adults) and target face side (left vs right) on accuracy, eye movements and RT. The perceptual measures of accuracy for the target present condition were hits (correct responses), misses (wrongly stating that the target was absent) and misidentifications (matching a wrong face). In the target absent condition if participants reported a match this was classified as a false positive.

The eye movement analyses set out to investigate eye movement patterns during this face-matching task and to examine the association between lateral face matching accuracy and eye movement behaviours. As no lateral judgements were provided by miss responses the relationship between perception and eye movements could not be investigated on these trials. Perceptual judgements were provided for misidentifications and false positives; however, overall only 6% and 17% of these judgements respectively were made by the younger group and therefore, further analysis of these measures was not conducted. Consequently, the following analysis focussed on hits as all participants provided judgements to both the left and right target face and so it enables the association between eye movements and perceptual judgements to be examined. The eye movement measurements for hits were proportion of initial saccades to the left target face, proportion of fixations to the left target face and duration of fixations to each target face (see Section 2.3 for details).

The RT analysis was also investigated for correct responses (hits). Response times were computed from the time each stimulus was presented until a correct response was given and the mean RT for each participant was then calculated.

Eye movement analysis procedures. As this study aimed to investigate attentional biases to the left and right during facial analysis, pre-defined rectangular regions of interest (ROI) measuring 203 pixels x 247 pixels were created around the left and right target and foil faces. Only fixations within and first saccades to these ROI were analysed.

To ensure that the position of the top two faces did not create biases in attention or response, the left/right position of these faces for the target present and target absent condition was counterbalanced between participants. Additionally, although Figure 4.1 shows the line-up numbered from left to right as 1-5 and 6-10, some literature has suggested that the leftward bias found during face processing is partly due to the left-right scanning style habituated in Western Society (e.g., Vaid & Singh 1989). Therefore the line-up numbering from right to left (5-1 and 10-6) was also counterbalanced across participants.

4.4 Results

Eye Movement Errors

The procedures detailed in Section 2.9 resulted in 4.96% of trials being removed from the following analysis.

Face Matching Accuracy

It should be noted that as has been previously detailed (Burton, 2013) participants find this task somewhat challenging and therefore errors were anticipated. As per previous research (e.g. Megreya & Burton, 2006a) the target present and target absent conditions were analysed separately. The mean (%) of hits, misses and misidentifications for both age groups in the target present condition is illustrated in Table 4.1. False positive responses in the target absent condition are detailed in Table 4.2.

Table 4.1.

Mean Accuracy (%) for the Target Present Condition Overall and Separately for Left and Right Faces.

	Younger					
	Overall		Left Face		Right Face	
	M	*SD*	*M*	*SD*	*M*	*SD*
Hits	.62	.16	.59	.18	.64	.17
Misses	.32	.15	.34	.17	.30	.17
Misidentifications	.06	.06	.07	.09	.06	.07
	Older					
	Overall		Left Face		Right Face	
	M	*SD*	*M*	*SD*	*M*	*SD*
Hits	.54	.15	.53	.18	.56	.17
Misses	.25	.13	.26	.17	.24	.15
Misidentifications	.21	.18	.21	.19	.20	.19

To calculate whether the groups' accuracy was above the level of chance, one sample *t*-tests were conducted against .5 for their hits overall and separately for the left and right target faces. The older adults' hits overall did not differ significantly from chance ($t(29) = 1.645$, $p = .111$, $r = .29$), whereas younger adults' hit rate was significantly above the level of chance ($t(29) = 4.12$, $p < .001$, $r = .69$). The results from one-sample *t*-tests against .5 revealed that younger adults performed significantly above the level of chance for hits when matching both the left ($t(29) = 2.74$, $p = .010$, $r = .45$) and right ($t(29) = 4.52$, $p < .001$, $r = .64$) target faces. Older adults, however, were less accurate; performing at chance level when matching the left target face ($t(29) = .81$, $p = .426$, $r = .15$) and the right target face ($t(29) = 1.95$, $p = .062$, $r = .12$).

Table 4.2.

False Positive Responses (%) for the Target Absent Condition Overall and Separately for Left and Right Faces.

	False Positives					
	Overall		Left Face		Right Face	
	M	*SD*	*M*	*SD*	*M*	*SD*
Younger	.17	.10	.22	.17	.14	.11
Older	.39	.30	.42	.29	.39	.30

To determine the impact of age and target face side on accuracy, mixed ANOVAs were conducted separately for the proportion of hits, misses, misidentifications and false positives (See Table 4.3). Following calculations to determine skew (z score of skew/SE) a positive skew was revealed for younger and older adults' scores when misidentifying both the left and right faces and a positive skew was also revealed for younger adult's false positive scores on the left target face. A log transformation removed the skew from the older adults' misidentification scores for both the left and right faces and the skew was reduced in all other conditions. The transformed data were then used for these analyses.

Table 4.3.

Results from Mixed Analysis of Variance (Age x Target Side) Results for Face Matching Accuracy.

	Hits				Misses				Misidentifications				False Positives			
	F	df	*p*	η_p^2	*F*	df	*p*	η_p^2	*F*	df	*p*	η_p^2	*F*	df	*p*	η_p^2
Age	3.60	1,58	.063	.06	3.79	1,58	.056	.06	17.30	1,58	<.001	.55	13.83	1,58	<.001	.19
Side	3.97	1,58	.051	.06	2.27	1,58	.138	.04	.83	1,58	.366	.01	10.75	1,58	.002	.16
Age * Side	.14	1,58	.706	.002	.19	1,58	.664	.003	.01	1,58	.943	<.001	2.15	1,58	.148	.04

Hits. As is detailed in Table 4.3, for hits the main effect of age was non-significant (p = .063). The main effect of target side approached significance (p = .051) such that when the target was positioned on the right side it was matched more accurately than when positioned on the left, however, the interaction was non-significant (p = .706).

Misses. The main effect of age approached the level of significance (p = .056) when the target was missed in the line-up, with younger adults missing more faces than older adults. However, no significant main effect of target position (p = .138) was revealed, consequently the position of the target face did not impact on the number of line-up faces missed and the interaction was also non-significant (p = .664).

Misidentifications. When the incorrect line-up face was selected (misidentification) the main effect of age was significant (p < .001) with older adults selecting the wrong face from the line-up more frequently than younger adults. However, both the target face position and the interaction were non-significant (p = .366 and p = .943 respectively).

False positives. When no matching face was in the line-up age had a significant effect (p < .001) with older adults making the most false positive errors. The side the target face was presented on also significantly impacted on false positive errors (p = .002), with the left target face being mismatched with a line-up face more frequently than the right target face, however, no significant interaction was revealed (p = .148).

Consequently, while no significant age group differences were revealed for hits or misses, older adults made significantly more face matching errors by performing more misidentifications and false positives than the younger group. A leftward bias for hits was also not revealed.

Initial Saccades

The proportion of initial saccades to the left target face (corresponds inversely for the right target face) was calculated as described in Section 2.3. One-sample *t* statistics against .5 (chance) were conducted for hits overall and for separately for hits to the left and right target faces (see Table 4.4).

A significant overall bias to generate initial saccades to the left was revealed for the older and younger adults ($t(29) = 8.07$, $p < .001$, $r = .83$ and $t(29) = 9.53$, $p < .001$, $r = .87$) but an independent *t*-test revealed no difference in strength of leftward bias between these two groups ($t(58) = -.95$, $p = .345$, $r = .12$).

Table 4.4.

Mean Proportion (SD) of Left Initial Saccades for Hits Overall and Separately for Hits to the Left and Right Target Faces. Conducted Through One-Sample t-tests Against Chance (.5).

	Initial Saccades					
Group	Overall		Left Face Hit		Right Face Hit	
Younger	.84***	(.20)	.82**	(.24)	.86***	(.24)
Older	.79***	(.20)	.78***	(.24)	.80***	(.19)

****p < .001, **p < .01*

When hits were made from the left target face a significant left bias for initial saccades was demonstrated by younger ($t(29) = 7.43$, $p < .001$, $r = .81$) and older adults ($t(29) = 6.22$, $p < .001$, $r = .76$). A significant left bias for initial saccades was also revealed for younger and older adults when their hit was based on the right target face ($t(29) = 11.39$, $p < .001$, $r = .90$ vs $t(29) = 8.85$, $p < .001$, $r = .85$). A mixed (Age x Hit Side) ANOVA revealed no significant main effect of age ($F(1,58) = 1.07$, $p = .304$, $\eta_p^2 = .02$), no significant main effect of hit side ($F(1,58) = 1.80$, $p = .185$, $\eta_p^2 = .03$) and the interaction was also non-significant $F(1,58) = .12$, $p = .730$, $\eta_p^2 = .002$). Consequently, a similar proportion of initial saccades was generated to the left target face when the hit was based on the left or right target face and age did not impact on this.

The initial bias to saccade leftwards when first analysing faces is well documented (e.g. Leonards & Scott-Samuel, 2005) even when subsequent judgements are based on the right side (Butler et al., 2005), and consequently it was anticipated that participants would generate their first eye movements to the left in this current study. What is less clear is whether this initial eye movement response would also be accompanied by a bias for further eye movements to be made to the left compared with the right target face for either age group; or alternatively whether the trend for greater accuracy to the right target faces illustrated in Table 4.1 would be reflected in proportionally more fixations and longer fixation durations being biased to the right target face.

It has previously been noted that during face processing, when judgements are based on the left side this is accompanied by an eye movement bias (proportionally more fixations and fixations of longer duration) also to the left side;

whereas when decisions are based on the right side no accompanying right eye movement bias is revealed (Butler et al., 2005). However, the impact of age on the LGB has not yet been examined when faces are matched. The following analysis therefore investigated whether accurate responses to each target face side were accompanied by an eye movement bias and to what extent, if any, age had on this.

Proportion of Fixations

As detailed in Section 2.3 the proportion of fixations to the left face (corresponds inversely for right faces) was calculated. Both age groups generated a similar proportion of fixations to the left target face (See Table 4.5). One-sample *t*-tests against .5 (chance) revealed this leftward bias to be significant overall for both groups ($t(29) = 52.81$, $p < .001$, $r = .99$ younger and $t(29) = 60.19$, $p < .001$, $r = .99$ older). An independent *t*-test revealed no differences in strength of bias between groups ($t(58) = .64$, $p = .522$ $r = .08$).

When the hit was made to the left target face both groups made 91% of their fixations to the left target face. One-sample *t*-tests against .5 (chance) revealed this to be significantly above the level of chance for the younger ($t(29) = 64.95$, $p < .001$ $r = .99$) and older adults ($t(29) = 73.70$, $p < .001$ $r = 99$). When the hit was made to the right target face 79% of both groups' fixations were still generated to the left target face (see Table 4.5) which, as calculated through one-sample *t*-tests against .5 (chance), was significantly above the level of chance for the younger ($t(29) = 32.14$, $p < .001$, $r = 99$) and older adults ($t(29) = 40.04$, $p < .001$, $r = .99$). Therefore, the majority of fixations were made to the target face on the left irrespective of the side used for an accurate match.

Table 4.5.

Means (SD) for the Proportion of Leftward Fixations When Making a Hit Response to Target Faces Overall and Separately for Each Target Face Side. Conducted Through One-Sample t-tests Against Chance (.5).

	Proportion of fixations		
	Overall	Left Target Face	Right Target Face
Younger adults	.85*** (.03)	.91*** (.03)	.79*** (.05)
Older adults	.84*** (.04)	.91*** (.03)	.79*** (.04)

****p < .001*

A mixed (Age x Hit Side) ANOVA revealed the main effect of hit side to be significant with hits to the left target face receiving more fixations than hits to the right target face (M = .91, SE = .01 and M = .79, SE = .01, $F(1,58) = 437.58$, $p <$ .001, $\eta_p^2 = .88$). No significant main effects of age (F (1,58) = .45, p = .505, η_p^2 = .01) or interaction ($F(1,58) = .01$, $p < .914$, $\eta_p^2 < .001$) were revealed.

Duration of Fixations

The mean duration of fixations (ms) to the left and right target faces was calculated for each participant overall (i.e. not based on the side of their response) in every trial (see Table 4.6) and also according to the side used for their response (Table 4.7)

Table 4.6.

Means (SD) for the Fixation Duration (ms) Overall for Left and Right Target Faces.

	Fixation Duration Overall	
	Left Face	Right Face
Younger	2339 (1242)	1918 (1058)
Older	3233 (1666)	2585 (1339)

This data contained 3 outliers which were replaced by the mean plus 2 *SD* (Field, 2009). A positive skew was also revealed in all but the following two conditions; older adults' fixation duration to the left target face with a left response and older adults' fixation duration to the left target face with a right response. The data were normalized using square root transformations.

Table 4.7.

Mean (SD) Fixation Duration (ms) to Left and Right Target Faces According to Side Used for Hit Response.

	Duration of Fixations			
	Left Target Face Hit		Right Target Face Hit	
	Left Face	Right Face	Left Face	Right Face
Younger	3004	1193	1692	2588
	(1735)	(760)	(944)	(1472)
Older	4146	1571	2308	3547
	(1931)	(866)	(1276)	(1746)

To determine whether fixation duration was affected by age, side used for hit or target face side a mixed 2 x 2 x 2 ANOVA was conducted. A significant main effect of age was revealed (F(1,58) = 6.44, p = .014, η_p^2 = .10) with older adults having a significantly longer mean fixation duration than younger adults (M = 2893, SE = 227 and M = 2119, SE = 227). Additionally a significant main effect of target face side was revealed (F(1,58) = 4.50, p = .038 η_p^2 = .07) with the left target face receiving a longer fixation duration than the right face (M = 2786, SE = 632 and M = 2251, SE = 198) and a significant main effect of hit side was also revealed (F(1,58) = 50.83, p < .001, η_p^2 = .47) with hits to the right target face having a significantly longer mean fixation duration than hits to the left target face (M = 2534, SE = 166 and M = 2478, SE = 161) which were qualified by a significant target face side x hit side interaction ($F(1,58) = 365.57$, $p < .001$, $\eta_p^2 = .86$). Post hoc analysis calculated using Tukey HSD by hand ($T = q_k\ (MSerror/n)$) revealed that fixation duration to the left target face was significantly greater when the response was based on the left rather than the right target face (left; M = 3575, SE = 236, right; M = 2000, SE = 144, $p < .01$) and fixation duration to the right target face was significantly greater when the response was based on the right rather than the left target face (right; M = 3067, SE = 208, left; M = 1382, SE = 105, $p < .01$) see Figure 4.2. Consequently, the target face used for a hit response received a significantly longer mean fixation duration than the foil face and age did not impact on this.

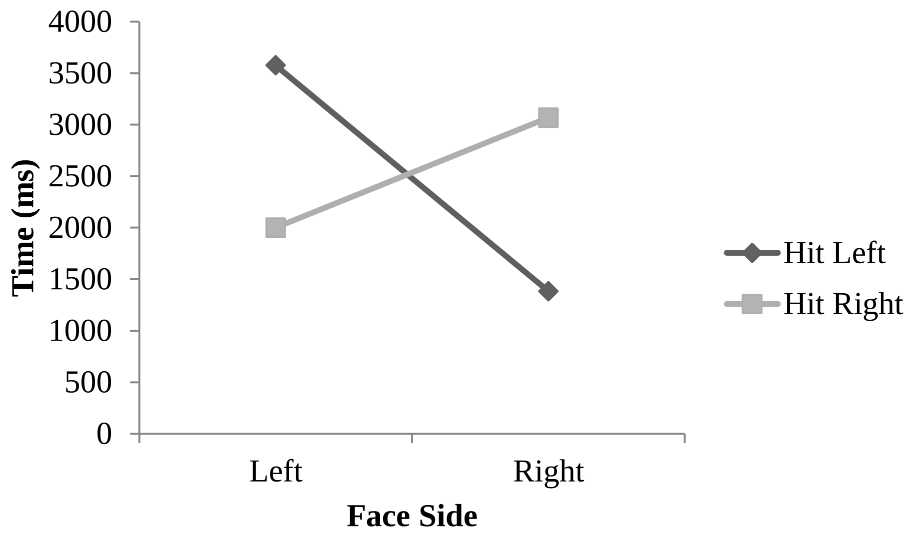

Figure 4.2. Target face side x hit side interaction for fixation duration.

Response Times

Response times (s) were then assessed for correctly matched faces to determine the impact of age and target face side (see Table 4.8). One outlier was revealed in the data of the younger adults, this was substituted for 2 x *SD* + mean and a positive skew (2.82) was normalised through log transformation. A mixed (Age x Side) ANOVA revealed a main effect of age with the younger group having a significantly faster RT than older adults (M = 13.80, SD = 6.78 and M = 20.06, SD = 8.47, $F(1,58) = 12.76$, $p = .001$, $\eta_p^2 = .18$). A significant main effect of target face side was also found with the left target face being matched with a line-up face more quickly than the right target face (M = 16.32, SD = 7.11 and M = 17.54, SD = 8.14, $F(1,58) = 4.70$, $p = .034$, $\eta_p^2 = .08$). No significant interaction was revealed ($F(1,58) = .07$, $p = .789$ $\eta_p^2 =.001$).

Table 4.8.

Mean Reaction Times (s) for Hits Overall and Separately For Left and Right Target Faces.

	Reaction Times		
	Overall	Left Target Face	Right Target Face
Younger adults	13.69 (5.73)	13.26 (6.38)	14.33 (7.18)
Older adults	19.95 (8.45)	19.37 (7.84)	20.76 (9.10)

4.5 Discussion

The aims of this study were to determine differences in older and younger adults' lateralization of accuracy, eye movements and RT when matching one of two target faces with a face in a ten face line-up. The results showed that overall, when the target was present in the line-up younger and older adults had a hit rate of 62% and 54%, similar to the 58% accuracy reported by Megreya & Burton (2006a) using this same task with younger adults as participants. This reflects observations of the two-in-ten task being challenging and prone to error (Burton, 2013), which was particularly noticeable for the older adults in this current experiment. Indeed, the hit rate of older adults was not significantly different from chance. The older adults also made a larger number of misidentifications and false positive responses compared with the younger group which not only highlights their difficulty in face matching using this task, but also provides support for previous studies which note a higher number of false alarms made by older compared with younger adults (Boutet & Faubert, 2006; see a review in Searcy et al., 1999).

Previous research has indicated that poorer face matching in older adults can be attributed to memory demands when presentation of the target and foil faces precedes the line-up faces (Bindemann et al., 2012). This current experiment presented all the faces at the same time in order to remove the memory component and as such differences in face matching accuracy are not due to memory load. Perceptual interference has also been noted to impact on face matching accuracy (Megreya & Burton, 2006a), however, as per Megreya and Havard (2011) the target and foil faces were separated by 9cm to avoid this. It is therefore unlikely that the spacing of the target and foil faces in this current experiment would have affected older adults' performance.

Potentially, the older group's difficulties in correctly matching faces may be due to the type of image used. Harris et al. (2014) found that when photographs of faces were subjected to contrast reversal (and so appeared as a negative of a photograph), judgements of identity were more difficult. The authors suggest that this is due to the removal of textural information which is important for identity judgements. Habak et al.'s (2008) research extends these findings as they found that by removing all texture and reducing facial information to just shape and geometry, younger and older adults' identity judgements did not differ. Consequently, the additional, finer level of facial detail such as skin texture and hair may have benefitted younger adults' performance more than older adults during this face matching task.

The number of comparisons required to match one of two potential targets in order to make an identification decision has also previously been noted to impact adversely on accuracy in younger adults (Bindemann et al., 2012), and this effect could be further exaggerated in an older cohort. Based on Bindemann and colleagues' work, reducing the number of faces in the line-up from ten to five improves accuracy in younger adults and logic suggests this would improve accuracy for older adults too. Further research could be conducted to investigate this.

An alternative suggestion for older adults' increased false identifications relates to perceptions of familiarity in unfamiliar faces (Bartlett, Strater & Fulton, 1991). Lee et al. (2011) found that older adults' neural responses in the FFA were equally active for same face and different face repetitions. As no adaptation was evident for face repetition in the older compared with the younger group this indicates that neural responses to different identities are less active in older adults. Further evidence for this effect comes from Goh, Suzuki and Park (2010). They found that when older and younger adults judged face pairs presented serially which were identical, adapted to be moderately similar through the use of morphing (40% morph difference), or different, older adults showed adaptation in the FFA to both identical and moderate faces. Younger adults in contrast showed adaptation to identical faces but only minimal adaptation to the moderate faces. Consequently, older adults' neural responses react similarly to faces which are identical as well as to faces which are similar but non-identical, offering an insight into why the older adults in this current experiment made more false positives and misidentifications compared with younger adults.

The results of this experiment did reveal a non-significant trend for the side of target face with more right than left target faces being accurately identified with their line-up face (p = .051). This was unexpected as participants have previously been found to match the left target face more accurately than the right using this task (Megreya & Burton, 2006a; Megreya & Havard, 2011). This previously documented leftward bias for accuracy in face perception is thought to reflect a RH dominance for face processing (Kanwisher et al., 1997; McCarthy et al., 1997; Pitcher et al., 2011) as well as habituated directional scanning (Megreya & Havard, 2011). From these current results there is no evidence that reading direction impacts on greater accuracy for the left target faces as all participants were native English readers (left-right) yet a trend for an accuracy bias was found for the right target face.

The reason for this trend for a rightward bias, and a lack of a significant leftward bias for hits in this current experiment is unclear. A potential reason is that although it has previously been reported that an LPB is demonstrated when facial identity is processed, the strength of this bias is not particularly large. For example, using left/left and right/right composite faces Coolican et al. (2008) asked participants to judge which image was most like the original face. With -1 indicating the maximum LPB and +1 the maximum right perceptual bias, their younger adults' mean of -.06 revealed a small, though significant LPB, whereas the older adults' mean response of -.02 did not demonstrate any significant lateral bias.

A similar pattern is demonstrated in other identity studies (e.g. Mattingley et al., 1993) and may suggest that the FFA, a region documented as being pivotal for face recognition (Andrews & Ewbank, 2004) invests more bilateral activation during identity judgements. Additionally, as was detailed in study 1, 25% of participants had a bias to the right when judging gender from faces. If judging identity is processed more bilaterally than gender, then laterality variances within the cohort recruited may be responsible for the rightward bias tendency in accuracy for this current experiment.

A different line of argument to this has been offered by Megreya and Burton (2006b) who suggest in the title of their article that "unfamiliar faces are not faces" because, as Burton (2013) interprets, when unfamiliar faces are assessed for identity purposes, they are processed more like patterns than faces. The reason Megreya and Burton came to this conclusion was the high correlation between matching inverted familiar faces with upright unfamiliar faces in their study. Potentially, the FFA along with other, non-face specific cortical structures may be required when matching identities and this should be investigated further.

The results also revealed that more false positives were made from the left compared with the right target face. In Goh et al.'s (2010) study, a significant positive correlation was revealed between greater adaptation in the right (but not left) FFA and higher discrimination thresholds. As greater differences between faces were reflected in higher adaptation (associated with novelty) unilaterally in the right FFA it is conceivable that more subtle facial differences would be reflected in lower adaptation of the right FFA, and face matching from the left target face would be particularly challenging.

Lateralization of eye movements was also analysed during this experiment, firstly to determine whether there is an association between side of accuracy and a bias in eye movements, and secondly to investigate the impact of age and target side on eye movements during face matching. Overall, (matches based on the left and right target faces were collapsed) a bias was revealed to the left target face for both age groups with their initial saccades, proportion of leftward fixations and duration of fixations with no differences for strength of bias according to age

To determine whether accurate face matching judgements are associated with a greater number or duration of eye movements, hits to the left and right target faces were analysed separately. It was found that a greater number of initial saccades were generated to the left target face than the right target face by both age groups, even when the right target face was subsequently used for a hit. This appears to support Leonards and Scott-Samuel's (2005) assertion that initial leftward saccades are a reflexive behavioural response when faces are viewed and corroborates other research showing a persistent left bias for these first eye movements irrespective of whether subsequent facial judgements are based on the left or right side (Butler et al., 2005). It was anticipated that no age group differences would be revealed for initial saccade direction overall or based on the side of hit. This eye movement is generated before a judgement is made and although hemispheric processing may differ between the two age groups (Cabeza, 2002; Park & Reuter-Lorenz, 2009) the combined effects of RH dominance and entrenched directional scanning appear to be reflected in a leftward bias for both age groups.

A similar pattern was revealed overall for proportion of fixations to the left versus right target face. Proportionally more fixations were generated to the left rather than the right target face by both age groups and when separated according to the side used for a hit, both groups continued to generate proportionally more fixations to the left rather than the right target face, even when the hit was made from the right target face supporting previous face processing research (Butler et al., 2005). However, no effect of age was demonstrated.

With regard to fixation duration, overall older adults had a longer fixation duration than younger adults and their RT was slower too which indicates that they required longer to fixate on the target and line-up faces in order to complete the task. These findings support previous research showing an effect of age on RT during face processing (Hildebrandt et al., 2013; Hildebrandt et al., 2011) and also show that the slower RT of the older group is due to them having longer – but not proportionally more – fixations that the younger group.

For both age groups the left target face received longer fixations than the right target face, despite the RT for the left target face being faster than the right.

This indicates that both age groups adopted a strategy of assessing and matching the left target face prior to the right target face when conducting this task. However, when the left target face was used for a hit it was fixated on for longer than the right face, and when the right target face was used for a hit it was fixated for longer the left face. This contrasts with Butler et al.'s (2005) gender study as they found that longer fixations were generated to the left side with a left response but not to the right side with a right response. In Butler et al.'s study, however, there was no right or wrong answer just a perception of gender from a chimeric image was required. In this current study participants were aware that an accurate match could be made in 50% of trials and therefore different viewing strategies may have been adopted for this compared with Butler and colleagues' task. Specifically, participants in this study appear to have dwelled for longer on the face used for a hit, potentially as a way to make sure that the correct target face was matched with its line-up face.

When assessing the link between lateral judgement biases and eye movement biases it is clear from these results that the rightward bias for accuracy was not reflected in the same lateral bias for eye movements. Instead, the opposite leftward bias was demonstrated for all the eye movements examined which indicates no relationship between perception and eye movements when matching faces, contrasting with Butler et al.'s, (2005) findings but supporting other research (Grega et al., 1988; Samson et al., 2014). Possibly the leftward eye movement bias for both age groups when conducting this task is an artefact of directional scanning and this appears to be supported by the RT data as the left target face was matched more quickly than the right by both groups. It would also help explain why the anticipated reduction in lateralized eye movements for older adults was not evident as the left-right directional scanning would be further habituated in this older group. In order to determine whether the left eye movement biases revealed in this study are indicative of behavioural responses for identity judgements, it may be useful to re-run this task with some modifications. For example, by using a one-in-ten task, where the target face is presented an equal number of times to the left and right side, comparisons of eye movements across trials might give a better indication of lateral eye movement biases without the potential confound of participants using directional scanning when assessing two target faces.

In summary the results of this experiment show that during a 2-in-10 face matching task hits were not lateralized to the left but eye movements were lateralized to the left. Age did not impact on either the lateralized bias for hits or eye movements which may suggest either that processing in face specific regions remains intact in older age, or that compensatory structures are recruited from the ipsi- rather than contra-lateral hemisphere. A faster RT was demonstrated for the left target face than the right which, in combination with the leftward eye movement biases appears to suggest that directional scanning is playing a key role for participants conducting this task.

Chapter 5

Investigating Older and Younger Adults' Eye movements and Perceptual Biases During a Lip-Reading Task

5.1 Abstract

Research has revealed that lip-reading judgements are based on the right side of the face which is thought to reflect the LH dominance for lip-reading. Judgements of line length are based on the left side, considered to reflect RH dominance. This unilateral dominance is noted to reduce in older adults as compensatory recruitment of structures in the non-dominant hemisphere are also required for efficient processing. Some face processing studies also suggest an association between the side of the face used for judgements and a bias to generate more eye movements to the same side, and theories of ageing predict that such lateral biases reduce in older adulthood. For RH tasks study 1 revealed an association between eye movements and judgements of gender. However, study 2 showed better accuracy to the right target face, but a bias for eye movements to the left target face, possibly resultant of directional scanning, and neither of these studies revealed an impact of age. To directly investigate the effect of age on LH and RH dominant tasks this study compared response biases of older and younger adults who judged lip-reading and line bisection. It also investigated, for the first time, whether lateral biases of perception and eye movements are associated in LH dominant tasks such as lip-reading, and whether age impacts on any such lateral biases. In this current study the eye movements of older and younger adults were tracked while they judged the letter being mouthed in a chimeric face paradigm in three time conditions. Poor accuracy for the single letter images resulted in only two chimeric letter combinations (E-L and L-E, out of a

possible 6 which also included F-M, M-F, O-U and U-O) being used for response analysis. The results of the lip- reading task revealed that across three time conditions a right perceptual bias was demonstrated for the E-L images and a LPB for the L-E images, consequently judgements were based on the side with the letter L. Participants also completed the Landmark task to determine whether their perceptual biases were face specific or reflected a more general bias when perceiving space. This task did not reveal any significant perceptual biases which may be due to differences in group size, and no significant correlations between responses on the Landmark task and the E-L and L-E faces were found. The eye movement analysis revealed no consistent lateral bias for initial saccades. Proportionally more fixations were made to the left side at 500ms and this bias reduced systematically with each increase in viewing time for all but the M-F chimeric images. Lateral biases for fixation duration differed according to the chimeric image shown. No reduction in eye movement or perceptual lateralisation was revealed for age, and potential reasons for this are discussed.

5.2 Introduction

As Broca (1861; 1865) and Wernicke (1874) established over a century ago through their clinical-pathological observations, language is lateralized to the LH in right handed people. These early findings have been consistently supported in subsequent work using the Wada test (Wada & Rasmussen, 1960) which was commonly used prior to the advent of scanning technology.

The Wada test involved injecting short-acting anaesthetic into the left or right carotid artery to anaesthetise the ipsilateral hemisphere. A series of language tasks could then be conducted to determine the hemispheric laterality of language processing. Findings from the Wada test show a LH dominance for language processing (e.g. Möddel , Lineweaver, Schuele, Reinholz & Loddenkemper, 2009). However, due to the invasive nature of this test, more recent studies have used neuroimaging such as fMRI or magnetoencephalography (MEG) instead and the validity of these methods have been established through comparisons with Wada test results (e.g. Binder, 2011; Kadis et al., 2011; Woermann et al., 2003). Consequently, strong, converging evidence points to language being lateralized to the LH as approximately 95% of right handed healthy adults demonstrate this lateralization with no relationship between degree of right handedness and strength of LH dominance (Knecht et al., 2000; Springer et al., 1999).

Hemispheric lateralization of language has also been noted through lip-reading tasks and is evident from patients with left and right hemispheric lesions. Campbell, Landis and Regard (1986) compared the lip-reading ability of patient D, a 61 year old with a RH lesion resulting in prosopagnosia but not language difficulties, with patient T a 65 year old with a LH lesion experiencing language, but not face processing difficulties. In this study a variety of lip-reading tasks included repeating lip-spoken phonemes, differentiating between speech and non-speech mouth movements presented photographically and identifying vowels from full face and profile angles in photographs. A double dissociation was revealed as patient D performed at ceiling level for all lip-reading tasks, but was unable to perform tasks of facial identification, non-verbal expression and gender judgements and consequently demonstrated face, but not lip-reading impairments. Patient T, in contrast, had impairments in lip-reading, but did not demonstrate loss of ability in the non-speech, face processing tasks. This highlights the dominance of the LH for lip-reading and the RH for face processing.

The dominance of the LH for lip-reading is also supported through research using fMRI technology (Ruytjens, Albers, van Dijk, Wit & Willemsen, 2006). Participants viewed a dynamic image of a female actor mouthing numbers between 6 and 25 and were asked to silently repeat the numbers being mouthed. Although both hemispheres were activated by this task; the areas with the largest activity were in the LH, particularly within the left temporal-parietal-occipital region

The LH dominance for language is reflected in a bias to judge lip-reading from the right visual field (RVF). For example in Campbell, De Gelder and De Haan's (1996) study an individual face expressing a Dutch phoneme was presented centrally on screen. This was followed by a subsequent face presented briefly in either the left or right visual field and participants were asked to determine whether the phoneme expressed on the second face was the same as on the first face. Their findings revealed a strong right visual field (RVF (LH)) advantage for accuracy when lip-reading. Dynamic images of speech (without sound) also have a RVF advantage for accuracy (Smeele, Massaro, Cohen and Sitting, 1998) and research using chimeric images (Burt and Perrett, 1997) revealed that participants base their judgements of speech sounds on the right side of the face suggesting a LH dominance for lip-reading.

A RVF advantage is not always reported though. In Campbell's (1986) study participants heard a speech sound and then saw a static face expressing a speech sound in either their left or right visual field. They were tasked with determining whether the speech expressed in the face matched the sound heard. For accurate responses RT was faster for faces presented in the LVF suggesting RH dominance for this task. In a subsequent study (Baynes, Funnell & Fowler, 1994) assessing the integration of visual and auditory speech the McGurk effect was assessed (MacDonald & McGurk, 1978; McGurk & MacDonald, 1976). This effect can occur when a word presented auditorily e.g. "bat" is heard at the same time as a visually presented word such as "vet" leading to a perception of hearing "vat". Baynes and colleagues noted that the McGurk effect was stronger when the visual stimulus was presented in the LVF which suggests a RH dominance. However, both of these studies required participants to respond according to both visual and auditory language stimuli, which could have increased task difficulty, affecting lateralization of hemispheric processing.

The strength of hemispheric lateralization for language, however, has been noted to vary across the lifespan. For example an fMRI study assessed the language laterality of children (aged 7-18) in a word fluency task (Holland et al., 2001). This study found that at all ages language was lateralized to the LH, but with increased age even greater activation was revealed in the LH and this activation also became more focussed on Broca's area as age increased.

A subsequent fMRI study assessing language lateralization in participants aged 5-67 years used the same word fluency task as Holland et al. 2001 (Szaflarski, Holland, Schmithorst & Byars, 2006) and also revealed that LH laterality increased from the ages of 5-17. Additionally, however, Szarflarski and colleagues found that the strongest LH laterality for language was observed for 20-25 year olds and this laterality then continuously decreased as age increased.

A reduction in LH laterality for language in older adults has also been observed for syntactic processing (Tyler et al., 2010). In this study, a target word was presented as both a word and image on screen and participants pressed a response key when they heard the same target word spoken as part of a sentence. The data obtained from fMRI scanning revealed greater activity in the RH for the older compared with the younger adults when conducting this task which may reflect a compensatory processing strategy for the older group as the behavioural results revealed that syntactic processing did not decline with age.

A recent French fMRI study assessing the impact of ageing on semantic and phonological processing using the Wisconsin Word Sorting Task (WWST; Simard et al., 2011) also revealed that older adults showed slightly more bilateral or RH activity compared with younger adults (Martins, Simard & Monchi, 2014). Additionally, this study also revealed that neural compensation in older adults was demonstrated by the recruitment of additional language processing regions and consequently a more extensive pattern of brain activity was evident in the older compared with the younger group.

Neuroimaging studies have also noted more bilateral activity in older adulthood during naming tasks (Persson et al., 2004) and verb generation (Wierenga et al., 2008) suggesting inter-hemispheric compensation in elderly participants for these language tasks. In a recent study repetitive transcranial magnetic stimulation (rTMS) was used to disrupt neural activity to the LH and RH of the dorsolateral prefrontal cortex during a naming task (Maneni, Brambilla, Petesi, Miniussi & Cotelli, 2013). As anticipated it was found that LH asymmetry was evident for younger adults, but lower performing older adults also demonstrated this asymmetrical processing to their LH. High performing older adults, in contrast, processed bilaterally across the dorsolateral prefrontal cortex. This, and the other studies discussed provide converging evidence that successful ageing relies on the engagement of both, rather than one dominant hemisphere and support the predictions of the HAROLD (Cabeza, 2002) and STAC (Park & Reuter-Lorenz, 2009) models.

As detailed in Section 1.11, the Landmark and line bisection tasks are frequently used to assess the impact of injury and individual differences, such as age, on perceptual biases to the left and right sides. In the Landmark task horizontal lines that are bisected through the centre are judged as being "left longer/right shorter" by younger adults revealing a LPB (RH), a bias which is noted to be weaker or non-existent in older adulthood (Schmitz & Peigneux, 2011). In contrast to lip reading tasks which are LH dominant, the Landmark task is RH dominant and as such provides a useful tool to investigate age related differences in hemispheric input through assessment of lateralised biases of perception.

As Yovel et al. (2008) demonstrated, the hemisphere which dominates during processing results in perceptual judgements being biased to the contralateral visual field. Consequently, RH tasks such as gender classification result in more decisions being based on information seen in the LVF (e.g. Burt & Perrett, 1997). Eye movements have also been reported to be biased to the left side during face processing (Butler et al., 2005), potentially indicating an association between perception and visual attention; although as has been documented in studies 1 and 2 of this current research project as well as in recently published work (e.g. Samson et al., 2014), this relationship has not consistently been revealed. Longer viewing times are also noted to strengthen the LPB and this has been attributed to an increase in eye movements to the left side (Butler et al., 2005; Butler & Harvey, 2006).

A right perceptual bias (RPB) has been exposed during lip-reading by younger adults (Burt & Perrett, 1997) which is thought to reflect dominance of the LH for this task (e.g. Möddel et al., 2009) and a LPB has been revealed in the Landmark task, reflecting RH dominance. Using a within groups design this study investigated the impact of ageing on LH and RH dominant tasks. It assessed perceptual judgements of space (RH) in the Landmark task and language (LH) using a chimeric face paradigm in three viewing time conditions. It was anticipated that the younger group would demonstrate a LPB for the Landmark task and a RPB for the lip-reading task which would increase in strength as viewing time increased, and that ageing would impact on the strength of these lateral biases. No known studies have investigated lateral eye movement biases for lip-reading tasks and the effect of ageing on lateral biases of attention and perception on lip-reading has not previously been investigated either. The aims of this study, therefore, were to investigate the association between lateral eye movements and perception using a LH dominant lip-reading task and RH Landmark task to examine the impact that ageing has on these lateral biases.

5.3 Method

Participants

Sixty two right handed adults were recruited for this experiment; however the data of one older participant was removed as they did not complete the task. A further older participant's data was removed due to an equipment failure. Consequently the data of 29 older adults (15 males; mean age = 69.10, *SD* = 4.41, range = 16 – 82 years) and 31 younger adults (6 males, mean age = 20.71, *SD* = 2.66, range = 18 - 30) were analysed. Participants were given a £10 gift voucher or course credit in return for their participation.

Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed no group differences between the older (M = 94.69, SD = 10.54) and younger adults (M = 90.26, SD = 10.54), $t(58) = 1.62$, $p = .111$, $r = .04$). The Test of Premorbid Function (TOPF, Wechsler, 2009) did reveal group differences with older adults scoring higher (M = 56.17, SD = 10.53) than younger adults (M = 36.35, SD = 9.57), $t(58) = 7.25$, $p < .001$, $r = .48$). It was also revealed that the older adults had spent significantly fewer years in full time education (M = 13.07, SD = 3.09) than the younger adults (M = 16.32 years, SD = 2.44), $t(58) = -4.54$, $p < .001$, $r = .26$). All of the older group and ten younger adults (4 males and 6 females, mean age = 21, SD = 2.87, range = 18 – 26 years) conducted the Landmark task in addition to the lip-reading task.

Stimuli – Lip-Reading

The images used for the stimuli in this study were sourced from the artists' reference site 3D:SK and consisted of high definition, colour photographs of twelve different actors (6 male/6 female, with six aged between 51-70 years and six aged between 18-30 years) who were mouthing the letters O, U, F, M, L and E. Each actor mouthed one pair of letters; either O and U, F and M, or L and E, and for each letter pair, 1 older male and 1 older female along with 1 younger male and 1 younger female were used for the stimuli. A total of 48 stimuli were created: Twenty four blended images of single letters (O, U, F, M, L, and E) and twenty four chimeric images (O left/U right and U right/O left; F left/M right and M left/F right; L left/E right and E left/L right). Each letter pair (e.g. O and U) was used to create 16 images, two single letter images (O and U) and two chimeric images (O left/U right and U left/ O right) per actor with four actors per letter pair, see Figure 5.1 for examples. Appendix I details the piloting process for these images.

Creation of Symmetrical Single Letter Images

As speech movements are generally expressed more dynamically on the right side of the face than the left (Nicholls & Searle, 2006) this may potentially lead to responses and eye movements being generated to the right side too. It was therefore necessary to eliminate this potential confound by developing symmetrical faces which consisted equally of elements from the original left and right face sides. In order to achieve this each face was vertically aligned and skin imperfections such as freckles were removed using GIMP software. Then using Fantamorph software, chains of key dots were located around the mouth, nose, eyes, irises, eye-brows, hair line, face sides, jaw and neck of each face and its mirror reversed image.

By aligning each key dot on the first face with its corresponding key dot in the mirror reversed face, a third image – which blended the right and left face sides together as one whole face – was produced. To ensure that the final blended single letter images were symmetrical in shape, colour, brightness and texture across the left and right sides, the left side of each image was matched with its mirror image and joined down the mid-line (see Figure 5.1 for examples). Thirty participants were independently recruited to rate these images to ensure that the letters were clearly identifiable from the blended images, see Appendix I for details.

Creation of Chimeric Faces

Each blended single letter face was used to make two different chimeric faces. Taking single letter images F and M as examples, the chimeric faces were developed by joining the F half face on the left with the M half face on the right. The vertical mid-line join was then removed through feathering 64 pixels left/right of the mid-line to create an F-M chimeric with a seamless join. By vertically flipping the F-M chimeric face, the M-F chimeric was created and this same process was used to develop L-E, E-L, O-U and U-O chimeric images. Both the blended single letter image images and the chimeric images were then cropped to remove the ears, hair and base of chin and were scaled to 804 x 852 pixels. A mid-line guide ensured that the images were centred and guidelines were employed to ensure that eye and mouth locations remained constant across trials.

Younger Male

E | Chimeric E-L | L | Chimeric L-E

Older Female

F | Chimeric F-M | M | Chimeric M-F

Older Male

O | Chimeric O-U | U | Chimeric U-O

Figure 5.1. Examples of blended single letter and chimeric stimuli.

Procedure

The sixteen images (8 chimeric and 8 single letter) for each letter combination were shown twice resulting in thirty two trials per block. These were presented in a random sequence in each of the three time condition blocks (500ms, 1000ms and freeview) resulting in nine blocks and 288 trials per participant. The time conditions and order of the letter combinations were counterbalanced between participants. Before starting the experiment, participants were informed that some of the images had been manipulated and might look slightly unusual but that they should decide the letter each face looked most like it was saying. Following calibration and validation procedures at the start of each trial block, on-screen instructions were presented for 3000ms. Instructions, for example “Please press the button then tell me if the face is saying F or M”, acted as a reminder of the letter combination to be viewed.

A central fixation point with a diameter of .3° was then displayed and when fixation was stable the trial commenced. Each face was individually positioned in the centre of the screen at a visual angle of 20° x 20°. A response pad was positioned centrally on the desk in front of participants and was controlled by their dominant right hand.

During the freeview condition the image remained onscreen for an unlimited time, in the 500ms and 1000ms conditions a blank screen replaced each image. Participants pressed the response key when their decision was made in the freeview condition and after stimulus offset in the 500ms and 1000ms conditions. This response key stopped eye movements being recorded and a verbal response was then provided for each trial. Self-paced rests were given at the end of each trial block.

Apparatus and Procedure for Landmark Task

The Landmark task consisted of 60 evenly and 60 unevenly bisected black lines. These lines measured 19cm and were presented horizontally, centrally against a white background on the same Viewsonic monitor used for the lip-reading task. The unevenly bisected lines had a small vertical line cutting through 1/2cm to the left or right of centre and all lines were presented for an unlimited time in a random sequence. As per the lip-reading task a chin rest maintained a stable head position. During this forced choice task, participants were asked to decide which section of the line was longer or shorter according to the displayed instruction above each bisected line. The index and second finger of their dominant right hand was placed lightly over the left and right cursor keys of the keyboard. Each bisected line remained on screen until a response was made; however, participants were instructed to respond quickly and instinctively. Responses were automatically recorded by the computer and decisions of “left longer/right shorter” for evenly bisected lines indicated a LPB and “right longer/left shorter” a right perceptual bias. This task took approximately 5 minutes to complete.

5.4 Results

In the lip-reading task a total of 17,280 trials were recorded of which 8,640 were chimeric images. As detailed in Section 2.9, trials with anticipatory saccades and improper fixations were removed. For the E-L and L-E chimeric images these procedures led to 118 trials being removed from the 500ms condition, 116 trials being removed from the 1000ms condition and 125 trials being removed from the freeview condition. For the F-M and M-F chimeric images 104 trials were removed from the 500ms condition, 101 trials were removed from the 1000ms condition, and

100 trials were removed from the freeview condition. For O-U and U-O chimeric images 126 trials were removed in the 500ms condition, 126 trials were removed in the 1000ms condition and 97 were removed from the freeview condition.

Accuracy

Participants' mean accuracy was calculated for each single letter image across all time conditions and one sample *t*-tests against .5 (chance) were then conducted, corrected for 36 comparisons (.05/36) and therefore the null hypothesis was rejected only if $p < .00139$, see Table 5.1. As is clear from this table, accuracy was significantly higher than chance for both age groups in all time conditions for the E and L images and for the O and U images. When judging the F images the younger group's accuracy was below the level of chance in the 500ms condition and older adults' accuracy was below the level of chance in the 500ms and 1000ms conditions. When judging M images both groups were above the level of chance in all time conditions.

Table 5.1.

Mean (SD) Accuracy for Single Letter Images Calculated Against Chance (.5).

		Single Letter					
			E			L	
		500ms	1000ms	Freeview	500ms	1000ms	Freeview
Younger	31	.79(.13)*	.83(.19)*	.84(.16)*	.82(.15)*	.85(.16)*	.87(.12)*
Older	29	.80(.14)*	.81(.13)*	.80(.15)*	.78(.15)*	.84(.17)*	.87(.19)*
			F			M	
Younger	31	.57(.20)	.65(.20)*	.64(.21)*	.94(.14)*	.92(.16)*	.92(.19)*
Older	29	.50(.21)	.62(.22)	.65(.22)*	.96(.11)*	.96(.09)*	.97(.09)*
			O			U	
Younger	31	.77(.17)*	.77(.13)*	.76(.17)*	.70(.17)*	.78(.22)*	.80(.19)*
Older	29	.75(.14)*	.78(.14)*	.72(.17)*	.67(.22)*	.69(.26)*	.71(.24)*

*$p < .05$

The initial intention was to remove all participants whose judgements for the single letter images were at or below chance level. However, despite the piloting procedure as described in Appendix I, the accuracy of an unexpectedly high number of participants did not exceed chance level (See Table 5.2).

Table 5.2.

Number of Participants at or Below the Level of Chance for Accuracy for Each Single Letter Image.

		Single Letter					
			E			L	
Group	*n*	500ms	1000ms	Freeview	500ms	1000ms	Freeview
Younger	31	2	2	1	1	1	1
Older	29	2	1	2	2	3	3
			F			M	
Younger	31	15	14	15	1	1	1
Older	29	19	11	9	1	0	0
			O			U	
Younger	31	2	2	2	5	4	4
Older	29	3	2	6	9	8	10

Removal of these participants would result in an inability to use the data for statistical analysis. The single E and L faces were the only letters where participants were clearly able to judge the letter being spoken. Consequently a perceptual bias analysis of the chimeric E-L and L-E images was conducted, but no analysis of perceptual bias for the other chimeric letter combinations was conducted due to poor accuracy of the single letter images. The perceptual bias and eye movement results are detailed for the E-L and L-E chimeric images and this is followed by the eye movement analysis for the F-M, M-F, O-U and U-O chimeric images. As with study 1 the primary aim of this experiment was to assess eye movement patterns and judgements of chimeric images and therefore no further analysis of the single letter images was conducted.

Perceptual Bias for E-L and L-E Images

As noted in Section 2.3 the mean proportion of responses made to the right side of the chimeric images was calculated for each participant. The data were not normally distributed. Log, square root and reciprocal transformations worsened the skew and therefore the untransformed data were used for this analysis. One sample *t*-tests against chance (.5) were then conducted (corrected) for each age group and chimeric image for the three time conditions (See Table 5.3).

Table 5.3.

Mean Proportion (SD) of Judgement Responses to Chimeric Images E-L and L-E.

		E-L	
	500ms	1000ms	Freeview
Younger	.64 (.22)**	.63 (.23)*	.62 (.21)*
Older	.68 (.25)**	.70 (.23)**	.76 (.21)**
		L-E	
	500ms	1000ms	Freeview
Younger	.39 (.23)*	.32 (.24)**	.37 (.22)*
Older	.29 (.21)**	.31 (.18)**	.29 (.21)**

Note: *Proportions >.5 indicate a rightward bias.* ***p*<.01, **p*<.05.

When judging the E-L chimeric images a significant RPB was revealed by the younger group in each time condition (one sample t-tests against .5 for 500ms; $t(30) = 3.58$, $p = .001$, $r = .29$, 1000ms; $t(30) = 3.09$, $p = .004$, $r = .31$ and freeview; $t(30) = 3.31$, $p = .002$, $r = .32$) and by the older group in each time condition (500ms; $t(28) = 3.87$, $p = .001$, $r = .35$, 1000ms; $t(28) = 4.75$, $p < .001$, $r = .38$ and freeview; $t(28) = 6.77$, $p < .001$, $r = .44$).

When judging the L-E chimeric images a significant LPB was revealed by the younger group in each time condition (500ms; $t(30) = -2.66$, $p = .012$, $r = .29$, 1000ms; $t(30) = -4.07$, $p < .001$, $r = .35$, and freeview; $t(30) = -3.36$, $p = .002$, $r =$

.10) and also by the older group (500ms; $t(28) = -5.51$, $p < .001$, $r = .41$, 1000ms; $t(28) = -5.52$, $p < .001$, $r = .41$ and freeview; $t(28) = -5.30$, $p < .001$, $r = .40$).

To determine whether age or time condition influenced the extent of lateral response bias two way independent ANOVAs (Age x Time Condition) were conduction separately for the E-L and L-E chimeric images. The E-L analysis revealed no significant main effects of age ($F(1, 58) = 2.73$, $p = .104$, $\eta_p^2 = .05$), time condition ($F(2,116) = .77$, $p = .465$ $\eta_p^2 = .01$) or interaction ($F(2,116) = 1.70$, $p = .187$ $\eta_p^2 = .03$). Analysis of the L-E images also revealed no significant main effects of age ($F(1, 58) = 1.96$, $p = .167$, $\eta_p^2 = .03$), time condition ($F(2,116) = .29$, $p = .752$ $\eta_p^2 = .01$) or interaction ($F(2,116) = 1.67$, $p = .193$ $\eta_p^2 = .03$). Consequently, a significant bias to judge based on the side of the letter L was revealed for the E-L and L-E images and age and time condition did not significantly impact on this.

Initial Saccades

As noted in Section 2.3 the mean proportion of initial saccades to the right was calculated. In studies 1 and 2 one-sample *t*-tests against chance (.5) were conducted to reveal significant lateral bias. However, due to there being 3 time conditions and 2 age groups for each chimeric letter combination (e.g. F-M) this would result in 36 *t*-tests being conducted and using Bonferroni corrections the null hypothesis could only be rejected if the *p* value is less than .00139. Consequently, as accuracy for the single L and E images was good, corrected *t*-tests were conducted on the chimeric E-L and L-E images only and were conducted on the other chimeric images only if a group difference was revealed.

Initial Saccades to E-L and L-E Chimeric Images

The mean proportion of initial rightward saccades in each time condition overall for the E-L and L-E chimeric images is illustrated in Table 5.4. Corrected one sample tests against chance (.5) were conducted for each age group and time condition, however no significant lateral biases were revealed (all *p*s > .073; see Table 5.4).

Table 5.4.

Mean Proportion (SD) of Initial Saccades to Chimeric Images E-L and L-E.

	E-L		
	500ms	1000ms	Freeview
Younger	.46 (.41)	.38 (.33)	.36 (.36)
Older	.55 (.37)	.58 (.38)	.42 (.41)
	L-E		
	500ms	1000ms	Freeview
Younger	.43 (.39)	.37 (.32)	.37 (.39)
Older	.51 (.39)	.48 (.38)	.44 (.41)

Note: A mean of <.50 indicates proportionally more initial saccades leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right.

It has been argued that when conducting exploratory analysis the application of Bonferroni corrections to multiple tests can result in important effects being missed (McDonald, 2014). This may result in false positives being reported, however, further research can be conducted to verify the results, whereas this is unlikely to occur if effects are not revealed. Bearing this in mind it was considered beneficial to also state that when the *t*-tests were left uncorrected only the younger group demonstrated a significant bias when judging the L- E images in the 1000ms condition ($t(30) = -2.25$, $p = .032$, $r = .26$) and when judging the E-L images in the freeview condition ($t(30) = -2.09$, $p = .045$, $r = .26$) and this was to the left side of the face in both cases.

Mixed (Age x Time Condition) ANOVAs on the proportion of initial saccades were conducted for the E-L and L-E chimeric images separately. For both the E-L and L-E images no significant main effects of age (E-L; $F(1, 58) = 2.61$, $p = .112$, $\eta_p^2 = .04$ and L-E; $F(1, 58) = 1.17$, $p = .283$, $\eta_p^2 = .02$), time condition (E-L; $F(2, 116) = 1.97$, $p = .145$, $\eta_p^2 = .03$ and L-E; $F(2, 116) = .80$, $p = .454$, $\eta_p^2 = .01$) or interactions were revealed (E-L; $F(2, 116) = .70$, $p = .498$, $\eta_p^2 = .01$ and L-E; $F(2, 116) = .07$, $p = .932$, $\eta_p^2 = .001$). Consequently, neither age nor time condition significantly impacted on the proportion of initial saccades generated to the right side of the face.

Initial Saccades to F-M and M-F Chimeric Images

Table 5.5 illustrates the mean proportion of initial saccades to the right side of the face for the F-M and M-F images in each time condition. An initial inspection of the data in Table 5.5 appears to indicate a bias to initially saccade to the side showing the letter F. However, this was not consistently supported through one-sample *t*-tests against .5 as a significant left lateral bias was only demonstrated by older participants viewing the FM chimerics in the freeview condition $t(28) = -2.63$, *p*= .014, *r* = .44, and following bonferonni corrections this significant effect was no longer found. No other significant lateral biases were revealed for the FM or MF chimeric images, all *p*s > .238.

Table 5.5.

Mean Proportion (SD) of Initial Saccades to Chimeric Images F-M and M-F.

		F-M	
	500ms	1000ms	Freeview
Younger	.42 (.37)	.43 (.39)	.49 (.42)
Older	.49 (.43)	.49 (.42)	.34 (.34)
		M-F	
	500ms	1000ms	Freeview
Younger	.52 (.41)	.52 (.39)	.55 (.41)
Older	.59 (.40)	.53 (.40)	.48 (.37)

Note: A mean of <.50 indicates proportionally more initial saccades leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right.

Mixed (Age x Time Condition) ANOVAs were conducted separately for the F-M and M-F chimeric images. No significant main effect of age (F-M; (1, 58) = .01, p = .907, η_p^2 < .001 and M-F; F(1, 58) = .001, p = .979, η_p^2 < .001) or time condition was revealed (F-M; F(2, 116) = .49, p = .616, η_p^2 = .01 and M-F; F(2, 116) = .31, p =

.737, η_p^2 = .01) and the interactions were also non-significant (F-M; $F(2, 116) = 2.47$, $p = .089$, η_p^2 = .04 and M-F; $F(2, 116) = .79$, $p = .457$, η_p^2 = .01). Therefore, neither age nor time condition significantly impacted on the proportion of initial rightward saccades when these images were judged.

Initial Saccades to O-U and U-O Chimeric Images

The mean proportion of initial rightward saccades for the O-U and U-O images is presented in Table 5.6.

Table 5.6.

Mean Proportion (SD) of Initial Saccades to Chimeric Images O-U and U-O.

		O-U	
	500ms	1000ms	Freeview
Younger	.46 (.43)	.51 (.42)	.39 (.38)
Older	.59 (.41)	.58 (.42)	.51 (.45)
		U-O	
	500ms	1000ms	Freeview
Younger	.51 (.39)	.50 (.41)	.42 (.37)
Older	.61 (.41)	.59 (.39)	.56 (.42)

Note: A mean of <.50 indicates proportionally more initial saccades leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right.

Mixed (Age x Time Condition) ANOVAs on the O-U or U-O chimeric images revealed no significant main effect of age (O-U; $F(2, 116) = 1.78$, $p = .187$, $\eta_p^2 = .03$ and U-O; $F(1, 58) = 1.98$, $p = .165$, $\eta_p^2 = .03$) or time condition (O-U; $F(2, 116) = 1.22$, $p = .299$, $\eta_p^2 = .02$ and U-O; $F(2, 116) = .65$, $p = .526$, $\eta_p^2 = .01$) and the interactions were also non-significant (O-U; $F(2, 116) = .09$, $p = .910$, $\eta_p^2 = .002$ and U-O; $F(2, 116) = .10$, $p = .904$, $\eta_p^2 = .002$). It is clear from these results that across all chimeric images (E-L, L-E, F-M, M-F, O-U and U-O) the age of the participant and the time condition did not impact significantly on the proportion of initial saccades generated to the right side of the face.

Proportion of Fixations to the Right Side of the Face

In studies 1 and 2 one-sample *t*-tests against chance (.5) were conducted to reveal a significant lateral bias for the proportion of leftward fixations when judgements of gender and identity were made. In this current study the mean proportion of fixations to the right side of the face was calculated (as detailed in section 2.3), however, as per the initial saccade analysis one sample *t*-tests were not conducted unless group differences were revealed as corrections to 36 *t*-tests would result in the null hypothesis being rejected only if $p < .00139$.

Proportion of Fixations to the Right Side of E-L and L-E Chimeric Images

Table 5.7 presents the mean proportion of rightward fixations for the E-L and L-E images. Corrected one sample *t*-tests against chance (.5) were conducted for each age group for the E-L and L-E chimeric images in each time condition.

When judging the E-L images significant lateral biases to generate proportionally more fixations to the left side of the face were revealed for both age groups in the 500ms time condition (younger; $t(30) = -3.97$, $p < .001$, $r = .34$, older;

$t(28) = -6.81$, $p < .001$, $r = .53$) and for the younger group in the 1000ms time condition ($t(30) = -4.29$, $p < .001$, $r = .35$).

Analysis of the L-E faces also revealed significant lateral biases to generate proportionally more fixations to the left side of the face for both age groups in the 500ms (younger; $t(30) = -6.54$, $p < .001$, $r = .42$, older; $t(28) = -7.54$, $p < .001$, $r = .54$) and 1000ms time conditions (younger; $t(30) = -6.46$, $p < .001$, $r = .42$, older; $t(28) = -6.37$, $p < .001$, $r = .51$).

Table 5.7.

The Mean Proportion (SD) of Fixations for Chimeric Images E-L and L-E.

		E-L	
	500ms	1000ms	Freeview
Younger	.36 (.20)**	.37 (.17)**	.51 (.21)
Older	.32 (.15)**	.42 (.17)	.57 (.16)
		L-E	
	500ms	1000ms	Freeview
Younger	.33 (.15)**	.33 (.15)**	.43 (.18)
Older	.29 (.15)**	.34 (.14)**	.50 (.17)

Note: A mean of <.50 indicates proportionally more fixations leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right **p<.01.

Mixed (Age x Time Condition) ANOVAs were conducted separately for the E-L and L-E chimeric images. In the E-L chimeric condition a significant main effect of time condition was apparent (F(2, 116) = 38.79, p < .001, η_p^2 = .40). Post hoc analysis was then required to determine which time conditions significantly differed and Field (2009) notes that the best procedure is the Ryan, Einot, Gabriel and Welsch Q (REGWQ). However, as the groups in this current study were of different sizes this procedure was not appropriate. For groups of different sizes Field recommends Bonferroni when the number of comparisons is not too large because although it is viewed as a conservative test (lacking statistical power) it has more power than Tukey and consequently Bonferroni was the method chosen for post hoc comparisons of the main effects in this current study. Field (2009) also notes that when comparing several means Tukey HSD has more power and therefore this method was used for significant interactions in this study. A harmonic mean was calculated as follows 2/[(1/29) + (1/31)] = 30.30 to account for the unequal group sizes.

Bonferroni analysis revealed that with each increase in time condition significantly more fixations were made to the right side (500ms M = .34, SE = .02 and 1000ms M = .40, SE = 02, p = .027; 1000ms M = .40, SE = .02 and freeview M = .54, SE = .02, p < .001). No significant main effect was revealed for age (F(1, 58) = .45, p = .506, η_p^2 = .10) and the interaction was also non-significant (F(2, 116) = 3.00, p = .054, η_p^2 = .05).

In the L-E chimeric condition a mixed (Age x Time Condition) ANOVA revealed a significant main effect of time condition ($F(2,116) = 31.05$, $p < .001$, $\eta_p^2 = .35$) and Bonferroni analysis showed that significantly more rightward fixations were made in the freeview compared with the 500ms condition ($M = .47$, $SE = .02$ and $M = .31$, $SE = .02$) and in the freeview compared with the 1000ms condition ($M = .47$, $SE = .02$ and $M = .33$, $SE = .02$ both *p*s < .001). Thus, a similar proportion of rightward fixations were made in the 500ms and 1000ms conditions when viewing these images and proportionally more rightward fixations were generated in the freeview condition than either the 1000ms or 500ms conditions. No significant main effect of age ($F(1, 58) = .20$, $p = .661$, $\eta_p^2 = .003$) was revealed and the interaction was also non-significant ($F(2, 116) = 2.80$, $p = .065$, $\eta_p^2 = .05$).

Proportion of Fixations to the Right Side of F-M and M-F Chimeric Images

The mean proportion of rightward fixations for the F-M and M-F chimeric images is presented in Table 5.8.

Table 5.8.

The Mean Proportion (SD) of Fixations for Chimeric Images F-M and M-F.

		F-M	
	500ms	1000ms	Freeview
Younger	.26 (.14)	.45 (.20)	.45 (.21)
Older	.32 (.18)	.44 (.20)	.38 (.39)
		M-F	
	500ms	1000ms	Freeview
Younger	.65 (.19)	.56 (.20)	.57 (.21)
Older	.61 (.20)	.58 (.22)	.54 (.14)

Note: A mean of <.50 indicates proportionally more fixations leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right.

A mixed (Age x Time Condition) ANOVA was conducted on the proportion of rightward fixations for the F-M images and revealed a significant main effect of time condition ($F(2,116) = 23.35$, $p < .001$, $\eta_p^2 = .29$). Bonferroni post hoc comparisons revealed that proportionally more fixations were made to the right side in the 1000ms ($M = .45$, $SE = .02$) and freeview condition ($M = .42$, $SE = .02$) compared with the 500ms condition ($M = .29$, $SE = .02$ both *p*s < .001), and proportionally more fixations were made to the right side in the freeview compared with the 1000ms condition ($p < .001$). No significant main effect of age ($F(1, 58) =$

.01, p = .914, η_p^2 < .001) or significant interaction was demonstrated (F(2, 116) = 3.03, p = .052, η_p^2 = .05). These results reveal a systematic increase in rightward fixations as viewing time is also increased.

This pattern was not demonstrated for M-F chimeric images as the mixed (Age x Time Condition) ANOVA revealed no significant main effects of time condition (F(1.56, 90.36) = 2.14, p = .134, η_p^2 = .04) or age (F(1, 58) = .42, p = .518, η_p^2 = .01) and no significant interaction (F(1.56, 90.36) = .37, p = .636, η_p^2 = .01). Mauchly's test of sphericity was significant and had an estimate of .72, therefore Greenhouse-Geisser correction was applied to the main effect of time condition and the time condition x age interaction (Field, 2009).

Proportion of Fixations to the Right Side of O-U and U-O Chimeric Images

For the mean proportion of rightward fixations for O-U and U-O chimeric images see Table 5.9.

Table 5.9

The Mean Proportion (SD) of Fixations for Chimeric Images O-U and U-O.

		O-U	
	500ms	1000ms	Freeview
Younger	.33 (.17)	.33 (.21)	.46 (.19)
Older	.38 (.18)	.38 (.16)	.49 (.20)
		U-O	
	500ms	1000ms	Freeview
Younger	.35 (.17)	.43 (.18)	.46 (.19)
Older	.41 (.20)	.46 (.13)	.49 (.20)

Note: A mean of <.50 indicates proportionally more fixations leftward, >.5 proportionally more rightwards and .5 an equal proportion to the left and right.

Mixed (Age x Time Condition) ANOVAs revealed a main effect of time for O-U chimeric images ($F(2, 116) = 11.87$, $p < .001$, $\eta_p^2 = .17$) which Bonferroni post hoc analysis revealed was due to proportionally more fixations to the right side of the in the freeview ($M = .47$, $SE = .03$) compared with the 500ms ($M = .36$, $SE = .02$) and 1000ms conditions ($M = .35$, $SE = .02$ both *p*s <.001). No significant main effect of age ($F(1, 58) = 1.43$, $p = .237$, $\eta_p^2 = .02$) or significant interaction was revealed ($F(2, 116) = .91$, $p = .907$, $\eta_p^2 = .002$). For the U-O chimeric faces a mixed (Age x Time Condition) ANOVA revealed a significant main effect of time condition

($F(1.80, 104.13) = 6.72$, $p = .003$, $\eta_p^2 = .10$). Bonferroni post hoc comparisons revealed that proportionally more rightward fixations were made in the 1000ms (M = .47, SE = .03) compared with the 500ms condition (M = .38, SE = .02 p = .009). Additionally, more rightward fixations to the right were made in the 500ms and 1000ms conditions compared with freeview (M = .47, SE = .03 both ps < .001). No significant main effect of age ($F(1, 58) = 1.10$, $p = .298$, $\eta_p^2 = .02$) or significant interaction were revealed ($F(1.80, 104.13) = .19$, $p = .806$, $\eta_p^2 = .003$), as Mauchly's test of sphericity was significant with an estimate of .84 (> .75), Huynh-Feldt corrections were applied (Field, 2009). This analysis shows that an increase in stimulus exposure time resulted in an increase in the proportion of fixations to the right when viewing both O-U and U-O faces.

Duration of Fixations

The mean duration of fixations to the left and right sides of the E-L, L-E, F-M, M-F, O-U and U-O chimeric images was calculated for each participant in every trial. The data had 9 outliers and these were replaced by the mean plus 2 *SD* (Field, 2009). The overall data were not normally distributed. Attempts to normalise the data through square root, log and reciprocal transformations were not successful and worsened the skew in some cases. Consequently, the analyses were calculated using untransformed data and so interpretations of these results should be treated with caution.

Duration of Fixations for E-L and L-E Chimeric Images

The mean duration of fixations to the left and right sides of the E-L and L-E chimeric images is illustrated in Table 5.10.

Table 5.10.

The Mean Duration of Fixations (ms) for Chimeric Images E-L and L-E.

	E-L					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	296	313	604	495	695	664
	(156)	(145)	(235)	(234)	(534)	(395)
Older	313	309	598	540	881	1238
	(117)	(119)	(220)	(234)	(589)	(762)
	L-E					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	318	300	503	605	725	561
	(134)	(124)	(237)	(234)	(341)	(400)
Older	315	303	455	691	1163	1010
	(134)	(142)	(235)	(228)	(771)	(499)

A mixed (Age x Side x Time Condition) ANOVA for the E-L images revealed a main effect of age (F(1,174) = 10.20, p = .002 η_p^2 = .06) with the older adults having a greater mean fixation duration (ms) than younger adults (M = 647, SE = 30 and M = 511, SE = 29). This was qualified by a significant age x side interaction ($F(1,174) = 3.93$, $p = .049$ $\eta_p^2 = .02$), however, possibly due to Tukey HSD being a conservative test (Howell, 2002), no significant interaction effects were revealed. From an assessment of the interaction (see Figure 5.2) it was clear that younger and older adults' mean fixation duration differed more for the right but not left side. Consequently, two independent t-tests (corrected) were conducted which confirmed that older adults' mean fixation duration was significantly greater than younger adults when looking at the right but not left side ($t(178) = 2.88$, $p = .002$, $r = .21$ and $t(178) = 1.08$, $p = .14$, $r = .07$).

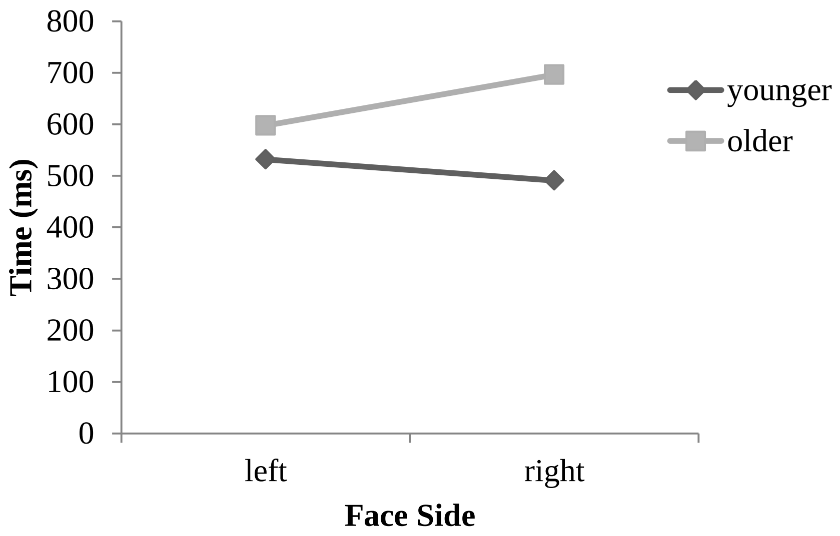

Figure 5.2. Age x side interaction for duration of fixations for E-L chimeric images.

A significant side x time condition interaction was revealed ($F(2,174) = 4.18$, $p = .017$, $\eta_p^2 = .05$; see Figure 5.3). Post hoc analysis using Tukey HSD revealed that mean fixation duration (ms) to the right side of the face was significantly greater in the freeview than the 1000ms condition (M = 951, SE = 49 and M = 518, SE = 49, p < .01), but mean fixation duration (ms) to the left side of the face did not differ significantly for freeview compared with 1000ms (p > .05).

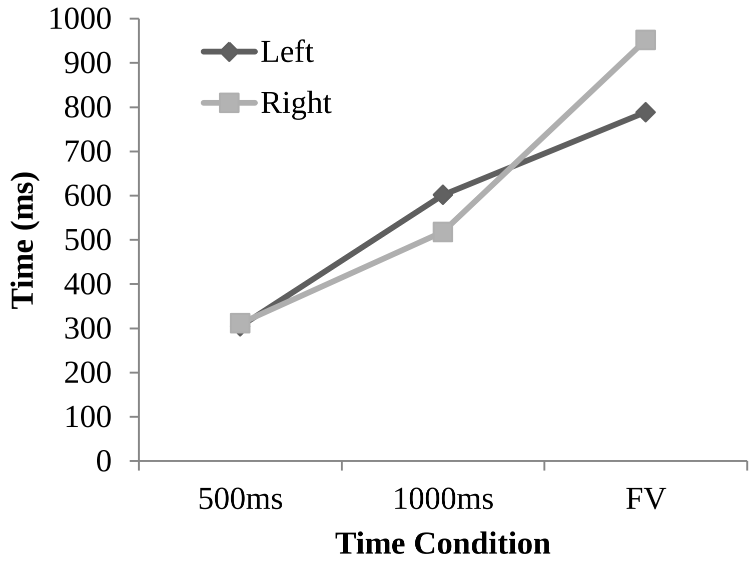

Figure 5.3. Side x time interaction for duration of fixations to E-L chimeric images (FV = Freeview).

A significant side x age x time condition interaction was also revealed ($F(2,174) = 3.18$, $p = .044$, $\eta_p^2 = .04$). Tukey HSD post hoc analysis was conducted, and as is clear from Figure 5.4 the younger and older adults' mean fixation duration to the left and right sides did not differ significantly in the 500ms or 1000ms time conditions (all ps > .05). The younger group demonstrated no significant fixation duration differences between the 1000ms and freeview time conditions for either face side (ps > .05), whereas the older adults' fixation duration to both sides of the face was significantly greater in the freeview condition than the 1000ms condition (freeview left side; M = 881, SE = 66, freeview right side; M = 1238, SE = 70, 1000ms left side; M = 598, SE = 66, 1000ms right side; M = 540, SE = 70, $ps < .01$). The older groups' mean fixation duration to the right side in the freeview condition was significantly greater than the younger group's (younger; M = 664, SE = 68, $p < .01$). Consequently, with unlimited viewing time the older adults looked for significantly longer to the right than the left side of the face and for significantly longer at the right side than younger adults. No other main effects or interactions were significant (all $ps > .01$).

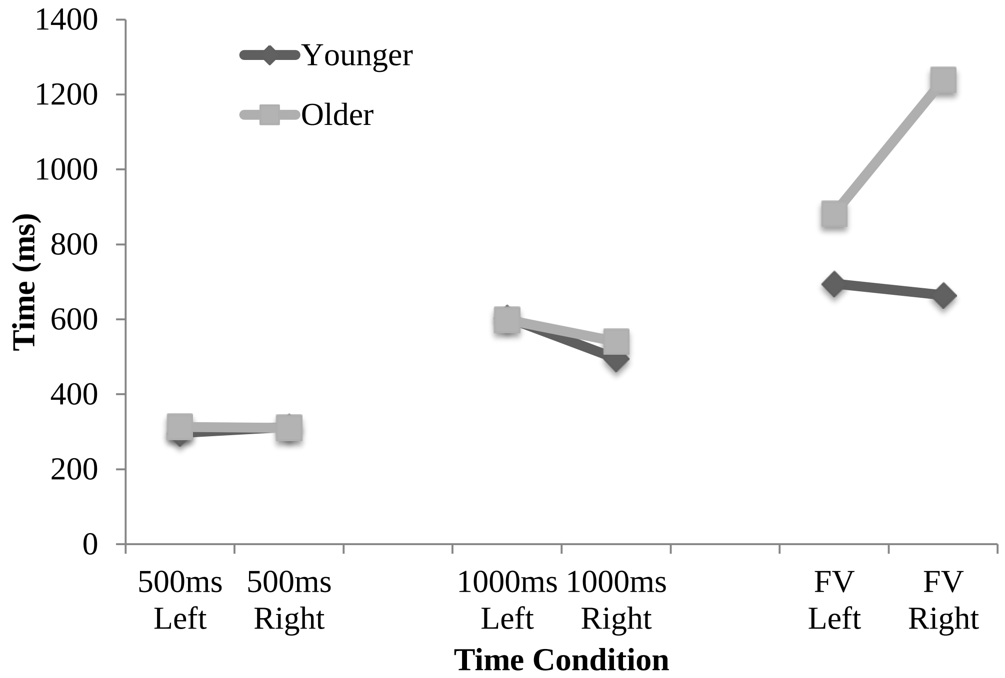

Figure 5.4. Side x age x time condition interaction for duration of fixations for E-L chimeric images (FV = Freeview).

A mixed (Age x Side x Time Condition) ANOVA for the L-E images revealed a significant main effect of age with younger adults revealing a significantly shorter fixation duration than older adults (*M* = 502.28, *SE* = 25.99 and *M* = 656.66, *SE* = 26.87, *F*(1,174) = 17.06, $p < .001$ $\eta_p^2 = .09$) and a significant main effect of time condition (*F*(1,174) = 73.86, $p < .001$ $\eta_p^2 = .46$) which were qualified by a significant age x time condition interaction (*F*(1,174) = 14.98, $p < .001$ $\eta_p^2 = .15$; see Figure 5.5).

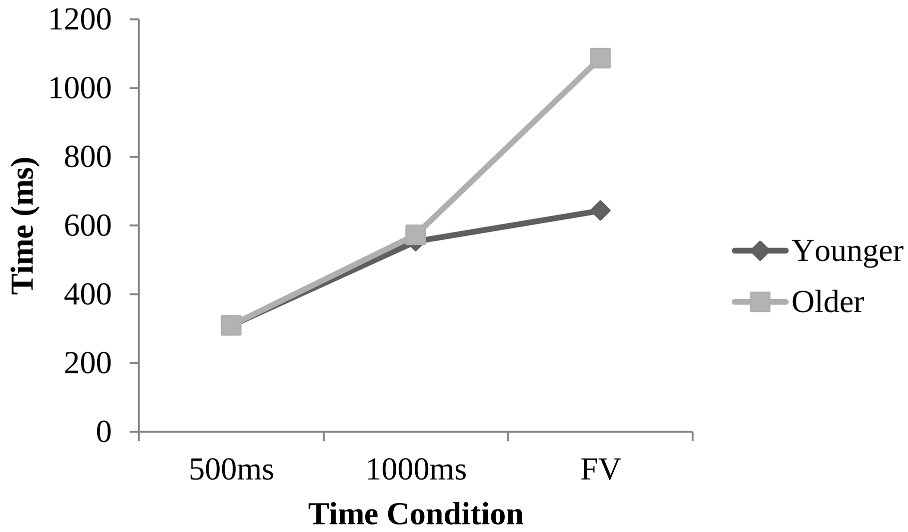

Figure 5.5. Age x time condition interaction for fixation duration for L-E chimeric images (FV = Freeview).

Post hoc analysis conducted using Tukey HSD revealed that younger and older adults' mean fixation duration did not differ significantly in the 500ms (*M* = 309, *SE* = 45) or 1000ms time conditions (*M* = 554, *SE* = 45, $p > .05$). Older adults' mean fixation duration in the freeview condition (*M* = 1087, *SE* = 46) was significantly greater than in the 1000ms (*M* = 573, *SE* = 46, $p < .01$), but younger adults' was not (*M* = 643, *SE* 45 and *M* = 554, *SE* = 45, $p > .05$) and older adults' fixation duration was significantly greater than the younger adults in the freeview condition ($p < .01$).

A significant side x time condition interaction was also revealed ($F(1,174) = 7.51$, $p = .001$ $\eta_p^2 = .08$; see Figure 5.6).

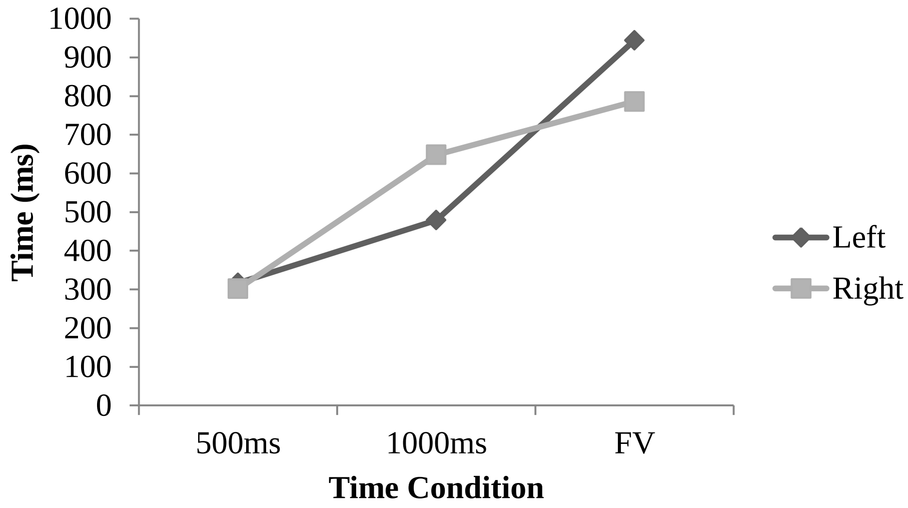

Figure 5.6. Side x time condition interaction for L-E fixation duration for chimeric images (FV = Freeview).

Tukey HSD analysis revealed that fixation duration to the left side of the chimeric face was significantly greater in the freeview condition ($M = 944$, $SE = 48$) than the 1000ms condition ($M = 479$, $SE = 48$) and fixation duration to the right side of the face was significantly greater in the 1000ms ($M = 648$, $SE = 39$) than the 500ms condition ($M = 302$, $SE = 39$, ps $< .01$). This is a mirror reverse of the side x time condition interaction for E-L chimeric images and indicates that participants fixated for longer on the L side of the chimeric image when time was unlimited and on the E side of the chimeric when time was limited to 1000ms.

Duration of Fixations F-M and M-F Chimeric Images

The mean fixation duration to the left and right sides of the F-M and M-F faces is presented in Table 5.11.

Table 5.11.

The Mean Duration of Fixations for Chimeric Images F-M and M-F.

	F-M					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	352 (137)	261 (135)	617 (242)	487 (240)	503 (401)	638 (533)
Older	338 (135)	283 (148)	645 (245)	496 (247)	1205 (580)	748 (421)
	M-F					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	261 (169)	342 (149)	461 (235)	646 (224)	650 (503)	829 (526)
Older	270	351	441	677	792	1124

(142)	(138)	(264)	(261)	(529)	(624)

Mixed ANOVAs were calculated separately for F-M and M-F images to determine the effect of age, side of face and time condition on the mean fixation duration. For the F-M images a significant main effect of age with older adults having a significantly longer mean fixation duration than younger adults (M = 619.63, SE = 26.58 and M = 517.62, SE = 25.71, $F(1,174) = 15.85$, $p < .001$ η_p^2 = .08) and a significant main effect of time condition was revealed ($F(1,174) = 56.21$, $p < .001$ η_p^2 = .39), which were qualified by a significant age x time interaction ($F(2,174) = 13.51$, $p = .003$, η_p^2 = .13; see Figure 5.7).

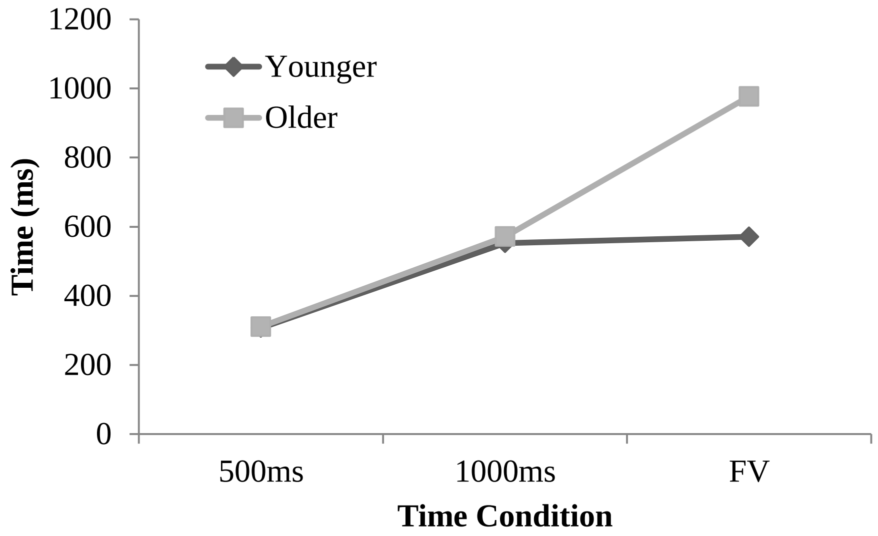

Figure 5.7. Age x time condition interaction for fixation duration for F-M chimeric images (FV = Freeview).

Post hoc analysis calculated using Tukey HSD revealed that the mean fixation duration of older and younger adults did not differ significantly in the 500ms

(M = 310, SE = 44 and M = 307, SE = 43) or 1000ms time conditions (M = 571, SE = 44 and M = 552, SE = 43, ps > .05), however, in the freeview condition older adults' mean fixation duration was significantly greater than younger adults (M = 976, SE = 44 and M = 570, SE = 43, p < .01). A significant main effect of side was also revealed ($F(1,174) = 14.04$, $p < .001$, $\eta_p^2 = .08$) qualified by a significant age x side interaction ($F(2,174) = 8.50$, $p < .004$, $\eta_p^2 = .05$) see Figure 5.8.

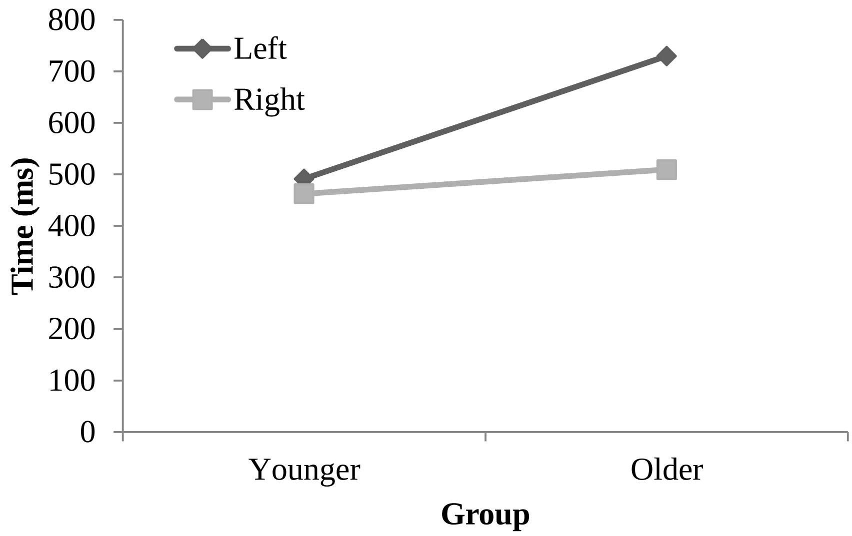

Figure 5.8. Age x side interaction for fixation duration for F-M chimeric images.

Tukey HSD calculations revealed that younger adults' mean fixation duration did not differ significantly for the left or right sides of the face (M = 491.35, SE = 34.09 and M = 462.49, SE = 33.49, p > .05), whereas older adults' mean fixation duration was significantly greater to the left than right side of the face (M = 729.80, SE = 35.25 and M = 509.45, SE = 34.63, p < .01). Older adults mean fixation duration was also significantly longer to the left side of the face than younger adults

($p < .01$). A significant age x side x time condition interaction ($F(2,174) = 3.28$, $p < .040$ $\eta_p^2 = .04$) was also revealed, see Figure 5.9.

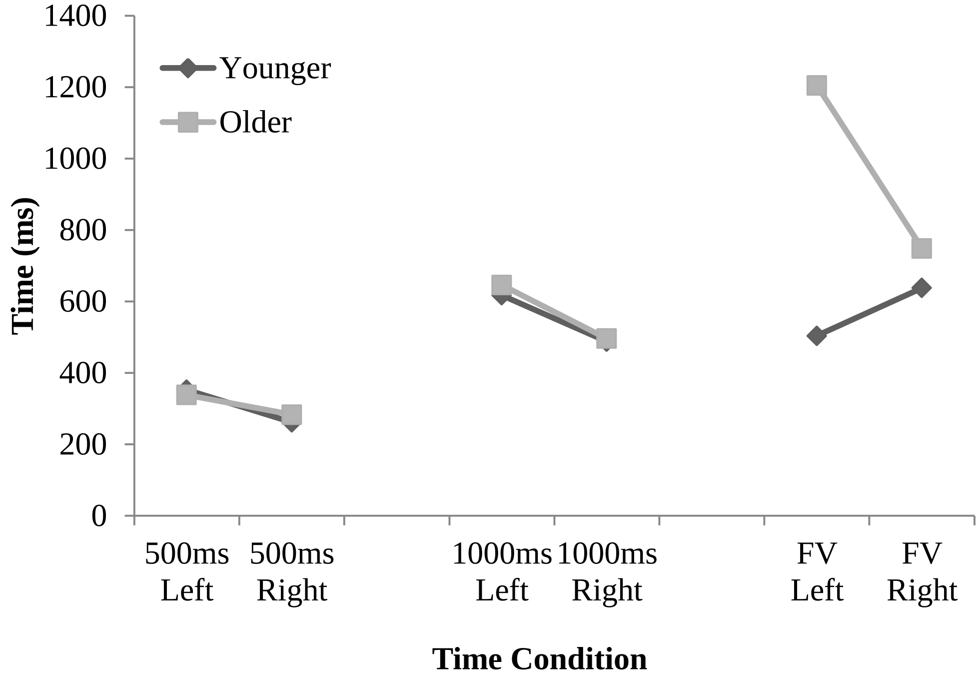

Figure 5.9. Age x side x time condition interaction for fixation duration for F-M chimeric images (FV = Freeview).

Tukey HSD analysis revealed no significant differences in mean fixation duration between older and younger adults for either side of the face in the 500ms and 1000ms time conditions (*p*s > .05). In the freeview condition older adults' mean fixation duration was significantly greater than younger adults when looking at the left ($M = 1205$, $SE = 61$ and $M = 503$, $SE = 59$, $p < .01$), but not the right side of the face ($M = 748$, $SE = 59$ and $M = 638$, $SE = 58$, $p > .05$).

For the M-F images a significant main effect of time condition was revealed ($F(1,174) = 56.38$, $p < .001$, $\eta_p^2 = .39$) and Bonferroni post hoc comparisons showed that mean fixation duration increased significantly with each increase in viewing time condition (500ms; M = 306, SE = 36, 1000ms; M = 556, SE = 36 and freeview M = 849 and SE = 36, all ps < .001). A significant main effect of side was revealed ($F(1,174) = 30.38$, $p < .001$, $\eta_p^2 = .15$) with the right side receiving a significantly longer mean fixation duration than the left (M = 661, SE = 27 and M = 479, SE = 25). No other main effects or interactions were significant (all ps > .086).

Duration of Fixations O-U and U-O Chimeric Images

For the mean duration of fixation to the left and right sides of the O-U and U-O faces see Table 5.12.

Table 5.12

The Mean Duration of Fixations for Chimeric Images O-U and U-O.

	O-U					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	212	210	635	460	791	583
	(85)	(83)	(286)	(279)	(484)	(431)
Older	202	245	594	526	946	821
	(84)	(77)	(262)	(258)	(554)	(459)
	U-O					
	500ms		1000ms		Freeview	
	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
Younger	196	228	432	675	577	866
	(88)	(91)	(252)	(243)	(418)	(633)
Older	197	250	407	715	725	1149
	(91)	(75)	(214)	(205)	(549)	(569)

A mixed (Age x Side x Time Condition) ANOVA for the O-U images revealed a significant main effect of age ($F(1,174) = 5.02$, $p = .026$, $\eta_p^2 = .03$) and time condition ($F(1,174) = 100.53$, $p < .001$, $\eta_p^2 = .54$) and a significant age x time condition interaction ($F(1,174) = 3.48$, $p = .033$, $\eta_p^2 = .04$; see Figure 5.10).

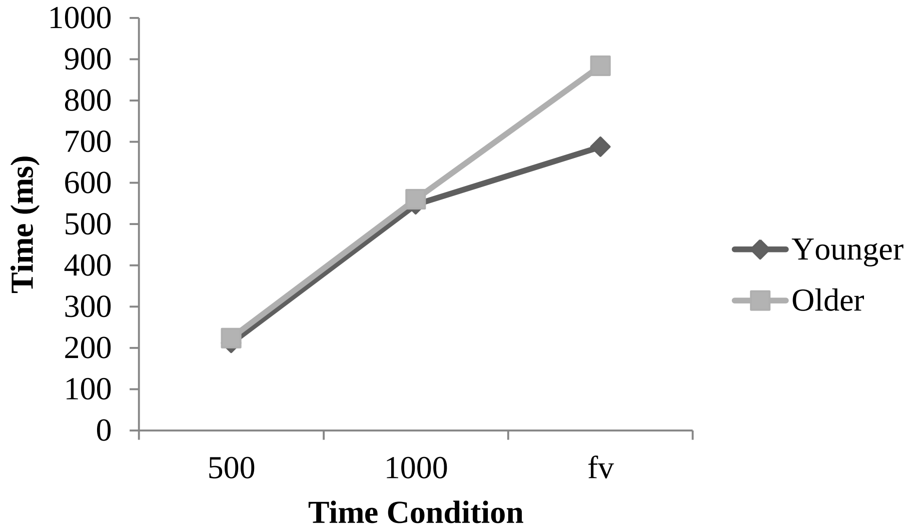

Figure 5.10. Age x time interaction for fixation duration for O-U chimeric images (fv = Freeview).

Tukey HSD analysis revealed that the mean fixation duration (ms) of the older and younger adults did not differ significantly in the 500ms ($M = 223$, $SE = 40$ and $M = 211$, $SE = 39$) 1000ms ($M = 560$, $SE = 40$ and $M = 547$, $SE = 39$) or freeview time conditions ($M = 883$, $SE = 40$ and $M = 687$, $SE = 39$, $p > .05$). However, the older groups' mean fixation duration was significantly greater in the freeview than the 1000ms condition ($p < .01$) whereas the younger group's was not ($p > .05$). A significant main effect of side was also revealed ($F(1,174) = 6.39$, $p = .012$, $\eta_p^2 = .04$) with the left side receiving a significantly greater mean fixation duration (ms) than the right ($M = 564$, $SE = 25$ and $M = 474$, $SE = 22$), no other main effects or interactions were demonstrated ($p > .086$).

For the U-O images a mixed (Age x Side x Time Condition) ANOVA revealed a significant main effect of age (F(1,174) = 4.74, p = .031, η_p^2 = .03) and time condition (F(1,174) = 97.02, p < .001, η_p^2 = .53) which were qualified by a significant age x time condition interaction (F(2,174) = 3.65, p = .028, η_p^2 = .04; see Figure 5.11).

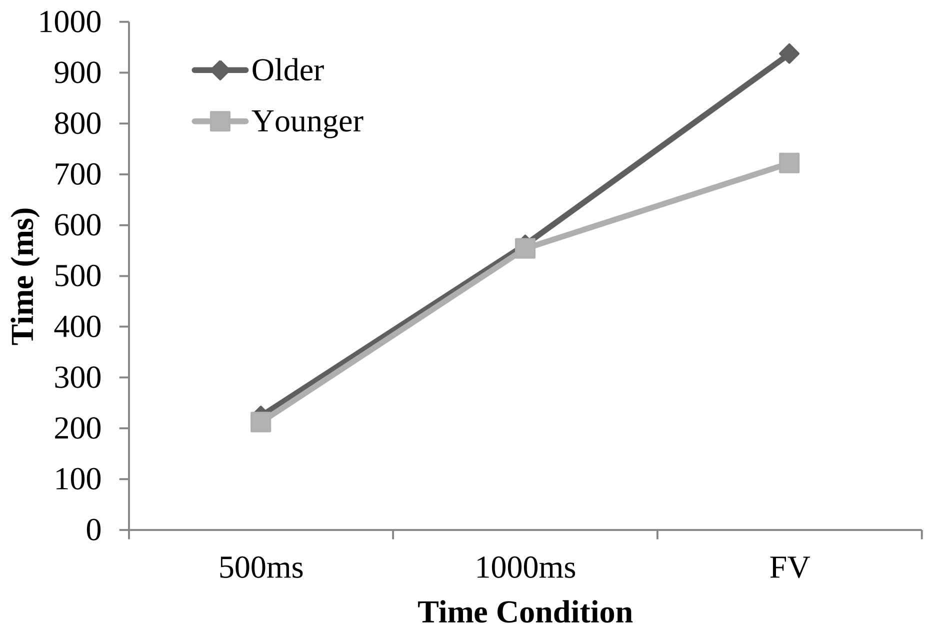

Figure 5.11. Age x time condition interaction for fixation duration for U-O chimeric images (FV = Freeview).

Tukey HSD analysis revealed that older and younger adults' mean fixation duration (ms) did not differ significantly in the 500ms (M = 224, SE = 44 and M = 212, SE = 43), 1000ms (M = 561, SE = 44 and M = 554, SE = 43), or freeview conditions (M = 937, SE = 44 and M = 722, SE = 43, ps > .05). However, the older adults' mean fixation duration was significantly greater in the freeview compared with the 1000ms condition (p < .01) whereas the younger group's was not (p > .05).

A significant main effect of side was also revealed ($F(1,174) = 36.36$, $p < .001$, $\eta_p^2 = .17$) qualified by a significant side x time condition interaction ($F(2,174) = 6.40$, $p = .002$, $\eta_p^2 = .07$; see Figure 5.12).

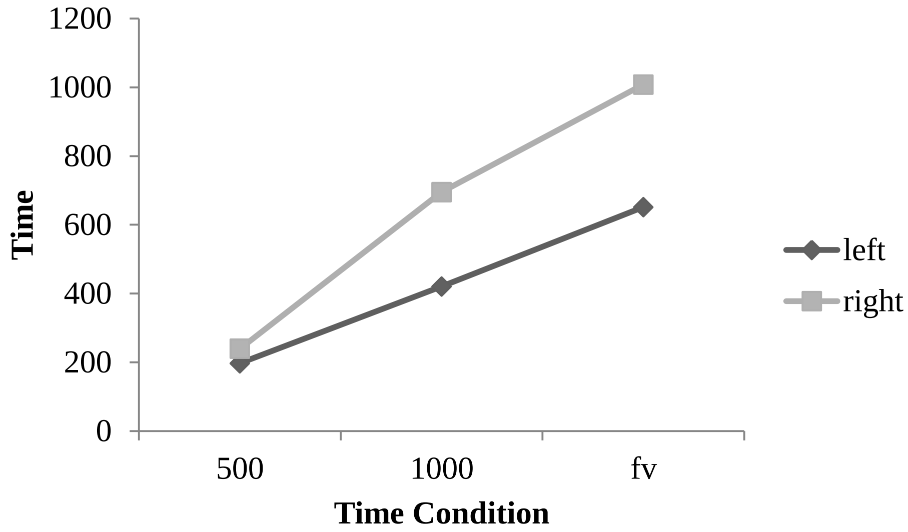

Figure 5.12. Side x time condition interaction for fixation duration for U-O chimeric images (fv = Freeview).

Tukey HSD revealed that in the 500ms condition mean fixation duration did not differ significantly for the left and right sides ($M = 197$, $SE = 40$ and $M = 239$, $SE = 48$, $p > .05$), however in both the 1000ms and freeview time conditions mean fixation duration was significantly greater to the right than the left side of the face (1000ms $M = 695$, $SE = 48$ and $M = 420$, $SE = 40$, freeview $M = 1008$, $SE = 48$ and $M = 651$, $SE = 40$, ps < .01). No other significant main effects or interactions were revealed for the O-U or U-O images (all ps >.082).

Landmark Task

To determine whether lateral biases were face specific or reflected a more general perception of space the Landmark Task was added to this study. Some participants had already conducted the face perception task and were invited back to conduct the Landmark task. Not all of the younger participants returned to complete the Landmark task, therefore this analysis is based on a sample of 10 younger and 29 older participants. The LPB was calculated per participant in every trial where the line was bisected evenly. The younger adults judged more evenly bisected lines as "left shorter/right longer" than the older adults (M = .62, SD = .17 and M = .54, SD = .24), this reveals a possible right perceptual bias on an evenly bisected line as the left side of the line was neglected resulting the right side appearing longer than the left. One sample t-tests against .5 (chance) revealed that this right perceptual bias was non-significant for both groups although a trend is evident for the younger compared with older adults ($t(9)$ = 2.17, p =.058, r = .59 and $t(28)$ = .96, p = .347, r = .18). An independent t-test showed the difference between the groups to be non-significant ($t(37)$ = .88, p = .384, r = .14) however, due to the small size of the younger group, particularly in comparison with the older group, these results should be treated with caution. Pearson's correlations were then performed to examine the association between results on the Landmark task and responses to E-L and L-E chimeric faces. No significant correlations were revealed for the older group's Landmark responses (M = .46, SD = .24) and their judgements of the L-E images (M = .30, SD = .15; r = -.03, p = .886) or the E-L images (M = .72, SD = .18; r = -.12, p = .550). No significant correlations were revealed for the younger group's responses to the Landmark task and the L-E faces (M = .39, SD = .17; r = .14, p = .696), although a trend towards a positive correlation was revealed for their responses to the Landmark and E-L faces (M = .63, SD = .19; r = .89, p = .052) indicating a possible association between their rightward responses in these two tasks.

5.5 Discussion

The aims of this study were to determine whether viewing time or age impact on lateralization of perception and eye movements in a lip-reading task and to compare lateralized perceptions in the LH lip-reading task with the RH Landmark task. As is detailed in Appendix I, the single letter images that were used to determine accuracy were rated to ensure that the letters being mouthed could easily be determined. Despite this, many participants were unable to accurately identify some of the letters. This was particularly apparent for both age groups when judging the letter F, and to a lesser extent when judging the letter U. Participants, particularly the older group, experienced difficulties judging the letter O, whereas most participants were able to accurately judge M, E and L (see Table 5.2). If only a small number of participants were at or below the level of chance for accuracy they would have been removed from the analysis and the perceptual and eye movement responses of the remaining participants would have been examined. However, as Table 5.2 illustrates at least one participant was at or below chance level for each single letter in each time condition. Removing all of these participants would have resulted in groups too small for any statistical analysis to be meaningful. It was therefore concluded that due to the difficulties in identifying the letter F and U from the single letter images, interpreting lateral responses to the F-M, M-F and O-U, U-O chimeric stimuli would be unreliable and therefore perceptual judgements have not been investigated for these images. Analysis of the eye movement data was conducted on these chimeric images to determine the impact of age on lateralisation of initial saccades, proportion of rightward fixations and fixation duration when lip reading judgements were made.

The majority of participants were able to judge the single letters E and L, so perceptual biases to the chimeric E-L and L-E images were investigated. Perceptual responses to these chimeric images were then compared with the sub-group's perceptions of line length in the Landmark task.

Analysis of the E-L chimeric images appeared to confirm expectations of a RPB as a significant bias to base judgements on the right side was revealed by both age groups in all three time conditions, supporting previous work using younger adults (Burt & Perrett, 1997). However, analysis of the L-E chimeric images revealed the mirror opposite response bias with both groups' judgements being based on the left side in all time conditions and with no significant difference in strength of bias for the E-L or L-E images in any of the time conditions. Consequently it appears that lateralised response biases did not reflect a hemispheric speciality for this task, but instead indicates that responses were based on the side mouthing the letter L. It is not surprising, therefore, that no impact of age was revealed as responses were due to the appearance of the stimuli rather than hemispheric dominance.

The perceptual responses of the sub-group who conducted the Landmark task was also unexpected as the younger adults demonstrated a trend (p = .058) to judge more evenly bisected lines as "left shorter/right longer", hence exhibiting a tendency towards a RPB. Previous literature reveals a LPB for this task in younger adulthood, (e.g. Beste et al., 2006), and although this is considered a robust phenomenon it is not consistently revealed in the literature (Braun & Kirk, 1999; Cowie & Hamill, 1998; Manning, Halligan & Marshall, 1990). As only 10 younger participants conducted this task interpretations of a lack of bias for this age group should be accepted tentatively. The older group also demonstrated no significant lateral bias when conducting this task. Based on previous literature it was anticipated that the older group would have either a reduced LPB compared with the younger group, or would demonstrate no lateral bias (for a review see Jewell & McCourt, 2000), therefore the lack of bias in the older group could be considered to support previous research. No association between responses in the Landmark task and lip-reading task were found, although the younger group demonstrated a trend towards a positive correlation (p = .052) for the E-L images and Landmark task as their responses for both tasks tended towards a rightward bias. It should be noted, however, that comparing a group of 10 (younger) with a group of 29 (older) participants may result in unusual and potentially misleading outcomes, therefore all participants in the fourth study of this research programme conducted both the Landmark and emotion judgement task to verify these results.

Analysis of lateralisation for initial saccades to the E-L or L-E images revealed no significant biases by either group in any of the time conditions. In studies 1 and 2 of this research programme a significant overall leftward bias for initial saccades was revealed when judging gender and identity, a bias which has been argued to reflect RH specialization for face processing (Butler et al., 2005) as well as left – right directional scanning (Megreya & Havard, 2011; Vaid & Singh, 1989). As stated in section 2.2, the participants in this current study were native English readers and consequently had left - right directional scanning. If this habituated reading style impacts on initial eye movements it would be anticipated that first saccades would also consistently be generated to the left side of the face, but this was not the case when assessing the L-E and E-L faces. Potentially in processing language (LH) using a face processing task (RH) the left bias for initial eye movements was reduced as greater involvement of the LH was required. Alternatively, it is possible that participants adopted a different strategy as this was a more difficult task.

Assessments of the proportion of fixations generated to the right side of the face for E-L images revealed no lateral bias for either age group when time was unlimited and no bias for the older group in the 1000ms time condition. However, significantly more fixations were generated to the left compared with the right side of the face by both groups in the 500ms condition. The L-E data also revealed no lateral biases in the freeview condition for either age group, but in the 500ms and 1000ms time conditions both age groups revealed a leftward bias, generating significantly more fixations to the left than the right side of the face. For both the E-L and L-E faces proportionally more fixations were generated to the right side of the face in the freeview compared with the 1000ms or 500ms time conditions.

Previous research has noted that the LPB strengthens as viewing time is extended (100ms, 300ms and freeview) using a RH dominant task, and this has been interpreted as reflecting increased eye movements to the side used for a decision (Butler et al., 2005; Butler & Harvey, 2006). Using a LH task, these current results show for the first time that a greater proportion of fixations are made to the right as viewing time increases, potentially indicating hemispheric dominance of the LH. However, Butler and Harvey's assertion that perceptual bias is strengthened by increased eye movements is not supported from this E-L and L-E eye movement data. An examination of the proportion of fixations revealed no association between these eye movements and the side used for judgement as letter judgements were based on the side showing the letter L in all time conditions, but proportionally more eye movements were generated to the right as time increased for both the E-L and L-E chimeric faces.

Additionally for the E-L and L-E images there were no significant differences in fixation duration to the left and right sides of the face for either group in the 500ms condition. However, in the 1000ms condition fixation duration was longer to the side showing the letter E and in the freeview condition fixation duration was longer to the side with the letter L, a bias which was particularly apparent for the older group when assessing the E-L images. This does not appear to be due to problems identifying the letter being spoken because the accuracy results show that the majority of participants were above the level of chance when judging the single E and L images. It also does not seem to reflect hemispheric dominance as fixation duration was not consistently longer to one side of the face compared to the other and so may instead be due to the appearance of the L.

When the letter L is spoken the tip of the tongue is placed behind the top teeth and the underside of the tongue is visible to the viewer. When judging which letter a chimeric L-E or E-L image most looks like, the appearance of the L side of the image could be somewhat more distracting than the E side and therefore may receive longer fixations than the E side, particularly when viewing time is unrestricted. If this is the case though, why would the side showing the letter E receive a longer fixation duration in the 1000ms condition? One suggestion is that when spoken, the letter E partly resembles a smile and research assessing visual attention to emotional expressions has found that healthy adults have an attentional bias to smiling faces which are presented for 1000ms (Joorman & Gotlib, 2007) and their fixation duration is longest to happy compared with neutral, angry and sad expressions (Isaac, Vrijsen, Rinck, Speckens & Becker, 2014).

It is speculated, therefore, that a face saying the letter E maybe perceived as a smile and when viewed for 1000ms it captures attention resulting in longer fixation durations being made to the side of the chimeric face showing it. However, after 1000ms greater fixation duration is made to the L side of the chimeric image, possibly because after this time the letter E is not perceived as a smile or alternatively because the more conspicuous appearance of the letter L being mouthed leads to visual attention being prioritized to it when viewing time is unlimited. What is clear, however, is that the side used for a decision did not consistently receive proportionally more fixations, nor a greater fixation duration and therefore an association between perception and eye movements is not apparent when judging E-L and L-E chimeric images.

Significant lateral biases of the eye movements to F-M, M-F, O-U and U-O images were not calculated due to the large number of statistical corrections that would have needed applying. However, based on the proportion of initial saccades generated to the right side of the face it is clear that the typical leftward bias previously documented in face processing studies (e.g. Bindemann et al., 2009; Butler et al., 2005) was not consistently demonstrated in this current study. For example proportionally more initial saccades to the left were made when viewing the F-M images and this could be argued to reflect the instinctive response noted when first analysing faces (Leonards & Scott-Samuel, 2005). However, with the exception of the older group in the freeview time condition, proportionally more initial saccades were made to the right when viewing M-F images.

As the side the F was on received proportionally more initial first saccades, one interpretation could be that the salience of the F was greater than the M and the greater proportion of initial saccades to the side featuring F reflects this. However, if F was more salient than M it would be expected that it would be easy to differentiate from M too, but accurate identification of F was the poorest of all the single letters and therefore this interpretation is questionable. When assessing the proportion of rightward initial saccades there appears to be no pattern of laterality across the chimeric images. Proportionally more initial leftward saccades are evident in some conditions (e.g. the E – L images in the freeview time condition) and proportionally more initial rightward saccades in other conditions (e.g. O-U in the 1000ms condition) and no impact of age was revealed. This may indicate a lack of hemispheric dominance for this task as RH face processing and LH language are both required. It does show, however, that during lip reading judgements an initial left saccade is not a reflexive action as has previously been argued for face processing in general (Leonards and Scott-Samuel, 2005).

The data also revealed no effect of age on direction of initial saccades for any of the chimeric letter combinations. In studies 1 and 2 it was argued that although age differences were not revealed for initial saccades, this does not necessarily mean that older and younger adults process faces in the same way. Potentially greater bilateral recruitment may be in operation for the older adults, but the instinctive left – right directional scanning may conceal this difference for their initial saccades. The results from this current study, however, do not support this as initial saccades did not persist in being biased to the left, they were also biased to the right in some conditions and yet no differences according to age were demonstrated.

As this is the first study to analyse older and younger adults' initial saccades during lip-reading it is unclear why proportionally more initial saccades were sometimes made to the left and sometimes to the right by both groups. One explanation is that as lip reading is a LH dominant task (Campbell et al., 1986; Ruytjens et al., 2006) this may have disrupted the RH processing typically revealed during face processing (Kanwisher et al., 1997; McCarthy et al., 1997), impacting on the left lateralization of initial saccades which has previously been noted in the literature (Bindemann et al., 2009; Butler et al., 2005; Leonards and Scott-Samuel, 2005). This potentially reflects a complex interplay between these two hemispheres during this task and further research is required to investigate this.

With regard to the fixation analysis, the results of this study revealed that proportionally more leftward fixations were made in the shortest (500ms) time condition. However, the strength of this bias reduced systematically as viewing time increased. This was the case for all chimeric letter images with the exception of M-F images which received proportionally more rightward fixations in the 500ms condition and a non-significant reduction in the strength of this bias from the 1000ms to the freeview time conditions. Consequently the F-M and M-F images received proportionally more fixations to the side mouthing the letter F in all time conditions. It is clear from the accuracy data that participants had difficulty lip-reading the letter F from single letter images, but they were easily able to lip-read the letter M. This therefore indicates that when assessing a chimeric image showing these two letters, proportionally more fixations went to the side which was more difficult to lip-read and as such does not appear to reflect hemispheric processing for this particular letter combination (F-M & M-F).

For all other letter combinations more fixations were generated to the left side with this leftward bias being strongest in the 500ms condition. One explanation for this is that face processing structures in the RH may respond quickly when faces are assessed resulting in proportionally more fixations being made to the left side in the shortest time condition. Then, as viewing time is extended the language processing areas of the LH are increasingly recruited in order to make these lip-reading judgements, and very recent research assessing activity of the inferior occipital gyrus (IOG) corroborates this idea (Sato et al., 2014).

The IOG is the most posterior of face processing areas, and because it is associated with the visual analysis of faces, the IOG has been suggested to represent the initial stages of the face processing hierarchy (e.g. Haxby et al., 2000; Pitcher et al., 2011). Recently, event related potentials (ERP) in the IOG were investigated when participants viewed faces, houses and mosaics presented upright and inverted (Sato et al., 2014). Assessments of the upright images revealed a negative deflection of the IOG (within the right IOG) peaking at approximately 170ms to faces relative to houses and mosaics. This supports EEG research which documents a heightened negative deflection in the IOG in this time scale for faces compared with other stimuli (e.g. Jonas et al., 2012). Sato and colleagues also found that gamma oscillations, which Buzáki & Wang, (2012) note as reflecting computational activity in neural networks, were stronger in the right IOG as early as 110ms when faces were viewed, an effect not revealed for the mosaics or houses.

Further ERP analysis used a repetition suppression paradigm to assess differences in activity when perceptions and subsequent vocalizations were made according to stimuli of specific letters and of faces forming different vowels (Möhring, Brandt,Mohr, Pulvermüller & Neuhaus, 2014). It was hypothesized that comparisons between cross modal activity (presentation of face then letter and vice versa) and intra modal activity (presentation of face then face, and letter then letter) would be greater in the LH. However, the results did not support this as the N170 amplitude in the RH was greater than the LH. This suggests that when the visual stimulus contains both language and face information, the face is processed at an earlier stage than language. The combined results of these studies indicate that the early activation of structural areas in the RH appear to be responsive to faces compared with other stimuli and to prioritise the processing of faces over the processing of speech. This may be the reason that the leftward bias for fixations was evident at the earliest time frame (500ms) with a reduction in this bias as viewing time increased as language systems in the LH were required for judgements.

No impact of age was revealed for the proportion of rightward fixations in any of the time conditions. Based on the theories of ageing which predict greater symmetrical processing in older adulthood this result was not anticipated (Cabeza, 2002; Park & Reuter-Lorenz, 2009). However, studies 1 and 2 did not reveal group differences for RH judgements and gender and identity and therefore this current LH study supports these previous two experiments.

Assessment of the fixation duration data revealed that as per the proportion of rightward fixation results, fixations were longer to the side of the F-M and M-F chimeric images showing the letter F. The older group in particular spent longer looking at the F of the F-M chimeric images in the freeview condition potentially reflecting their difficulty in deciphering this letter from the chimeric image and therefore greater dwell time to the left and right of these chimeric images is not considered to reflect hemispheric dominance.

Fixation duration to the O-U and U-O images showed that, with the exception of the O-U images in the 500ms time condition, fixation duration was longer to the side showing the letter O. It is clear from the accuracy data that participants, particularly older participants, were less accurate in judging the letter U from the single letter images. They also took longer in the freeview condition than younger adults when judging the chimeric images which may reflect their difficulty when deciding the letter. However, as speed of processing reduces in older age (see Salthouse, 1996) it was anticipated that the older group would take longer to make their decisions compared with the younger group. This group difference was also demonstrated for each chimeric letter combination not just O-U and U-O and consequently may not reflect particular difficulties with this letter combination. From the results it is clear that hemispheric dominance did not determine lateral bias for fixation duration because the bias was based on the side of the letter O and this appeared with equal regularity on the left and right sides.

One interpretation offered to explain greater fixation duration to the O side of the chimeric face is salience as the size of the mouth when saying O is larger and potentially more salient than when saying U. However, several studies have shown that eye movements generated up to 250ms after stimulus onset may be salience driven, but eye movements after this time are generally goal driven (Donk & van Zoest, 2008, 2011; van Zoest & Donk, 2005, 2008, 2010). Therefore the interpretation of salience reflecting fixation duration biases at 500ms, 1000ms and freeview time conditions does not seem likely. Instead fixation duration may have been longer to the side saying the letter O because it was easier to differentiate from U due to the larger mouth shape formed when saying it.

In conclusion a RPB was demonstrated for E-L images, a LPB was demonstrated for L-E images and no significant lateral perceptual bias was revealed for the Landmark task and age did not impact on this. The appearance of the letter L seemed to drive letter judgements and consequently participants' responses to these images appear to be due to the stimuli rather than hemispheric processing. The lack of significant perceptual bias for the Landmark task may be due to differences in group size. The perceptual biases for the E-L and L-E images were not associated with eye movements as no lateral biases were revealed for initial saccades, a left bias was revealed for proportion of fixations which systematically reduced with increased viewing time and duration of fixation was longer to the E at 1000ms and to the L when free viewing. Eye movement analysis of the other chimeric images (F-M, M-F, O-U and U-O) revealed no lateral biases for initial saccades, a systematic increase in fixations to the right with increased time and fixation duration to these images was longer to the side of the face showing the letter which participants had most difficulty accurately judging (F and O). No reduction in hemispheric laterality was revealed for the older group which contrasts with the theories of ageing (Cabeza, 2002; Park & Reuter-Lorenz, 2009) but, as has been discussed for each of the chimeric images in turn, is considered to be due to the images used and therefore cannot be attributed to cortical changes resultant of age .

It is evident from this task that lip-reading static images can be difficult, particularly for certain letters such as F, and this appears to impact on eye movements when judging the letters being mouthed from chimeric images. Although the images were rated to ensure that participants would be able to identify the letters being spoken it would be advantageous in future studies to examine the results after a few participants have completed the task. This way issues with the stimuli could be identified and corrected before the full study is conducted.

Chapter 6

Examining the Effects of age on Judgements of Emotional Expression and Line Length

6.1 Abstract

Perception of facial emotions is noted to be unilaterally dominated. However, competing theories indicate that either the right hemisphere predominantly processes all emotions (the right hemisphere hypothesis; RHH), or that negatively valenced emotions are processed in the right hemisphere and positively valenced emotions are processed in the left hemisphere (valence hypothesis). Differences in emotion perception in older compared with younger adults has been noted for some emotions, but accuracy in judging the emotional expression of happiness tends to be preserved or even superior in older adulthood. The change in emotion perception in later life may be due to structural changes affecting functioning across the left and right hemisphere. Alternatively, it may be due to older adults having a positivity bias as, due to their awareness of time being limited, they may preferentially focus on positive aspects in their environment to enhance their well-being. Using a divided visual field paradigm younger and older adults judged the valence and intensity of emotional expressions (anger, disgust, fear, happy, sad and neutral). They also completed the Landmark task (RH) which assesses differences in perceptions of line length. If age impacts on hemispheric dominance it could be expected that older adults would have reduced lateralisation compared with the younger group in the emotion and line perception tasks. The results showed no lateral biases for either group in the emotion or Landmark task, although an association between accuracy in judging positively valenced emotions in the left visual field and responses to the

Landmark task were revealed for the younger group. Both the RHH and valence hypothesis were unsupported and consequently cortical changes were not apparent in the older group. The older adults did, however, judge emotionally expressive and emotionally neutral images more positively than younger adults suggesting a positivity bias for this group.

6.2 Introduction

Of fundamental importance when interacting socially, is the ability to accurately perceive emotions from other people’s facial expressions (Ekman, 1964; Ekman and Friesen, 1969). Research has consistently demonstrated that facial expressions are vital in communicating social information such as the emotional states of others (for a review see Shariff & Tracy, 2011). Consequently, a growing body of work is not only focussing on the way affective facial expressions are processed cortically, but also on the impact that individual differences such as ageing have on this.

There are two dominant theories for lateralisation of emotion processing, the right hemisphere hypothesis (RHH; Borod et al., 1998) and the valence hypothesis (Adolphs, Jansari & Tranel, 2001; Ahern & Shwartz, 1979; Jansari, Tranel & Adolphs, 2000; Wedding & Stalans, 1985). The RHH predicts that all emotions are predominantly processed in the right hemisphere regardless of valence (positive/negative emotion), and of Ekman and Friesen’s (1975) six basic emotions; happiness and surprise are considered to be positive and sadness, fear, anger and disgust negative. Contrasting with the RHH, the valence hypothesis asserts that each hemisphere is specialised to process emotions according to valence; the right hemisphere dominating for negative emotions and the left for positive emotions. As has been noted (Abbott, Wijeratne, Hughes, Perre & Lindell, 2014) the hypothesis that emotions are lateralized according to valence was born following the observation that depressive symptoms have been observed in LH stroke patients whereas instances of euphoria and mania appear more prevalent in patients with RH damage.

Historical evidence for the RHH (Borod et al., 1998) was initially documented by Hughlings-Jackson (1879) who noted that patients with damage to the LH were able to curse and express other emotions despite being unable to repeat sentences, read or write. Consequently, he noted that the RH is the dominant hemisphere for emotion processing. More up to date research on individuals with unilateral brain damage offers support to Hughlings-Jackson's original observation. For example, patients with anterior, middle and inferior temporal lobe resections were tested between 2-8 years following surgery and compared with controls (Anderson, Spencer, Fulbright & Phelps, 2000). The task assessed their ability to identify and rate the intensity of the facial expressions (anger, sadness, fear, disgust, surprise, happiness and a neutral) presented to them. Patients with right temporal lobectomies judged the emotional expressions as being less intense than patients with left temporal lobectomies and controls, with no difference in the level of intensity for the left temporal lobectomy and control groups.

In a similar study, patients with unilateral LH or RH brain damage along with a control group conducted two tasks in which they identified single emotional expressions and distinguished between two emotional expressions using a "same/different" response paradigm (Borod et al., 1998). The results from this study concur with those of Anderson and colleagues (2000) and are further supported by more recent research (e. g. Charbonneau, Scherzer, Aspirot & Cohen, 2003; Kucharska-Pietura, Phillips, Gernand & David, 2003) all of which demonstrate that damage to the RH significantly and detrimentally impacts on emotion processing compared with left brain damaged and control groups who do not differ significantly.

Support for the RHH (Borod et al., 1998) also comes from non-clinical studies using chimeric face stimuli where a bias to judge both positive and negative emotional expressions from the left half face (RH) has also been noted (e. g. Bourne, 2011; Levy, Heller, Banich & Burton, 1983; Luh, Rueckert & Levy, 1991; Sackeim, Gur & Saucy, 1978). This left visual field advantage has also been demonstrated when the stimuli are presented so briefly (150ms) that saccades to stimuli presented in the left and right visual fields are either non-existent or severely restricted (Alves, Aznar-Casanova & Fukushima, 2009). Additionally, an fMRI study using chimeric images offers support for the RHH in showing RH activation for happy and sad emotions (Killgore & Yurgelun-Todd, 2007).

Although evidence for the RHH (Borod et al., 1998) continues to accrue, a growing number of studies also highlight the impact of emotional valence on hemispheric lateralisation. In particular, the dominance of the LH for processing positive emotional expressions is well documented in clinical as well as scanning studies. As this is inconsistent with the idea that the RH uniquely processes all emotions, it casts doubt on the RHH. For example, in a study which presented eye-regions rather than whole faces (Shamay-Tsoory, Lavidor & Aharon-Peretz, 2008) patients with unilateral left pre-frontal cortex (PFC) damage were more accurate for negative compared with positive emotions in both the basic (happy, sad, fearful, surprised, disgusted and angry) and complex-social (interested, worried, confident, fantasizing, preoccupied, friendly and suspicious) categories. Right PFC patients, however, demonstrated no effect of valence. This indicates that damage to the LH impacts on the processing of positive emotions; a finding which has also been revealed using transcranial magnetic stimulation (TMS) as only disruption to the left (not right) pre-supplementary motor area (pre-SMA) affected recognition of facial expressions of happiness. Disruption to the left and right pre-SMA did not affect recognition of anger or fear (Rochas et al., 2013).

Additional support for the LH and RH specialising for positive and negative emotion processing respectively has been revealed in fMRI work (Beraha et al., 2012; Canli, Desmond, Zhao, Glover & Gabrieli, 1998; Killgore & Yurgelun-Todd, 2007). In line with the valence hypothesis, these studies recorded higher levels of activity in the RH in response to negative images and facial expressions, and greater activity in the LH for positive images and facial expressions.

Behavioural paradigms, such as the divided visual field technique, also indicate processing differences according to valence. Reuter-Lorenz and Davidson (1981) tachistoscopically presented emotionally expressive faces and found a left visual field bias (RH) for sad expressions and a right visual field bias (LH) for happy expressions. Similarly, in a discrimination task, Jansari et al. (2000) revealed a bias for negative facial emotion presented in the left visual field (RH) and a bias for positive facial emotion in the right visual field (LH). These studies therefore show that perceptions of emotions are affected by the visual field these expressions are presented in. This appears to indicate that both hemispheres selectively process emotions according to valence supporting the valence hypothesis which is arguably the prevailing theory of emotion processing currently (for a review see Abbott, Cumming, Fidler & Lindell, 2013).

As discussed it appears from the literature that emotions are processed laterally, with either the RH dominating the processing of all emotions (Borod et al., 1998), or the RH and LH specializing according to valence (Jansari et al., 2000). The uncertainty in the research literature regarding lateralisation of valence may to a certain extent be due to methodological differences such as participants' gender. Indeed Abbott and colleagues' (2014) meta-analysis reports that many such studies only recruited male participants, or a significantly higher proportion of male to female participants. However, fMRI research has identified gender differences in lateralisation of emotion processing for happy and sad faces (Lee et al., 2002), therefore an important consideration when investigating lateralisation of emotion processing is to include the same number of male and female participants. It may also be due to differences in the number and valence of the emotional expressions studied as assessments of all six basic emotions would provide greater insight into perceptual lateralisation differences according to valence than assessments of just two or three emotional expressions.

Notwithstanding these methodological differences, hemispheric lateralization for emotion processing is predicted to reduce in older adulthood as it is argued that efficient processing relies on the additional recruitment of the non-dominant hemisphere (Cabeza, 2002; Park & Reuter-Lorenz, 2009). Cabeza (2002) states that compensatory recruitment of the non-dominant hemisphere is required by older compared with younger adults when conducting the same task, resulting in a reduction in hemispheric lateralisation for the older group. If hemispheric asymmetry reduces in older adulthood, then it would be anticipated that differences between older and younger adults would be evident in emotion processing as this is processed laterally.

Differences between these groups have been exposed with older adults being less accurate in identifying facial expression of emotions, compared with younger adults (e. g. Calder et al., 2003; Isaacowitz, et al., 2007; Keightley, Winocur, Burianova, Hongwanishkul & Grady, 2006; Moraitou, Papantoniou, Gkinopoulos & Nigritinou, 2013; Sullivan & Ruffman 2004; Sullivan, Ruffman & Hutton, 2007; Suzuki, Hoshino, Shigemasu & Kawamura, 2007; Suzuki & Akiyama, 2013, West et al., 2012), and for a meta-analysis of the literature see Ruffman, Henry, Livingstone and Phillips (2008). This change could be attributed to a more general age related decline as it is well documented that older adults have slower reaction times and a reduction in speed of processing, working memory and executive function. So, arguably, a reduced accuracy in emotion perception could be a further example of this age related difference.

However, Sullivan and Ruffman (2004) found an effect of age despite controlling for fluid and crystallized intelligence and the labelling of dynamic and still facial expressions of emotion. Similarly, Keightley and colleagues (2006) found that older adults' poorer performance in emotion identification was unrelated to age differences on tests of working memory, inhibition and verbal recall. Additionally, as age impacts differently on perceptions of negative and positive emotions this does not suggest a general age related decline. For example overall, perceptions of negative emotions are noted to be adversely affected by increased age compared with positive emotions (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Ruffman et al, 2008, West et al., 2012), although older adults have been found to be being better at identifying disgust than younger adults (Calder et al., 2003, Suzuki et al., 2007, West et al., 2012). Perceptions of the positive facial expressions of happiness and surprise appear to be the least affected by ageing, with older adults' responses often being equivalent to (Calder et al., 2003; Keightley et al., 2006., Isaacowitz et a., 2007, Suzuki et al., 2007; West et al., 2012) or surpassing younger adults (Moreno, Borod, Welkowitz & Alpert, 1993).

Age differences have also been revealed in some studies using chimeric faces, with younger adults demonstrating a LPB (RH) by judging happy (left)-neutral (right) images as happier than neutral (left)-happy (right) faces; an effect not recorded for older adults (e. g. Failla et al., 2003). Although see Coolican et al. (2008) for a lack of age difference in this regard. Consequently, the notion that an overall cognitive decline will be reflected in emotion processing does not fit with the evidence available, as perceptions of positive emotional expressions do not appear to be detrimentally affected in older adulthood.

In addition to emotion processing, laterality differences have been revealed for older and younger adults conducting the Landmark task. This task is typically used as an assessment tool for patients who have suffered unilateral hemispheric damage to determine the consequence of their injury on perceptions of space. Patients with lesions in their RH consistently demonstrate a RPB (e. g. Vossel, Eschenbeck, Weiss & Fink, 2010) by stating that evenly bisected lines are right longer/left shorter, whereas healthy young participants typically demonstrate a LPB by making left longer/right shorter judgements to evenly bisected lines (Schmitz & Peigneux, 2011). An effect of age has been reported by these authors on perceptual biases when the Landmark task is conducted, with older adults revealing a non-existent and near reversal of the LPB compared with younger adults. The Landmark task was included in this study to determine whether older and younger adults' lateral biases are specific to faces or reflect a more general bias.

Accuracy differences in perceptions of positive and negative emotional expressions may be due to cortical changes resultant of older age as hemispheric asymmetry reduces (Cabeza, 2002; Park & Reuter-Lorenz 2009). Alternatively, older adults may be prone to a ‘positivity effect’, or an inclination to ‘look on the bright side’ as they are increasingly aware that their time is finite. According to the socioemotional selectivity theory (SST; Carstensen, Isaacowitz & Charles, 1999) which is a lifespan theory of motivation, when time left is perceived as short, people are motivated to optimise emotional well-being by focussing on emotionally positive rather than emotionally negative information. The strength and vulnerability integration (SAVI) model of emotional well-being across adulthood (Charles, 2010) incorporates the SST’s temporal perspective as being important for prioritizing positive emotional experiences in older adulthood. Additionally, the SAVI model posits that older people have developed strategies that promote well-being which in turn act to continually regulate their emotional experiences. So older adults use previous experience as well as their acceptance of time left being finite to generate and maintain their positivity.

Stereotypically older age is associated with a pessimistic focus on sadness, loneliness and loss, and research has found that older people share the view that ‘other older people’ are inclined towards this way of thinking (Hummert, Garstks, Shaner, & Strahm, 1994; Nosek, Banaji & Greenwald, 2002). This is despite evidence that the majority of older people rate themselves as being satisfied (Myers & Diener, 1995). Indeed Cartstensen et al. (2011) found that older adults report themselves as being happier than younger adults, an effect which was robust even when factors associated with positive mood (e.g. physical health, personality, verbal fluency and demographic variables) were taken into consideration. Positive mood has also been found to be maintained for longer by older adults compared with younger adults when conducting a tedious, and therefore possibly unpleasant, face rating task (Voelkle et al., 2013).. This positivity effect in older adults has consistently been supported by research and in one of the first studies assessing this, a dot-probe task, revealed an attentional bias towards positive (happy) and away from negative (sad and angry) faces in older but not younger adults (Mather & Carstensen, 2003).

Recently, because of their ambiguity, morphed emotional expressions have become a useful tool in investigating perceptual differences for specific emotional expressions across age groups (e.g. Johnson & Whiting, 2013; Kellough & Knight, 2012; Slessor, Miles, Bull & Phillips, 2010). Morphed emotional expressions are classified as ambiguous because they contain either more than one emotion (e. g. happiness and sadness) or because the intensity of a single emotion reduces as the addition of a neutral expression increases (e.g. 100% emotion, 80% emotion/20% neutral, 60% emotion /40% neutral and so on).

Using full (happy, fearful, angry and neutral) and partly morphed emotions (20% and 40% emotion morphed with neutral) in two time conditions (60ms and 2000ms) Johnson and Whiting (2013) revealed that older but not younger adults demonstrated a positivity bias. They showed a response bias for happy over neutral responses for happy/neutral morphs, the younger group in comparison revealed the opposite response pattern by judging these images as neutral rather than happy. The older group also judged the fearful/neutral morphs as being neutral (therefore more positive than negative) compared with the younger adults, and when the morphs were presented for 60ms this effect was significantly larger than at 2000ms. This, the authors argue, indicates a partly automatic positivity effect for emotion processing in older adulthood. No age bias was revealed for the angry/neutral morphs in either presentation condition, although in this study angry faces were the most difficult to discriminate from neutral faces and so this may be an effect of the stimuli.

In a similar experiment (Bucks, Garner, Tarrant, Bradley & Mogg, 2008) older and younger participants were presented with 60/40 and 40/60 morphs of angry/happy, happy/sad, and sad/angry faces and were asked to rate (very, moderately, slightly) the degree of anger, happiness or sadness for each image. The groups did not differ in their ability to judge the dominant emotion, however younger adults were more likely to judge morphs of angry/happy faces as being angry compared with the older group and were also more likely to judge happy/sad morphs as being sad compared with the older group. No group differences were revealed for sad/angry morphs. Consequently, this indicates that older adults have a reduced tendency, compared with younger adults, to report negative emotional expressions when they are combined with positive emotional expressions.

A positivity effect has been revealed in studies using facial expressions of emotion such as those detailed above and also in other visual attention tasks using a variety of different stimuli and paradigms (for a review see Reed, Chan & Mikels, 2014). As such, the positivity effect appears to be a robust phenomenon when life span is limited. What is not clear is whether this positivity in later life is due to a change in motivation as argued by Carstensen et al. (1999) or whether it reflects hemispheric lateralization differences in older adulthood (Cabeza, 2002; Park & Reuter-Lorenz, 2009).

The intention of this study was to determine whether age related differences in emotion perception are due to changes in cortical lateralisation or to a positivity effect in older adulthood. In the emotion perception task it was predicted that younger adults would either demonstrate a laterality effect for accuracy and intensity judgements of all emotions when viewed in the left visual field (RHH; Borod et al., 1998), or for negative emotional expressions in the left visual field and positive emotional expressions in the right visual field (valence hypothesis, Adolphs et al., 2001; Ahern & Shwartz, 1979; Jansari et al., 2000; Wedding & Stalans, 1985). It was also predicted that younger adults would demonstrate a LPB in the Landmark task and that the laterality effects in both tasks would be reduced in older adulthood (Cabeza, 2002; Park & Reuter-Lorenz, 2009). To support the valence hypothesis accuracy for positively valenced emotional expressions should be better when presented in the right visual field (LH) and therefore a negative correlation between these judgements and the Landmark (RH) responses was anticipated. To support the RHH (Borod et al., 1998) a significant negative correlation was anticipated for accuracy of negatively valenced expressions in the right visual field and proportion of leftward responses in the Landmark task.

According to the socioemotional selectivity theory (SST, Carstensen et al., 1999) people who are increasingly aware that they have a finite length of time left to live attend to, and remember positive over negative information resulting in a positivity effect. Based on this theory it was hypothesized that older adults would demonstrate a positivity effect by judging the negative emotional expressions less accurately and as being less intense than the younger group and by judging the positive expression of happiness more accurately and as being more intense than the younger group. Additionally, to support the SST, it was hypothesized that older adults would perceive neutral expressions less negatively compared with younger adults.

6.3 Method

Participants

A convenience sample of 64 participants was recruited for this experiment. Thirty two older adults aged between 65 and 82 years (16 males; mean age = 70.38, *SD* = 4.63) and 32 younger adults (16 males; mean age 22.31, *SD* = 3.60). Participants received a £10 High Street gift voucher or course credit in return for taking part. Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed group differences with the older adults (M = 96.13, SD = 6.93) having significantly higher right laterality than the younger adults (M = 88.53, SD = 11.63; $t(62) = 3.17$, $p = .005$, $r = .37$). Test of premorbid functioning (ToPF; Wechsler, 2009) scores also showed significant differences between the groups with the older adults (M = 55.63, SD = 11.17) scoring higher than the younger adults (M = 41.03, SD = 11.43; $t(62) = 5.17$, $p < .001$, $r = .55$) and a significant difference was revealed for the time spent in full time education for the older (M = 13.13, SD = 3.37) or younger adults M = 16.88, SD = 2.80; $t(62) = -4.84$, $p < .001$, $r = .52$). Due to this task requiring perceptions of emotion to be determined a state version of the positive and negative affect schedule (PANAS; Watson, Clark & Tellegen, 1988) was completed prior to the experiment being conducted. In this 20 item (10 positive affect and 10 negative affect) 5 point scale, participants rate from “very slightly or not at all” to “extremely” in response to how they are feeling right now to key words such as “interested”, “upset”, “enthusiastic” and “irritable”. A minimum score of 10 and a maximum score of 50 is achievable for both the negative and positive affect scales. No significant difference in positive affect was revealed by the older (M = 32.38, SD = 7.30) and younger adults (M = 30.53, SD = 8.39; $t(62) = .94$, $p = .352$, $r = .12$) and no significant difference in negative affect was revealed either (older M = 11.75, SD = 3.56 and younger M = 12.69, SD = 3.91; $t(62) = -1.00$, $p = .320$, $r = .13$).

Apparatus

The experiment was conducted on a Dell laptop computer attached to a Dell 2009 WT 20 inch monitor using 13.66 inches presentation area. The experimental resolution was set at 1024 x 768 pixels with no scaling with the same presentation area (13.66 inches) on the laptop screen and monitor, and a refresh rate of 60 Hz. The displays ran using Windows 7 operating system controlled by E-prime software version 2. Participants viewed the stimuli on the monitor which had a small video camera recording them throughout the experiment to verify that they kept their gaze to the centre of the screen throughout the task. This apparatus was used for both the emotion and Landmark tasks, for further details of the Landmark test method see Section 5.3.

Procedure

Throughout the warm up, practice session and main task participants were tested individually in a quiet laboratory with a computer screen positioned 57cm centrally in front of them. A chin rest was used to keep their head stable.

Warm up

To enable participants to become accustomed to the presentation time of the images a warm up session was conducted. The stimuli consisted of 18 white letters presented on a black screen (3 each of the following R, B, D, K, H and P) in Courier

New font, with a viewing angle of 5.25° x 6.75° (the same size as the face images used in the practise session and main task). An equal number of letters were presented for 180ms 4° (as measured from the side of the image closest to the screen centre) to the left, right and centre of the screen. After presentation of each letter a backing mask was presented for 500ms. A message then appeared on screen which directed participants to look at the cross in the centre of the screen and then informed them that a letter would appear briefly to the centre, left or right side. Participants were requested to continue to look at the centre of the screen throughout the task and to state each letter out loud and their responses were noted. All participants completed this warm up session with no errors in accuracy.

Practice Session and Main Task

A practice session was then completed by participants. As per the warm up session a message informed participants to look at the cross in the centre of the screen which preceded each stimulus, it then informed them that a face would appear to the centre, left or right and they should state the valence (positive, negative, neutral) and if positive or negative should also state the level of emotional intensity from 1-10 (10 being the most emotionally intense) out loud (perceptions of neutral expressions were rated as 0). These judgements were inputted onto the laptop by the experimenter. Participants were explicitly asked to remain focussed on the centre of the screen and not to look towards the stimuli appearing to left or right sides. Presentation of each face was replaced by a backing mask which was shown for 500ms. If participants found the 180ms presentation time too difficult to judge the emotional expression accurately the presentation time was increased incrementally at 10ms until judgements were accurate. All the younger participants conducted the task in 180ms, however, none of the older group could accurately detect the valence of the images at this presentation time and therefore presentation times for this group varied (M = 236.88ms, SD = 10.61, range = 230ms – 250ms). For each participant the presentation time used in the practice session was also used in the main task.

The stimuli in the practice session and main task were sourced from the FACES database (Ebner, Riediger & Lindenberger, 2010) and comprised of high definition colour photographs of older and younger, male and female actors with positive, negative and neutral emotional expressions. Images used for the practice session were not used for the main task and consisted of 6 images, (3 males, 3 females, 3 older, 3 younger) expressing happy (2 images), sad, angry, disgusted and fearful emotions. Ninety six images measuring 204 x 256 pixels with a visual angle of 5.25° x 6.75° were used for the stimuli in the main task with images presented in a random sequence once to the centre and once 4° (as measured from the side of the image closest to the screen centre) left and right of centre. This resulted in participants completing 288 trials (6 blocks of 48) of which 96 had a positive valence, 96 a negative valence (24 anger, 24 disgust, 24 fear and 24 sad) and 96 a neutral expression (see Appendix II for the rating procedure). The experiment took approximately 30 minutes to complete.

Data Analysis

The following analysis investigated the impact of age (older vs younger) and presentation side (left vs right) on accuracy and intensity judgements of emotional and neutral expressions. It also investigated the impact of age (older vs younger) on perceptions of line length for evenly bisected lines using the Landmark task.

6.4 Results

Accuracy

Each participant's video footage was analysed and trials where saccades were made towards the stimuli removed. The images presented at the centre of the screen were used to assess accuracy for positive, negative and neutral judgements. One sample *t*-tests against .33 (chance) revealed that both younger (M = .93, SD = .05) and older adults' (M = .92, SD = .05) accuracy was significantly above the level of chance when making these judgements ($t(31) = 68.76$, $p < .001$, $r = .99$ and $t(31) = 61.98$, $p < .001$, $r = .99$) and an independent *t*-test showed no significant difference in accuracy between the groups ($t(62) = -.98$, $p = .331$, $r = .12$). The aim of this study was to determine the impact of presentation side on judgements of emotional expression for the two age groups and therefore no further analysis was conducted on the images presented at the centre of the screen.

Accuracy and Intensity Ratings of the Basic Emotions

For analysis of the emotions recognition accuracy rates were subjected to a 5 x 2 x 2 ANOVA with emotional expression (anger, disgust, fear, happy, sad) and side (left/right) the within participants factors and age (younger/older) as the between participants factor. Four data points were revealed as outliers and were replaced by 2 x *SD* plus the mean (Field, 2009). The data were skewed. Log, square root and reciprocal transformations did not normalise the distribution or improve the skewness and therefore untransformed data was used for the following analysis.

As is illustrated in Table 6.1 accuracy rates differed across emotions and this main effect was revealed to be significant. As Mauchly's test of sphericity was violated Greehouse-Geisser corrections were applied ($F(2.59, 160.76) = 66.89$, $p < .001$, $\eta_p^2 = .52$). Bonferroni post hoc comparisons revealed accuracy to sad images

(M = .70, SE = .02) was significantly lower than all other emotional expressions (anger M = .92, SE = .01; disgust M = .92, SE = .01; fear M = .93, SE = .01 and happy M = .95, SE .01; all ps < .001) and accuracy for happy expressions was significantly higher than anger (p = .039). The main effect of age approached significance ($F(1, 621) = 3.90$, $p = .053$, $\eta_p^2 = .06$, 95% CI [-.08, .00]). No other main effects or interactions were significant (all ps > .213).

Table 6.1.

Mean (SD) Accuracy for Each Emotional Expression in the Left and Right Visual Field.

	Younger Adults		Older Adults	
Facial Expression	LVF	RVF	LVF	RVF
Anger	.93 (.11)	.94 (.08)	.89 (.13)	.90 (.11)
Disgust	.96 (.07)	.92 (.13)	.88 (.15)	.91 (.13)
Fear	.95 (.10)	.95 (.11)	.91 (.17)	.91 (.11)
Happy	.95 (.05)	.95 (.07)	.96 (.05)	.94 (.06)
Sad	.75 (.19)	.73 (.21)	.67 (.19)	.67 (.26)

Participants also rated each emotional expression for intensity and the mean responses for all accurately judged emotional expressions are illustrated in Table 6.2.

Table 6.2.

Mean (SD) Intensity Ratings for Accurately Judged Emotional Expressions in the Left and Right Visual Field. The Scale Ranged From 1 to 10 with 10 Being the Most Intense.

	Younger Adults		Older Adults	
Facial Expression	LVF	RVF	LVF	RVF
Anger	5.33 (1.49)	5.74 (1.62)	5.34 (1.91)	5.54 (2.12)
Disgust	5.71 (1.55)	5.70 (1.73)	5.34 (2.01)	5.28 (2.06)
Fear	5.89 (2.11)	5.94 (2.09)	5.34 (1.93)	5.56 (1.98)
Happy	5.87(1.46)	5.94 (1.31)	6.03 (1.81)	5.96 (1.89)
Sad	4.52 (1.63)	4.32 (1.53)	4.09 (1.62)	4.21 (1.80)

To determine the impact of emotional expression, presentation side and age on intensity ratings a mixed 5 x 2 x 2 ANOVA was conducted. A significant main effect of emotion was revealed and due to Mauchly's test of sphericity being violated Greenhouse-Geisser corrections were applied ($F(3.04, 188.41) = 42.75$, $p < .001$, $\eta_p^2 = .41$). Bonferroni post hoc comparisons revealed that the mean intensity for the sad expression was significantly lower ($M = 4.29$, $SE = .20$, 95% CI[.66, .75]) than all other emotional expressions (anger $M = 5.49$, $SE = .22$, 95% CI[.89, .94]; disgust $M = 5.51$, $SE = .23$, CI[.89, .94]; fear $M = 5.68$, $SE = .25$, CI[.90, .96]; happy, $M = 5.95$, $SE = .20$, CI[.94, .96], all *p*s < .001) and the mean intensity for the happy expressions was significantly higher than that of anger ($p = .015$). No other main effects or interactions were significant (all ps > .213). Consequently, the side the emotional expressions were presented on and the age of the participants did not impact on intensity judgements for basic emotions.

Valence Hypothesis

To test the impact of age on the valence hypothesis facial expressions were grouped according to positive (happiness) and negative (anger, disgust, fear and sadness) emotional expressions and a mixed 2 (valence) x 2 (side) x 2 (age) ANOVA was conducted. One data point was revealed to be an outlier and this was replaced with the mean plus 2 *SD* (Field, 2009). The data were not normally distributed, reciprocal transformations improved the skew and this transformed data was used for the following analysis. The mean accuracy rates for positive and negative emotional expressions are detailed in Table 6.3.

Table 6.3.

Mean (SD) Accuracy for Positive and Negative Emotional Expressions in the Left and Right Visual Field.

	Positive Valence		Negative Valence	
	LVF	RVF	LVF	RVF
Younger	.95 (.05)	.95 (.07)	.89 (.07)	.88 (.08)
Older	.96 (.05)	.94 (.06)	.84 (.10)	.85 (.12)

And a mixed 2 x 2 x 2 valence (positive/negative), side (left/right) and age (older/younger) ANOVA was then calculated. A main effect of valence was revealed with positive emotional expressions more accurately judged (M = .95, SE = .01, 95%

CI [.97, .98]) than negative emotional expressions (*M* = .87, *SE* = .01, 95% CI [.92, .94]; $F(1, 62) = 47.57$, $p < .001$, $\eta_p^2 = .43$) which was qualified by a significant valence x age interaction ($F(1, 62) = 4.65$, $p = .035$, $\eta_p^2 = .07$, see Figure 6.1). A Tukey HSD analysis revealed that younger and older adults made significantly more accurate responses to the positive (*M* = .95, *SE* = .01, 95 % CI [.93, .97] and *M* = .95, *SE* = .01, CI[.93, .97]) than the negative emotional expressions (*M* = .89, *SE* = .02, CI [.86, .92] and *M* = .85, *SE* = .02, CI [.81, .88]; *p*s < .01), and the younger adults were significantly more accurate at judging the negative emotional expressions than the older adults (*M* = .89, *SE* = .02 CI [.86, .92] and *M* = .85, *SE* = .02, CI [.81, .88]; p < .01). No other main effects or interactions were significant all *p*s > .109.

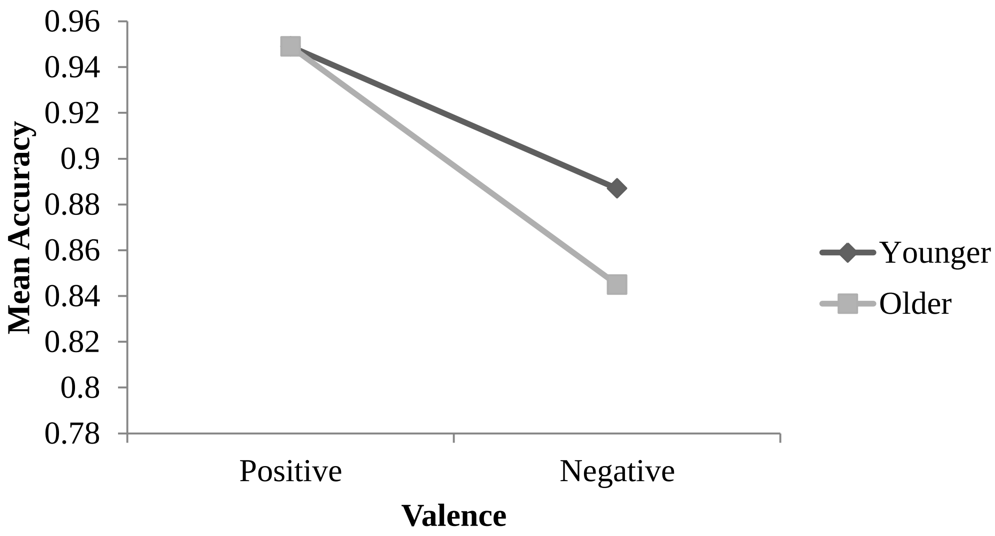

Figure 6.1. Valence x age interaction for mean accuracy of emotionally expressive faces.

In addition to the accuracy data analysis, intensity ratings for accurately judged positive and negative emotional expressions were also examined (see Table

6.4). A mixed (Valence x Side x Age) ANOVA was conducted on participants' mean emotional intensity ratings. This revealed a significant main effect of valence with the positive emotional expressions (*M* = 5.97, *SE* = .20, 95% CI [4.89, 5.72]) being rated higher than the negative emotional expressions (*M* = 5.30, *SE* = .21, 95% CI [5.66, 6.38] ; $F(1,62) = 28.51$, $p < .001$, $\eta_p^2 = .32$, 95% CI [.42, .92]). No other main effects or interactions were significant (all *p*s > .084), consequently neither age nor side impacted significantly on intensity ratings.

Table 6.4.

Mean (SD) Intensity Ratings for Positive and Negative Expressions of Emotion in the Left and Right Visual Field.

	Positive Valence		Negative Valence	
	LVF	RVF	LVF	RVF
Younger	5.87 (1.46)	6.01 (1.35)	5.41 (1.57)	5.49 (1.58)
Older	6.03 (1.81)	5.96 (1.89)	5.11 (1.74)	5.21 (1.85)

Neutral Images

As neutral images are not emotionally expressive and are neither positively nor negatively valenced they were not included in the analysis of the basic emotions or valence analysis detailed previously. However, the impact of age and presentation side on accuracy and perceptions of valence for neutral expressions has not previously been researched and therefore it was important to conduct analysis on the neutral image data separately. The overall accuracy for the neutral images presented in the centre of the screen for the older (*M* = .75, *SD* = .18) and younger adults (*M* = .67, *SD* = .19) was also assessed and one-sample *t*-tests against .33 (chance) revealed the accuracy rate to be significantly higher than chance for both groups (older $t(31) = 14.00$, $p < .001$, $r = .93$; younger $t(31) = 10.41$, $p < .001$, $r = .88$). An independent *t*-test revealed a non-significant trend for older adults to be more accurate than younger adults ($t(62) = 1.95$, $p = .055$, $r = .24$). Participants did not judge all neutral images as being neutral and instead judged some as either positive or negative and provided a level of intensity with these judgements. The mean error rate for positive and negative judgements of neutral images was examined for each side of presentation (see Table 6.5).

Table 6.5.

Mean (SD) Error Rate for Positive and Negative Valence Judgements of Neutral Expressions in the Left and Right Visual Field.

	Positive Valence Judgement		Negative Valence Judgement	
	LVF	RVF	LVF	RVF
Younger	2.06 (2.84)	1.68 (2.10)	8.78 (5.59)	8.75 (4.80)
Older	2.06 (2.66)	1.47 (2.53)	5.56 (3.98)	6.31 (4.53)

A mixed (Age x Side x Valence Judgement) ANOVA revealed a significant main effect of age ($F(1, 62) = 7.44$, $p = .008$, $\eta_p^2 = .11$, 95% CI [.46, 2.98]) with older adults having a significantly lower mean error rate than younger adults (*M* = *3.85, SE* = .38, 95% CI [2.61, 4.74] and *M* =5.32, *SE* = .38, CI [4.68, 6.46]), and a significant main effect of valence judgement ($F(1, 62) = 151.19$, $p < .001$, $\eta_p^2 = .71$, 95% CI [4.84, 6.72]) with significantly more negative than positive judgements (M = *7.35*, SE = .45, 95% CI [6.23, 8.58] and M =1.82, SE = .26, CI [1.29, 2.35]) which were qualified by a significant age x valence judgement interaction ($F(1, 62)$ = 11.72, $p = .001$, $\eta_p^2 = .16$, CI [4.84, 6.72]). Post hoc analysis using Tukey HSD revealed no significant differences between the younger and older groups for positive judgements of neutral images (M = 1.88, SE = .37, 95% CI [1.12, 2.63]and M = 1.77, SE = .37, 95% CI [1.01, 2.52]; $p > .05$), however, the younger group judged more neutral images as being negatively valenced than the older group did (M = 9.26, SE = .64, 95% CI [[7.89, 10.65] and M = 5.94, SE = .64, 95% CI [4.56, 7.32]; $p < .01$; see Figure 6.2). No other main effects or interactions were significant (*p*s >.291).

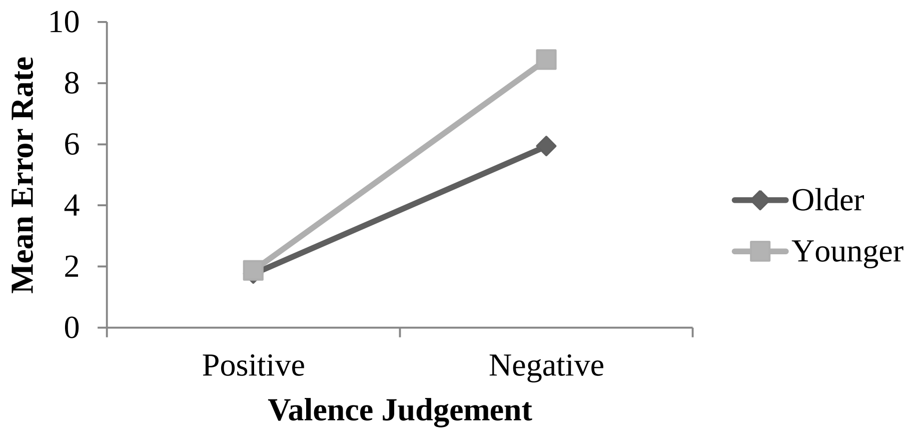

Figure 6.2. Age x valence judgement interaction for the error rate for neutral images.

The mean intensity for positive and negative judgements of neutral images was calculated per participant for each presentation side (see Table 6.6). A mixed side x age x valence ANOVA was then conducted to determine the impact of these factors on intensity judgements for neutral images. This revealed a significant main effect of valence (F(1, 62) = 41.28, p < .001, η_p^2 = .40, 95% CI[.83, 1.58]) with negative judgements of neutral images (M = 3.35, SE = .19, 95% CI [2.97, 3.74]) receiving significantly higher intensity ratings than positive judgements of neutral images (M = 2.15, SE = .24, 95% CI [1.67, 2.63]). No other main effects or interactions were significant (all ps > .282) and consequently neither the age of the participant nor the side of presentation impacted on intensity ratings.

Table 6.6.

Mean (SD) Judgements of Positive and Negative Affect for Neutral Emotional Expressions.

	Positive		Negative	
Group	LVF	RVF	LVF	RVF
Younger	2.42 (2.40)	2.10 (2.45)	3.43 (1.66)	3.36 (1.67)
Older	2.12 (2.07)	1.97 (2.34)	2.99 (1.58)	3.64 (2.03)

Landmark Task

To determine whether any age related differences in emotion processing were linked to changes in lateral biases in perceptual processing, performances on the Landmark test were analysed. In this task a higher score indicates a stronger LPB. One sample t-tests against .5 (chance) revealed no lateral biases on the evenly bisected lines on the Landmark test for the younger (M = .50, SD = .22; t(31) = .07, p

= .947, *r* = .01, 95% CI [-.08, .08]) or older adults (*M* = .48, SD = .19; *t*(31) = -.56, *p* = .582, *r* = .09, 95% CI [-.09, .05]). An independent *t*-test was conducted to determine differences between the groups and no significant difference in lateral bias was revealed (*t*(62) = -.41, *p* = .680, *r* = .05, 95% CI [-.01, .08]).

The relationship between LPB on the Landmark task and accuracy for the valence of the emotions in each visual field was then assessed. Pearson's correlations revealed a significant positive correlation for younger adults' LPB in the Landmark task (*M* = .50, *SD* = .22) and accuracy of positively valenced emotional expressions in the left visual field (*M* = .95, *SD* = .04, *r* = .41, *p* = .019). No significant correlation was revealed for younger adults' responses in the Landmark task and accuracy for negatively valenced emotional expressions in the right visual field (*M* = .88, *SD* = .07, *r* = .09, *p* = .621). No significant correlations were revealed for the older adults responses to the Landmark task (*M* = .48, *SD* = .19) and their accuracy for the positively valenced expressions in the left visual field (*M* = .96, *SD* = .05, *r* = .15, *p* = .414), or for their accuracy to negatively valenced expressions in the right visual field (*M* = .85, *SD* = .12 *r* = .03, *p* = .887).

Lateral judgements on the Landmark task and intensity judgements of emotional valence were also investigated. Pearson's correlations revealed no significant correlations for younger or older adults' responses in the Landmark task and their intensity judgements of positively valenced expressions in the left visual field (*M* = 6.03, *SD* = 1.81, *r* = -.08, *p* = .673) or to negatively valenced expressions in the right visual field (*M* = 5.20, *SD* = 1.84, *r* = .04, *p* = .812). Consequently the younger participants' LPB in the Landmark task was correlated with an increase in accurate judgements of positively valenced emotional expressions shown in the left visual field. No other correlations were significant *p*s > .771.

6.5 Discussion

The intention of this study was to determine whether there are age related differences in emotion perception and if these are due to changes in cortical lateralisation or to a positivity effect in older adulthood. It was found that when judging the valence of emotionally expressive faces both age groups were more accurate in judging the valence of the positive compared with negative images. This offers support for previous literature which has also noted no age related differences in perceptions of positive emotional expressions (Calder et al., 2003; Keightley et al., 2006, Isaacowitz et al., 2007, Suzuki et al., 2007; West et al., 2012). Both groups also rated the positively valenced images as having greater intensity than the negatively valenced faces.

One potential reason for the greater level of accuracy and higher ratings of intensity for positively valenced emotional expressions is that only one positive emotional expression (happiness) was included in this study and therefore it may have stood out from the negative (sad, anger, fear, disgust) expressions. A ceiling effect for perceptions of the emotional expression of happiness has been suggested previously, possibly due to this expression being more easily processed (e. g. Juth, Lundqvist, Karlsson & Öhman, 2008; Orgeta, 2010). However, from the analysis of the basic emotion data this interpretation appears unlikely as accuracy for happy emotional expressions was only significantly higher than accuracy judgements for sad and angry emotional expressions. No significant differences in accuracy were revealed between the emotional expressions of happy and fear, or happy and disgust and this same pattern was revealed for intensity judgements of the basic emotional expressions. The emotional expression of happiness was also rated as more intense than anger and sadness, but was not rated as more intense than fear or disgust. If the suggestion by Juth et al. and Orgeta is correct, then it would be anticipated that accuracy and/or intensity judgements for happy faces would be significantly greater than all other emotional expressions, but this outcome was not supported by the current data. It is also clear from the results that both accuracy and intensity judgements for sad faces were significantly lower than all other emotional expressions. Possibly this is because the facial expression of sadness is more muted than happy, fearful, angry and disgusted expressions and consequently may not have been as salient as these other expressions of emotion. These results show that the significantly higher accuracy and intensity judgements for positive images were not due to the expression of happiness, but were driven by the significantly less accurate and reduced intensity responses to the negatively valenced sad faces.

The data also revealed that younger and older adults had similar levels of accuracy when judging the positively valenced emotional expressions; however, when judging the negatively valenced faces younger adults' accuracy was superior to the older group's. This finding supports previous research showing that age impacts more detrimentally on perceptions of negative emotional expressions in older adulthood (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Ruffman et al., 2008, West et al., 2012). Additionally, when judging the valence of emotionally neutral expressions younger and older adults made a similar number of positive response errors, but younger adults judged more neutral images as being negatively valenced than the older group did. Consequently, the older group incorrectly judged more negatively valenced faces as being neutral or positive, demonstrating a positivity bias to these emotionally expressive images and a positivity bias was also revealed by the older group compared with the younger group for valence judgements of emotionally neutral images.

The results from the PANAS scores (Watson et al., 1988) did not indicate differences in positive or negative affect between the two age groups and therefore the results cannot be attributed to the older group feeling more positive or the younger group feeling more negative. Instead the results support the SST which proposes that older adults preferentially interpret information positively to enhance their own emotional state (Carstensen et al., 1999). The results also extend the growing literature documenting a positivity effect for emotion perception in older adults (Bucks et al., 2008; Johnson & Whiting, 2013; Kellough & Knight, 2012; Slessor et al., 2010) as none of these previous studies have documented age related perceptions of valence and intensity for neutral images.

Slessor et al. (2010) did use neutral expressions along with images showing spontaneous and forced smiles, and participants were asked whether the person in the photograph was feeling happy or not feeling happy (rather than judge the valence as this current study did). While their results revealed support for the SST as older adults perceived both the spontaneous and forced smiles as looking happy more often than the younger group, no age related differences were revealed for the neutral images. The difference in the current study's results and Slessor and colleagues' may be due to participants specifically being asked about the emotion of happiness rather than valence. In this current experiment participants were asked to respond according to whether the emotional expression was positive, negative or neutral and no specific emotional expressions were mentioned as it was each participant's interpretation of these expressions which was of interest. The combined results of this current study and Slessor et al.'s work appear to indicate that age differences in perceptual judgements of neutral images reflect differences in perceiving positivity/negativity rather than happiness/lack of happiness. Further research should aim to identify whether this age related difference is determined by perceptions of less frequently researched specific positive emotions such as pleasantness, contentment etc., or whether it is instead due to older adults exhibiting a more general positivity bias as has been previously documented (Charles, Mather & Cartsensen, 2003).

The neutral facial expressions used as stimuli in this task were subjected to the rating process described by its creators (Ebner et al., 2010) and were also unanimously rated as expressing no emotion and of having zero emotional intensity by older and younger naïve volunteers recruited for rating these images (see Appendix II). Consequently, although they were classified as being neutral from these processes, the perceptual responses of positivity and negativity along with the mean intensity ratings of 3.35 and 2.15 respectively out of a possible 10 indicates that some emotional ambiguity was perceived in these facial expressions. Interestingly, participants of both age groups judged more neutral expressions as being negatively than positively valenced. Both age groups also gave significantly higher intensity judgements to neutral images perceived as being negative compared with neutral images perceived as being positive. This contrasts with the intensity ratings for the emotionally expressive images which resulted in higher intensity judgements being made to the positive compared with negatively valenced expressions. One possible reason for this is that participants judged the positively valenced emotional expressions more accurately and as having higher intensity than the negatively valenced emotional expressions. This accuracy for the positively valenced expressions may have resulted in images that were lacking in positive emotional expressions as being perceived as negative, even though in the case of neutral faces, they may in fact have expressed no emotion.

Unexpectedly, the data did not reveal differences in accuracy or intensity according to the visual field these emotional expressions were presented in and therefore neither the RHH (Borod, et al., 1998) nor the valence hypothesis (Adolphs et al., 2001; Ahern & Shwartz, 1979; Jansari et al., 2000; Wedding & Stalans, 1985) are supported by these results. Previous research has indicated that either the RH dominates all emotion processing (Alves et al., 2009; Anderson et al., 2000; Bourne, 2011; Charbonneau et al., 2003; Kucharska-Pietura et al., 2003; Levy et al., 1983; Luh et al., 1991; Sackeim et al., 1978) or it dominates when processing negative emotions and the LH dominates for positive emotions (Beraha et al., 2012, Canli et al., 1998; Reuter-Lorenz & Davidson, 1981; Shamay-Tsoory et al., 2008). However, there is some conjecture in the literature that neither of these models fully account for emotion processing.

For example, although some researchers (Alves et al., 2009) interpret their findings as supporting the RHH (Borod et al., 1998), a LVF (RH) advantage was not revealed for all emotions. Alves and colleagues presented an emotional target face (happy, surprise, fearful, sad, neutral) and a distractor simultaneously to each visual field and participants were asked to indicate the location of the target. Although faster responses were found for expressions of happiness and fear when presented in the left visual field indicating a RH advantage, no effect of presentation side was revealed for sadness and surprise and a right visual field (LH) was found for neutral expressions and this overall finding does not support the valence or RHH hypothesis.

Other perceptual studies which appear to support the RHH (Borod et al., 1998) have only used a small number of emotional expressions for example happiness and neutral (Levy et al., 1983), smiling, sad and neutral (Luh et al., 1991) in these free viewing chimeric studies. This is problematic as the conclusion that the RH dominates for emotion processing could instead be argued to reflect the RH advantage for face processing in general.

Some experiments documented as supporting the valence hypothesis have also only used a limited number of emotional expressions for example happy and sad (Reuter-Lorenz & Davidson; 1981), happy, neutral and sad (Adolphs et al., 2001). However, as the emotions of happiness and sadness do not necessarily fully reflect positive and negative valence, the RHH (Borod et al., 1998) and valence hypothesis were not fully supported by these results.

In a recent study Najt, Bayer and Hausmann (2013) used a similar paradigm to the current study and asked participants to judge whether emotional expressions (anger, disgust, fear, happiness, sadness, surprise and neutral) presented to the left or right side were “emotional” or “”emotionally neutral”. No effect of visual field was found for judging positive emotional expressions (happiness and surprise) and although the authors did find an effect for negative emotional expressions overall, in the left visual field (RH) no effect of presentation side was revealed for the emotion of disgust. Najt and colleagues’ study was beneficial as a wide range of emotional expressions were investigated, however, not only do their results offer a lack of support for both the RHH and valence hypothesis, they also potentially indicate that the emotional expressions of happiness, surprise and disgust may be bilaterally processed as the visual field these expressions were presented in made no impact on accuracy.

The processing of some emotions may indeed rely on both rather than one dominant hemisphere as support for this line of argument has been revealed through brain scanning research. In Killgore and Yurgelun-Todd's (2007) fMRI study using chimeric faces it was revealed that the RH was active when processing both happy and sad emotions, but the LH was also active when processing happy expressions. This indicates that the emotional expression of happiness is processed in both hemispheres rather than being unilaterally dominated by either the left or right side. The authors note that their results offer support to both the RHH and the valence hypothesis; however, it could also be argued that their results support neither hypothesis as they both predict unilateral dominance for specific emotions, not the bilateral processing of happiness. Their findings do, however, show that at least one emotion (happiness) is processed across both hemispheres. This exposes a limitation of their research - that only happy, sad and neutral expressions were used - and, therefore, possible bilateral activation patterns for other emotional expressions were not, but should be investigated.

The theories of ageing predict that efficient processing in tasks which have previously been considered to be unilaterally dominant in younger adulthood, such as emotion processing, rely on greater input from the non-dominant hemisphere in older adulthood (Cabeza, 2002; Park & Reuter-Lorenz, 2009). However, if younger adults process at least one (Killgore & Yurgelun-Todd, 2007) and possibly more emotions bilaterally, it is unsurprising that no impact of age on lateral judgements of valence and intensity was revealed in this current study. Using this current paradigm it would be useful to compare hemispheric activation in older and younger adults using fMRI technology not only to examine differences in processing across the groups, but to determine whether emotions other than happiness are processed across both hemispheres in younger adulthood.

The lack of lateralisation in younger and older participants was also exposed in the Landmark task. Against predictions, no left bias was revealed for the younger group, indeed no bias to either side was revealed for either age group. While this supports the findings of the subgroup tested in study 3, it contrasts with previous literature which reveals a leftward bias for younger adults (e. g. Bowers & Heilman, 1980) and less consistently indicates an age related reduction in this bias for older adults (Beste et al., 2006; Failla et al., 2003; Fujii et al., 1995) and for a review see Jewell and McCourt (2000). However, differences in right and left biases have been noted in line bisection tasks where participants determine the midpoint of a line (Braun & Kirk, 1999; Cowie & Hamill, 1998; Manning, et al., 1990) possibly indicating that strength of RH dominance may differ between participants. Potentially the participants recruited for this study were less RH unilaterally dominant as individual differences other than age have been reported to impact on perceptual lateralisation judgements during face processing (Bourne & Vladeanu, 2011) and therefore this may have affected lateral judgements for the Landmark task in this current study and in the line bisection tasks of previous studies too (Braun & Kirk, 1999; Cowie & Hamill, 1998; Manning, et al., 1990). Although different cohorts of older and younger participants were recruited for each study in this research programme, study 1 revealed differences in strength of perceptual bias for both older and younger adults with over 20% of participants from both age groups demonstrating a RPB. It is therefore conceivable that the lack of perceptual bias in either of the age groups that conducted the Landmark task in studies 3 and 4 is a reflection of lateral processing differences within, but not between groups.

Interestingly though, a positive correlation was revealed between younger adults' accuracy in judging positively valenced emotional expressions in the left visual field and their LPB in the Landmark task. Based on the valence hypothesis accuracy for positively valenced emotional expressions should be better when presented in the right visual field (LH) and therefore a negative correlation between these judgements and the Landmark (RH) responses was expected. To support the RHH (Borod et al., 1998) a significant negative correlation should have been revealed for accuracy of negatively valenced in the right visual field LPB for the Landmark task, but this was not revealed and therefore neither the valence nor RHH are supported. Indeed no other significant correlations were found for either age group. As this correlation shows that a LPB in the Landmark task was correlated with increased accuracy to judgements of positively valenced emotional expressions shown in the left visual field, it indicates that positive emotional expressions and perceptions of line length are processed similarly in younger adulthood. The reasons for this relationship are unclear and consequently further research is required to investigate it.

In summary the results of this study show support for the SST (Carstensen et al., 1999). Older participants demonstrated a positivity bias to emotionally expressive faces by incorrectly judging the negatively valenced faces as being either neutral or positive, and therefore judged them more positively than the younger group. When judging the valence of neutral images older adults made fewer negative response errors than the younger group and consequently had a positive bias compared with the younger cohort. In contrast the younger group judged more neutral images as being negatively valenced than the older group and therefore demonstrated a negativity bias to these images compared to older adults. Intensity judgements of emotionally expressive faces were higher for positive compared with negative faces whereas intensity judgements of neutral faces were higher when participants perceived these faces to be negatively rather than positively valenced. The side the faces were presented on did not impact on judgements of valence or intensity for either age group, and therefore the RHH (Borod et al., 1998) and the valence hypothesis (Adolphs et al., 2001; Ahern & Shwartz, 1979; Jansari et al., 2000; Wedding & Stalans, 1985) are unsupported. Similarly, no lateral biases for older and younger adults were revealed for perceptions of line length during the Landmark task, although younger adults appear to process line length and positively valenced emotional expressions similarly. These results do not indicate hemispheric specialism for processing emotional expressions or line length, but do suggest that older adults perceive facial information more positively than younger adults.

Chapter 7

General Discussion

Based on recent figures the global population of children under the age of 15 fell from approximately 38% in 1965 to 26% in 2013; a decline which is predicted to continue. In conjunction with this fall in birth rate the number and proportion of people aged 60 and over has consistently increased and based on the most up to date projections from United Nations data the number of people aged 60 years or over will outnumber children by 2047 (UN, 2013). In conjunction with the demographic shift to an ageing population come both challenges and rewards. Specifically, challenges include the ability of countries to provide financially for an increasing number of older adults while the working population declines. A decline in health and cognitive functioning are also associated with increased age and as such place greater demand on health care and long term care (UN, 2012). However, the contribution of older adults in ways which are not measured financially are clearly detailed in the UN (2012) report. For example older adults, particularly older females, all over the world provide care for grandchildren so that parents are able to work and will take on guardianship of the child if their parents are no longer able to care for them. Older adults are also a source of knowledge based on their own experiences of culture and history, and they are the most active age group working in the third (voluntary) sector.

The importance of maintaining good mental health and reducing cognitive decline in older adulthood, therefore, cannot be understated. As a consequence, research into age related disorders such as Alzheimer's disease and dementia is now a priority for the UK government as set out in the Prime Minister's Challenge on

Dementia 2020 report (Department of Health, 2015). In addition to focussing on these age related disorders, studies using healthy older adults are also crucial because they document the ways the brain adapts to maintain efficient functioning in older adulthood. Some theories predict that ageing impacts on asymmetric hemispheric dominance resulting in tasks such as face processing becoming less unilaterally dominant in older adulthood (Cabeza, 2002; Park & Reuter-Lorenz, 2009). As faces are used to judge, amongst other things, people's mood, emotion, gender, age and identity, differences in looking at and perceiving this information resultant of age may impact on social interaction and understanding.

Aims of Thesis

The aims of this thesis were to test the theories of ageing (Cabeza, 2002; Park & Reuter-Lorenz, 2009) by investigating age related differences in attention and perception when decisions about faces are made. Specifically, whether lateral biases of eye movements and perception reduce in older compared with younger adults, and to determine whether perceptual biases are specific for faces or are a more general bias when visually processing space. Healthy older and younger adults were recruited for a series of experiments which assessed their lateral biases of perception and eye movements when facial judgements about gender, identity, lip-reading and emotion were made and perceptual biases were also investigated using the Landmark task. A summary and interpretation of these studies is now detailed followed by the strengths and limitations of this research and a final conclusion.

Summary and Interpretation of Results

In study 1 eye tracking technology was used to investigate the eye movements (initial saccades, proportion of fixations and fixation duration) of older and younger adults as they judged the gender of chimeric faces in two time conditions. Younger adults judged the gender of the faces on the left side of the face in both time conditions, demonstrating an LPB. This bias was also revealed by the older group in the freeview but not in the 1000ms condition. However, as the bias mean scores were the same in both (.53), the lack of significance appears to be due to greater standard deviation in the 1000ms condition compared with the freeview condition (.07 and .06). Despite previous research suggesting a stronger bias with greater viewing time (Butler & Harvey, 2008) the current data did not support this and no effect of age was found either.

An overall leftward bias for initial saccades was demonstrated by both age groups in each time condition and no impact of age or time condition was found. Based on participant’s left – right reading style (Vaid & Singh, 1989; Megreya & Havard, 2011) and as initial saccades are noted to be instinctively driven to the left side when faces are viewed (Leonards & Scott-Samuel, 2005), this left bias was expected for both age groups. An initial saccade bias to the left remained when gender judgements were based on the left side for both groups in each time condition. However, when the gender judgement was based on the right side this left bias was only revealed by the older group in the freeview condition and by the younger group in the 1000ms condition. Age and time condition were not found to impact on the proportion of initial saccades made to the left, but more initial saccades were made to the left when a subsequent response was based on the left side too.

The overall data revealed no lateral bias for the proportion of fixations or mean duration of fixations for either time condition. However, when a response was based on the left side, proportionally more fixations were made to the left, but when a response was based on the right proportionally more fixations were not made to the right. Interestingly though, when a response was based on the left, fixation duration was similar to the left and right sides, but when a response was based on the right fixation duration was greater to the right than the left side. Age and time condition did not impact on these biases.

It was clear that age did not consistently impact on eye movement or perceptual biases in this study. It was also apparent that eye movements were not dependably biased to the left as would be anticipated from this RH task, and therefore the association between perception and eye movements was unclear. A close investigation of the data revealed that a substantial minority of older and younger participants in each time condition demonstrated a RPB. An analysis based on participants' perceptual bias (strong left, weak left, right) showed that left lateral response biases were associated with left lateral eye movement biases for initial saccades and proportion of fixations, but no consistent link between a RPB and rightward eye movements was shown.

The results of study 1 do not support the theories of ageing (Cabeza, 2002; Park & Reuter-Lorenz, 2009) which predict greater symmetrical processing across the hemispheres in older compared with younger adulthood, as no significant age differences were found. This does not necessarily mean that older adults do not experience a reduction in hemispheric lateralisation though, it just shows that this study did not reveal it. Study 2 used faces, which were not modified to become chimeric, in a divided visual field paradigm to assess group differences in eye movements and perceptual biases when facial identities were matched.

When matching one of two target faces with a face in a ten face line-up both age groups revealed a trend to be more accurate in matching the right than the left target face. Previously a LPB has been shown for accurately matched faces using this task (Megreya & Burton, 2006a; Megreya & Havard, 2011), and a LPB was revealed by older and younger adults in study 1 for judgements of gender. The target faces were shown an equal number of times to the left and right side and this rightward trend was not expected, however, a potential reason for this may be gleaned from the eye movement and RT data.

When faces were accurately matched (hits) more initial saccades and fixations were made to the left target face and fixation duration was also longer to the left than the right target face. The proportion of fixations was biased to the left target face when the hit was on the left and also when the hit was on the right, additionally RT was faster for hits to the left than right face. Although fixation duration was greater to the right face when the hit was on the right, it was also greater to the left face when the hit was on the left. The leftward eye movements and the faster RT for hits to the left target face combine to indicate that the left target face was matched before the right target face. Consequently, when participants accurately matched the right target face, they had already discounted the left target face and may have been more confident that the correct match was on the right side resulting in a tendency to correctly match more right than left target faces.

Like study 1 an association between leftward judgements (hits) and leftward eye movements was revealed for initial saccades and proportion of fixations supporting previous research (Butler et al., 2005) and study 2 also found this association for the duration of fixations. Study 1 revealed a bias for judgements to be based on the left side; in contrast a trend for better accuracy was found for the right target face in study 2. As noted, the lateralised response differences in these two experiments may be due to task differences rather than reflect right or left dominance for gender and face matching respectively.

Supporting study 1, no age differences were revealed. This may indicate that hemispheric laterality does not reduce in older adulthood, or could indicate more specifically that hemispheric laterality of the RH does not reduce. To investigate this a lip-reading task and the Landmark task were conducted in study 3 to assess lateralisation of perception and eye movements using a LH task and to compare these perceptual biases with those demonstrated in a RH task. No perceptual biases for either age group were demonstrated in the Landmark task, although a trend to the right was evident in the younger group. This rightward trend was not anticipated as this is a RH dominant task and therefore a LPB was expected. However, a rightward trend for accuracy was also revealed in study 2 which may be because the right target face was matched after the first, or it may suggest that strength of RH dominance varies across participants resulting in differences in lateralisation of perceptual bias as was indicated through the results of study 1. For the lip-reading task perceptual biases to E-L and L-E chimeric faces were dictated by the side of the chimeric face the letter L was situated on and therefore should not be interpreted as reflecting hemispheric dominance.

In contrast with studies 1 and 2, study 3 revealed no consistent lateral biases for the initial saccades in any of the time conditions. Studies 1 and 2 were RH tasks and a bias to generate initial saccades to the left is consistently revealed in the literature using such tasks (Bindemann et al., 2009; Butler et al., 2005; Leonards &

Scott-Samuel, 2005). The lack of bias for initial saccades in study 3 may indicate that the language element of the task (LH) interrupted RH processing at the onset of facial analysis, resulting in neither hemisphere being dominant. As a consequence, the natural propensity to generate the first eye movement to the left was suppressed and no lateral bias revealed.

Previous literature has also shown a bias to the left for proportion of fixations in younger adulthood when a response was made on the left side (Butler et al., 2005) and study 1 showed that this bias strengthens as time is extended during facial analysis. The results of study 3 show for the first time that when lip reading, a bias to make proportionally more fixations to the left is still observed in the 500ms time condition, but a greater proportion of fixations to the right is made as time increases (to all chimeric images except M-F). This suggests that in the first 500ms of facial analysis proportionally more fixations are made to the left side potentially because face processing is prioritised over language processing in this time scale. However, as viewing time extends, input from the language dominant LH grows, resulting in an increase in the number of fixations generated to the right side. The fixation duration data in study 3 did not reveal particular hemispheric dominance and instead appeared to be stimuli driven. Consequently, no conclusions on hemispheric dominance and fixation duration can be drawn from this data.

Study 4 assessed participants' perceptions using a divided visual field emotion processing task and the Landmark task. No lateral biases were revealed for accuracy of valence or intensity judgements for either age group in the emotion task and no lateral biases were revealed for either group in the Landmark task. Consequently, throughout this programme of research it has been revealed that age did not impact on perceptual biases when faces are analysed, nor does it impact on lateral biases for space perception in general. It has also shown no reduction in laterality of eye movements and therefore the HAROLD (Cabeza, 2002) and STAC (Park & Reuter-Lorenz, 2009) models of ageing are not supported. It is clear from study 4 that older adults demonstrated a positivity bias compared with younger adults when judging the emotionally expressive and neutral faces. This fits with Carstensen et al.'s (1999) SST as a positive interpretation of negative and neutral expressions was made by the older compared with the younger adults.

Strengths, Limitations and Future Directions

As previous literature has indicated that either the RH reduces in dominance in older age (Goldstein & Shelly, 1981) or that each hemisphere relies on input from the non-dominant hemisphere (Cabeza, 2002; Park & Reuter-Lorenz, 2009) the first strength of this current thesis is that it employed both LH and RH dominant tasks. The gender, face matching and Landmark tasks are all predominantly processed in the RH, the emotion task tests either solely in the RH (Borod et al., 1998) or the right and left hemisphere dependent on valence (Adolphs et al., 2001; Ahern & Shwartz, 1979; Jansari et al., 2000; Wedding & Stalans, 1985) and the lip reading task is processed in the LH. Consequently, the impact of ageing on each hemisphere was assessed and the results were linked back to the predictions of the theories of ageing. The majority of face processing literature focusses on RH dominant tasks, and therefore this thesis is a valuable addition to the literature as the impact of ageing on LH face processing was also included.

A second strength is that the association between eye movements and perception were assessed. The face processing literature lacks a consensus as to whether perceptual biases are linked to eye movement biases. Study 1 revealed that with a LPB more initial saccades and proportionally more fixations were made to the left side and fixation duration was greater to the right with a RPB. This appeared to be driven by participants with a strong and weak LPB as eye movements were not associated with RPB participants' lateral judgements. Study 2 revealed that initial saccades were generated to the left target face and side used for a hit did not impact on this, proportionally more fixations were made to the left face with a LPB and fixation duration was greater to whichever target face used for a hit, target face side did not impact on this. Study 3 could not be used to assess the relationship between eye movements and perception as judgements were determined by the stimuli and therefore did not reflect typical face processing.

Further strengths of this research are that in the literature to date there has been no exploration of whether eye movements and perception are associated in older adulthood and additionally whether lateral eye movement biases reduce in with age. The current findings suggest no differences between older and younger adults and consequently the associations detailed above do not change with increased age and no reduction in asymmetry was revealed in the older groups either. Therefore this research has added to the face processing literature for lateral biases of perception, eye movements and the association between the two using both LH and RH tasks and has investigated changes to these resultant of increased age. There were some potential limitations, some of which could lead to future research and these are now detailed.

Sample size. As no consistent age differences were revealed in these studies for lateral biases of perception and eye movements the question of sample size may be raised i.e. were the sample sizes too small. Based on previous literature this appears unlikely as will now be detailed. For each study in this research project approximately 30 older and 30 younger participants were recruited (study 1 recruited an additional 22 older and 24 younger for the 1000ms condition) and to ensure that results could not be attributed to specific participants new groups of older and younger adults were recruited for each study. Butler and Harvey (2008) assessed the data of 14 older and 24 younger participants in their study investigating age related differences in perceptual laterality for gender judgements. Consequently, their older group was less than half the size of the older groups recruited in studies 1 (freeview), 2, 3 and 4, and their younger group was also smaller than the groups recruited for this project. However, Butler and Harvey revealed differences according to age with their older group demonstrating a reduced LPB compared with the younger group.

Failla et al. (2003) recruited 30 participants aged sixty to seventy and 24 participants aged twenty to thirty. They noted significant age related differences in LPB for happy/neutral chimeric faces and the line bisection task with younger adults demonstrating a stronger LPB in both tasks compared with the older group. Fujii et al. (1995) had 36 participants in each age group and also noted significant age differences in the line bisection task. Cherry et al. (1995) found a non-significant trend for perceptions of happy/neutral chimerics, although their group sizes were smaller at just 20 participants in each group. Based on these results, groups of 30 participants should be large enough to reveal any effect of age. Perhaps the older adults recruited for these current studies are ageing at a slower rate than would typically be expected of their age group, and this is why reduced biases of eye movements and perception were not consistently revealed. However, it is unclear why this would be the case because a random recruitment method was used and therefore anybody aged 65 or over (60 in study 1) who did not have any of the criteria which would exclude them (see Section 2.2) could take part.

The impact of ageing on hemispheric laterality is not consistently revealed in the literature (Coolican et al., 2008; Levine & Levy, 1986; Moreno et al., 1990). The STAC (Park & Reuter-Lorenz, 2009) is a lifespan model of compensation which, in part, details the way that brain regions reduce in volume with age. A clear reduction is illustrated from the age of 20 to 82 with the greatest reduction apparent at the upper end of this age range. Therefore another possibility for not finding a consistent effect of age on lateral biases of attention and perception in this current thesis is that reduction in hemispheric lateralisation occurs with greater frequency later in older adulthood than was examined here. To determine whether this is the case future research should focus on recruiting a greater proportion of healthy older adults in their 70s, 80s and 90s. It would also be useful to use brain scanning technology such as fMRI to determine whether the lack of age related differences in eye movements and perception during facial analysis is because both age groups are processing faces the same way or whether compensatory recruitment is required in older adulthood.

Alternatively, the inconsistency in the literature may indicate that individual differences other than age have impact, as it has been revealed that anxiety impacts on lateralised perceptions of emotions (Bourne & Vladeanu, 2011; Heller, Nitschke, Etienne & Miller, 1995). Bourne and Vladeanu revealed that across all six emotions (anger, disgust, fear, happiness, sadness and surprise) participants with higher levels of trait anxiety had a strong LPB when judging neutral/emotion chimeric faces, whereas participants with high levels of social anxiety had strong RPB. It is unclear whether anxiety impacts on lateral biases when processing emotion specifically or if this difference is more general and would therefore be revealed using non emotional stimuli, such as gender, identity or lip reading. This would be a useful next step for research as it would show whether these differences are due to motivation or hemispheric dominance.

Limitation of study 3. A specific limitation of study 3 was in developing the stimuli. Although the single images were piloted (see Appendix I) accuracy in the main experiment was poor (see Tables 5.1 and 5.2) and therefore perceptual responses could not be included for most of the chimeric images. Despite the judgements of the E and L single letter images being highly accurate, letter judgements for the chimeric images (E-L and L-E) were based on the side with the letter E at 1000ms and based on the side with the letter L in the freeview condition. This was not foreseen from the accuracy data as it appeared that participants were easily able to judge the letters being spoken.

Only one other study is known to have used chimeric images expressing language to examine lateral perceptual biases, and this study found a RPB (Burt & Perrett, 1997). Fewer chimeric images were used in Burt and Perrett's (1997) freeview study and in these images the left and right sides of the face were expressing similar looking letters, for example s and e. One of the reasons for including a greater variety of letters in this current study was to ensure that lateral biases of attention and perception were due to hemispheric dominance rather than as a result of specific letters (e.g. e and s). However, as is clear, the images were not ideally suited for this experiment. Chimeric images are somewhat unusual to look at whichever facial attribute they are presenting and it appears from this current study that chimeric images expressing language may appear too unusual and as a consequence are looked at, and processed differently to faces which have not been made chimeric. This issue may have been missed if only a small number of images were used in one time condition. Future research focussing on age related differences for perception and eye movements when lip reading would therefore benefit from using whole, rather than chimeric images along with a range of different viewing time conditions.

Static versus dynamic images. Static images were used as stimuli throughout this research project in order to extend previous literature using similar static stimuli and to limit the number of extraneous confounds when comparing results. While the perception of facial gender and identity may not benefit from dynamic stimuli, perceptions of speech may well do as speech requires movement and as such accurate perceptions of speech may partly rely on input from the motor system. This may be one reason why accuracy for some of the single letters in the lip-reading task was so low. For example in an fMRI study (Calvert & Campbell, 2003) participants were shown still images of a resting face (mouth shut with a letter superimposed on the lips), still images of a face expressing speech and dynamic images of speech. Participants looked for sequences of monosyllables in the still and dynamic images, and reported the letter shown on the resting face. Accuracy for the still and dynamic images was not significantly different (66.5% and 68%) whereas accuracy for the resting face was significantly greater than the two speech conditions (98%, ps < .01).

Compared with the resting face, the still speech face created greater activation in the FFA; additionally, as would be anticipated from a speech reading task, activation of the supramarginal gyrus (including the STS), middle temporal and inferior frontal regions was greater in the LH compared with the RH. However, the difference in activation between the dynamic and still images was stark with dynamic images almost doubling the amplitude of still images. Both still and dynamic images generated activity within the STS which is noted to process gaze, emotional expression and lip reading (Puce et al., 1998; Hoffman & Haxby, 2000). However the dynamic images produced the greatest activation in the visual motion regions, still images activated the ventral premotor cortex and intraparietal sulcus more highly. The combined results indicate that dynamic images of speech produce greater cortical activation than still images and that dynamic and still images of speech are processed somewhat differently. It may therefore be useful to assess the impact of age on lip reading using dynamic images as they are not only more ecologically valid than static images, but the greater cortical activity when viewing them may be reflected in participants' behavioural responses.

Concluding Remarks

In conclusion this present thesis did not found evidence to indicate that age impacts on lateral biases of perception when judging gender, identity, lip-reading, emotion or space (Landmark task). It also found no evidence to indicate that age impacts on lateral eye movement biases when judging gender, identity or emotion. Eye movements and perceptual biases are more consistently associated to the left side; however, an association to the right side is also apparent for fixation duration. All of these findings add to the existing literature.

It is clear that further research is required to determine whether older and younger adults are processing faces in the same way, or whether recruitment of additional cortical structures results in similar behavioural responses between the groups. Scanning technology would be useful in this regard. The impact of individual differences other than age should also be explored as this research is in its infancy. Based on the results of study 1, along with Bourne and Vladeanu's (2011) work it appears that hemispheric lateralisation differs among participants. The reasons for this and the impact this has on perceptions of different facial attributes have not yet been fully investigated.

8. References

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Appendix I

Piloting Process for Images used in the Lip-Reading Study

The images were of male and female actors aged between 18 – 20 and 51 – 70 who were photographed as they spoke the letter sounds E, L, F, M, O, U, A and T. Twenty three different actors, (six females and six males aged 18-20 and six females and five males aged 51-70) saying each of the letter sounds resulted in 184 images which were piloted for the stimuli. Each image was presented individually on A4 paper and to mirror the instructions given to participants in the experiment, a choice of two letters was provided (see Figure II.1 for an example). For the images of actors mouthing the letters E and L, the choice of letters was “E or L”, for F and M the choice was “F or M”, for O and U the choice was “O or U” and for the images mouthing A and T the choice was “A or T”. This reflected the coupling of letters used for the chimeric faces.

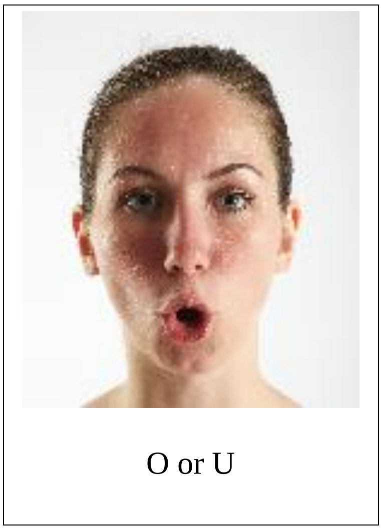

Figure I.1. Example of image used in piloting process

Thirty raters were recruited to pilot the images, fifteen adults aged between 18-30 and fifteen adults aged 65 or over. The raters were asked to state which, of the two letters, each actor looked like they were saying. Raters responded to each image in their own time by stating one letter and accuracy was noted. Any images which received more than three errors from either the older or younger raters were not included in the study. The creation of chimeric stimuli required that images of the same actor judged accurately as saying both letter sounds (e.g. O and U) were selected. Following the rating process it was clear that the letters A and T were too difficult to differentiate as 8 older and 7 younger participants were unable to judge them accurately. These letters were therefore not included in the study.

Appendix II

Piloting Process for Images used in Study 4

Images of 18 older males, 18 older females, 18 younger males and 18 younger females (all Caucasian) expressing the emotions of anger, happiness, sadness, fear, disgust and a neutral expression were selected from the FACES database (Ebner et al., 2010) resulting in 432 images. Additionally, as the FACES Database does not include the emotional expression of surprise the Cal/Pal Face Database (Minear & Park, 2004) was accessed for this emotional expression and 18 younger females, 8 younger males, 9 older males and 8 older females. All images were printed individually onto A4 paper, numbered and held in a lever arch file.

15 older and 15 younger volunteers judged the valence of each image as positive, negative or neutral and rated its level of intensity from 0 – 10 with 0 expressing no emotional intensity (neutral) and 10 being the most intense and their responses were noted. The images which all participants agreed the valence of were retained. This resulted in the expression of surprise not being used as participants in both age groups were unable to judge whether it was negatively or positively valenced and some participants judged it as neutral because they considered that it was neither positively nor negatively valenced. Separate groups of 10 older and 10 younger volunteers were then asked to choose which emotion (from a choice of anger, fear, disgust and sadness) were shown in each of the remaining 288 negatively valenced images. The positively valenced images were not required for this process as only one (happiness) could be used in the experiment and all raters unanimously

perceived it as positive. Negatively valenced images were retained only if all participants correctly judged the emotional expression shown.

All emotional expressions were divided into groups according to the gender and age category of the actor (e. g. older female, older male, younger female, younger male). The level of intensity for each emotional expression for each category of actor was then assessed. Four images of each actor category which received a similar level of mean intensity from participants' ratings were retained for use in the experiment (96 images). The following mean intensities for each actor category according to their emotional expression is presented in Table II.1.

Table II.1.

Mean Intensity Ratings for Each Emotional Expression According to Each Category of Actor.

Expression	Category of Actor			
	Older Female	Younger Female	Older Male	Younger Male
Anger	6.43	6.26	6.20	6.76
Disgust	7.93	6.86	6.75	7.13
Fear	6.77	6.90	6.73	6.86
Happy	6.73	7.07	6.98	6.66
Sad	5.54	5.84	6.16	6.77
Neutral	0	0	0	0

This stimuli was used for the experiment and consisted of 32 actors (8 older females, 8 older males, 8 younger females and 8 younger males) expressing the positive emotion of happiness. Thirty two actors expressed the negative emotions with 2 older females, 2 older males, 2 younger females and 2 younger males each expressing sadness, anger, fear and disgust. The thirty two actors (8 older females, 8 older males, 8 younger females and 8 younger males) who presented a neutral expression also expressed either a positive or negative emotion. Each actor was shown no more than twice, once with a positive or negative emotional expression and (if used a second time) with a neutral expression.