FACE PROCESSING AND SEX CATEGORIZATION: A BEHAVIOURAL AND EYE-TRACKING STUDY

by

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To my friends and loved ones
for the inspiration,
the motivation,
the unfailing support,
and for reminding me to smile

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ABSTRACT

Effects of gaze direction, head position, and inverted stimulus orientation were investigated on categorizations of the sex of photographs of human face stimuli as demonstrated by behavioural (accuracy, RTs) and eye-tracking measures. Male and female observers participated. A morphing procedure produced stimuli of varying degrees of sexual-ambiguity. Results indicated a bias to categorize sexually-ambiguous faces as male and decreased task efficiency with more sexually-ambiguous stimuli. Optimal processing efficiency occurred when gaze direction and head position were directionally congruent, and this effect disappeared with more sexually-ambiguous stimuli. Head position aided processing of female faces shown in ¾ view and male faces shown in frontal view. Overall, female participants made categorization decisions faster than male participants and females were more affected by changes in gaze direction and head position. Lastly, eye movement recordings supported the theory of configural processing for upright faces and a shift to feature-based processing for inverted faces.

LIST OF ABBREVIATIONS USED

ASD	Autism Spectrum Disorder
SSH	Shared Signal Hypothesis
ERP	Event-Related Potential
STS	Superior Temporal Sulcus
FIE	Face Inversion Effect
fMRI	Functional Magnetic Resonance Imaging
SREB	SR Research Experiment Builder
AOIs	Areas of Interest
IEC	International Electrotechnical Commission
LED	Light Emitting Diode
RTs	Reaction Times
FLSD	Fisher’s Least Significant Difference
RE	Right Eye
LE	Left Eye
SD	Standard Deviation
GIMP	GNU Image Manipulation Program
LIFTED	Lateral Inhibition, Face Template, and Eye Detector model

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CHAPTER 1: INTRODUCTION

1.1 Overview

The human face contains a wealth of information that we as humans are proficient at extracting (Tanaka & Gauthier, 1997). Changeable aspects of faces such as facial expression, gaze direction (i.e., where a person is looking), head position (i.e. direction in which a person's head is pointing), and the position of the lips during speech can change in an instant, whereas other facial aspects are invariant such as age, sex, and ethnicity (Bruce & Young, 1986). As face experts, humans have the ability to extract configural information – relations between facial features – to identify one face from another, which becomes disrupted when the face is presented upside down (see section 1.3.5). Importantly, accurate perception of facial features guides our social interactions by allowing us to make inferences regarding the current mental states of those we interact with, thus facilitating our appropriate response behaviours. The eyes in particular play an important role in social interactions as gaze direction is often an accurate indicator of the direction of attention (Itier & Batty, 2009). Similarly, head position is another indicator of the direction of attention that has been shown to influence the perception of gaze direction, suggesting the two are inherently linked.

Understanding the effect that gaze direction has on facial processing is important for understanding the social limitations experienced by those who cannot, or choose not, to make eye contact. Atypical eye contact behavior is associated with the communication deficits exhibited by individuals with Autism Spectrum Disorder (ASD), and is on the current list of diagnostic criteria (American Psychiatric Association, 2013). Studies have demonstrated that mutual eye contact (i.e., direct gaze) can induce a physiological response in individuals with ASD (Joseph et al., 2008; Kylliainen & Hietanen, 2006; Senju & Johnson, 2009) and those with high social anxiety (Wieser et al., 2009) – an effect that is not seen in typically developed individuals. Similarly, direct gaze has shown to improve facial recognition memory in typical developing children – an effect that is not demonstrated in children with ASD – suggesting a link between gaze direction and face recognition abilities in ASD (Zaki & Johnson, 2013). Other conditions, such as strabismus – a misalignment of the visual axes – prohibit mutual eye contact, and the social consequences are often a driving force behind seeking surgical correction (Nelson et al., 2008).

1.2 Purpose of the Study

With clinical relevance in mind, it was the primary goal of the current study to further investigate the connection between gaze direction and head position, and more specifically, its effect on the task of sex categorization, in normal observers. This study will provide a baseline for comparisons to clinical populations (e.g., ASD, social anxiety, and strabismic populations). Behavioural measures of task performance (i.e., accuracy and reaction time) will be augmented by the inclusion of eye-movement tracking to decipher which areas of the facial stimuli facilitate sex categorization. To slow down the sex categorization task and thus ensure rich eye-tracking data, a morphing procedure was used to create varying degrees of sexual ambiguity in the facial stimuli.

A secondary goal of the current study was to compare performance in faces presented upright to those presented with an inverted orientation to further analyze the face inversion effect. Manipulating face orientation is known to influence the mode of face processing applied to facial stimuli, such that upright faces are processed using configural information while inverted faces are processed on a feature-by-feature basis (Maurer, Le Grand, & Mondloch, 2002). This manipulation allowed us to determine if sex categorization relies on configural versus feature-based processing, and for the first time using eye-tracking technology, compare the areas of the face observers attend to when faces are presented with upright versus inverted orientations. Any sex differences found among participants in their ability to perform the sex categorization task were also analyzed.

1.3 Face Processing

1.3.1 Levels of Processing

Like objects, faces can be identified at different levels. In object recognition models, three levels of processing are described and differentiated by their specificity: superordinate (e.g., vehicle), basic (e.g., car), and subordinate (e.g., 1969 Chevy Impala), listed in order of increasing specificity. Initial recognition occurs on the level that triggers that objects representation in memory, known as the ‘entry level’ (Jolicoeur, Gluck, & Kosslyn, 1984; Tanaka & Gauthier, 1997). Typically, object recognition, or the ‘entry level', occurs at the basic level; however, experts have the ability to identify objects equally as fast at the subordinate level, or highest specificity, when dealing with objects within their own realm of expertise. This suggests that either the basic level can be bypassed with expertise, or the two levels can be accessed simultaneously (Tanaka & Taylor, 1991). In other words, car enthusiasts can identify a "1969 Chevy Impala" as efficiently as they can label it as a "car". By definition, an expert is someone who is highly knowledgeable and experienced within their specific domain of interest, thus allowing them to access more specific categorization levels than a novice in that area (Tanaka & Taylor, 1991).

Humans are considered experts in face recognition (Carey, 1992; Diamond & Carey, 1986; Tanaka & Gauthier, 1997), and despite vast similarities between faces, individuals can be identified within fractions of a second (Carey, 1992). In other words, as experts we can identify a familiar human face as being "Joe's" as quickly as we can identify it as a face (Tanaka, 2001). From birth, humans demonstrate a strong preference for faces setting the course for developing strong facial processing skills. By adulthood, our ability to commit and retain individual faces in memory appears limitless (Haxby, Hoffman, & Gobbini, 2000). The eye region is said to contain the most variability across individuals (eye color, shape, protrusion, palpebral fissure width, inter-pupillary distance, eyebrows, eyelashes, etc.), which may explain the central role of the eyes as a fundamental source of information in all facial processing tasks (gaze detection, sex categorization, emotion and identity recognition)(Itier & Batty, 2009). As a result of our facial expertise, the organizational shift allowing for retrieval of information at the subordinate level can reach the highest level of specificity, such that it contains only a single exemplar – a person's unique identity (Tanaka, 2001; Tanaka & Gauthier, 1997).

1.3.2 An Organizational Model of Face Recognition

According to an organizational model proposed by Haxby et al. (2000), unique identity recognition is made possible by underlying representations of invariant facial aspects in memory (i.e., age, sex, and ethnicity), that are neurologically distinct from representations of changeable aspects (e.g. facial expression and gaze direction) which facilitate the processing of socially relevant information (Hoffman & Haxby, 2000). The model suggests that invariant and changeable aspects are processed independently, which explains why moment-to-moment changes in facial expression, for example, do not hinder our ability to recognize familiar faces. In support of Haxby et al.'s (2000) model, numerous studies have demonstrated that processing of facial expression and gaze direction (i.e., changeable aspects) are inherently linked (Adams & Franklin, 2009; Adams & Kleck, 2005) and that facial expression has no reported effect on identity recognition (Calder & Young, 2005; Campbell et al., 1996). The effect of gaze direction on identity recognition has largely been ignored, however, a recent study found that averted gaze direction may disrupt configural face processing (Young et al., 2014).

Further support for the theory of separate pathways for changeable and invariant aspects of face processing is provided by reports of prosopagnosia – a disorder of face perception characterized by an inability to recognize familiar faces – also referred to as 'face blindness'. In prosopagnosia, unique identity recognition is impaired, whereas ability to recognize facial expressions can remain intact (Calder & Young, 2005). However, inconsistent with the theory of separate pathways is the finding that accurately judging the sex and age of a face, which are considered to be invariable traits, may also be preserved in prosopagnosia (Glaser, 1999). If neurological representations of invariant facial aspects (i.e., sex and age) underlie unique identity recognition and share a common neurological pathway, in theory, sex and age judgements should also be disrupted. Figure 1.1 illustrates the distributed neural system put forth by Haxby et al. (2000).

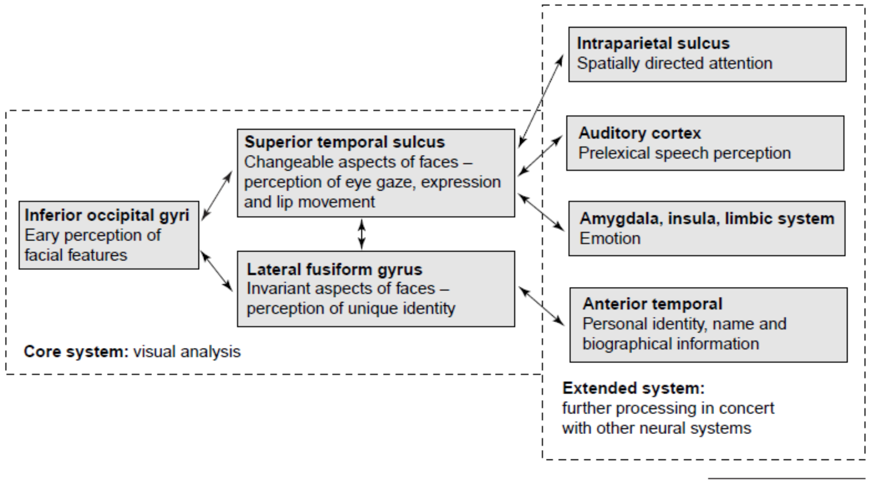

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Fig. 5. A model of the distributed human neural system for face perception. The model is divided into a core system, consisting of three regions of occipitotemporal visual extrastriate cortex, and an extended system, consisting of regions that are also parts of neural systems for other cognitive functions. Changeable and invariant aspects of the visual facial configuration have distinct representations in the core system. Interactions between these representations in the core system and regions in the extended system mediate processing of the spatial focus of another's attention, speech-related mouth movements, facial expression and identity.

Figure 1.1 A neurological model of face perception (Haxby et al., 2000).

1.3.3 Gaze Detection

Compared to nonhuman primates, the human eye is unique in that there is a large contrast between the white sclera and dark iris allowing for more accurate gaze detection (Kobayashi & Kohshima, 1997). One reason for this may be that since predators rely on remaining concealed, it is therefore advantageous that their ocular gaze go undetected by their prey. Humans, however, have evolved to rely heavily on social communication, thus the depigmented sclera of humans is considered an evolutionary adaptation because it permits the use of eye communication (Kobayashi & Kohshima, 1997). Human facial structure has also evolved to accentuate the eye region: less face protrusion, highly salient cheekbones and a range of facial muscles surrounding the eye region (e.g. eyelids and eyebrows) regulate subtle changes in facial expression (Itier & Batty, 2009). As a result, human face recognition is impaired when the eye region is hidden from view (Bruce et al., 1993; Itier & Batty, 2009; Roberts & Bruce, 1988).

Gaze detection is believed to be automatic and extremely accurate (Langton et al., 2000; Macrae et al., 2002), and evidently, humans can detect iris displacement as little as 1.8mm from a one meter distance, or a visual angle of 0.103 degrees (Anstis, Mayhew, & Morley, 1969; as cited in Langton et al., 2004); though iris and sclera visibility can be regulated by the eyelids and eyebrows (Campbell et al., 1999; Watt, Craven, & Quinn, 2007). Human ability to detect gaze direction influences the development of social cognition and has important social implications (Baron-Cohen, 1994). For example, eye contact or lack thereof has been shown to influence the perception of emotions. A direct gaze, or mutual eye contact, is considered approach-oriented because it implies that a direct social exchange is about to occur, and can be interpreted as either positive or negative (Adams & Kleck, 2005; von Grunau & Anston, 1995). Studies have shown that direct gaze facilitates the recognition of approach-oriented emotions (i.e., happy and angry). Similarly, an averted gaze, or avoiding eye contact, is considered avoidance-oriented because it causes attention to shift away from the observer, and studies have shown that averted gaze enhances the perception of avoidance-oriented emotions (i.e., fear and sadness)(Adams & Franklin, 2009; Adams & Kleck, 2005; Akechi et al., 2010; Hadjikhani et al., 2008).

Adams & Kleck (2005) coined the term Shared Signal Hypothesis (SSH) to refer to their prediction that optimal performance in emotion recognition would ensue when gaze direction was matched or congruent with the underlying behavioural intent revealed by emotional expression. Subsequently, the role of gaze perception in emotional processing has been thoroughly documented (Adams & Franklin, 2009; Adams & Kleck, 2005; Akechi et al., 2010; Hadjikhani et al., 2008; Ganel, Goshen-Gottstein, & Goodale, 2005; Lobmaier, Tiddeman, & Perrett, 2008). In fact, viewing the eyes alone was found to be equally valuable for emotion recognition as viewing the whole face (Baron-Cohen et al., 1997); however, this effect may arguably have been driven by the inclusion of eyebrows in the eyes-only condition (see Figure 1.2). Evidence has also surfaced to suggest the reciprocal effect is true – facial expression influences ability to detect gaze direction (Ewbank, Jennings, & Calder, 2009). Further evidence is provided by event-related potential (ERP) studies showing larger N170 amplitude (reflecting the neural processing of faces) when gaze and expression are congruent (Akechi et al., 2010), and fMRI reports of amygdala activation – an area of the brain associated with emotional processing – during gaze detection (Straube et al., 2003; Wicker et al., 2003).

The evidence supporting a reciprocal relationship between gaze direction and facial expression is in keeping with the organizational model of face recognition put forth by Haxby and colleagues (2000) because both gaze direction and facial expression are changeable facial aspects. A recent study, however, reported that averted gaze direction may disrupt the configural processing seen with upright faces that is required for identity recognition, contradicting the theory of separate pathways (Young et al., 2014).

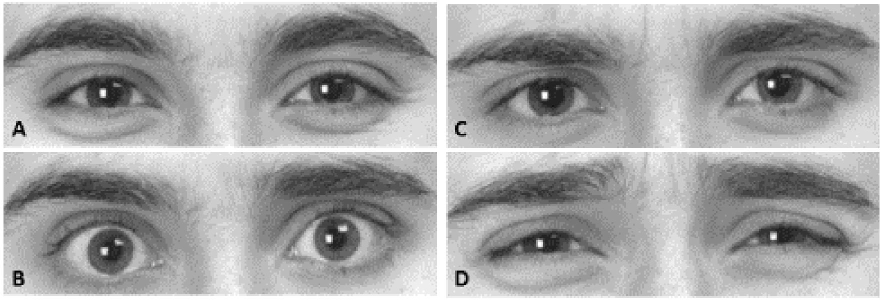

Figure 1.2: Eyes-only condition showing a) happy b) afraid c) disgust and d) distress (Baron-Cohen et al., 1997)

1.3.4 Influence of Head Position – The Wollaston Effect

William Wollaston in 1824 was arguably the first to suggest that our ability to detect gaze is influenced by head position, and demonstrated this by layering the same set of eyes against a head that was pointing straight ahead and one that was turned. He found that perception of gaze direction is drawn towards the direction of the head turn – a phenomenon now referred to as the Wollaston Effect (Kluttz et al., 2009). More recent studies have reproduced this effect experimentally (Anstis et al., 1969; Cline, 1967; Gibson & Pick, 1963), and have established that higher error rates (Anstis et al., 1969) and slower reaction times (Itier et al., 2007) in a gaze direction judgment task occur when gaze direction and head position are incongruent.

Infants as young as three months old are able to follow changes in their caregivers' head position, and not until 14 months are they able to track the eyes alone (Butterworth & Jarrett, 1991; Moore & Corkum, 1998; as cited in Langton et al., 2004). Until recently, isolated studies investigating ability to detect head position were relatively few; supposedly because accuracy rates approach ceiling (Sun, Gao & Han, 2010). Langton & Bruce (1999) established that changes in head position are able to trigger an instant reflexive shift in an observer's spatial attention – similar to the attention shift seen when viewing an averted gaze – and Wilson et al. (2000) concluded that the threshold for detecting changes in head position is much higher for faces viewed from the side. By experimentally dissociating internal features (eyes, nose, mouth) from head contour, Wilson et al. (2000) established that eliminating internal features does not affect our ability to detect head position, but the angle of the nose does become more valuable when viewing a face from the side. They concluded that differentiating head position relies on two main cues: "deviation of the head profile from bilateral symmetry, and deviation of nose orientation from vertical" (Wilson et al. 2000).

The notion that head position strongly influences gaze perception continues to be upheld, and facial processing, specifically in a gaze judgement task, is more accurate when these two changeable features are congruent, or when the direction of the nose matches that of the visual axis (Hietanen, 1999; Itier et al., 2007c; Langton et al., 2004). To date, however, reports have focused more on how these features influence and interact with each other, and less on how they may affect processing of other facial components.

The current study investigates the effects of gaze direction and head position on our ability to determine the sex of a face, which will be further discussed in section 1.4.1.

1.3.5 Face Inversion Effect

Stimulus orientation is another aspect of face recognition that research investigations have placed particular emphasis on. It has been consistently demonstrated that recognition performance for mono-oriented objects is highest when presented in their upright orientations compared to their upside-down, or inverted, orientations (Farah, Tanaka, & Drain, 1995; Freire, Lee, & Symons, 2000; Valentine, 1988; Yin, 1969); however, Yin (1969) found that recognition performance is disproportionately reduced for inverted faces compared to inverted objects – a phenomenon now referred to as the face inversion effect (FIE). The FIE suggests that faces are processed differently than other mono-oriented objects, as an explanation for why they are affected more by inversion (Rossian & Gauthier, 2002). Many theorists agree that the FIE is the result of our own expertise with upright human faces (Diamond & Carey, 1986), and more recently it has been proposed that this expertise relies on a processing mode referred to as configural processing (Maurer et al., 2002).

Configural processing involves processing the face as a whole unit and can be divided into three types: first-order relations (identifying that there are two eyes above a nose and a mouth), holistic processing (combining the features into a whole unit), and second-order relations (spatial relations among features). Featural processing, on the other hand, involves processing local features such as the eyes, nose and mouth individually. It is configural processing that is said to be disrupted during inversion of faces while featural processing remains intact (Hole & Bourne, 2010; Leder & Bruce, 2000; Maurer et al., 2002; Van Belle et al., 2010).

The FIE has largely been reported in recognition studies (Farah et al., 1995; Rossion & Gauthier, 2002; Valentine, 1998), but has also been shown to affect emotion recognition (Prkachin, 2003; Valentine & Bruce, 1985), and sex categorization (Campanella, Chrysochoos, & Bruyer, 2001; Zhao & Hayward, 2010). It appears, that ability to detect head position remains intact during face inversion (Wilson et al., 2000), as does the influence of head position on gaze detection (Langton et al., 2004). A recent study reported that inversion effects on face recognition are more pronounced for faces with a direct gaze than averted gaze (Young et al., 2014). These results are consistent with the finding that recognition of internal features (eyes, nose, and mouth) is disrupted more by inversion than recognition of external features (hair, face contour, forehead, ears)(Wilson et al., 2000).

1.4 Sex Categorization

Categorization is a fundamental cognitive process that consists of grouping stimuli into meaningful categories to maximize processing efficiency and memory retention (Freedman et al., 2001). Sex categorization is the ability to distinguish a biological male from a biological female – a skill that certainly has evolutionary significance. A person's sex is one aspect of their identity that is said to have a significant impact on their sense of self (Jackson & Warin, 2000), and both adults and children alike are extremely fast and accurate at identifying one's sex through facial characteristics (Campanella et al., 2001; Hole & Bourne, 2010). In fact, these findings have been demonstrated in children as young as nine months old (Fagot & Leinbach, 1993 as cited in Hole & Bourne, 2010) suggesting that humans are experts at distinguishing human males from females.

Young children tend to rely on sex-stereotypical cues (e.g., hair length and facial hair) for sex discrimination (Wild et al., 2000 as cited in Hole & Bourne, 2010), whereas adults have the ability to discriminate sex based on differences in the physical structure of a face. For example, female faces tend to have shorter and rounder faces than males (Enlow, 1982 as cited in Hole & Bourne, 2010), and males tend to have a more prominent jaw and protuberant nose (Bruce et al., 1993). The distance between a male's eye and brow region is also said to be shorter (Campbell et al., 1999a as cited in Hole & Bourne, 2010); however, this is arguably the result of the social convention for women to groom their eyebrows creating a more dramatic brow line (Bruce et al., 1993). The importance of eyebrows and skin texture was demonstrated by Bruce et al. (1993) when they reported higher categorization performance for natural photographs than for laser scans; however, performance remained high with laser scans suggesting the overall structure of the face provides important sex information as well. It is therefore unsurprising that the eyebrows and eyes are reported as the most important features for sex categorization (Brown & Perrett, 1993).

1.4.1 The Wollaston Effect in Sex Categorization

To date, sex categorization studies have largely been surpassed by investigations into emotion and identity recognition, presumably because our ability to distinguish males from females approaches ceiling, or 100% accuracy (Campanella et al., 2001; Cellerino, Borghetti, & Sartucci, 2004; Hole & Bourne, 2010). It has been suggested that gaze direction influences sex categorization; however, results have so far been conflicting (Itier & Batty, 2009; Macrae et al., 2002; Pageler et al., 2003; Vuilleumier et al., 2005).

In 2002, Macrae et al. hypothesized that gaze direction would influence speed of sex recognition, and more specifically that direct gaze would yield faster processing times than averted gaze. Their reasoning was that humans are hypersensitive to gaze detection, particularly to those looking directly at us, and it would be evolutionarily advantageous for humans to process a face faster (including sex categorization) if that face was looking directly at us, regardless of whether the direct eye contact was associated with positive or negative intentions (Macrae et al., 2002). They examined the effects of direct and averted gaze on processing efficiency during a sex categorization task with a front view of the face, and included a ¾ view of the face to confirm that effects were not the result of low-level properties like facial symmetry. They found that reaction times were fastest for direct gaze regardless of head position, suggesting that mutual eye contact facilitates sex processing. Using a gaze direction judgement task, Pageler et al. (2003) also reported faster processing times for direct gaze, but only when paired with a frontal head position, not a side view head position. In contrast, Vuilleumier et al. (2005) reported slower reaction times for sex categorization with direct gaze compared to averted gaze suggesting that perceived eye contact actually interferes with sex categorization. Although it should be mentioned that in their study this effect was modulated by head position and sex of the observer, such that slower reaction times were seen with direct gaze when the face was seen in ¾ view by the opposite sex (i.e., sex of observer was opposite to that of the stimulus presented). The cause of the inconsistencies in the literature remains unknown, but may be due to the use of a variety of methodologies (Itier & Batty, 2009).

Further evidence to suggest a relationship between sex and gaze direction was provided by Slepian et al. (2011) who had participants perform a gaze direction judgement task. However, this relationship was also moderated by facial expression. They found that female models evoked more direct gaze responses when direct gaze was paired with 'joy' while male models evoked more direct gaze responses when direct gaze was paired with 'joy' or 'anger'. As mentioned previously, it is well established that processing of gaze direction and facial expression are linked (Adams & Kleck, 2005); however, the inclusion of the sex of a face in this relationship is inconsistent with the organization model proposed by Haxby et al. (2000) suggesting sex (an invariant trait) is processed separately from gaze direction and facial expression (changeable aspects). Sex differences between male and female participants were not analyzed by Slepian et al. (2011), but were analyzed in the current study.

1.4.2 Sex Differences in Categorization Ability

As mentioned, implicit, or passive, processing of sex appears to influence gaze direction judgments (Slepian et al., 2011), and the interaction between gaze direction and head position reported during sex categorization is mediated by whether the sex of the model matches the sex of the observer (Vuilleumier et al., 2005). The notion that sex categorization is slower when a face is presented with a direct gaze in a ¾ side view head position (Vuilleumier et al., 2005) is consistent with the finding that congruency between gaze and head position elicits more efficient processing (Itier & Batty, 2007c). Vuilleumier et al. (2005), however, also found processing was slower when the sex of the observer was opposite to that of the face presented. This result is consistent with the 'own-sex bias' reported by Herlitz and Loven (2013).

The 'own-sex bias' refers to enhanced memory for faces of one's own sex (Sporer, 2001). Cellerino et al. (2004) reported that participants were more efficient at sex categorization when the face presented was of the same sex as the observer. Although reports have demonstrated the own-sex bias in both men and women, other reports suggest the own-sex bias is unique to female observers (Herlitz & Loven, 2013). In a meta-analytic review, Herlitz and Loven (2013) reported an own-sex bias for females showing that females remember more female faces compared to male faces, but that a bias for male faces was not seen with male observers. They also reported that female participants outperformed male participants in a memory task even when only male faces were shown, suggesting female superiority in face processing tasks. Further evidence to support the own-sex bias in females is provided by reports that face recognition memory is unaffected by divided attention tasks suggesting female expertise with female faces does not consume cognitive resources (Loven, Herlitz, & Rehnman, 2011).

Female superiority in face processing is demonstrated from birth. Female infants hold eye contact with their caregivers longer than male infants (Lutchmaya, Baron-Cohen, & Raggett, 2002) and this eye contact increases dramatically from three days old to three months old in female infants only (Leeb & Rejskind, 2004). Female infants also hold eye contact longer with female caregivers compared to male, consistent with the own-sex bias (Leeb & Rejskind, 2004). Studies have also reported female superiority in emotion recognition tasks (Hampson, van Anders, & Mullin, 2006) and face detection and identity tasks (McBain, Norton, & Chen, 2009).

1.5 Eye-Tracking

Technological advancements have made functional magnetic resonance imaging (fMRI) and event-related potential (ERP) studies popular because they provide direct and objective neuroanatomical evidence that can be used to either support or refute current facial processing models that are based on behavioural evidence (Bentin et al., 1996; Zaki, Weber, & Ochsner, 2012). fMRI studies have allowed researchers to identify the lateral fusiform gyrus, or occipitotemporal gyrus, and the occipital face area as the areas of the brain that are responsible for identity recognition, and the superior temporal sulcus (STS) as the area specific to detecting gaze direction (Haxby et al., 2000; Kingstone et al., 2004; Pelphrey, Viola, & McCarthy, 2004).

To date, very few researchers have relied on tracking eye movements to support their behavioural findings – a major contribution that the current study will make to the literature. Most studies of face processing currently incorporating eye-tracking techniques focus on the gaze patterns of participants with social anxiety (Wieser et al., 2009) or Autism Spectrum Disorder (ASD; Falck-Ytter et al., 2010; Riby & Hancock, 2009; Snow et al., 2011). Through the use of control groups in these studies, it has been reported that typical individuals are more likely to focus on faces over objects than those with ASD (Snow et al., 2011), and they are more likely to fixate on the eye region (Dalton et al., 2005). This atypical eye contact is believed to be an underlying cause of the social and communicative deficits associated with ASD (Riby & Hancock, 2009). Typical individuals are also more likely to spend time focusing on internal facial features (eyes, nose, mouth) than external features (hair, face contour, forehead, ears) during facial processing that those with ASD (Althoff & Cohen, 1999 as cited in Itier & Batty, 2009). Recent eye-tracking studies have also reported sex differences in facial scanning reporting that females spend more time looking in the eye region than males, and that this was associated with higher performance in emotion recognition tasks (Hall, Hutton, & Morgan, 2010). The effect of inversion on sex categorization has not yet been fully investigated using eye-tracking technology either; however, Barton et al. (2006) did use a scleral contact lens to track fixations in a familiarity task and found that within that task, inversion produced more fixations to the mouth.

1.6 Research Questions and Hypotheses

The current study investigated the effects of gaze direction, head position and inversion on sex categorization using behavioural (accuracy and reaction times) and eye-tracking outcomes (e.g., dwell times in designated interest areas) (see section 2.3). First, the current study investigated whether a model`s gaze direction (direct or averted) affects sex categorization, and if so, whether this effect was further mediated by head position (front or ¾ side view). Thus far, the literature remains inconclusive regarding the effects of gaze and head position on sex categorization; however, it was hypothesized that accuracy would be higher and reaction times would be faster for faces in which gaze and head position were congruent (consistent with Itier & Batty, 2007c and Langton et al., 2004).

Second, the current study investigated the extent to which sex categorization was dependent on configural processing by analyzing its susceptibility to inversion. A diminished ability to categorize sex following inversion has been demonstrated (Campanella et al., 2001; Zhao & Hayward, 2010), and it was therefore hypothesized that inversion would lower accuracy rates and slow reaction times. Eye-tracking technology, however, has not yet been used to investigate changes in scanning behaviour as the result of inversion during a sex categorization task. Barton et al. (2006) found inversion produced more fixations to the mouth during a familiarity task; therefore, it was also hypothesized that our eye-tracking analysis would show a shift to featural processing such that there would be more fixations to individual features than was seen with upright faces.

Third, the current study used eye-tracking data to investigate which areas of the face would be focused on during sex categorization. It has been reported that the eyes and eyebrows are the most important features for sex categorization (Brown & Perrett, 1993); therefore, it was hypothesized that participants will spend more time fixating on these regions than on the nose or mouth. The eyes and eyebrows were analyzed as separate areas of interests (a first for face processing literature) because the eyebrows have been shown to regulate visibility of gaze direction (Watt et al., 2007), and there is typically a shorter distance between a male's eye and brow region compared to a females (Campbell et al., 1999a; as cited in Hole & Bourne, 2010). Eyebrows and skin texture also provide cues for sex categorization that improve performance beyond that of facial structure alone (Bruce et al., 1993), suggesting the eyebrows may play more of a role in sex categorization than originally thought. Furthermore, it was hypothesized that the nose would become more important for ¾ side view, as the shape of the nose is better depicted in a ¾ view of the face and males tend to have a more protuberant nose (Bruce et al., 1993; Wilson et al., 2000).

Due to the 'own-sex bias' and reports of female superiority in facial processing (Cellerino et al., 2004; Herlitz & Loven, 2013; Sporer, 2001), any differences found that were due to sex of the observer were further analyzed. It was hypothesized that female observers would have higher overall accuracy and faster reaction times compared to males, and specifically that better performance would be found for female face stimuli than male face stimuli. Lastly, to ensure rich eye-tracking data, a morphing procedure was used to create varying degrees of sexual ambiguity in the stimuli (similar to Campanella et al., 2001), and effects of this manipulation on sex categorization were therefore analyzed. It was hypothesized that both male and female participants would perform better when presented with faces that were less sexually ambiguous.

From a theoretical standpoint, results of the current study aimed to help resolve the contradiction in the literature regarding the role of direct versus averted gaze on sex categorization (Macrae et al., 2002; Vuilleumier et al., 2005). A further goal was to test the strict notion that changeable and invariant aspects of face processing are independent

(Haxby et al., 2000). On the basis of Haxby et al.'s (2000) model, gaze direction and head position should interact; however, these changeable aspects of face processing should not influence decisions about an invariant quality such as sex.

CHAPTER 2: METHODOLOGY

2.1 Participants

Fifty-six participants (28 males, 28 females) ranging from 18 to 30 years of age (Mean = 20.46 years, SD = 2.58 years) completed the experiment individually, from which the majority were recruited using the Dalhousie University, Department of Psychology and Neuroscience Sona System– an online experiment recruitment and management system. Other sources of recruitment included word-of-mouth and posters. Participants recruited through Sona received partial course credit as compensation, whereas the others received $10 per hour for their participation. Inclusion criteria required participants to be between 18-30 years of age, Caucasian (European descent), and have normal or corrected-to-normal visual acuity (i.e., contact lenses or glasses were accepted). Sixty-eight percent of participants did not require visual correction. The remaining 32% who wore glasses (18%) or contact lenses (14%) were asked to wear their best correction throughout testing. Specific age and ethnicity criteria were based on accessibility at Dalhousie University in Halifax, Nova Scotia, and to limit known effects of perceptually processing faces of another age (Wiese, Komes, & Schweinberger, 2013) and race (Meissner & Brigham, 2001). The vast majority of participants were right hand dominant (90%).

2.2 Facial Stimuli

To create the facial stimuli used in the experiment, models were hired for the creation of a Face Database – from which 15 male and 15 female faces depicting neutral facial expressions were selected. For each model, five images were selected with varying head positions (front view vs. ¾ side view) and directions of ocular gaze (direct vs. averted gaze). In the front view condition, both a left-averted gaze and right-averted gaze were included (Figure 2.1). The male and female faces were randomly paired and morphed into four different sex ratios: 20:80, 40:60, 60:40, and 80:20, referring to 20%, 40%, 60% and 80% ‘male’, respectively. Subsequently, all images underwent further image manipulation requiring cropping and airbrushing to eliminate sex-stereotypical cues (hairstyle, sideburns, and five o’clock shadow) (Figure 2.2). With four degrees of morphing applied to each of the five images depicting various combinations of head positions and gaze directions, 20 images were created for each of the 15 models pairs. All stimuli were presented in both an upright and inverted orientation for a total of 600 stimulus presentations throughout the experiment. For a more detailed description of the stimulus creation procedure, please refer to Appendix A.

Figure 2.1: Each gaze and head position condition prior to image manipulation (left to right): ¾ side view/averted gaze, ¾ side view/direct gaze, front view/direct gaze, front view/right-averted gaze, front view/left-averted gaze.

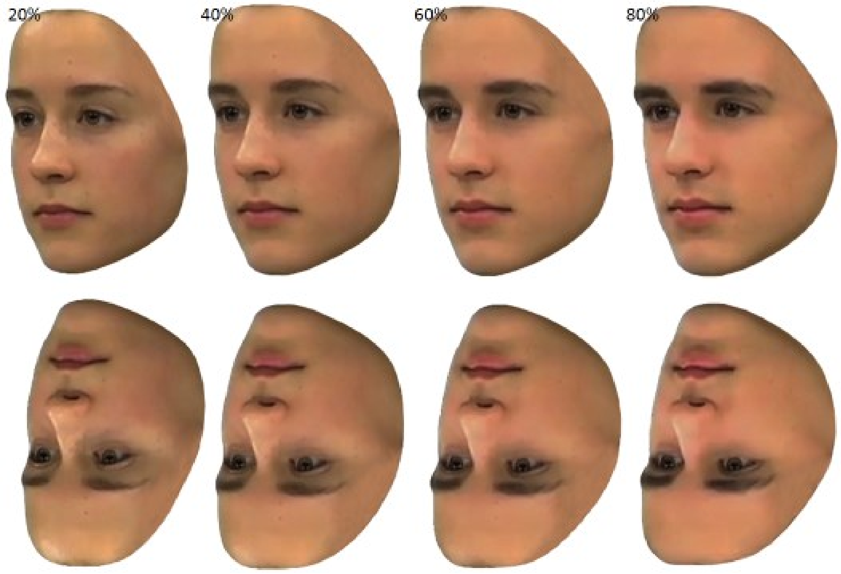

Figure 2.2 Examples of final stimuli in the upright and inverted conditions (only ¾ side view/averted gaze shown). Stimuli in other head and gaze conditions were similarly manipulated.

2.3 Apparatus and Program

2.3.1 EyeLink 1000 and SR Research Experiment Builder

The EyeLink 1000 is a customized high-speed camera with eye-tracking capabilities that is seamlessly integrated with SR Research Experiment Builder (SREB) – a flexible and comprehensive program for designing and administering experimental paradigms (EyeLink 1000 User Manual; SR Research Experiment Builder User Manual). It allows for monocular and binocular recordings and is compatible with eye glasses. The current study required two interconnected EyeLink Host PC’s (115/230V), each connected to their own monitor, keyboard, and mouse – one for the researcher (host monitor), the other for the participant (display monitor). The Desktop Mount camera (infrared illuminator on the right) was adjusted for monocular recordings of the right eye and placed just below the display monitor approximately 65-70cm away from the chin/forehead rest. A crossover Ethernet cable was used to connect the Host and Display PC’s. Figure 2.3 illustrates the experiment room set-up. A major advantage of the desktop mount is that no electronics are placed on or near the participants head or face; however, a disadvantage is that it requires the participant to sit still with their chin on a chin rest.

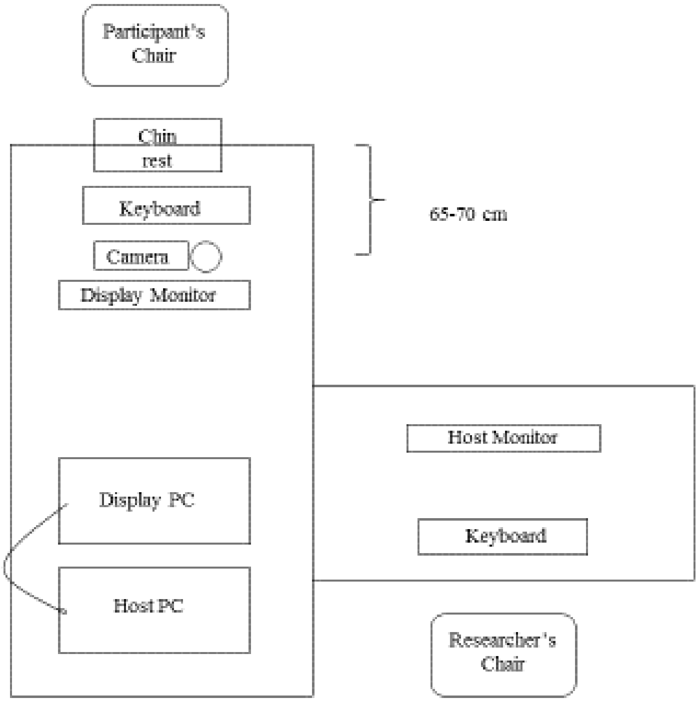

Figure 2.3: Illustration of testing room set-up.

All finished stimuli were imported into SREB which provides a datasource for keeping track of all images and their experimental conditions, and also allows randomization of stimulus presentation. The program also allows for consistent timing of stimulus presentation and accurate reaction time recordings. Areas of Interest (AOI’s) were defined for each stimulus using SREB and included the eyes (2), eyebrows (2), nasion, nose, mouth, cheeks (2), forehead, temples (2), and chin for detailed eye-tracking analysis. Figure 2.4

outlines all AOI's. Following completion of the experiment, Eyelink Data Viewer was used for compiling and outputting results in preparation for analysis. Data Viewer is an EyeLink tool that provides data visualization, filtering, interest area and reaction time definition, and most importantly, provides data file report output (EyeLink Data Viewer User's Manual).

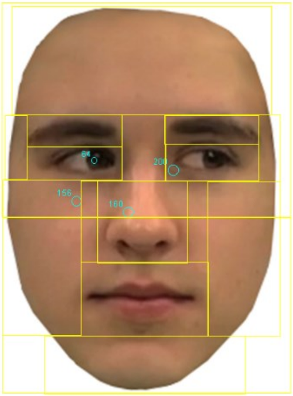

Figure 2.4: Defined Areas of Interest.

2.4 Procedure

Upon entering the testing room, participants were greeted by the experimenter and asked to read and sign a consent form. Once consent was obtained, participants were set-up on the eye-tracking system for calibration, were provided both written and verbal instructions for the sex categorization task, and subsequently completed practice trials (images used for the practice trials were not included in the testing sequence). For the task, participants were asked to indicate whether the face presented on the screen was male or female by pressing specified keys on the keyboard, and were told the objective was to be as fast and accurate as possible.

Prior to each stimulus presentation, a drift correct feature of Experiment Builder was used to ensure participants were paying attention. As a feature integrated with the eye-tracker, participants had to be looking at the dot in the center of the screen to proceed with testing, and were told to press the spacebar to initiate the sequence. Once initiated, a fixation cross would appear on either the left or right side of the screen for 1000ms immediately followed by a face in the center of the screen. Fixation crosses were laterally displaced rather than the typical centered location to attract gaze away from where the face was to be presented and therefore allowing analysis of the initial saccade to the face.

As reaction times were a dependent measure, there was no time limit for a response. The face would remain on the screen until a decision was made. Due to the large number of stimulus presentations, breaks were provided after every 50 images (approximately every five minutes), followed by re-calibration of the eye-tracking system. Once all trials were completed, participants received both oral and written debriefing and compensation. The study took up to one hour to complete.

2.5 Ethical Considerations

Ethical approval was obtained by Dalhousie University's Social Sciences and Humanities Research Ethics Board prior to testing. Testing took place in an individual setting and confidentiality and anonymity was maintained by using participant codes, and storing all documents in a locked filing cabinet in an office with restricted access. All participants were given adequate time to read and ask questions regarding the consent form (Appendix C). Contents of the consent form were also provided verbally, and all participants were informed that they may discontinue the study at any point throughout the procedure without penalization (i.e., they were still reimbursed). Benefits of participating in the study aside from course credit (or $10 compensation if not recruited through Sona) are the satisfaction of contributing to research and the opportunity to use a state-of-the-art eye-tracking device.

Discomfort was minimized by the use of the Desktop Mount for the EyeLink 1000 over the head mount, as no electronics or heavy equipment were required to be placed on the participants head. Despite these attempts, some participants complained of mild back and neck pain from leaning in to the chin rest. Both the chair and chin rest were adjusted for comfort in such situations. Few participants reported mild eye strain throughout the procedure as was expected with a computer task. Safe levels of infrared illumination from the EyeLink 1000 can eventually cause some discomfort due to the slight drying effect, especially for contact lens wearers. To minimize these risks, participants were seated at a safe distance (65-70cm) from the illuminator to prevent unnecessary exposure and breaks were provided after every 50 stimulus presentations (approximately every five minutes).

The EyeLink 1000 illuminators are compliant with the International Electrotechnical Commission (IEC) light-emitting diode (LED) safety standards as a Class 1 LED device. This standard regulates many aspects of LED and laser eye safety, including retinal, corneal and skin safety. Class 1 products are “safe under reasonably foreseeable conditions of operation, including the use of optical instruments from intrabeam viewing” (EyeLink 1000 user manual).

2.6 Statistical Analyses

Accuracy, reaction times (RTs), and interest area dwell time were the outcome measures for the current study and all were analyzed separately using repeated measures ANOVAs. Fisher’s Least Significant Difference (FLSD) was used for post-hoc analyses. To determine accuracy, all 20% and 40% morphs were classified as ‘female faces’, whereas all 60% and 80% morphs were classified as ‘male faces’. A correct response was defined as labeling the face as such. Reaction times began upon initial stimulus presentation and ended when a keyboard response was made to the sex categorization task. Interest area dwell time is defined as the length of time spent fixating on specific AOI’s. For all outcome measures except accuracy, only correctly answered trials were used for the analysis. All data was analyzed using R version 3.0.3.

The main behavioural analyses focused on the comparisons of the following within-subject factors: gaze (2: direct, averted), head position (2: front, ¾ view), orientation (2: upright, inverted) and morph (4: 20,40,60,80). For analysis of sex differences, participant sex (2: male, female), or sex of the observer, was included as a between-subjects variable and analyzed using a mixed ANOVA. Eye-tracking analyses added AOI’s as an additional within-subject factor.

2.7 Control Measures

For control purposes, stimulus presentation was completely randomized within two trial blocks (upright and inverted). The order of orientation block presentation was counterbalanced (i.e., half of the participants saw upright faces first followed by inverted faces, and vice versa). Similarly, whether the fixation cross was seen on the left or right side of the screen prior to stimulus presentation was counterbalanced, as was the key on the keyboard that participants were asked to press indicating whether the face was male or female (i.e., half the participants pressed “A” for female and “L” for male, and vice versa). Lastly, in terms of our stimuli with a front view head position, we included both a left-averted gaze and a right-averted gaze. No apriori reason led us to believe these differences would affect results, but were still included as controls.

CHAPTER 3: RESULTS

3.1 Outliers and Counterbalanced Measures

Of the 56 participants who completed the experiment, six (3 males, 3 females) were excluded from the analysis due to poor performance (N=3) or due to eye-tracking errors (N=3). Performance scores were plotted for each participant by taking their own average accuracy score and plotting it against their average RT. Figure 3.1 shows individual performance scores and indicates the outliers that were excluded.

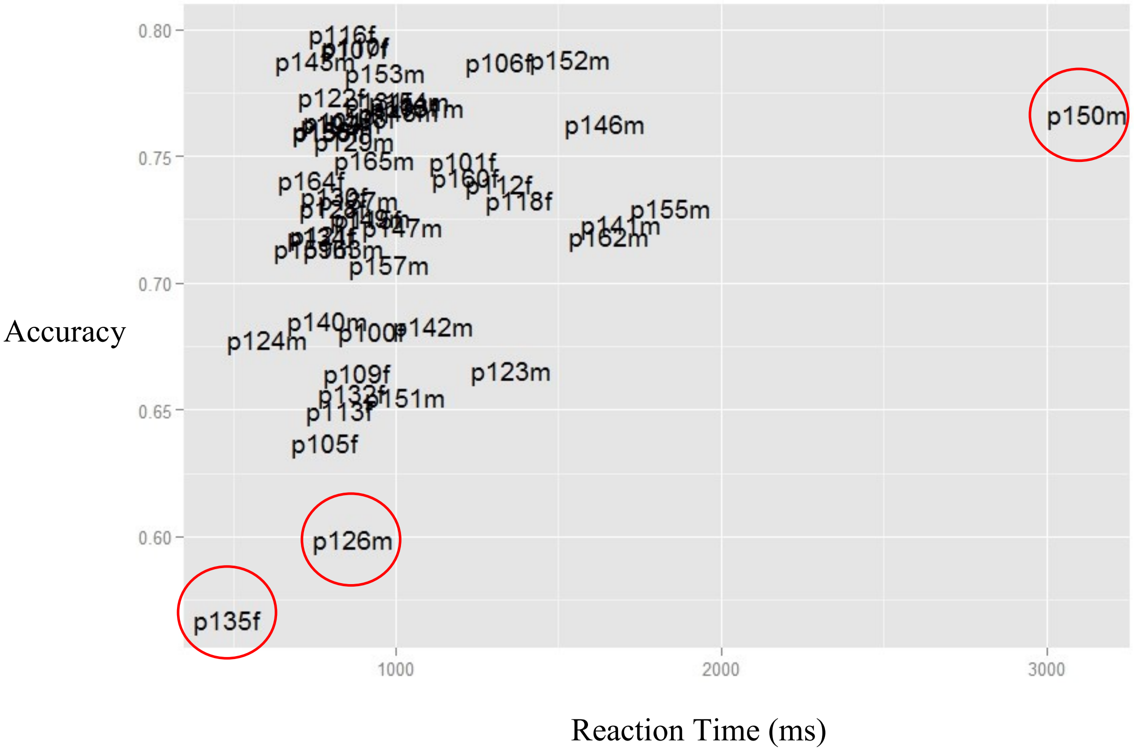

Figure 3.1. Performance scores for each participant. Red circles indicate outliers.

Preliminary analyses were performed on all counterbalanced measures (i.e., fixation cross location, keyboard response, order of orientation block, and left-averted versus right-averted gaze) to investigate whether these variables produced any confounds. No significant main effects were found for fixation cross location, keyboard response, and left versus right-averted gaze on accuracy scores or reaction times. As a result, trials with a left fixation cross and right fixation cross were collapsed together for further analyses, as were trials with different keys pressed indicating a response. Similarly, left-averted and right-averted gaze in front head position were collapsed together as 'averted gaze' for all subsequent analyses.

Preliminary analysis investigating order of orientation block presentation, or whether upright or inverted faces were presented first, yielded no significant main effects on accuracy; however, significantly slower reaction times were found when inverted faces were presented first (F(1,48) = 4.46, p = 0.04). Additionally, a two-way interaction was found between order of block presentation and head orientation (F(1,48) = 16.26, p < .001). Post-hoc analyses (FLSD = 91.58ms) indicated that slower reaction times were found for inverted faces when the inverted faces were presented first (M = 1286.66ms, SD = 487.33ms) compared to when the inverted faces were presented second (M = 972.28ms, SD = 200.44ms) suggesting practice effects. Order of presentation did not affect RTs for upright faces. As a result of these findings, upright and inverted orientations were analyzed separately.

3.2 Behavioural Analyses

3.2.1 Upright Orientation

Accuracy. Using data from upright faces only, a 2 (Gaze: Direct, Averted) x 2 (Head Position: Front, ¾ Side) x 4 (Morph: 20, 40, 60, 80) repeated measures ANOVA demonstrated a strong significant main effect of morph (F(1,49) = 30.41, p < 0.001). Post-hoc analyses (FLSD = 5.80%) indicated that highest accuracy rates were associated with 80% morph (93.72%), which was significantly more accurate than 20% morph (83.53%) and 60% morph (78.87%), which in turn were more accurate than the 40% morph (59.08%). Although near chance, accuracy for the 40% morph was still significantly greater than chance (50%). These effects suggest a bias to interpret sexually ambiguous faces as males. A two-way interaction was also found between morph and head position (F(1,49) = 7.36, p = 0.009), and post-hoc analyses (FLSD = 3.49%) demonstrated that accuracy rates were highest for ambiguous male faces (60% morph) when viewed with a front head position (Front: 81.80%, ¾ Side: 75.93%), and highest for ambiguous female faces (40% morph) in a ¾ side view (Front: 56.63%, ¾ Side: 61.53%). Figure 3.2 illustrates this interaction.

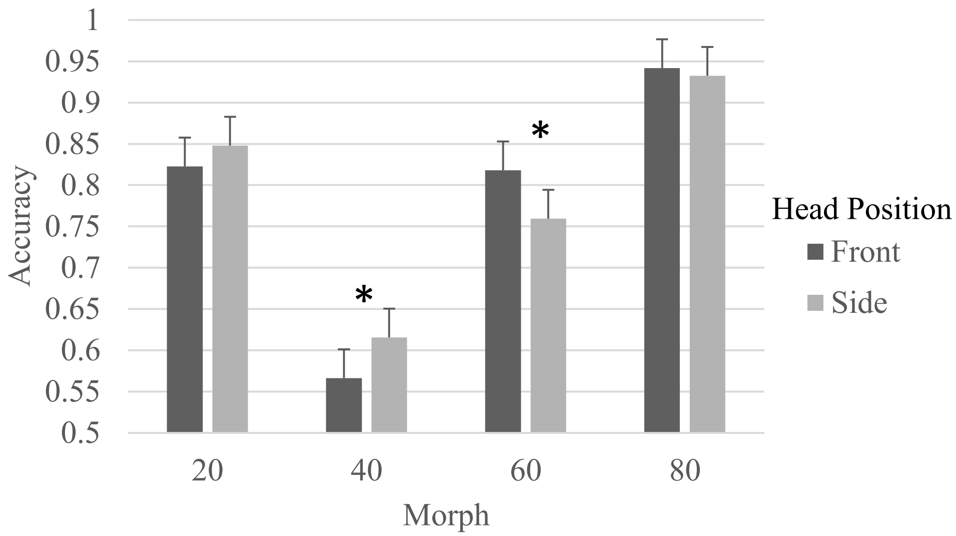

Figure 3.2: Accuracy – two-way interaction between morph and head position.
Note: error bars represent FLSD and * indicates a significant difference was found.

Reaction Times. Consistent with our accuracy findings, a main effect of morph was found for reaction times (F(1,49) = 16.18, p < 0.001) showing that fastest reaction times (FLSD = 47.21ms) were found for 80% morph (M = 843.86ms, SD = 192.87ms), which was significantly faster than reaction times for 20% (M = 921.66ms, SD = 245.05ms) and 60% morphs (M = 941.30ms, SD = 244.71ms), which in turn were significantly faster than reaction times for 40% morphs (M = 1006.72ms, SD = 313.70). Also consistent with our accuracy results was a significant two-way interaction between morph and head position for RTs (F(1,49) = 21.70, p < 0.001), in which post-hoc analyses (FLSD = 31.32ms) demonstrated that reaction times were fastest for ambiguous male faces (60% morph) when viewed with a front head position (Front: 924.71ms, ¾ Side: 957.89ms) and fastest for all female faces (20% and 40% morphs) in a ¾ side view (20% morph: Front: 959.19ms, ¾ Side: 884.12ms; 40% morph: Front: 1031.12ms, ¾ Side: 982.32ms). Figure 3.3 illustrates this interaction. Additionally, a main effect of head position was found (F(1,49) = 8.99, p = 0.004) for reaction times that was not found with accuracy scores. Post-hoc analysis (FLSD = 14.22ms) showed that, overall, participants were faster at identifying the sex of a face when in a ¾ side view (M = 917.78ms, SD = 231.59ms) compared to front view (M = 938.99ms, SD = 245.84ms); however, this effect may have been strongly influenced by the two-way interaction between morph and head position as illustrated in Figure 3.3.

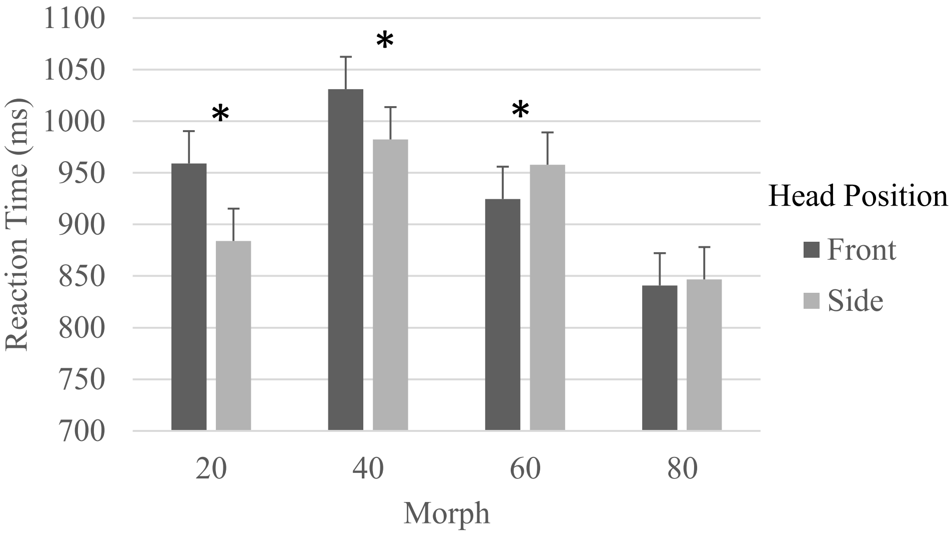

Figure 3.3: RTs – two-way interaction between morph and head position.

Although no sex differences were found for accuracy, a main effect of participant sex was found for RTs (F(1,48) = 4.30, p = 0.04), showing that, overall, female participants (M = 861.00ms, SD =147.89ms) were faster at sex categorization than male participants (M = 995.77ms, SD = 289.54ms). A two-way interaction was also found between participant sex and gaze direction (F(1,48) = 7.44, p = 0.009). Post-hoc analyses (FLSD = 19.42ms) demonstrated that female participants were significantly faster at sex categorization when gaze direction was averted (M = 849.17ms, SD = 139.78ms) compared to direct (M = 872.83ms, SD = 159.51ms). No significant difference in RTs between direct and averted gaze were found for male participants. Figure 3.4 illustrates this effect.

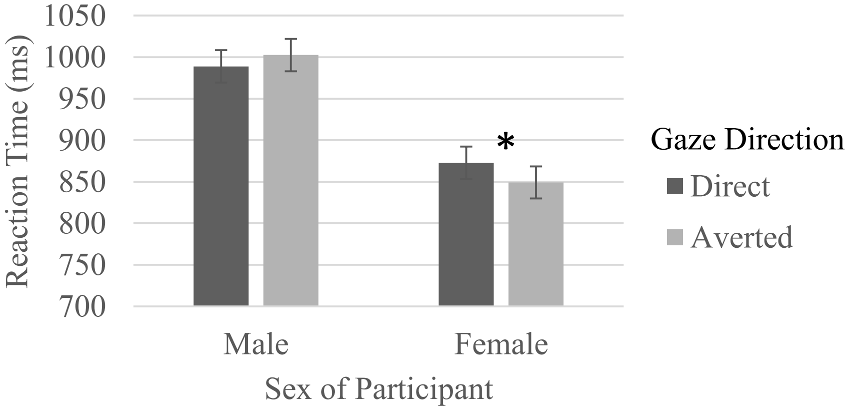

Figure 3.4: RTs – two-way interaction between participant sex and gaze direction.

Elimination of Sexual Ambiguity. Evidently, our accuracy and RT results for upright faces did not yield any significant main effect of gaze direction or any interactions between gaze direction and head position which were the main focus of the current study. A major difference between the current study and previous studies which found effects of gaze direction and head position on sex categorization (Macrae et al., 2002; Vuilleumier et al., 2005) was the inclusion of a morphing procedure creating sexually ambiguous faces. Therefore, a separate analysis excluding the more sexually ambiguous faces (40% and 60% morphs) was performed on upright faces to enhance ecological validity.

A 2 (Gaze: Direct, Averted) x 2 (Head Position: Front, ¾ Side) x 2 (Morph: 20, 80) repeated measures ANOVA was performed, and despite the exclusion of 40% and 60% morphs, a main effect of morph was found for accuracy scores (F(1,48) = 25.91, p < 0.001) showing that accuracy remained higher for male faces (93.75%) than for female faces (83.53%). Additionally, a two-way interaction between gaze direction and head position was established (F(1,48) = 6.69, p = 0.013). Post-hoc analyses (FLSD = 154%) indicated that in a ¾ side view head position, averted gaze (90.05%) was significantly more accurate than direct gaze (88.09%). No difference between direct and averted gaze was found for a front view head position; however, accuracy for averted gaze in front view (87.79%) was significantly lower than accuracy for averted gaze in side view (90.05%). Figure 3.5 illustrates this interaction.

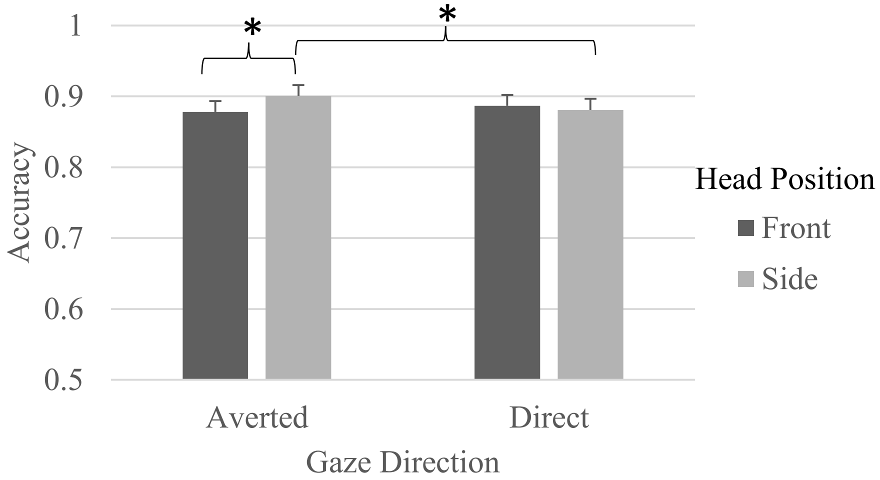

Figure 3.5: Accuracy – two-way interaction between gaze and head position (only 20/80% morphs)

Although no main effect of participant sex was found for accuracy, a three-way interaction between participant sex, morph, and head position was found (F(1,48) = 4.88, p = 0.032). Post-hoc analysis (FLSD = 3.76%) showed that, overall, accuracy was much higher for male faces than for female faces, and that female participants were more accurate at identifying female faces when the face was presented in ¾ side view (85.79%) compared to when the face was presented in front view (81.41%). A non-significant trend was also demonstrated that female participants were more accurate at identifying male faces when the face was presented in front view (95.31%) compared to when the face was presented in ¾ side view (92.10%). Head position did not have any effect on the performance of male participants. Figure 3.6 illustrates the three-way interaction.

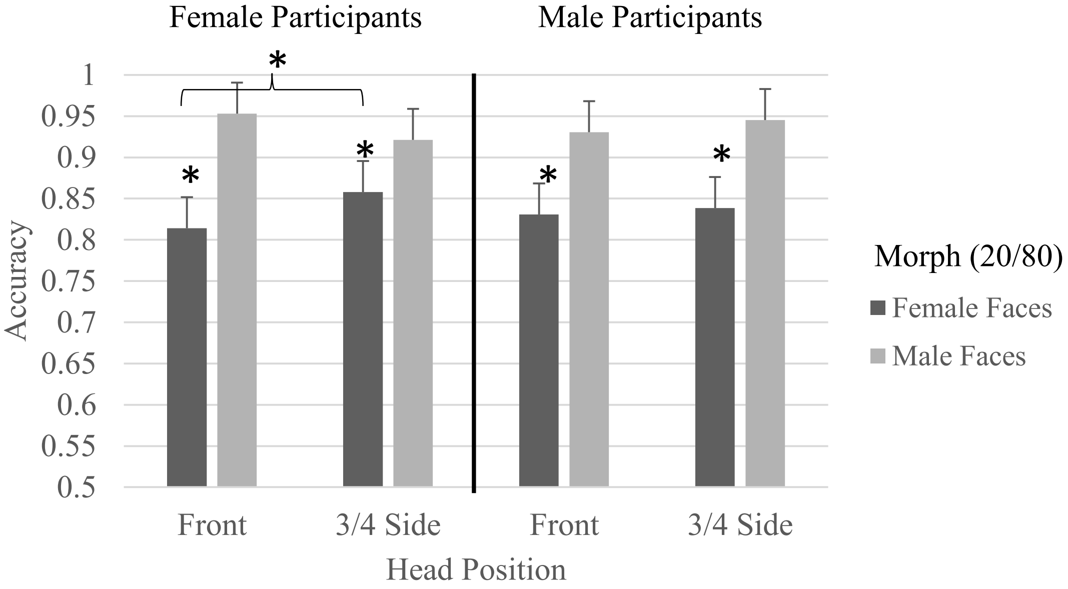

Figure 3.6: Accuracy – three-way interaction between participant sex, morph (20% morph = Female, 80% morph = Male), and head position.

Our reaction time analysis excluding sexually ambiguous morphs, however, yielded similar effects as our initial RT analysis including all degrees of morph. A main effect of morph was found (F(1,48) = 16.22, p < 0.001), such that participants were faster with male faces (M = 843.89ms, SD = 193.09) than female faces (M = 922.29, SD = 244.55). A main effect of head position (F(1,48) = 12.14, p = 0.001) was found showing faster RTs for ¾ side view (M = 865.53ms, SD = 197.99ms) compared to front view (M = 900.65ms, SD = 226.05ms). A two-way interaction between morph and head position was found (F(1,48) = 18.42, p < 0.001) demonstrating that for more female faces (20% morph), ¾ side view (M = 884.49ms, SD = 224.08) was significantly faster than front view (M = 960.08ms, SD = 277.86ms). Head position had no effect on processing efficiency of male faces (80% morph). Lastly, as seen in our original RT analysis, a two-way interaction was found between participant sex and gaze direction (F(1,48) = 4.44, p = 0.04). Post-hoc analysis (FLSD = 28.04ms) showed that female participants were faster at sex categorization when gaze direction was averted (M = 807.26ms, SD = 123.30ms) compared to direct (M = 843.63ms, SD = 151.64ms), but that male participants were not significantly influenced by gaze direction. No two-way interaction between gaze direction and head position was found for RTs as seen with accuracy, nor did we find a three-way interaction between participant sex, morph, and head position for RTs.

3.2.2 Inverted Orientation

Accuracy. Using data from inverted faces only, a 2 (Gaze: Direct, Averted) x 2 (Head Position: Front, ¾ Side) x 4 (Morph: 20, 40, 60, 80) repeated measures ANOVA demonstrated a main effect of morph (F(1,49) = 4.92, p = 0.03) for inverted faces that was similar to that found with upright faces. Post-hoc analyses (FLSD = 9.90%) showed that highest accuracy rates were found for the 80% morph (79.99%), which was significantly higher than accuracy scores seen with 20% morphs (69.38%), 60% morphs (62.77%), and 40% morphs (60.04%). So this effect, again, indicates a bias to interpret sexually ambiguous faces as male. As with upright faces, a two-way interaction was found between morph and head position (F(1,49) = 6.44, p = 0.01). Post-hoc analyses (FLSD = 5.82%) demonstrated that participants were more accurate with 80% male faces when presented in front view (83.10%) compared to side view (76.88%). This interaction is illustrated in Figure 3.7. No significant differences in accuracy were found between front and side view for 20%, 40% and 60% morphs; however, the trend remains that accuracy is highest for sex-ambiguous male faces (60% morph) when presented in front view and for sex-ambiguous female faces (40% morph) when presented in ¾ side view.

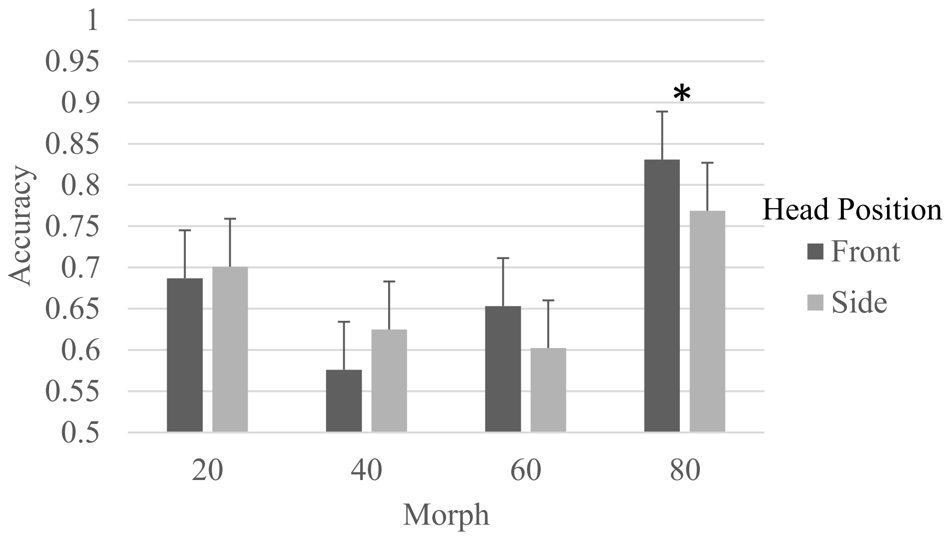

Figure 3.7: Accuracy – two-way interaction between morph and head position.

A two-way interaction between head position and gaze direction was also found with inverted faces (F(1,49) = 4.98, p = 0.03) – an effect that was only found for upright faces when sexually ambiguous faces (40% and 60% morphs) were eliminated. Post-hoc analyses (FLSD = 1.96%) showed that when a face is presented in ¾ side view, higher accuracy was seen with averted gaze (68.59%) compared to direct gaze (66.24%). No significant difference was found for accuracy rates between direct and averted gaze for front view head position; however, direct gaze with a front view head position (69.04%) was also significantly more accurate than direct gaze in ¾ side view. This interaction is illustrated in Figure 3.8.

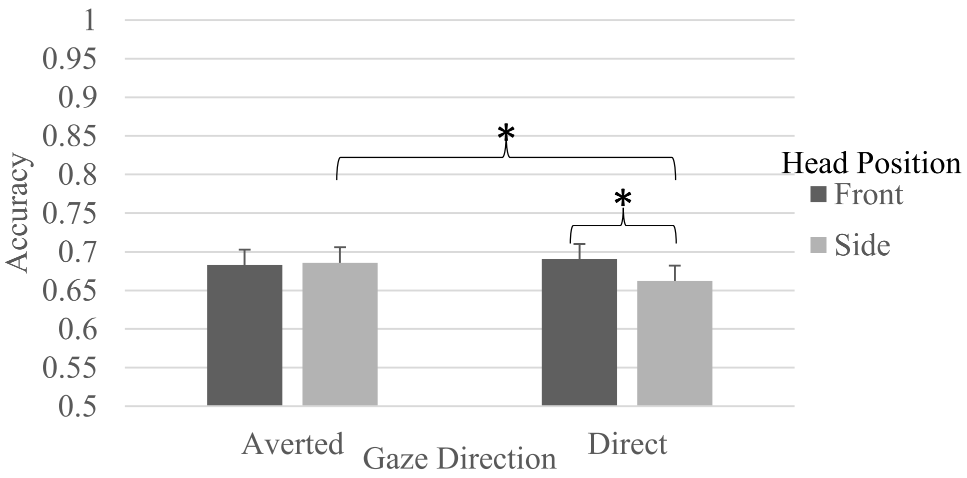

Figure 3.8: Accuracy – two-way interaction between gaze direction and head position.

Lastly, a three-way interaction between gaze, head position and morph (F(1,49) = 87.37, p < 0.001) revealed itself in our accuracy analysis of inverted faces. Essentially, for more 'female' faces (20% and 40% morphs), direct gaze facilitated sex recognition for faces presented in ¾ side view, while for more 'male' faces (60% and 80% morphs), direct gaze facilitated sex recognition for faces presented in front view. No significant differences were found between front view and ¾ side view head position for averted gaze in all morph degrees. Figure 3.9 illustrates the three-way interaction.

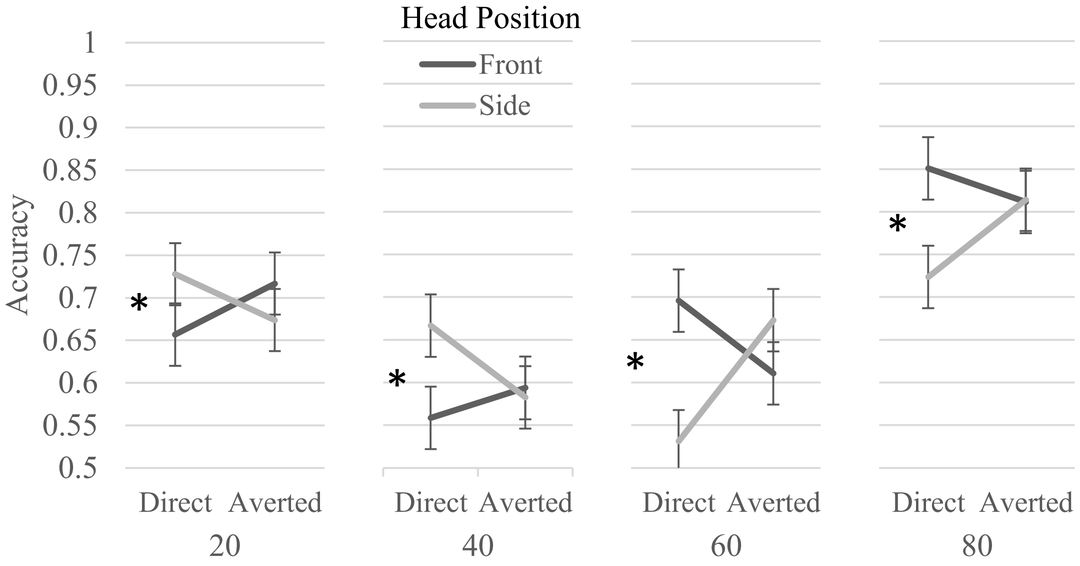

Figure 3.9: Accuracy – three-way interaction between morph, gaze direction and head position (FLSD = 3.66%)

Reaction Times. Due to the effect of order of orientation block presentation that was found for RTs of inverted faces (i.e., faster RTs were found for inverted faces when inverted faces were presented second), RTs for inverted faces when the inverted faces were presented second were eliminated from reaction time analysis of inverted faces. The reasoning for this is that the faster RTs that were found when inverted faces were presented second, or after the upright faces, is likely due to practice effects. Completing the sex categorization task for upright faces first may have primed the participants for the inverted faces.

When inverted faces were presented first, a main effect of morph was found (F(1,48) = 10.67, p = 0.002) as seen with accuracy. Post-hoc analysis (FLSD = 30.58ms) showed that 80% morph (M = 980.09ms, SD = 285.18ms) was significantly faster than the 20% morph (M = 1028.12ms, SD = 283.32ms), which in turn was significantly faster than the 60% (M = 1060.98ms, SD = 325.24ms) and 40% morphs (M = 1086.08ms, SD = 346.57ms). Also consistent with our accuracy findings was a two-way interaction found between morph and head position (F(1,48) = 9.41, p 0.004). Post-hoc analysis (FLSD = 31.10ms) indicated that for more female faces (20% morph), faster RTs were found for ¾ side view (M = 1003.19ms, SD = 275.41ms) than for front view (M = 1048.90ms, SD = 298.37ms). No significant differences between front view and ¾ side view were found for 40%, 60% and 80% morphs. No two-way interaction was found between gaze and head position in our RT analysis of inverted faces, nor a three-way interaction between gaze direction, head position and morph.

3.2.3 Face Inversion Effect

Accuracy. To investigate the FIE, a combined analysis of upright and inverted orientations was also performed using a 2 (Gaze: Direct, Averted) x 2 (Head Position: Front, ¾ Side) x 2 (Orientation: Upright, Inverted) x 4 (Morph: 20, 40, 60, 80) repeated measures ANOVA. A main effect of orientation was demonstrated (F(1,49) = 281.42, $p < 0.001$), showing that sex categorization was more accurate for upright faces (78.80%) compared to inverted faces (68.02%). A four-way interaction was also found between orientation, morph, head position and gaze direction (F(1,49) = 63.98, $p < 0.001$), suggesting that inversion enhances the influence of direct gaze on the interaction between morph and head position (i.e., higher accuracy for female faces presented in ¾ side view with a direct gaze and higher accuracy for male faces presented in front view with a direct gaze). Figure 3.10 illustrates the four-way interaction.

Reaction Times. Due to the practice effects for inverted faces mentioned previously, all RTs for inverted faces presented second were excluded from the RT analysis. All RTs for upright faces, regardless of whether the upright faces were presented first or second, were included in the analysis. A main effect of orientation was found (F(1,23) = 29.75, $p < 0.001$) as seen with accuracy, demonstrating that RTs were much faster for upright faces (M = 947.93ms, SD = 270.68ms) in comparison to inverted faces (M = 1272.45ms, SD = 469.94ms).

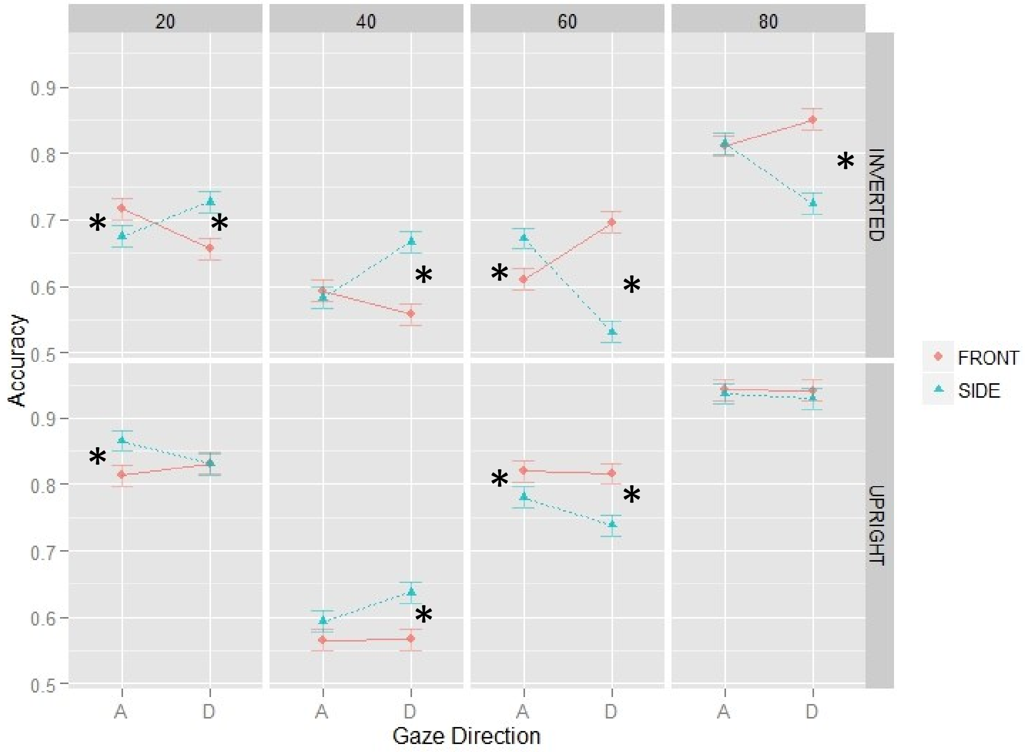

Figure 3.10: Accuracy – four-way interaction between morph, head position, gaze direction and orientation

3.3 Eye-Tracking Analyses

For eye-tracking analysis, only trials yielding correct responses were used. Initially, our intention was to analyze both number of total fixations and interest area dwell time; however, fixation count analyses simply reiterated our RT analysis (i.e., conditions which yielded longer RTs also yielded greater number of fixations). To avoid redundancy, fixation count is not reported. For interests sake, the average number of fixations for upright faces (M = 3.97, SD = 0.96) was significantly less than the average number of fixations for inverted faces (M = 4.85, SD = 1.43).

3.3.1 Upright Orientation

Initial interest area analysis included all defined interest areas: eyes (2), eyebrows (2), nasion, nose, mouth, cheeks (2), forehead, chin, and temples (2) for a total of 13 areas of interest (AOI). Figure 3.11 illustrates the percentage of time spent fixating on each AOI for each head position. All AOI's receiving less than one percent of total dwell time were excluded from further analysis, leaving six main AOI's to be investigated for upright faces: right eye (RE), left eye (LE), nasion, nose, mouth, and left cheek.

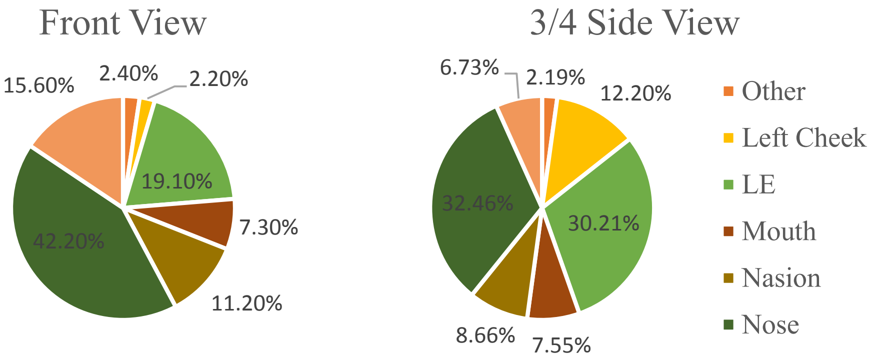

Figure 3.11. Percentage of total dwell time within each AOI for each head position (upright faces only).

A main effect of AOI was found (F(5,245) = 37.46, p < .001) showing that significantly more time was spent looking at the nose than any other area (M = 278.54ms, SD = 178.24ms), followed by the left eye (M = 171.41ms, SD = 138.60ms). This effect was moderated, however, by two-way interactions with gaze direction (F(5,245) = 2.53, p = 0.03), morph (F(5,245) = 13.91, p < 0.001), and head position (F(5,245) = 54.64, p < 0.001). Similarly, three-way interactions were found for gaze direction, head position and AOI (F(5,245) = 5.94, p < 0.001), as well as for morph, head position and AOI (F(5,245) = 2.90, p = .014). Finally, a four-way interaction was found for gaze direction, head position, morph and AOI (F(5,245) = 2.33, p = 0.044). Figure 3.12 illustrates the two-way interaction between head position and AOI that shows the nose was looked at the most overall, yet it was focused on significantly more in front view compared to ¾ side view where the left eye was fixated on more. Table 3.1 lists the mean dwell time for each AOI with respect to different gaze directions and head positions.

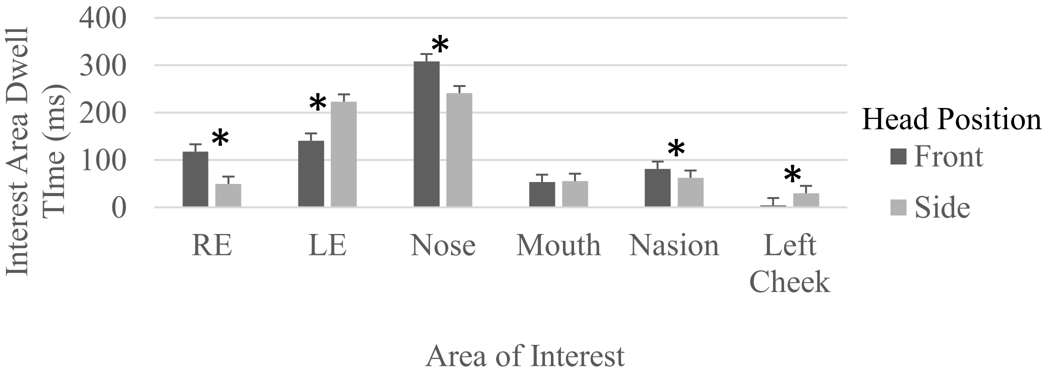

Figure 3.12: Dwell-time - two-way interaction between head position and AOI (FLSD = 15.38ms).

Table 3.1
Mean dwell-time (SD) for each AOI with respect to gaze direction and head position for upright faces (FLSD = 8.28ms)

	Front		¾ Side	
AOI	Direct	Averted	Direct	Averted
RE	123.87 (105.55)	111.95 (98.90)	48.24 (64.21)	51.33 (66.04)
LE	140.82 (127.45)	140.72 (124.99)	217.32 (160.69)	229.35 (175.06)
Nose	306.05 (191.85)	310.32 (194.23)	250.01 (179.80)	231.99 (163.16)
Mouth	50.18 (77.40)	57.52 (91.32)	58.42 (79.35)	53.08 (86.60)
Nasion	80.06 (62.30)	83.03 (64.78)	65.28 (45.72)	59.87 (52.91)
Left Cheek	4.62 (8.50)	4.48 (7.86)	32.30 (22.79)	27.72 (18.37)

3.3.2 Inverted Orientation

As with eye-tracking analysis for upright faces, only trials yielding correct responses were used. Additionally, due to the order of orientation block presentation established for inverted faces, only inverted faces presented first were included in the analysis. Initial interest area analysis again included all defined interest areas, and all AOI's receiving less than one percent of total dwell time (ms) were excluded from further analysis. Figure 3.13 illustrates the percentage of time spent fixating on each AOI for each head position.

A main effect of AOI was also found for inverted faces ($F(8,184) = 35.71$, $p < 0.001$) – an effect that was modulated by two-way interactions with gaze direction ($F(8,184) = 2.20$, $p = 0.03$) and head position ($F(8,184) = 25.41$, $p < 0.001$), as well as a significant three-way interaction with gaze direction and head position ($F(1,184) = 2.45$, $p = 0.02$). Table 3.2 summarizes mean dwell times within each AOI for both gaze directions and head positions. Figure 3.14 illustrates the two-way interaction found between AOI and head position.

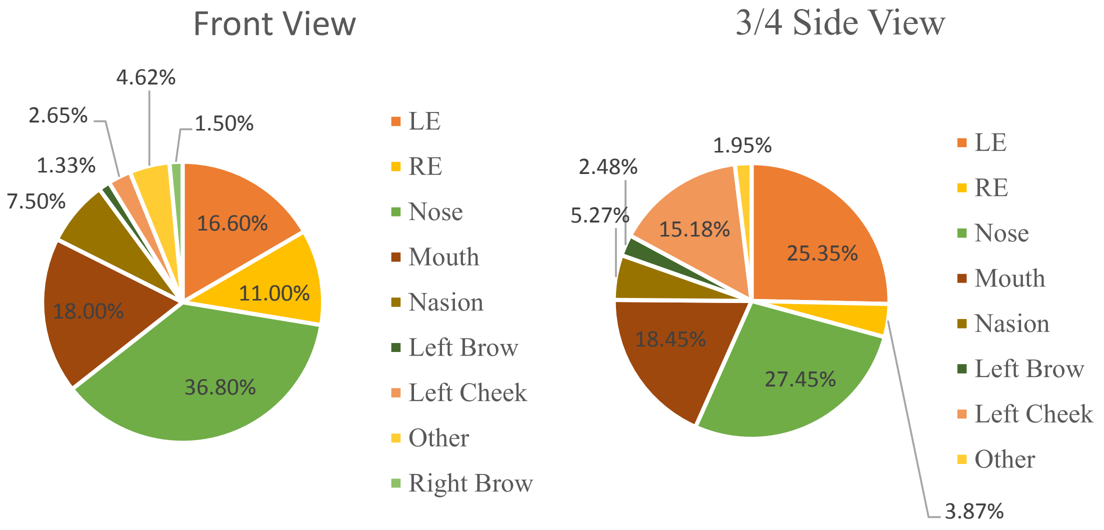

Figure 3.13: Percentage of total dwell time within each AOI for each head position (inverted faces only)

Table 3.2

Mean dwell time (SD) for each AOI with respect to gaze direction and head position for inverted faces (FLSD = 13.87ms).

	Front		¾ Side	
AOI	Direct	Averted	Direct	Averted
RE	138.36 (119.30)	126.36 (108.78)	47.83 (53.60)	41.74 (44.11)
LE	179.87 (91.74)	175.77 (85.22)	263.76 (144.30)	300.11 (156.23)
Nose	316.67 (187.40)	326.90 (210.27)	235.18 (146.92)	242.06 (177.91)
Mouth	189.84 (219.02)	189.03 (178.57)	180.20 (159.04)	200.81 (178.72)
Nasion	69.71 (42.22)	79.09 (49.48)	47.82 (34.25)	50.70 (44.26)
Left Cheek	8.19 (7.42)	9.44 (8.57)	58.36 (33.73)	53.26 (33.24)
Left Brow	18.61 (31.76)	23.48 (33.67)	29.40 (46.97)	34.62 (49.90)
Right Brow	17.83 (26.70)	19.75 (33.54)	4.23 (6.13)	4.37 (7.95)

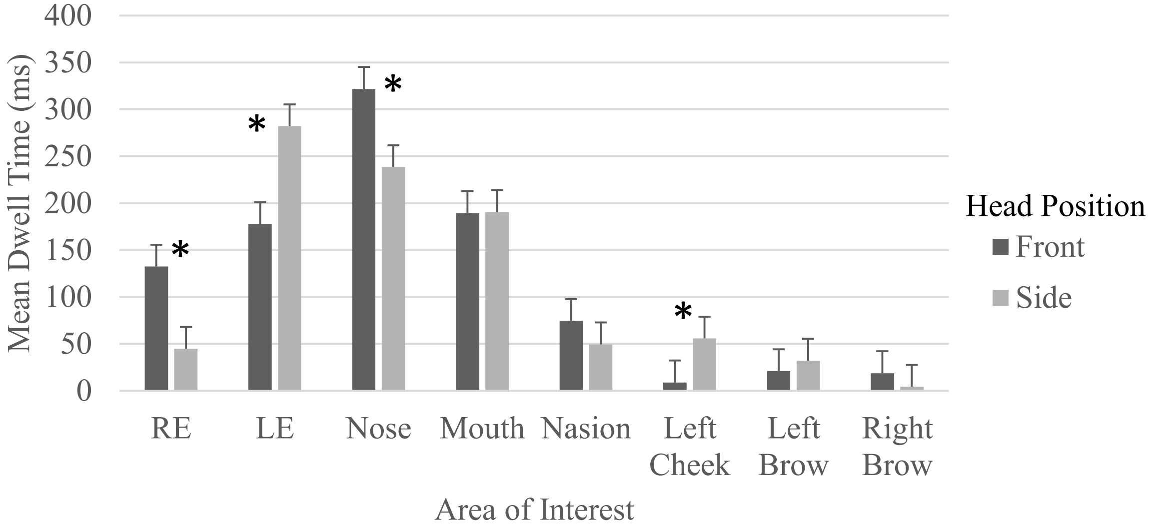

Figure 3.14: Dwell-time – two-way interaction between head position and AOI

3.3.3 Face Inversion Effect

A comparison of upright and inverted orientations in our eye-tracking analysis resulted in a two-way interaction between orientation and AOI (F(7,336) = 12.26, p < 0.001) and showed that the mouth is looked at significantly more when a face is inverted (M = 162.30ms, SD = 147.44ms) compared to when the face is upright (M = 54.80ms, SD = 82.64ms). Figure 3.15 illustrates this interaction.

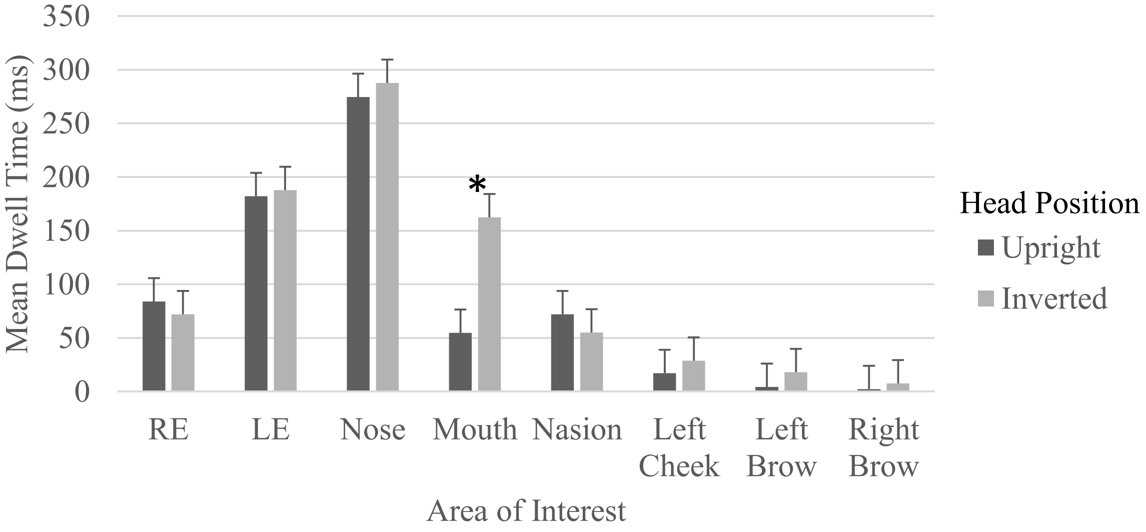

Figure 3.15: Dwell-time – two-way interaction between orientation and AOI

CHAPTER 4: DISCUSSION

The primary goal of the current study was to investigate the effects of gaze direction, head position, and inversion on sex categorization using both behavioural (accuracy, RTs) and eye-tracking outcomes (interest area dwell time). Although the effects of gaze direction and head position on sex categorization have previously been investigated, the reports to date are conflicting (Itier & Batty, 2009; Macrae et al., 2002; Pageler et al., 2003; Vuilleumier et al., 2005). The current study contributes to the existing literature by trying to resolve this conflict with new data and incorporating eye-tracking technology to distinguish which facial areas attract attention during a sex categorization task. Additionally, a face morphing procedure was used to ensure rich eye-tracking data similar to that used by Campanella et al. (2001).

4.1 Effects of Order of Orientation Block

Prior to conducting the experiment, it was expected that RTs would be faster for upright faces compared to inverted faces overall; however, it was not expected that order of orientation block (upright followed by inverted vs. inverted followed by upright) would yield any differences. The results showed that participants were significantly faster at sex categorization of inverted faces when they were presented after the upright block than when the inverted block was presented first. This finding is likely the result of transfer effects that appear to go in one direction. Upright face processing benefits transferred to inverted face processing. Whereas, inverted face processing benefits did not affect upright processing. The fact that these transfer effects were not seen with upright faces may suggest that performance for upright faces was already optimal, and therefore not susceptible to transfer effects. This effect of order of orientation block means that analyses of upright face responses always included both blocks; whereas, analyses of inverted face responses were sometimes restricted to the first block (i.e., all RT data involving inverted faces).

4.2 Discussion of Results and Conclusions

4.2.1 Effect of Morphing

A morphing procedure was initially used to slow down the sex categorization task to ensure rich eye-tracking data. The percentages of morph used were 20%, 40%, 60% and 80% in increasing order of masculinity. The percentages used by Campanella et al.

(2001) (10%, 30%, 50%, 70% and 90% masculinity) were not used because a 50% morph is neither male nor female, and therefore there was no correct response for the sex categorization task. It was hypothesized that accuracy would be lower for the morphs with greater sexual-ambiguity (i.e., 40% and 60% morphs).

It was found that degree of morph had a large and consistent effect on performance. Not surprisingly, performance was poorest for the most sexually-ambiguous stimuli. More importantly, the shape of the effect across morph degrees indicated that there was a bias to respond to sexually-ambiguous faces as male. Accuracy was highest and RTs were fastest at identifying the ‘most male’ face (80%) suggesting a processing bias for male faces that was exhibited by both male and female participants. Even for more sexually ambiguous faces (40% and 60% morph), accuracy was higher and RTs were significantly faster for ‘more male’ faces (60% morph). This effect was independent of the sex of the observer and so contradicts reports of an ‘own-sex bias’ for female participants (Herlitz & Loven, 2013) and the finding that processing is faster when participant sex matches that of the stimulus presented (Vuilleumier et al., 2005). A methodological difference between these previous studies and the current study is the fact that the previous studies did not incorporate a morphing procedure. This difference may account for why an ‘own-sex bias’ was not found in the current study and suggests that the bias does not extend to sexually ambiguous faces. In fact, recent studies incorporating a morphing procedure or facial distortion also concluded that sexually ambiguous faces are assumed to be male (Armann & Bulthoff, 2012; Cellerino et al., 2004; Hoss et al., 2005).

Interestingly, the effect of morph remained for inverted faces suggesting that processing of sex is at least partially feature-based rather than holistically-based. Some feature appears to be driving the sex categorization decisions, and due to the large influence of direct gaze on accuracy scores with inverted faces, that feature may be the eyes. The main effect of inversion, however, indicates that holistic processing is also making a large contribution to the decisions.

A two-way interaction was also found between morph and head position that was consistent across accuracy and RTs for both upright and inverted faces. This interaction indicates that male faces are processed more efficiently when viewed with a frontal head position; whereas female faces are processed more efficiently when viewed with a ¾ side view. To our knowledge, this effect has not been previously reported in the literature. A suggested explanation for this interaction comes from nonverbal communication studies of courtship. Males often communicate sexual interest with very few signals which typically express dominance. In contrast, females communicate sexual interest with a variety of signals which typically signify submission (Grammer, 1990). Adopting a frontal head position during social interactions is approach-oriented and may implicitly signify dominance, whereas adopting a ¾ side view head position is avoidance-oriented and suggests the targets full attention is not on the observer. Females may adopt a turned head posture, possibly unknowingly, to express submission as a non-verbal indication of sexual interest. If this is true, the findings from the current study indicate that the perceptual system has learned this association between sex of the target and dominance (or non-dominance) display.

Interestingly, typical RTs for sex categorization of non-sexually-ambiguous stimuli are just over 500ms (Macrae et al., 2002) whereas average RTs for upright faces in the current study ranged from 850ms to just over one second. Evidently, the morphing procedure succeeded in slowing down sex categorization.

4.2.2 The Wollaston effect

A primary goal of the current study was to investigate whether a model's gaze direction (direct or averted) would affect processing of sex, and whether head position (front or ¾ side view) mediates this effect. The notion that head position strongly influences gaze perception continues to be upheld in the current literature and is referred to as the Wollaston Effect (Anstis et al., 1969; Cline, 1967; Gibson & Pick, 1963; Kluttz et al., 2009). Higher error rates (Anstis et al., 1969) and slower RTs (Itier et al., 2007) in gaze direction judgement tasks occur when gaze direction and head position are incongruent (Langton et al., 2004). To date, however, reports have focused more on how these features influence and interact with each other, and less on how they may affect processing of other facial components. Furthermore, the few studies that do investigate the effects of gaze direction and head position on sex categorization report inconsistent findings (Itier & Batty, 2009; Macrae et al., 2002; Pageler et al., 2003; Vuilleumier et al., 2005). For the current study, it was hypothesized that accuracy would be highest and RTs would be faster for faces in which gaze direction and head position were congruent (consistent with Itier & Batty, 2007c and Langton et al., 2004).

Surprisingly, no main effects of gaze direction or head position were found for accuracy of upright faces, nor was a two-way interaction found between them (Wollaston effect). A main effect of head position was found with RTs demonstrating faster categorizing of sex in faces presented in ¾ side view; however, this effect was particularly driven by the more female stimuli (20% and 40% morphs)(see Figure 3.3). One way the current study differed from other studies reporting the Wollaston Effect is the incorporation of a morphing procedure. Thus, a separate analysis was performed eliminating sexual ambiguity (exclusion of 40% and 60% morphs), and as expected, a two-way interaction was found between gaze direction and head position on accuracy of upright faces as now described.

Our results showed that accuracy was higher for averted gaze than direct gaze in a ¾ side view, whereas gaze did not affect front view head position – a result that is consistent with the findings reported by Vuilleumier et al. (2005). Additionally, accuracy was higher for averted gaze in ¾ side view compared to averted gaze in front view (see Figure 3.5), consistent with our hypothesis that accuracy would be higher for faces in which gaze direction and head position are congruent, at least for ¾ side view, and consistent with findings by Langton et al. (2004) and Itier and Batty (2007c). These findings appear to be in opposition to Macrae et al. (2002) who reported that direct eye contact facilitates sex categorization regardless of head position; however, their study failed to include a ¾ side view head position paired with an averted gaze. Vuilleumier et al. (2005) suggested that slower RTs are found for direct gaze because mutual eye contact facilitates social communication and therefore requires longer processing times. They further supported this claim by demonstrating that recognition memory was greater for faces with a direct gaze.

An important contribution made by the current study is to resolve the apparent contradiction between the findings of Macrae et al. (2002) who advocate that direct gaze facilitates sex categorization, and Vuilleumier et al. (2005) who suggest direct gaze actually hinders sex categorization. Our findings are consistent with Vuilleumier et al.'s (2005) results as shown in Figure 4.1 demonstrating that gaze direction influences sex categorization with a ¾ side view head position, and categorization is fastest when averted gaze is paired with a ¾ side view head position (i.e. congruent). We further suggest that Macrae et al.'s (2002) conclusions were based on fewer conditions (i.e., did not include a ¾ head position with averted gaze) and that this accounts for the apparent discrepancy in their findings. Although Macrae et al. (2002) found a significant effect of gaze direction with a front view head position that was not seen in the current study or by Vuilleumier et al. (2005), their results remain consistent with the congruency theory such that direct gaze facilitated sex categorization when paired with a frontal head position.

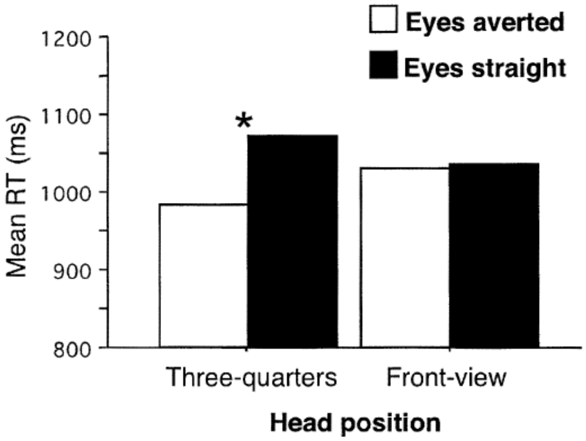

Figure 4.1: Two-way interaction between gaze direction and head position on RTs (Vuilleumier et al., 2005)

Gaze patterns identified by our eye-tracking analysis were also consistent with the congruency theory. For upright faces with a frontal head position, participants spent more time looking at the eye region with direct gaze rather than averted gaze, whereas with a ¾ side view head position, participants spent more time looking at the eye region when gaze was averted compared to direct (see Table 3.1).

From a theoretical standpoint, the results of the current study only partially support the organizational model proposed by Haxby et al. (2000) suggesting that the processing of invariant and changeable aspects of human faces are neurologically distinct. The two-way interaction between gaze direction and head position (i.e., changeable aspects) that was found for non-sexually ambiguous faces supports the notion that changeable aspects are processed together. Inconsistent with Haxby's model, however, was the fact that this interaction also influenced sex categorization, despite the fact that sex is an invariant aspect of a face. Similarly, head position alone had a large influence on sex categorization suggesting the two are processed simultaneously. The effect of head position on sex categorization, however, could be a learned effect that does not have a neurological basis. In which case, the effect may not be relevant to the neurological model.

4.2.3 Effects of Sex of the Observer

Although not a primary focus of the current study, sex differences of the observers were analyzed due to the numerous reports of this effect in facial processing (Cellerino et al., 2004; Goodman, Phelan, & Johnson, 2012; Herlitz & Loven, 2013; Sporer, 2001; Vuilleumier et al., 2005). The 'own-sex bias' refers to enhanced memory for faces of one's own sex (Sporer, 2001) and female superiority in face processing is commonly reported (Cellerino et al., 2004; Loven et al., 2011; McBain et al., 2009). It was therefore hypothesized that females would have higher overall accuracy and faster RTs compared to males, and specifically better performance for female face stimuli compared to male face stimuli. Our results showed that female observers did have significantly faster reaction times than male observers for upright faces; although there were no sex differences found for accuracy scores.

Similar to our findings with gaze direction and head position, sex of observer differences had a larger effect when sexual ambiguity was eliminated. A two-way interaction between participant sex and gaze direction was found for RTs both in the original analysis and when sexual ambiguity was eliminated. However, in our analysis of only 20% (more 'female') and 80% (more 'male') morphs, a three-way interaction was also found between participant sex, morph, and head position on accuracy rates. Female participants were more accurate at identifying female faces presented in ¾ side view compared to front view (see Figure 3.6). Head position had no effect on male participant accuracy. With RT analysis, female participants were significantly faster at sex recognition when gaze direction was averted compared to direct, while gaze direction had no effect on the performance of male participants. Taken together, these effects suggest that females are more susceptible or more attuned to identifying changes in gaze direction and head position because only female performance was influenced by changes in gaze direction and head position. Lastly, no sex of observer differences were found in our eye-tracking analysis.

4.2.4 Eye-Tracking

A major contribution of the current study is that it provides the first data on eye-tracking analysis during sex categorization. The EyeLink 1000 was used to track eye movements during a sex categorization task to identify which areas of the face facilitate sex recognition. It has been reported that the eyes and eyebrows are the most important features for sex recognition (Brown & Perrett, 1993); therefore, the eyes and eyebrows were defined as separate interest areas, and it was hypothesized that participants would spend more time fixating on these regions compared to the nose or the mouth. Eyebrows and skin texture provide cues for sex categorization that improve performance beyond that of facial structure alone (Bruce et al., 1993) suggesting that the eyebrows play more of a role in sex categorization than originally thought. It was also hypothesized that the nose would become more important for ¾ view, as the shape of the nose is better depicted in a ¾ view of the face, and males tend to have more protuberant noses (Bruce et al., 1993; Wilson et al., 2000).

Only trials yielding correct responses were used for eye-tracking analysis, and only AOIs receiving more than one percent of overall dwell time were investigated. For upright faces, only six areas were examined (the eyes (2), nose, mouth, nasion, and left cheek). More time was spent fixating on the nose than any other AOI, regardless of head position, suggesting the nose plays an important role in sex categorization. This is consistent with Roberts and Bruce (1988) who found that masking the nose slowed sex categorization more than masking the eyes or the mouth; however, they also reported poor accuracy rates when showing the nose alone suggesting that the role of the nose is configural and based solely on its relationship to other facial features. Additionally, significantly less time was spent fixating on the nose in ¾ side view compared to front view, while significantly more time was spent fixating on the LE (and left cheek) in side view compared to front view. This finding suggests that instead of relying on individual features to aid sex categorization, participants were actually attempting to locate the centre of the image to provide optimal viewing of the face as whole. This result is consistent with the theory of configural processing for upright faces. So, the nose may be an important feature because it is the center-most feature of the face, allowing the other features to fall in peripheral vision. A recent model proposed by Nemrodov et al. (2014) describes the importance of these feature placements for configural processing, suggesting that lateral inhibition of the parafoveal features relative to the foveal feature (nose) constitutes configural processing. This model is referred to as the Lateral Inhibition, Face Template, and Eye Detector (LIFTED) model.

4.2.5 Face Inversion Effect

The Face Inversion Effect (FIE) refers to disproportionately reduced recognition performance for inverted faces compared to inverted objects, and is believed to be the result of our own expertise with upright human faces (Diamond & Carey, 1986; Yin, 1969). The prevailing theory behind the FIE is the theory of configural processing which suggests that human faces, when presented in an upright position, are processed holistically (combining features into a whole unit), and suggests we rely heavily on inter-feature relations to enhance recognition performance (Maurer et al., 2002). Configural processing is believed to be disrupted during inversion forcing a shift to featural processing (Hole & Bourne, 2010; Leder & Bruce, 2000; Maurer et al., 2002; Van Belle et al., 2010). The FIE has been reported in sex categorization studies (Campanella et al., 2001; Zhao & Hayward, 2010); however, the current study was the first to utilize eye-tracking techniques to support the theory of configural processing in relation to sex categorization. Our goal in including inverted face stimuli in this study was to investigate the extent to which sex categorization is dependent on configural processing by analyzing its susceptibility to inversion, and it was hypothesized that inversion would cause lower accuracy rates and slower RTs.

As expected, overall RTs became slower and overall accuracy was lower when faces were inverted; however, our behavioural findings continued to demonstrate a strong main effect of morph and a two-way interaction between morph and head position consistent with our findings with upright faces (i.e., a strong preference for ‘male faces’ was demonstrated and greater likelihood of labeling a face as male if presented in front view). This result suggests that some information regarding the sex of a face is preserved with inversion and furthermore that the morphing procedure affected features that were diagnostic of sex. Similarly, sensitivity to head position remained intact with inverted faces, consistent with reports by Wilson et al. (2000). The interaction between gaze direction and head position showing accuracy was higher when gaze and head position were congruent (i.e., front view with direct gaze and vice versa) also remained intact with inversion, consistent with Langton et al. (2004). Given that these effects were found with upright and inverted stimuli, they are presumably based to some extent on featural and not configural information.

An interesting finding from the inverted face responses was the powerful three-way interaction between morph, gaze direction and head position on accuracy scores demonstrating that direct gaze, or mutual eye contact, becomes more important with inversion. With upright faces, we found that female faces were consistently identified more efficiently when in ¾ side view and male faces were identified more efficiently when in front view. With inverted faces, however, this effect was mediated by mutual eye contact such that accuracy was highest for female faces (20% and 40% morphs) when seen in ¾ side view with a direct gaze, and accuracy was highest for male faces (60% and 80% morphs) when seen in front view with a direct gaze (see Figure 3.9). The greater significance of gaze direction seen with inversion suggests a shift to featural-based processing – a finding that is also supported by our eye-tracking analysis.

It was hypothesized that our eye-tracking analysis would reflect a shift to featural processing by showing more fixations to individual features than was seen with upright faces. This result would remain consistent with Barton et al. (2006) who reported inversion produced more fixations to the mouth during an identity recognition task. Upon initial analysis of all AOIs, it was found that more AOIs received greater than one percent of dwell time than the six AOIs analyzed for upright faces (eyes (2), nose, mouth, nasion, and left cheek), including both the right and left eyebrows (see Figure 3.13). Right away this suggests a shift to featural processing given that more areas were fixated on when faces were inverted. Also consistent with a shift to featural processing, a direct comparison of AOI dwell time in upright and inverted faces demonstrated that more time was spent fixating on the mouth during inversion as Barton et al. (2006) found for an identity task (see Figure 3.15). It is conjectured that this occurred because in an inverted face, the mouth is in the location that the eyes normally would occupy in an upright face.

4.2.6 Summary

Overall, the primary goal of the current study was to further investigate the connection between gaze direction and head position, and more specifically, its effect on the task of sex categorization. Results indicated that optimal processing efficiency of sex occurred when gaze direction and head position were directionally congruent, and this effect disappeared with more sexually-ambiguous stimuli. The morphing procedure that was used to produce stimuli of varying degrees of sexual ambiguity served the purpose of slowing down RTs to ensure rich eye-tracking data, and results indicated a bias to categorize sexually ambiguous faces as male, regardless of orientation. This bias for male faces in sexually ambiguous stimuli was consistent across male and female observers. A strong interaction was also found between degree of morph and head position such that a ¾ side view head position aided processing of female faces, and a frontal view head position aided processing of male faces. Overall, female participants were faster at sex categorization than male participants, and were more affected by changes in gaze direction and head position than males.

A secondary goal of the current study was to compare performance in faces presented upright to those presented with an inverted orientation to further analyze the face inversion effect using eye-tracking methods. Our results indicated that more AOIs were fixated on when a face was inverted, and significantly more time was spent fixating on the mouth during inversion than seen in the upright orientation. Additionally, longer time spent fixating on the nose in a front view head position than the ¾ side view head position suggests observers locate the center of an image to facilitate optimal processing efficiency. These results support the theory of configural processing applied to upright faces that shifts to featural processing with inversion. Lastly, our behaviour data for inverted faces revealed a significant three-way interaction between gaze direction, head position and morph. Essentially, for more ‘female’ faces (20% and 40% morphs), direct gaze facilitated sex recognition for faces presented in ¾ side view, while for more ‘male’ faces (60% and 80% morphs), direct gaze facilitated sex recognition for faces presented in front view.

4.3 Clinical Perspectives

Although the primary intention of the current study was to provide further insights into face processing, specifically in terms of the effects of gaze direction, head position, and inversion on sex categorization, the results also provide a baseline for clinical comparisons in both psychology and ophthalmology. For example, studying the social and communication deficits of children and adults with ASD has become common practice in many psychological circles, and atypical eye contact is currently on the list of diagnostic criteria (American Psychiatric Association, 2013). Understanding the role of eye contact in face processing in typical individuals provides a standard for comparisons to clinical populations to further assess the extent to which they deviate from the norm. Direct gaze has been reported to induce a physiological response in individuals with ASD (Joseph et al., 2008; Kylliainen & Hietanen, 2006; Senju & Johnson, 2009), and previous eye-tracking studies have shown they spend less time examining the eye region (Jones & Klin, 2013) and avoiding faces in general (Riby & Hancock, 2009).

In terms of ophthalmology, the current study is mainly clinically relevant to disorders of ocular motility, or ocular misalignment, referred to as strabismus. Strabismus can have severe physiological consequences (e.g., double vision, eye strain, amblyopia, reduced binocular function, etc.), but can also have a negative psychosocial impact (Olitsky et al., 1999; Satterfield, Keltner, & Morrison, 1993). A common complaint of strabismic patients is an inability to make eye contact, which can highly limit their social interactions (Nelson et al., 2008). Furthermore, strabismic patients may adopt a head posture (e.g., tilted or turned head) to compensate for their ocular misalignment. It has been established that changes in gaze direction and head position influence face processing in straight-eyed individuals; however, to our knowledge, no studies have yet investigated the effects of gaze direction on face processing when the eyes are pointing in different directions (see section 4.5).

4.4 Limitations

The major limitations of the current study stem from a need to control potential confounds and ensure standardization which limits the ecological validity of the results. First, the study was conducted in a lab setting where participants were presented images of faces that were morphed, airbrushed, and cropped at the hairline. Although these image manipulations were required for experimental control, their ecological validity is limited. However, live human models were used for the creation of facial stimuli which are more realistic than the schematic diagrams used in previous studies. The images were also presented in colour which is more realistic than the black and white or grey scale images used in other studies (Macrae et al., 2002; Vuilleumier et al., 2005).

Second, another limitation that arose during the creation of our stimuli was that while the morphing procedure successfully created a sex continuum from a female face to a male face, it also created a transition from one model's identity to the others.

This limitation was unavoidable and also reported by Campanella et al. (2001). A final limitation related to the fact that the stimuli presented only ¾ side view faces of the left side of the face (or a right head turn). Including stimuli with both a right-turned and left-turned head would have substantially increased the number of stimulus presentations required for a balanced design, and would have resulted in longer testing times and more stimulus presentations of each individual model. We chose a right-turned head position over a left-turned head position because when a model's head is turned to the right, their facial features are placed in the observer's left visual field. In terms of the visual pathway, the left visual field projects to the nasal retina of the LE and the temporal retina of the RE, which are in turn processed by the right hemisphere – the hemisphere associated with expert facial processing (Le Grand et al., 2003).

Further limitations of the current study were introduced by the inclusion criteria that age and ethnicity of participants was restricted to ages 18 to 30 years and Caucasian (European descent), respectively. Allowing all ages and all ethnicities to participate would have introduced confounds that are highly reported in face processing literature. It is well established that humans are experts at facial processing tasks when dealing with faces of similar age and ethnicity (Meissner & Brigham, 2001; Valentine & Bruce, 1986; in Valentine, 1988, Wiese et al., 2013). To avoid additional confounds, we limited the study to participants of this age range and ethnicity.

A final limitation of the current study is that although eye-tracking allows for precise mapping of the pupillary axis, this does not necessarily indicate where a participant's attention truly lies. This became apparent after testing when multiple participants reported that the eyebrows and/or jawline aided their categorization, yet neither of these features received any dwell time on interest area analysis. Again, we suggest this is the result of configural-based processing, where participants fixate on the center of the image to simultaneously process all features for optimal processing. Eye movements only allow us to determine where overt attention is allocated, not covert attention.

4.5 Future Directions

The results of the current study provide future directions for numerous literature pathways mainly with relevance to both psychology and ophthalmology. For psychology, the incorporation of eye-tracking technology can provide further evidence to support theories of facial processing, as the current study did for the theory of configural processing and the congruency theory between gaze direction and head position. The current study could also be altered to incorporate an identity recognition task, emotion recognition task, or memory tasks to further investigate the relationship between gaze direction and head position, while also incorporating eye-tracking methodologies. To date, there appears to be no empirical investigation into the relationship between stimulus sex and head position – a strong interaction found in the current study. Future studies could further explore this interaction and its relationship to eye contact. Future studies could also make use of dynamic stimuli to examine whether kinetic changes in gaze direction or head position have more salient effects on processing. Lastly, the study could also be altered to allow for testing of individuals with ASD to examine their gaze patterns during sex categorization, and further investigate their atypical eye contact behaviours (Joseph et al., 2008).

With relation to ophthalmology, the current study could be repeated with patients who have long-standing strabismus to investigate whether their facial scanning is comparable to straight-eyed individuals, or if they are more attuned to ocular changes as a result of their own ocular condition. Conversely, images of strabismic patients could be used as stimuli to investigate whether normal processing and facial scanning techniques are altered by the detection of ocular misalignment. Overall, the current study provides a solid baseline for further investigations that may prove to be clinically relevant.

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APPENDIX A: STIMULUS CREATION PROCEDURE

To create the stimulus set, 40 models (20 male, 20 female) were hired to pose in front of two broadcast quality Sony DSR 450 video cameras with standard broadcast Canon ECTV lenses. The cameras were leased from the Video and Audio Production Unit of Dalhousie University's Instructional Media Services Department along with the services of two videographers. Two videos were taken simultaneously at different angles onto DVCam tape, from which stills were later extracted.

Video-shoot

To set up, an adjustable chair was placed in front of a black back drop with evenly distributed florescent overhead lighting (320 LUX) for the models. The video cameras were placed at 90° (Camera 1) and 120° (Camera 2) from the model's point-of-view allowing for simultaneous recordings of the face from a frontal view and a ¾ left side view[1]. Both cameras were placed at a standard distance (five metres) from the chair and at a standard height (51 inches to the center of the lens). Varying height across the models was controlled by making vertical adjustments to the chair. An "X" was marked on the wall with tape approximately 60° from the model's point-of-view at the same height and distance as the cameras. Figure A.1 illustrates the video-shoot set-up.

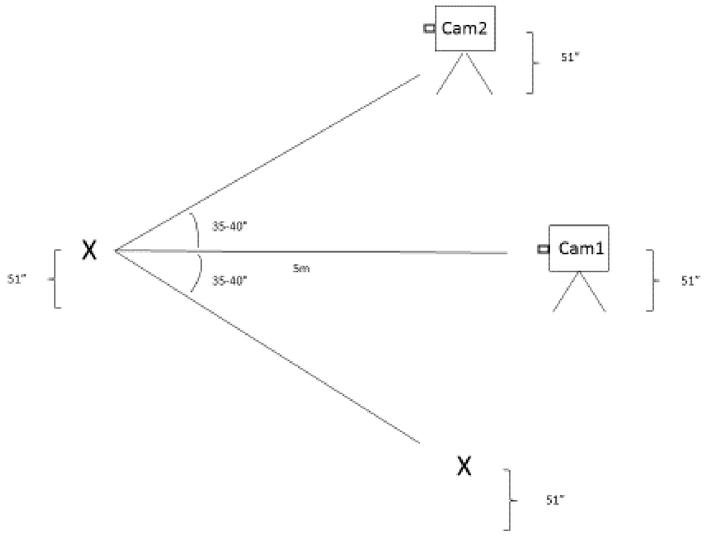

Figure A.1: Video-shoot set-up.

To prepare for the shoot, all male models were asked to be clean shaven, and all female models were asked to refrain from wearing make-up. All models received an email prior to the shoot with a copy of the release form and images of the Ekman emotions (see Figure A.2) they would be asked to mimic. Prior to taping, all models were asked to remove glasses and facial piercings, tie their hair back, put on the black tee shirt provided, and sign a release form. A mirror was provided to practice the emotions prior to taping. When necessary, a black headband was worn to pull hair back off their face.

Figure A.2. Ekman emotions from top left to bottom right: anger, fear, disgust, surprised, happy and sad (Ekman & Friesen, 1971).

First, the chair was adjusted to compensate for model height so that the entire head could be viewed in both cameras, and zoom was adjusted accordingly. When ready, both cameras began recording simultaneously so the videos would be synced in time. While staring into Camera 1, models were asked to display the following emotions (in order): neutral, sad, disgust, happy (no teeth showing), happy (with teeth showing), surprised, angry, fear. Models were also asked to return to a neutral face between each of the emotions. The emotions were then repeated while looking into Camera 2 and again looking at the “X” on the wall to their right. This allowed for eye-gaze manipulations without moving their head position. Models were thanked and paid $15 for their time.

Image Manipulation

For the current study, stills were extracted from the videos of neutral expressions only providing us with five images per model – one image for each condition (see Figure

2.1). Male and female pairs were then randomly chosen and subsequently morphed together using the software program FantaMorph.

Abrosoft FantaMorph

To morph selected male and female images together, a professional photo-animation software program Abrosoft FantaMorph was used. The two images to be morphed were uploaded into the program (female face on the left, male face on the right) which generates an animated image on a spectrum of 0-100% beginning with the female face (0%) and ending with the male face (100%). The program locates 102 points within and around each face that are matched to its corresponding point in the second image: 28 around the head, 16 around the nose, 20 around the mouth, 8 around each eyebrow, and 11 around each eye (see Figure A.3). The corresponding points are combined to produce the final animation. From this animation, four stills were taken for each male-female pair: 20:80 (i.e., 20% male and 80% female), 40:60, 60:40, and 80:20. Morphs are referred to by their percentage of "male" (see Figure A.4). With four degrees of morphing for each of the five conditions, a total of 20 images were created for each of the male-female pairs. Of the 20 possible morph pairings, only 15 were usable. Five morphed pairs were excluded after the pilot study for having highly memorable features (e.g., highly distinguishable eyebrows).

The GNU Image Manipulation Program (GIMP):

The final alterations to the images were made using a graphics manipulation software program called GIMP 2.8. Each face was cropped using the 'free-select tool' around the hairline and jawline to eliminate the backdrop and the ears, neck and hair from each photo. For faces with sideburns, the image was cropped to include the sideburns which were later airbrushed out using the 'smudge tool'. Lastly, to create the inverted stimuli, all images were rotated 180° using the 'rotate tool' and side view faces were also flipped using the 'flip tool' to ensure facial features would still be presented in the left visual field in the inverted condition. See Figure 2.2 for examples of the final stimuli in the upright and inverted conditions.

Figure A.3: FantaMorph software showing original images (top) and resulting morphed animation sequence (bottom). The morph demonstrated in this figure depicts a 50% morph on the 0-100% spectrum.

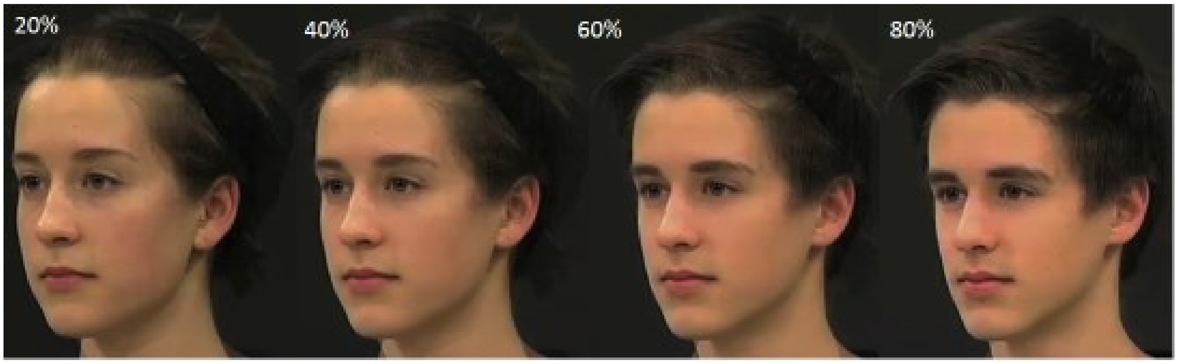

Figure A.4. The four degrees of morphing created using FantaMorph software.

APPENDIX B: MODEL RELEASE FORM

Face Processing and Gender Recognition: An Eye-Tracking Study
Psychology & Neuroscience Department
Dalhousie University
Release Form

I authorize the taking of photographic portraits, and hereby grant permission for the use, re-use, and/or alteration of any or all photos taken. I hereby waive any right that I may have to inspect or approve the finished product.

☐ **YES** ☐ **NO**

I consent to having my photos used for any kind of dissemination of the current studies' work, including posters, journal publications, etc. (If your photos are chosen to be used you will *never* be referred to or mentioned by name).

☐ **YES** ☐ **NO**

I consent to having my photos shared with other research teams requiring the use of facial stimuli.

☐ **YES** ☐ **NO**

I have read, understood, and agree to the terms of this release. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction.

Signature of Participant: _________________________ Date: _______________

Signature of Researcher: _________________________ Date: _______________

☐ I have received payment for my services

Questions
If you have any questions, please contact Stephanie Sobey at stephsobey@dal.ca or Dr. Patricia McMullen at 494-7025, mcmullen@dal.ca.

APPENDIX C: PARTICIPANT CONSENT FORM

Face Processing and Gender Recognition: An Eye-Tracking Study
Psychology & Neuroscience Department
Dalhousie University
Consent Form

Principal Investigator: Stephanie Sobey
Thesis Supervisor: Dr. Patricia McMullen

You are invited to take part in a research study being conducted by Stephanie Sobey who is a graduate student at Dalhousie University, as part of her Master of Science thesis in Clinical Vision Science. Your participation in this study is voluntary and you may withdraw from the study at any time without penalty. The study is described below. This description tells you about the risks, inconvenience, or discomfort that you might experience. Although participation in this experiment may not directly benefit you, the knowledge gained may benefit others in the future. If you have any further questions or concerns, please contact either Stephanie Sobey or Dr. Patricia McMullen. Contact information is provided below.

Purpose of the Study
Humans are exceptionally fast and accurate at identifying the sex of other humans even when they have never met before. The purpose of the current study is to examine gaze patterns using an eye-tracking camera while participants view faces and complete a gender recognition task. Gender differences in eye-tracking will also be investigated.

Study Design (What you will be asked to do)
To do this, you will complete a compute task. A series of faces will be presented on the computer screen and you will be asked to indicate whether the face is male or female by pressing a specified key on the keyboard. Prior to the task, you will be asked to place your chin on the chin rest provided and asked to remain still so that your eye movements can be tracked using an infra-red light source and camera. Breaks will be provided as needed and you are free to withdraw from the study at any time without penalty. The study is expected to take up to 1 hour to complete.

Who Can Participant?
You are eligible to participate in this experiment if you are Caucasian, between the ages of 18 and 30, and if you have normal or corrected-to-normal vision. You are asked to refrain from wearing eye make-up as this will interfere with the eye-tracking system (make-up remover will be provided by the experimenter as needed). *Note: individuals who were hired as face models for the current study are not eligible to participate.

Who Will be Conducting the Research?
The research for this study will be conducted by the principal investigator, Stephanie Sobey, or a volunteer research assistant working with Dr. Patricia McMullen of the Psychology and Neuroscience Department (Visual Cognition Lab) at Dalhousie University.

Potential Risks and Discomfort

Minimal discomfort may arise due to boredom and temporary eye strain as the result of looking at a computer screen for a period of time. Safe levels of infrared illumination from the EyeLink 1000 can eventually cause some discomfort due to the slight drying effect, especially for contact lens wearers. To minimize these risks, participants will be seated at a safe distance from the illuminators to prevent unnecessary exposure, and breaks will be provided as needed. The experiment is expected to take up to 1 hour to complete. Again, you are free to withdraw at any time without penalty.

The EyeLink 1000 illuminators are compliant with the International Electrotechnical Commission (IEC) LED safety standards as a Class 1 LED device. This standard regulates many aspects of LED and laser eye safety, including retinal, corneal and skin safety. Class 1 products are "safe under reasonably foreseeable conditions of operation, including the use of optical instruments from intrabeam viewing" (EyeLink 1000 user manual).

Possible Benefits

There are no known direct benefits of participating in the current study aside from having the opportunity to use a state-of-the-art eye-tracking device and gain basic exposure to research methodology. Your participation may however allow us to gain useful information related to face processing, visual cognition and gender perception.

Compensation/Reimbursement

You will receive 1 credit point or $10 for your participation in this study.

Confidentiality and Anonymity

Data will be collected on an individual basis and your name will not be recorded with your data. Your name is only required for consent and compensation purposes. Information collected during this experiment will be stored in a secure database which will only be accessible to the research team and will be destroyed five years after the potential publication of the study. You will never be referred to or mentioned by name in any report associated with this experiment. The results of the current study will be available from the principal investigator once the study has been completed. If this experiment's findings are published, your name will not be used and no information disclosing your personal identity will be released or published.

Questions

If you have any questions, please contact Stephanie Sobey at stephsobey@dal.ca or Dr. Patricia McMullen at 494-7025, mcmullen@dal.ca.

Problems or Concerns

If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director of Human Research Ethics Administration at Dalhousie University, for assistance at (902) 494-1462, ethics@dal.ca.

APPENDIX D: PARTICIPANT RECRUITMENT POSTER

RESEARCH PARTICIPANTS NEEDED

Face Processing & Gender Recognition:
An Eye-Tracking Study

Psychology & Neuroscience Department
Dalhousie University

Research Participants needed for eye-tracking research.
Experiment will take up to 1hr to complete.
Payment will be $10 per hour.

What you will do:
Complete a gender recognition computer task while an eye-tracking camera follows your eye movements

Qualifications:

- Caucasian
- Ages 18-30
- Normal (or corrected-to-normal) vision

*Note: you are not eligible to participate if you were hired as a face model for this study

If interested, or if you have any questions, please contact:
Stephanie Sobey
stephsobey@dal.ca