EYE MOVEMENT BEHAVIORS FOR LEARNED FACES

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Abstract

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Humans demonstrate a perceptual specialization for faces that is astonishing. This project attempts determine if and where within the perceptual process face perception and face recognition diverge at the level of eye movement behaviors. Participants were exposed to a series of 36 faces, of which six were randomly selected to be learned over five subsequent exposures; the same face identities served as both the novel faces (block 1) and the learned faces (block 5), allowing for the measurement of eye gaze patterns during initial face perception (novel) and face recognition (learned). These six faces were randomly assigned to different orders within five presentation blocks along with 30 interspersed novel distractor faces (six novel faces per block). Eye movement patterns were recorded using the Gazepoint eye tracker and measured in the form of fixation duration and number of fixations for a set of regions of interest (ROIs). A linear mixed effects model was run for both fixation duration and number of fixations accounting for the potential effects and interaction of ROI and familiarity (i.e., face perception vs face recognition). It was determined that participants spent more time and looked the most often at the eyes of the faces they viewed (more so than any other ROI) regardless of their level of familiarity with the face. This suggests that while novel and familiar faces

may be processed in overlapping but distinct manners, the way people visually scan a face may not differ for the processes of face perception and face recognition

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Introduction

On any given day, you are very likely to encounter many faces, whether they be unfamiliar or familiar. Human beings have the amazing capacity to process faces in a very short time and form rapid social judgments about someone just from their face (e.g., Bar, Neta, & Linz, 2006; Rule, Ambady, & Adams, 2009; Todorov, Pakrashi, & Oosterhof, 2009; Todorov, Loehr, & Oosterhof, 2010). The fact that people can distinguish faces among other objects is astonishing, but even more amazing is the speed with which a face can be identified — it takes less than 200ms to recognize a visual stimulus as a face (Crouzet & Thorpe, 2011) and to form perceptual judgments (e.g., trustworthiness) about the individual (Willis & Todorov, 2006) — which speaks to the specialized visual processing of faces above other stimuli.

Indeed, humans spend more time looking at faces than any other category of stimuli across their lifespan (Haxby, Hoffman, & Gobini, 2000) leading to perceptual expertise for faces. This expertise involves a distributed neural system for face processing proposed by Haxby and colleagues (2000, see Figure 1) in which many brain regions exist that consistently respond more strongly to viewing faces than to other visual stimuli. One of the components of this distributed neural system, the fusiform face area (FFA, located within the lateral fusiform gyrus) is activated more strongly by faces than other visual stimuli (Kanwisher, McDermott, & Chun, 1999; Rossion, Caldara, Seghier, Schuller, Lazeyras, & Mayer, 2003; Sergent, Ohta, & MacDonald, 1992). This region is thought to play a critical role in the perception of the unique identity of that face (Haxby, et al.,

2000) and has been shown to respond more strongly to familiar faces than novel faces (Rossion, Schiltz, & Crommelinck, 2003; c.f. Rossion et al., 2003). Another core region that responds more strongly to faces than other objects, the inferior occipital gyrus (IOG also known as the occipital face area (OFA), Haxby et al., 2000), is involved in the early perception of facial features regardless of whether the individual is unknown or familiar. However, this region has previously been shown to respond more strongly to novel than familiar faces (Cloutier, Li, Misic, Correll, & Berman, 2017). These findings suggest that familiar and novel faces may be processed in overlapping, yet distinct manners.

Face Processing Strategies

Face processing, which is performed for both known and unknown individuals, relies on two distinct processing strategies: configural (or holistic) and featural (or part-based) processing (Bruce & Young, 1986; Piepers & Robins, 2012; Cabeza & Kato, 2000; Rossion, Dricot, Devolder, Bodart, Crommelinck, Gelder, & Zoontjes, 2000; Schwaninger, Lobmaier, & Collishaw, 2002; Tanaka & Sengco, 1997). Configural processing occurs in a gestalt fashion in which emergent features of the face combine to provide a larger overall meaning than each of the features combined. It involves the perception of the relations between different features of a face rather than simply the features themselves. Configural processing can then be broken down into detecting the basic configuration of a face, processing those basic features holistically, and understanding the relational distance between the basic features (Maurer, Le Grand, & Mondloch, 2002). Featural or part-based processing differs from configural processing in that it takes individual aspects of a face and generates meaning from those aspects.

Featural processing works at encoding individual aspects of a face to establish meaning from those specific aspects. Although early work on face recognition, which occurs only for known individuals, suggested that recognition relied primarily on holistic processing, more recent work suggests that both featural and configural processing make important but dissociable contributions to face recognition (Cabeza & Kato, 2000).

Face Perception vs Face Recognition

Face perception (the ability to process a visual stimulus as a face and process the constituent parts and their configuration) and face recognition (the ability to correctly identify an individual from their face) are generally seen as two separate processes. Face perception and face recognition both utilize configural and featural processing strategies, however, there is evidence of separation of these processes in select brain regions. The core system of Haxby's model identifies separate brain regions for the initial perception of a face (i.e., the IOG) and the recognition of the identity of that face (i.e., the FFA; Gobbini & Haxby, 2007; Haxby, et al., 2000). Additional temporal regions, belonging to the extended system, are recruited to continue recognition of the identity of a face. The IOG is involved in the early detection of facial features and has been shown to respond more equally to upright and inverted faces (Yovel & Kanwisher, 2005; cf Haxby, Ungerleider, Clark, Schouten, Hoffman, & Martin, 1999), highlighting the featural processing that occurs in this region. This region provides input to the FFA and STS (Haxby et al., 2000). The FFA then processes invariant aspects of the face, such as identity (Hoffman & Haxby, 2000) and is sensitive to configural disruptions such as the face inversion effect (FIE; Gauthier et al., 1999; Haxby et al., 1999; Kanwisher et al., 1998; Zhang et al., 2015). This model builds on the cognitive model first proposed by Bruce and Young (1986) and although additional similar models have been proposed (Althoff & Cohen, 1999; Heisz & Shore, 2008), this current model is the most widely supported in the field.

Featural processing relies on both internal and external facial features. Internal features of a face include the eyes, the nose, and the mouth whereas external features of a face include the hairline and jaw. Face processing and face recognition rely on both internal and external facial features to some degree — however there tends to be a greater reliance on internal features than external features for both processes (Althoff, & Cohen, 1999; Bonner, Burton, & Bruce, 2003; Ellis, Shepherd, & Davies, 1979; Henderson, Williams, & Falk, 2005; Kano, Call, & Tomonaga, 2012; Sæther, Van Belle, Brennen, & Øvervoll, 2009; Stacey, Walker, & Underwood, 2005). Despite both processes utilizing internal features more than external features, research has suggested that as we get to know a person, internal facial features become increasingly important suggesting that face recognition may rely on internal features to a greater degree (Ellis et al., 1992) but external features to a lesser degree (Bonifacci, Desideri, & Ottaviano, 2015; Bonner et al., 2003; Ellis et al., 1979) than does face processing. Ellis and colleagues (1979) found that viewers were better able to identify famous faces when shown the internal features compared to the external features. They did not, however, observe this stronger reliance on internal features for unknown faces. This enhanced reliance on internal features for face recognition has also been demonstrated by the *Bubbles* technique in which the internal features of a face, such as the eyes, the nose, and the mouth provide better contextual information for face recognition than other external aspects of a face such as the hairline and jaw (Gosselin, & Schyns, 2001). Overall, these studies suggest that the way we look at faces we know versus faces we do not know may differ.

Visual Scanning of Faces

The perception of any visual stimulus, including a face, begins with the observer's eyes. Eye movements are broadly categorized into fixations (eye remains steady on a specific location) and saccades (movements of the eyes between fixations). The location of a fixation is considered the locus of attention (Mehoudar, Arizpe, Baker, & Yovel, 2014). Eye tracking studies of face processing have typically focused on two primary fixation variables for analysis: first fixation and fixation duration. (Althoff & Cohen, 1999; Bonifacci et al., 2015; Heisz & Shore, 2008; Henderson et al., 2005; Hills & Pake, 2013; Hsiao & Cottrell, 2008; Peterson & Eckstein, 2013; Sæther et al., 2009). First fixation refers to the specific location within a face where the participant initially looks or fixes their gaze. Typically, this can include a facial feature or the space between features (Hsiao & Cottrell, 2008; Peterson & Eckstein, 2013, 2014). Because fixations represent visual attention, the point of first fixation on a face is generally assumed to represent the aspect of that face that first grabs visual attention (Hsiao & Cottrell, 2008; Peterson & Eckstein, 2013, 2014; Sæther et al., 2009). Fixation duration refers to the proportion of the overall viewing time spent looking at specific features or parts of the face (Bonifacci et al., 2015; Henderson et al., 2005; Stacey et al., 2005).

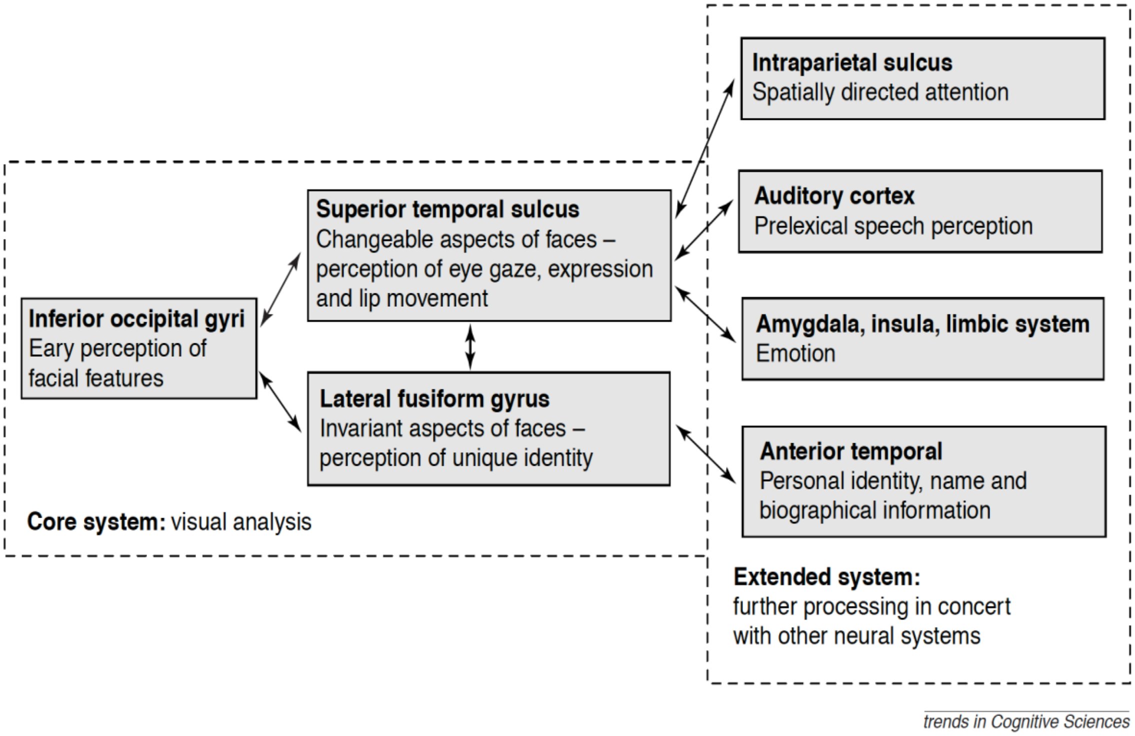


Figure 1. The distributed neural system for face perception propose by Haxby et al. (2000)

Note. The core system of the distributed neural system model involves three regions in the occipital-temporal extrastriate visual cortex that respond more strongly when viewing faces than when viewing other images, and these three regions specialize in different types of visual information concerning faces. The extended system is comprised of other areas outside the visual extrastriate cortex that influence the strength of the core system responses to faces; this extended system is also thought to play a role in both face perception and face recognition.

Humans demonstrate specific, functional scanning paths when viewing faces with an overall triangular pattern that generally includes the eyes and the mouth (Heisz & Shore, 2008; Henderson et al., 2005; Kano et al., 2012). The initial fixation that often occurs when viewing a face tends to be either on the eyes (Gosselin, & Schyns, 2001) or on the vertical midline of the face directly below the eyes (Hsiao & Cottrell, 2008; Peterson & Eckstein, 2013; Sæther et al., 2009). A key question that remains, however, is whether the same scanning strategies are used for all faces, or if face perception and face recognition involve different scanning strategies given the different processing strategies outlined above.

Studies investigating visual scanning patterns of face perception suggest that the first fixation is typically made along the vertical midline, between the eyes and mouth (Or et al., 2015; Peterson et al., 2016). While there are some studies investigating face perception alone, visual scanning patterns during face perception are most often considered as part of a larger face recognition study, with scanning patterns assessed when participants view both known and unknown faces during an old/new face recognition task (Henderson et al., 2005; Hills & Pake, 2013; Kelly et al., 2011). In studies that have compared visual scanning for unknown and known faces, the task demands between the two processes (perception vs recognition) usually differ when employed in the same study (Heisz & Shore 2008; Henderson et al., 2005; Stacey et al., 2005). For example, Heisz and Shore (2008) used a recall task for face perception and an old/new recognition task for face recognition. The recall task introduced novel faces to participants with an associated name that participants were instructed to remember as a test for whether or not the faces were correctly associated with their assigned names. The old/new recognition task used those same learned faces and novel faces to determine whether participants actually recognized the faces they were supposed to. This is indicative of a common problem across face perception studies — different task demands for face perception and face recognition can produce different results (Althoff & Cohen, 1999; Bonifacci et al., 2015; Crouzet & Thorpe, 2011; Haxby et al., 2000; Hsiao & Cottrell, 2008; Stacey et al., 2005).

As outlined above, behavioral studies indicate that as we get to know a person, the internal features of their face may become more important for face processing which suggests that visual scanning patterns may differ for face perception compared to face recognition. Ellis and colleagues (1979) found that for face perception, the internal and external features of a face are relatively equally informative, but for face recognition, the internal features of a face provide more diagnostic information than the external features. Similarly, Young et al (1985) had participants complete a face matching task in which they had to correctly match internal or external features with the complete image of that face for both novel and familiar faces. They found that participants were much faster at matching internal features to the whole face for familiar faces than novel faces, indicating the importance of internal facial features for face recognition. Behavioral research has also suggested an increased reliance on the internal features for known faces compared to unknown faces (e.g., Ellis et al., 1979; Gosselin, & Schyns, 2001). This increased reliance occurs gradually as an individual learns to recognize a face (Bonner et al., 2003). Bonner and colleagues (2003) continuously exposed participants to novel faces over the span of three days. At each test session, participants completed a matching task that consisted of matching either internal or external features of a face with the full face. At the end of the third day, participant performance improved in matching skills for the internal features but remained relatively stable for external features of the learned faces.

Surprisingly, however, very few eye tracking studies have shown increased fixation duration for internal features when viewing known versus unknown faces. Stacey and colleagues (2005) presented participants with images of famous and non-famous faces while their visual scanning patterns were recorded, and in only one of the three experiments they observed increased fixation duration on the internal facial features for famous faces (face recognition) versus non-famous faces (face perception). The remaining two experiments showed no significant differences in fixation duration for the internal features across these two face types. With a similar paradigm, Althoff and Cohen (1999) observed the opposite pattern; across two different studies, they found that participants spent significantly *less* time looking at the internal facial features for famous faces (recognition) compared to non-famous faces (perception). Using personally known individuals for face recognition rather than famous faces, Bonifacci and colleagues (2015) observed no significant differences in fixation time and overall number of fixations for the internal features of known individuals during face recognition when compared to unknown individuals during face perception — although their results were in the predicted direction of increased fixations on internal features for known vs unknown individuals, this difference was not statistically significant.

Studies of visual scanning patterns for face recognition have used a diverse range of “known faces.” This includes both images of famous faces the participant knows conceptually but does not have a personal relationship with (Althoff & Cohen, 1999; Stacey et al., 2005) and images of faces participants have personal relationships with (Bonifacci et al., 2015); both approaches allow researchers to study visual scanning patterns for relatively known faces. Using famous faces enables researchers to use a common set of stimuli that can be used across all participants but sacrifices personal knowledge of the individual depicted, while using personally known faces permits a greater depth of knowledge about the individual depicted but does not necessarily allow for a common set of stimuli to be used across all participants.

A more recent approach to studying face recognition has relied on subjects learning to recognize a previously unknown set of faces rather than using famous or personally known stimuli. In this paradigm, researchers display novel faces to participants that become familiar over repeated exposure during the study itself (Heisz & Shore, 2008; Henderson et al., 2005; Hills & Pake, 2013; Hsiao & Cottrell, 2008; Kelly et al., 2011; Peterson & Eckstein, 2013, 2014; Sæther et al., 2009). The viewing conditions of learned faces vary across these studies with differing amounts of time spent learning different faces (Peterson & Eckstein, 2013) or even forcing participants to fixate in specific areas when learning faces (Henderson et al., 2005; Peterson & Eckstein, 2014). Overall, however, these learned-face studies have failed to find consistent visual scanning differences between novel and familiar faces (Heisz & Shore, 2008; Henderson et al., 2005; Hills & Pake, 2013; Kelly et al., 2011; Peterson & Eckstein, 2013, 2014; Sæther et al., 2009).

Several of these studies using this paradigm have reported the greatest fixation duration (i.e., most time spent looking at) in the eye region for both the known and unknown faces (showing eyes > any other feature for both face types; Heisz & Shore, 2008; Henderson et al., 2005; Hills & Pake, 2013). When comparing fixation duration of features for the known versus unknown faces, Henderson and colleagues (2005) found that participants spent more time viewing the eyes during face recognition compared to face perception. Heisz and Shore (2008), however reported that fixation duration on the eyes increased for the recognition task, but the difference in fixation on the eyes for novel vs known faces was not significantly different. Similarly, Hsiao and Cottrell (2008) did not find significant differences in fixation duration for the eyes when comparing novel to known faces. Other work has suggested that face recognition may rely on increased fixation on the mouth (Peterson & Exckstein, 2014) and hair (Hills & Pake, 2013) regions (i.e., fixation duration for these regions is greater for known faces compared to novel faces). Additional work utilizing eye tracking technology is necessary to clarify the importance of various facial features for face perception versus recognition.

The Current Study

The current study was designed to explore potential changes in eye movement behaviors as faces transitioned from novel to familiar. A low frequency eye tracker was used to measure eye movement behaviors (Titz, Scholz, & Sedlmeier, 2017). While previous studies have investigated visual scanning patterns for learned faces, they have generally compared eye movements for the learned or “known" faces to unknown distractor faces presented in the final run. This study compared eye movements in response to viewing the *same* individual faces before and after learning so that visual scanning patterns could be compared for the same faces when they were both novel and familiar to determine how visual scanning patterns shifted as a given face transitioned from unknown to known.

Hypothesis 1 - Fixation Duration. It was difficult to make clear predictions about the data given the equivocal results found throughout the literature. Previous behavioral studies indicate that there is an increased reliance on internal features as we come to know a face. This suggested that we would see increased fixation duration for ROIs corresponding to internal features (eyes, nose, mouth) when the faces were familiar as compared to when the faces were novel. This pattern would be reflected in a significant interaction between ROI and familiarity for the fixation duration data. Previous eye tracking studies have provided equivocal evidence for increased fixation duration on internal features during face recognition. However, because the behavioral studies (Bonner et al., 2003; Ellis et al., 1979; Gosselin, & Schyns, 2001) have used a continuous recognition task, which was used in the current study, I predicted a significant ROI by familiarity interaction for the fixation duration data.

Hypothesis 2 - Number of Fixations. Number of fixations is a variable measured in past research to compare differences in face perception and face recognition (Althoff & Cohen, 1999; Bonifacci et al., 2015). These previous studies reported conflicting results. Bonifacci and colleagues (2015) found no difference in the number of fixations between novel and familiar faces while Althoff and Cohen (1999) did find a difference. I predicted a significant main effect of ROI whereby the eyes and nose had the greatest number of fixations. I did not have a clear prediction about the possible interaction between ROI and familiarity based on past research. A significant interaction would indicate that the most informative features of a face change as faces become familiar.

Method

Equipment

A Gazepoint GP3 eye tracker, attached to a tripod sitting below the monitor, was used in this study to monitor visual scanning for faces at a rate of 60 Hz (Titz et al., 2017). The Gazepoint eye tracker includes a feature that ensures participants maintain a consistent distance from the monitor. This built-in sliding scale moved to one end of the monitor or the other and turned a dark red if the participant sat too close or too far from the eye tracker and monitor. When the participant sat at an ideal distance from the eye tracker and monitor, the scale moved toward the middle of the monitor and turned bright green. So long as participants sat at that ideal distance and were fully calibrated to the eye tracker, the tracker had no issues measuring eye movement data. This feature controls for variability in head position and movement both within and across participants.

Stimuli

Facial images taken of individuals that did not live in or around Arcata, California were used as both the test and distractor faces; this ensured that each face viewed during the study started as a novel face. The images were taken from the 3DSK face set which contained 100 total Slovakian Caucasian faces, 50 of which were male and 50 were female (e.g., Hahn, Fisher, DeBruine, & Jones, 2014; Wang, Hahn, DeBruine, & Jones, 2016). Each face in the set had a direct gaze and neutral expression. Faces were masked and were presented on a white background aligned on inter-pupillary distance to ensure that eyes were presented in the same position across all images. All faces were delineated (i.e., a 189-point “facemap” was applied to each face) using Webmorph (DeBruine, 2017) to aid in consistent selection of the location of specific facial features (see Figure 2). These mapped points served as the anatomical boundaries for the regions of interest (ROIs, also called areas of interest or AOIs) analyzed.

Measures

Fixation duration. The duration of each fixation made when viewing a face was recorded using the Gazepoint eye tracking software. Measuring the duration of time spent fixating on each mapped feature revealed which features were important for face perception and face recognition. Based on previous studies, specific facial regions of interest (ROIs) were the hair, forehead, ears, jaw, eyes, nose, mouth, chin, and cheeks (Bonner et al., 2003; Sæther et al., 2009; Henderson et al., 2005). Importantly, both internal and external features were included in this set of ROIs.

Number of fixations. The number of fixations made in each ROI when viewing a face were measured using the Gazepoint eye tracking software. Measuring the number of fixations on each mapped featured revealed which features were informative for both face perception and face recognition when participants viewed each face.

Participants

The participants used in this study were recruited using convenience sampling through the Humboldt State University research recruitment page. All participants had normal or corrected to normal vision. Data were collected for 34 participants in this study. The group sample was composed of individuals over the age of 18 and included both males and females. Out of all of the participants, 13 identified with an ethnicity that was not European American White.

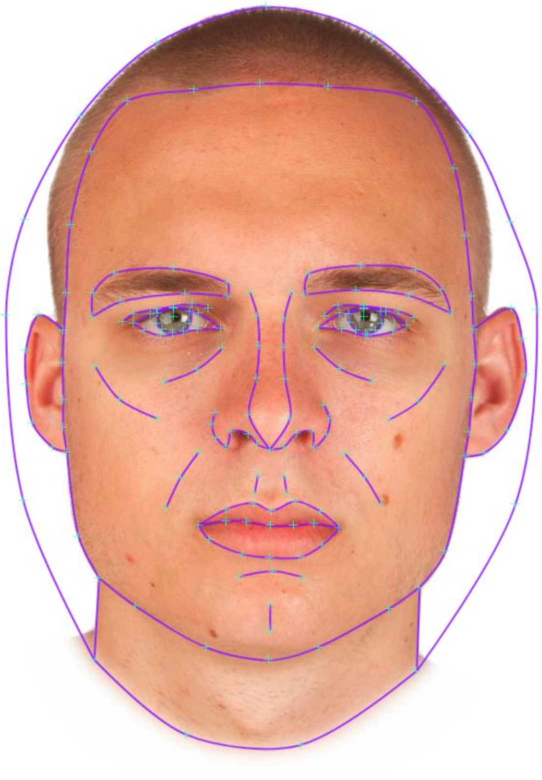


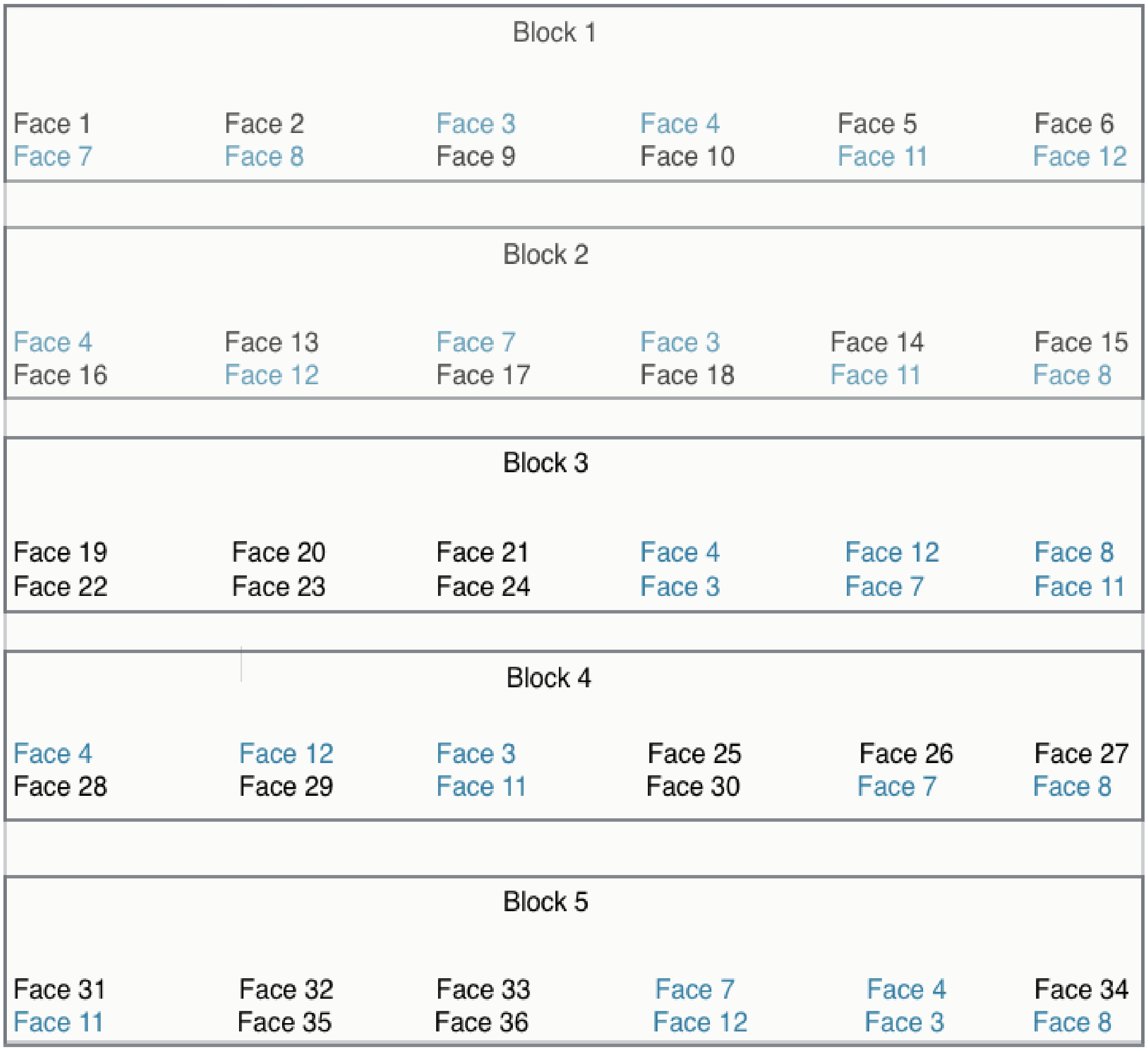
Figure 2. Example face map specifying (x,y) coordinates of landmark and semi-landmark point.

Procedure

This experiment was conducted with an adapted continuous recognition method (Estes & Maddox, 1995). Participants were tested on six faces that became familiar over five consecutive blocks; previous research has indicated that five presentation blocks is sufficient for recognition to take place (Heisz & Shore, 2008). The six faces were randomly selected from the 3DSK face set and then assigned to participants; each set of familiarized faces was built in to eight different lists, of which each of the familiarized faces were different for each list. Participants were assigned to one of these eight lists in a counterbalanced fashion. Another six faces were added to each block to act as a control for the familiarized faces, also randomly selected, and those faces were completely novel for each block. This means that for each block, a random selection of six faces from the 3DSK set were shown that were not shown before for the specific participant (see Figure 3 for a visual representation of image presentation for one of the eight lists).

A total of 36 faces (18 male and 18 female) were viewed by each participant, six familiarized faces (half of which were male and half female) and 30 novel faces (half of which were male and half female). Order effects for this task were unlikely due to the random presentation of each face during each block. Fatigue, however, was possible during this experiment, but likely did not occur not only for the familiar faces, but for the novel faces as well. Figure 3 shows an example of the visual layout of the presentation of each block of faces for a single participant assigned to one of the eight lists. Following Helena and Tomc (2016) and Hsiao and Cottrell (2008), each face in this study was displayed for a total of three seconds. Previous research suggests that this is sufficient time for both face perception and face recognition to occur (Hsiao & Cottrell, 2008). Participants were asked to rest comfortably and to minimize head movements. Small movements did not affect the eye tracker measurements, and position from the monitor to the participant was kept constant according to the built-in scale on the tracker. Once the participants were relatively comfortable, the calibration period of the study began. To begin, participants first performed the nine-point eye calibration procedure required by the GazePoint eye tracker. Then the participants were taken through a practice experiment that was set up the same way as the experiment. The practice presented two faces (one male and one female) that were not selected for any of the eight lists to become familiar. Following the practice, participants were asked if they had any questions, and the experiment began.

In every block, each of the 12 faces (six target faces and six distractor faces) was displayed for three seconds after a fixation cross appeared on the screen. Each fixation cross was randomly selected to appear at one of the four corners of the screen (top left, top right, bottom left, and bottom right) and participants were instructed to stare at the cross until it was removed from the screen and the face appeared. After the face disappeared, the participant then indicated whether the face they had just viewed was new or old. This was done by displaying a question on the screen that asked the participant if they had seen the face before, with the answers of either “yes” or “no.” Participants answered by using their eyes—by staring at either the “yes” or “no” answers. For the first block, it was expected that the participants would indicate that each face was new by staring at the “no” response thereby indicating a new face was viewed. Each subsequent block occurred in the same way with the participants indicating whether the faces they were shown were new or old by responding “no” or “yes” respectively. Only data from target faces correctly identified as having been seen before in Block 5 was used in the analyses reported here. Once the last block has been completed, the participant went through a period of debriefing, and were thanked for their voluntary participation in the study.



Block 1

Face 1	Face 2	Face 3	Face 4	Face 5	Face 6
Face 7	Face 8	Face 9	Face 10	Face 11	Face 12

Block 2

Face 4	Face 13	Face 7	Face 3	Face 14	Face 15
Face 16	Face 12	Face 17	Face 18	Face 11	Face 8

Block 3

Face 19	Face 20	Face 21	Face 4	Face 12	Face 8
Face 22	Face 23	Face 24	Face 3	Face 7	Face 11

Block 4

Face 4	Face 12	Face 3	Face 25	Face 26	Face 27
Face 28	Face 29	Face 11	Face 30	Face 7	Face 8

Block 5

Face 31	Face 32	Face 33	Face 7	Face 4	Face 34
Face 11	Face 35	Face 36	Face 12	Face 3	Face 8

Figure 3. The distribution of the 36 faces across the five experimental blocks is detailed below.

Note. This example represents one of the eight lists generated that participants were randomly assigned to view. This is List 5, demonstrating the full set of faces randomly selected from the 3DSK image set (100 faces). Each blue text face (Face 3, 4, 7, 8, 11, 12) is one that was randomly selected to become familiarized, and thus appears in all five blocks. Each black text face is one that was randomly selected to be a novel distractor face, and thus there are different black text faces in each of the five blocks.

Results

ROI Mapping

For each of the six randomly selected faces in each of the eight different lists, there were nine ROIs applied using the Gazepoint analysis software. Each ROI was labeled and then drawn on the face in the shape of a box fitted around the ROI as best as possible without overlapping boarders with the surrounding ROIs. The cheeks, the ears, and the jaw were mapped as two separate regions, reflecting the right and left side of the face—the average fixation duration and number of fixations for each set was used in the final analyses reported here. See Figure 4 for an example face depicting the 9 ROIs from the study. There are some regions on the face that could not be included in an ROI, but there was an attempt to cleanly cover most of the face with a designated ROI.

Eye Tracking Data

The first step in data analysis was to extract the eye movement data for each participant from the GazePoint software. Eye movement data was recorded during the designated three seconds of viewing time during the continuous recognition task. The eye tracking variables were fixation duration (for each of the facial ROIs defined above) and number of fixations (for each of the facial ROIs defined above). The fixation data for the six target faces that transitioned from novel (Block 1) to familiar (Block 5) were extracted. For fixation duration, the total time (s) spent looking at each ROI was averaged across the six faces when they were novel vs familiar. The data was also cleaned by only analyzing the familiar faces that the participant correctly responded “yes” to during the Block 5 old/new task. This means that if a face was repeated for each Block, and the participant identified it correctly after it was displayed in Block 5, the eye movement patterns for that face were analyzed. However, if a participant falsely identified a novel face by responding “yes” when asked if they recognized it or a familiar face as new by responding “no” during the Block 5 old/new task, the data for those faces was excluded.

Statistical Analyses

Data were collected for 34 participants in this study and with that sample size there was power of 80% to detect effects as small as 0.4. Linear mixed models were used to test for possible effects of familiarity (old, new) and ROI (hair, forehead, eyes, nose, cheeks, ears, mouth, jaw, chin) as well as their interaction on fixation duration and number of fixations. Analyses were conducted with R version 3.4.4 (R Core Team, 2016) using nlme version 3.1-131.1 (Bates et al., 2014). The dependent variables analyzed were fixation duration and number of fixations (separate models were run for each). Random slopes were specified maximally following Barr (2013) and Barr et al. (2013).

For both fixation duration and number of fixations, a null model was generated (in which there were no predictor variables). A second model was then generated in which the DV was predicted by familiarity (i.e., was compared between the two face types - old and new). A third model was then generated which also included ROI as a predictor. Lastly a final model was generated which included the interaction between familiarity and ROI. Comparisons of these models (see Tables X and Y for model comparisons) indicated that for both fixation duration and number of fixations including ROI as a predictor significantly improved model fit, whereas including familiarity or the interaction among these two predictors did not. This means that while there was no difference in terms of fixation duration (*b* = -0.002, *t*(34) = -0.12, *p* = .90) or number of fixations (*b* = -0.11, *t*(34) = -1.68, *p* = .10) between old and new faces, the ROIs within each face did differ in terms of time spent in each area when each face was being viewed (see Figure 5 for visual representation of these effects, see Appendix A for statistical comparisons among ROIs) and in the number of fixations made (see Figure 6 for visual representation of these effects, see Appendix B for statistical comparisons among ROIs) in each ROI. However, the fixation duration and number of fixations in these ROIs did not change as a function of familiarity with the faces.

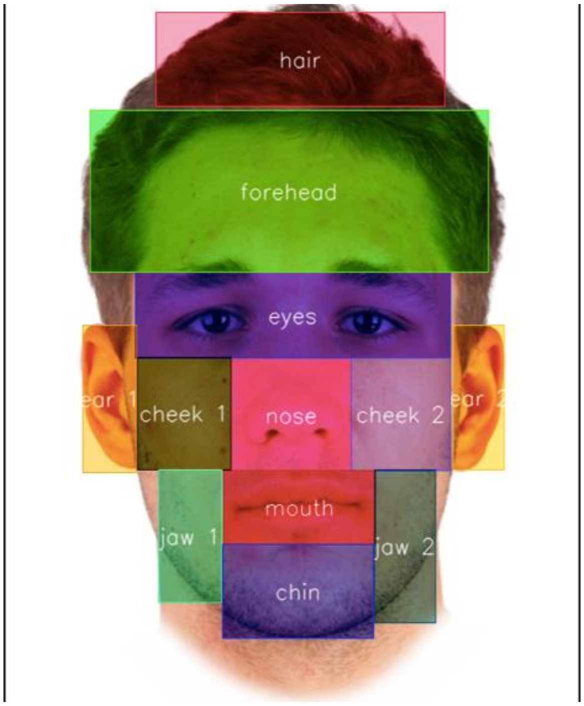


Figure 4. A face with ROIs mapped onto it.

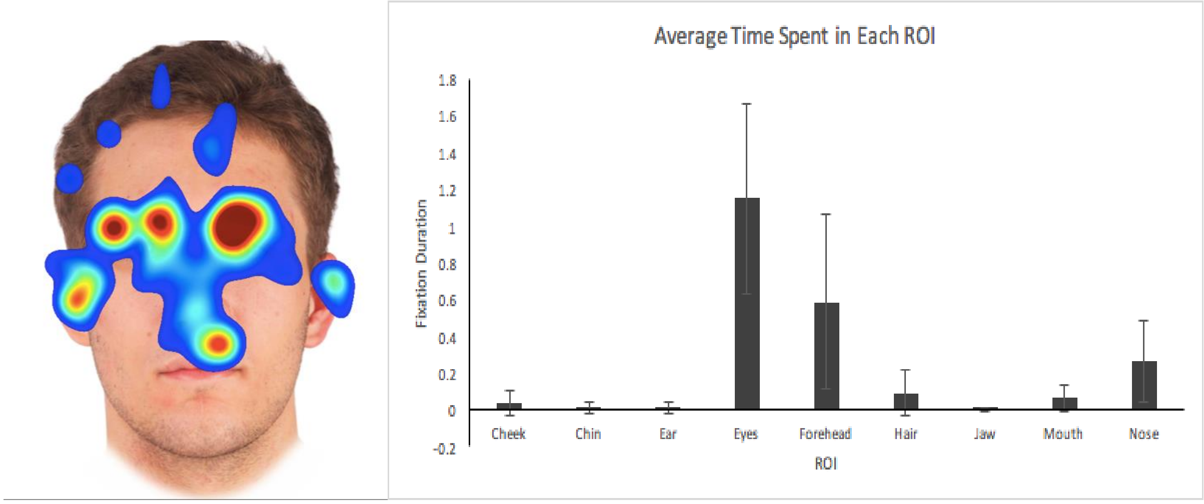


Figure 5. A visual and graphical representation of the effect of ROI on fixation duration.

Note. A heat map was taken from one of the target faces with multiple participant fixations included to show a more standardized pattern of fixation duration for this specific face. Areas with redder coloration indicate longer average fixation duration, whereas areas with bluer coloration indicate areas with shorter average fixation duration. The graph was created from the averaged fixation duration for each face broken down by ROI to show how each region was represented during the time spent viewing each face. Error bars represent SD. See Appendix A for full table of Bonferroni corrected pairwise comparisons of these ROIs.

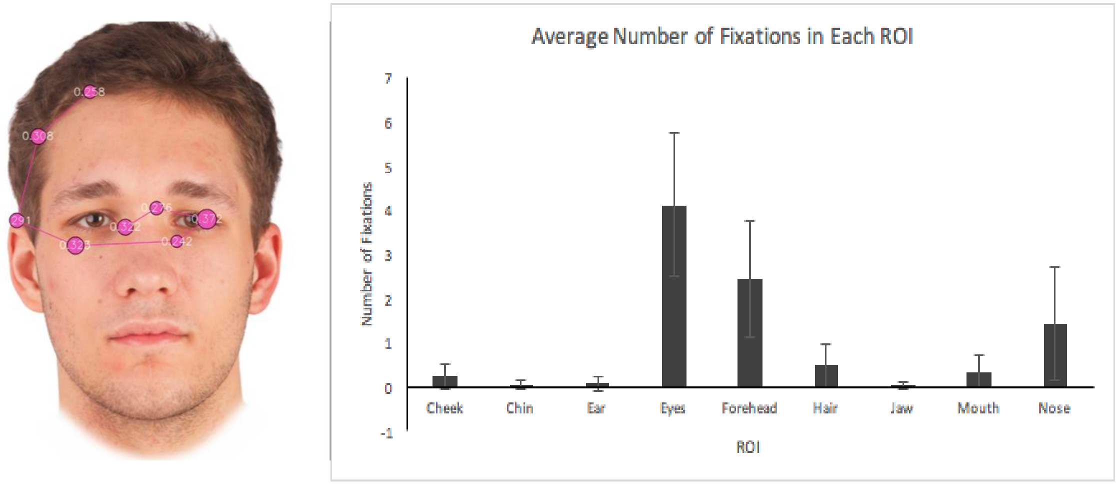


Figure 6. A visual and graphical representation of the effect of ROI on number of fixations on each ROI.

Note. A fixation map was taken from one of the target faces with a single participant's fixation data included to demonstrate where this participant fixated within the face. The graph was created from the averaged number of fixations for each face broken down by ROI to show how each region was represented during target face display time. Error bars represent SD. See Appendix B for full table of Bonferroni corrected pairwise comparisons of these ROIs.

Discussion

This study attempted to explore where within the perceptual process face perception and face recognition diverge specifically by looking at eye movement behaviors as faces became familiar. Participants were exposed to a series of 36 faces, six of which were learned over five different exposures. A low frequency eye tracker was used to measure two variables: fixation duration and number of fixations made during the first viewing (when the faces were novel, targeting face perception) and last viewing (when the faces were known, targeting face recognition) of each of the six faces. After data was collected on these two variables, a linear mixed effects model was conducted in order to determine how the processes of face perception and face recognition may have differed within specific predetermined ROIs for both fixation duration and number of fixations.

For both variables, the linear mixed effects models demonstrated that there was no difference in eye movement behavior between the novel and familiar faces overall, but that there were differences in how individuals used various regions of the face for both face perception and face recognition. More specifically, regardless of the level of familiarity of the face, participants spent more time and looked more often at the eyes than any other region of the face. That there was no interaction between familiarity and ROI which suggests that individuals may not alter their visual scanning patterns of various regions of the face as a face transitions from novel to familiar.

These findings are consistent with some past literature that worked with learned faces. The greatest fixation duration reported in this study was in the eyes of faces viewed compared to all of the other ROIs, regardless of familiarity. Similar with Heisz and Shore (2008) and Hsiao and Cottrell (2008), there was no significant difference detected in fixation duration on the eyes for face perception and face recognition. This finding was, however, inconsistent with past reports that there is increased fixation in the hair (Hills & Pake, 2013) and mouth (Peterson & Eckstein, 2014) regions during face recognition compared to face perception. These findings add to the lack consistency in observed visual scanning differences between novel and familiar faces across face studies that needs to be further explored.

The ROI that received the greatest number of fixations was the eyes of the faces viewed regardless of familiarity. Consistent with Bonifacci and colleagues (2015), there was no difference in the number of fixations made between face perception and face recognition for the eye region in the current study. This differs from findings from Althoff and Cohen (1999), who reported differences in face perception and face recognition for famous familiar faces and non-famous novel faces. Surprisingly, however, it was the eyes, the forehead, and the nose of the six target faces that received the greatest number of fixations as opposed to the eye and the nose of faces as predicted, which has been reported in past work (Bonifacci et al., 2015).

This study’s findings for both fixation duration and number of fixations failed to find an enhanced reliance on internal features for face recognition compared to face perception as has been reported in previous work (Gosselin & Schyns, 2001). This lack of detection could be due to the fact that the shift of a greater reliance on internal features occurs more gradually (Bonner et al., 2003) and may not be able to be determined after only five exposures. Stacey and colleagues (2005) reported similar findings to this study in that only one of their experiments reported a difference in the reliance on internal features for face recognition compared to face perception while the rest demonstrated no such difference. In each of these studies, the faces compared were famous and non-famous faces for face recognition and face perception respectively and could therefore not account for the lack of difference reported in this study.

One potential limitation of this work is the Own Race Bias (ORB, also called the Other Race Effect or Cross Race Bias; Lindsay, Jack, & Christian, 1991; O'Toole Deffenbacher, Valentin, & Abdi, 1994; Rhodes Locke, Ewing, & Evangelista, 2009; Tanaka Kiefer, & Bukach, 2004; Wiese, Kaufmann, & Schweinberger, 2012), which reflects the finding that individuals are better able to recognize and differentiate between faces of their own race more easily than faces of another race (e.g., Horry, Cheong, & Brewer, 2015; Lindsay et al., 1991; Meissner & Brigham, 2001). For studies of face processing when accepting participants of many ethnicities, the ethnicity of the stimuli and the observer are an important consideration. The ORB is thought to be the result of a greater reliance on configural processing strategies for faces of one's own race and ethnicity (Tanaka et al., 2004). Interestingly, however, the degree to which own race bias affects face recognition may differ across racial groups, with White participants demonstrating the greatest effect of own race bias in terms of discriminability between faces of the same race (Horry et al., 2015; Meissner & Brigham, 2001).

Ethnicity was initially planned to be controlled in this study, but due to the way the research recruitment page for Humboldt State University is set up, attempting to limit participation to individuals identifying as European American White was rather impossible. It was also deemed an unnecessary limitation to the research to prevent willing participants from donating time and energy just because of their ethnicity. Thus, ethnicity was not controlled for in this study. This is likely unproblematic because all participants were assumed to be experienced with White faces due to the demographic of the population of Arcata, California.

It would be interesting to include ethnicity as an avenue of interest for further exploration. Research using eye-tracking methodology has demonstrated that there are differences in visual scanning patterns and initial fixations based on ethnicity of the viewer and/or face (e.g., Hills & Pake, 2013; Kelly et al., 2011). When comparing White and Black individuals, White individuals' first fixations landed closer to the eyes of the faces they viewed while Black individuals' first fixations landed closer to the noses of the faces they viewed, regardless of the ethnicity of the face shown (Hills & Pake, 2013). For some British Born Chinese individuals, the eye movement patterns used in face perception exhibited a blend of Eastern and Western pattern similarity rather than supporting either a Western pattern or an Eastern pattern fully (Kelly et al., 2011).

This study found that participants spent more time and looked most at the eyes of the faces viewed regardless of the level of familiarity. This tells us that while novel and familiar faces are processed in overlapping but distinct manners, the initial steps for face perception and face recognition may not be entirely distinguishable. More research is needed to explore this concept, but this study acts to illuminate the notion that while face perception and face recognition are different processes, the way in which we move our eyes for both may not be as different as initially decided.

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APPENDICES

Appendix A

Table of Bonferroni corrected pairwise comparisons of ROIs with fixation duration

	Cheeks	Chin	Ears	Eyes	Forehead	Hair	Jaw	Mouth
Chin	0.34246	—	—	—	—	—	—	—
Ears	0.42451	1.00000	—	—	—	—	—	—
Eyes	< 2e-16	< 2e-16	< 2e-16	—	—	—	—	—
Forehead	2.5E-12	1.7E-13	2.4E-13	8.4E-05	—	—	—	—
Hair	0.06773	4.1E-05	4.4E-05	< 2e-16	3.4E-10	—	—	—
Jaw	0.01100	1.00000	1.00000	< 2e-16	7.5E-14	4.6E-06	—	—
Mouth	1.00000	1.7E-06	5.7E-05	< 2e-16	2.5E-11	1.00000	4.7E-07	—
Nose	3.7E-10	9.8E-13	3.2E-12	< 2e-16	0.00042	5.1E-05	3.7E-13	1.7E-09

Appendix A.

Appendix B

Table of Bonferroni corrected pairwise comparisons of ROIs with Number of Fixations

	Cheeks	Chin	Ears	Eyes	Forehead	Hair	Jaw	Mouth
Chin	6.8E-05	—	—	—	—	—	—	—
Ears	0.0018	1.0000	—	—	—	—	—	—
Eyes	< 2e-16	< 2e-16	< 2e-16	—	—	—	—	—
Forehead	< 2e-16	< 2e-16	< 2e-16		—	—	—	—
Hair	0.0365	5.1E-09	3.5E-08	< 2e-16	< 2e-16	—	—	—
Jaw	2.7E-06	1.0000	1.0000	< 2e-16	< 2e-16	3.0E-09	—	—
Mouth	1.0000	3.8E-08	8.0E-06	< 2e-16	< 2e-16	1.0000	9.8E-09	—
Nose	2.0E-10	5.3E-12	2.8E-11	< 2e-16	0.0025	7.3E-06	3.1E-12	5.9E-11

Appendix B.