# The Use of Facial Features in Facial Expression Discrimination

by

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## AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

**Abstract**

The present four studies are the first to examine the effect of presentation time on accurate facial expression discrimination while concurrently using eye movement monitoring to ensure fixation to specific features during the brief presentation of the entire face. Recent studies using backward masking and evaluating accuracy performance with signal detection methods (*A'*) have identified a happy-face advantage however differences between other facial expressions of emotion have not been reported. In each study, a specific exposure time before mask (150, 100, 50, or 16.67 ms) and eight different fixation locations were used during the presentation of neutral, disgusted, fearful, happy, and surprised expressions. An effect of emotion was found across all presentation times such that the greatest performance was seen for happiness, followed by neutral, disgust, surprise, and with the lowest performances seen for fear. Fixation to facial features specific to an emotion did not improve performance and did not account for the differences in accuracy performance between emotions. Rather, results suggest that accuracy performance depends on the integration of facial features, and that this varies across emotions and with presentation time.

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## **Chapter 1:** INTRODUCTION

Numerous studies have investigated how human faces are processed as they provide individuals with vast amounts of information for making judgments during social interactions. Based on facial information alone individuals can make judgments regarding age, gender, familiarity, identity, and the emotional state of an individual. Six basic emotions have been identified: anger, disgust, fear, happiness, sadness, and surprise (e.g., Darwin, 1874, 1998; Ekman & Friesen, 1971). In fact, facial expressions represent important emotional signals and are so biologically and socially important that accurate judgments can be made with face-exposure durations that are only milliseconds in length (e.g., Kirouac & Doré, 1984). Therefore, humans must have, through evolution and learning, developed complex neural systems to correctly detect and identify the meaning of emotional faces, in order to facilitate proper social interaction. Under certain circumstances (i.e., impending threat or warning) little time is available for thorough processing of facial expressions; one must quickly extract the facial information in order to respond appropriately. Recent research suggests that we encode specific features on the face that individuate each expression during the discrimination of facial expressions of emotion (Schyns, Petro, & Smith, 2007; Schyns, Petro, & Smith, 2009; van Rijsbergen & Schyns, 2009). However, it remains unknown whether the fixation to these facial features, specific to each emotion, subsequently improves accuracy performance during the brief presentation of facial expressions. The main purpose of the following four experiments was to investigate whether fixation to facial features proposed to individuate each expression would improve facial expression discrimination and therefore decrease the minimum presentation time required for accurate identification.

The current method used to prevent further processing of a visually presented face is by backward masking; a target face is briefly presented closely followed by a masking stimulus (see Wiens, 2006). By varying the time interval between the presentation of the target and mask, (called the stimulus onset asynchrony or SOA) one can create situations where the target is easily identifiable, (long SOAs) or render the target unidentifiable (short SOAs). Very short SOAs disrupt further processing of the face. Additionally, the greater the similarity between the target face and mask, the stronger the masking effect (Loffler, Gordon, Wilkinson, Goren, & Wilson, 2005). Conducting an emotion discrimination task without the use of backward masking would result in unjustified claims regarding the amount of visual processing time required to discriminate the facial expressions.

The first known study to investigate the minimum presentation time required for accurate facial expression discrimination using backward visual masking was conducted by Kirouac and Doré (1984). Fearful, surprised, happy, disgusted, angry, and sad facial expressions were presented at times ranging from 10 ms to 50 ms, followed by a mask. Participants performed with relatively high accuracy for all emotions except fear during the 40 and 50 ms conditions, showing that human observers are especially competent to process very rapid changes in facial appearance. Results of this study were unclear as not all statistical analyses were reported and the nature of the mask used was not stated. Following this Esteves and Ohman (1993) presented neutral, angry, and happy expressions from 20 ms to 300 ms, followed immediately by an upright neutral face mask. The main conclusion was that the presentation time of the expression was the principal factor influencing the discrimination of the masked emotional faces. In all experiments, identification of the emotional expressions of the target was improved as the presentation time increased. Accurate identification depended on the time available to process the target (i.e., the time elapsed until the onset of the masking picture). Findings demonstrated above chance identification for happy, angry, and neutral faces from 50 ms or longer, and below chance discrimination for all expressions presented for 30 ms. Results were replicated by Esteves, Parra, Dimberg and Ohman (1994) allowing for the conclusion that “the previously used masking parameters were indeed effective and did not allow subjects to consciously perceive the masked stimuli after the stimulus disappeared” (p.377). Both studies however were limited by a low number of trials (i.e., 12 trials per condition) and failure to report effect size, leaving the question open for further investigation.

All of the studies reported thus far evaluated participant’s discrimination performance by recording the percentage correct (hit) values. This method has, however, been shown to be highly sensitive to response bias when performing forced-choice tasks (Green & Swets, 1966; Macmillan & Creelman, 1991). In more recent studies, the minimal presentation time required for accurate facial expression discrimination has been evaluated according to signal detection theory methods, thus providing a measure of sensitivity that is uncontaminated by response bias in forced-choice detection tasks. Following signal detection theory, these studies have reported *A’* which is a non-parametric analog of the *d’* sensitivity measure. Unlike *d*’, *A’* does not require the assumption of a normal signal to noise distribution and can be used with a relatively small number of trials. Using the *A’* sensitivity measure, Calvo and Esteves (2005) found above chance discrimination for angry, happy, and sad expressions presented for 20 ms, whereas Maxwell and Davidson (2004) reported above chance discrimination for neutral, happy, and angry expressions with presentation times as short as 17 ms. In both studies, discrimination accuracy was higher for happy facial expressions than the other facial expressions of emotion, which did not differ from each other. Maxwell and Davidson (2004) were the first to report response bias data in their results, within a signal detection design. The results demonstrated that masked neutral faces were systematically classified as being angry compared to happy and this complimented previous results of Esteves and Ohman (1993) without a signal detection design. Most recently, Milders, Saharie, and Logan (2008) reported that the minimum presentation time required for the accurate identification of a happy expression was 10 ms, and 20 ms for fearful, angry, and neutral expressions. No difference was seen between the emotions across presentation times (ranging from 10 ms to 50 ms), except for a consistent happy-superiority effect. This study was limited as only two neutral faces served as mask stimuli and, as a result, each face-mask pair was repeated several times. Some learning of face-mask pairs may have taken place and might have contributed to the increased sensitivity at shorter presentation times. Additionally, response bias data were not reported and only neutral, angry, fearful, and happy expressions were studied.

Signal detection procedures have also been used to compare the ability to detect and label facial expressions of emotion in an upright and inverted orientation. Specifically, Prkachin (2003) presented digitized slides of facial expressions of emotion (happiness, sadness, anger, disgust, surprise, and fear) on videotape for 100 ms. Results revealed that during the presentation of upright facial expressions, *A'* values were higher for happiness, sadness, and surprise than anger, disgust, and fear. Following this, Derntl, Seidel, Kainz and Carbon (2009) reported that with a presentation time of 200 ms the highest accuracy was demonstrated for happy and neutral faces, followed by angry and fearful faces. Both of these studies found differences between the emotions beyond the happy-superiority effect. However, both were limited as neither study used backward visual masking and Derntl et al. (2009) evaluated responses using the hit rate and not *A'*. In general, despite differences in participants, stimuli and procedures, all known studies currently in the literature have revealed a happy-face superiority effect with above chance level discrimination of happy faces at presentation times of at least 20 ms. However, no known study to date has reported differences between the other facial expressions of emotion for the minimal presentation time required for accurate discrimination performance when using backward masking and evaluating discrimination capability using bias-free signal detection methods.

Facial expression discrimination studies have consistently reported that participants respond more accurately to brief presentations of masked and unmasked happy faces than to faces displaying other facial expressions of emotion (e.g., Esteves & Ohman, 1993; Kirouac & Dore, 1983; Milders at al., 2008). One possible explanation for this robust effect is that the distinctive mouth region is used, leading to decreased time required to process a happy facial expression. Several findings provide indirect evidence for this possibility. First, happy facial expressions are recognized with a higher level of accuracy when only the bottom half of the face is shown compared to the top half of the face (Calder, Young, Keane, & Dean, 2000). Second, the identification of happy facial expressions is unaffected by inversion, a manipulation that disrupts holistic face processing (Farah, Tanaka, & Drain, 1995), which suggests that the discrimination of this emotion is based on the detection of individual parts (McKelvie, 1995). Third, studies show that happy facial expressions are efficiently recognized faster than other facial expressions in emotion discrimination studies recording response times (RTs) as well as accuracy (Hietanen & Leppanen, 2003). It is therefore possible that the accurate identification of happy faces with brief presentation times is achieved by using the smiling mouth as a shortcut (instead of processing the whole face holistically).

Recent studies using a new technique called *Bubbles* (Gosselin & Schyns, 2001) have provided empirical support for the use of the mouth region in the discrimination of happy facial expressions. Randomly positioned Gaussian windows (Bubbles) with different spatial frequency bandwidths were presented with only some, randomly selected regions visible on each trial. During the categorization of the faces, locations that lead to correct responses were sequentially recorded, making it possible to reveal the most useful or most diagnostic regions for the identification of a given facial expression. Results from studies using this technique have suggested that in tasks requiring discrimination between facial expressions (including neutral faces), specific locations on the face (which vary with each emotion), provide the most important and diagnostic information for the accurate identification of that expression. For instance, the eyes were shown to be the primary diagnostic feature for fear, the mouth for happiness and surprise, and the corners of the nose for disgust. These findings indirectly extended and supported previous literature that claimed that the facial area providing the best accuracy varies with each emotion presented (Boucher & Ekman, 1975; Calder et al., 2000; Martin, Slessor, Allen, Phillips, & Darling, 2011). Specifically, Calder et al. (2000) showed that happy and disgusted facial expressions were best identified when participants were shown only the bottom half of the face relative to when only the top was shown. For fearful and angry faces performance was higher when the top half of the face was shown relative to the bottom half. When presented with a surprised face, there was no difference in performances between the top only and bottom only conditions. Martin et al. (2011) primed participants to process facial expressions using local (i.e., feature-based) or global (i.e., holistic) processing orientation. When primed with local processing, participants performed significantly faster and more accurately for all six basic facial expressions of emotion than when primed with global processing. Further evidence for the importance of individual features comes from visual scanning studies (Adolphs, Gosselin, Buchanan, Tranel, Schyns, & Damasio, 2005; Sullivan, Ruffman, & Hutton, 2007). Those who fixated more on the mouth region of happy and disgusted faces demonstrated superior identification of these emotions, whereas increased fixation on the eye region was associated with better discrimination of fearful, angry, and sad expressions (Sullivan et al., 2007). Adolphs et al. (2005) reported that instructing a patient with amygdala damage to focus on the eye region of a fearful expression improved her ability to recognize fear to the same level as control participants. Despite accounts supporting the importance of facial features for accurate emotion discrimination performance, it is still to be determined whether fixation on these featural locations would improve discrimination performances for a given expression and concurrently decrease the minimal presentation time required for that discrimination.

Four experiments were designed to extend upon previous signal detection studies investigating the minimum presentation time required for accurate discrimination of emotions (e.g., Maxwell & Davidson, 2004; Milders et al., 2008). These experiments all investigated whether fixation on the diagnostic facial features, as suggested by Schyns et al. (2009), would affect discrimination accuracy performances, and whether this varied with emotion. In order to ensure fixation to specific locations on the face, eye-tracking was used during the presentation of happy, fearful, surprised, disgusted, and neutral expressions. In each study a specific exposure time before mask (Expt. 1=150 ms, Expt. 2 =100 ms, Expt. 3 =50 ms and Expt. 4 =16.67 ms) and eight different location conditions (chin, forehead, left cheek, left eye, nose, mouth, right cheek, and right eye) were used per emotion. In order to test for differences in accuracy beyond the reported happy-superiority effect and between fixation locations, 150 ms was selected as the starting point. This time was chosen based on the suggestion by Schyns et al. (2009) that diagnostic facial features are encoded after 150 ms of processing time has elapsed. Inverted neutral faces served as the mask stimuli in order to avoid confusion when neutral target faces were presented. Milders et al. (2008) demonstrated that the effectiveness of upright neutral mask stimuli was greater than a dynamic checkerboard masking stimulus. However, no known study has compared the effectiveness of other types of masking stimuli while reporting the presentation time required for facial expression discrimination. Secondary aims were to identify the response biases for each condition.

To the best of my knowledge, this is the first study to address these questions while concurrently using eye movement monitoring to ensure fixation to specific locations during the brief presentation of the entire face. Therefore, the novel aspects of the present study were: i) the use of eye tracking to manipulate fixation on diagnostic facial features, ii) inverted neutral mask stimuli, iii) the inclusion of surprised and disgusted expressions in a masking paradigm and iv) the analyses of response biases. As reviewed above, previous signal detection evidence has shown an overall happy-superiority effect, with higher *A'* values for happiness than other emotions (e.g., Maxwell & Davidson, 2004; Milders at al., 2008), at presentation times as short as 17 ms. This is in line with studies that have measured emotion identification accuracy for consistently brief exposure durations without manipulating presentation time and without masking (e.g., Rapesak et al., 2002; Palermo & Coltheart, 2004; Williams et al., 2009). Happiness is consistently reported with the greatest identification accuracy (~88-99%) and fear generally with the lowest accuracy (~51-75%) in studies without masking. Based on these findings a happy-superiority effect was expected at all presentation times during all four experiments. Additionally, the lowest accuracy performance was expected for fearful expressions at all presentation times. Following the work of Schyns et al. (2009) using the bubbles technique a greater identification performance was expected during fixation on the specific diagnostic facial feature for a given expression, relative to non-diagnostic locations for that emotion. For example, presentation of a happy face expression, with fixation on the mouth (i.e., the diagnostic cue for happy expressions), should yield higher identification performance as indexed by higher *A'* values, relative to fixation on the forehead (i.e., non-diagnostic cue for happy expressions). When comparing among the four presentation time groups it was predicted that there would be increased discrimination performance with increased exposure time, across all emotions. Additionally, few signal detection studies have analyzed results in terms of response bias, and those that have, analyzed different emotions than those reported here. Therefore, the analyses of response bias data were largely exploratory with no clear predictions.

**Chapter 2:** EXPERIMENT 1-150 ms

## 2.1 Method

*Participants*

A total of 18 undergraduate students aged 18-25 years (*M* = 19.5) all with normal or corrected-to-normal visual acuity were recruited from the University of Waterloo (UW) for course credit and tested. Participants were prescreened and only selected if born and raised in North America, as the strategy employed to extract visual information from faces differs across cultures (e.g., Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Three participants were rejected due to a low number of trials per condition (< 20) after removing saccade-contaminated trials, resulting in usable data from 15 participants (9 female, aged 18-20 years; *M* = 19.2).

*Stimuli*

Ten static photographs of faces (5 men, 5 women) with neutral, disgusted, fearful, happy, and surprised expressions (for a total of 50 stimuli) were selected from the NimStim set of facial expressions (see Tottenham et al., 2009 for a full description and validation of the stimuli). Images were converted to grayscale in Photoshop CS4 Extended and cropped to be 24.02 cm (W) X 35.00 cm (H) at a resolution of 72 pixels/inch. Hair and part of the neck remained on the final stimuli to maintain ecological validity (see Figure 2.1) however care was taken to ensure that all images excluded piercings, facial hair and any other easily identifiable and distinguishable external features. Each image was viewed against a gray background and subtended 26.75º horizontally and 19.08º vertically of visual angle at a viewing distance of 0.70 m. Eight neutral faces (4 men, 4 women) of different identities from the target faces, were selected from the same stimuli set and served as masks. The mask stimuli were converted to grayscale and rotated by 180 º (inverted) in Photoshop CS4 Extended. Eight different fixation-cross locations were assigned to each of the five expressions for each identity. For each stimulus, exact coordinates corresponding to eight feature locations on the face were recorded: chin, forehead, left cheek, left eye, mouth, nose, right cheek, and right eye. Each picture had a different set of symmetrical fixation-cross locations. Fixation-crosses on the forehead, nose and chin were aligned with one another vertically and similarly for the eye and cheek locations horizontally. It is important to note that no two fixation-crosses were presented in the exact same location due to variations within the identities and expressions.

**Figure 2.1** Example of the stimuli used; all images were shown in grayscale. From left to right: neutral, disgust, fear, happiness, and surprise. Note that each of the 10 identities expressed all emotions.

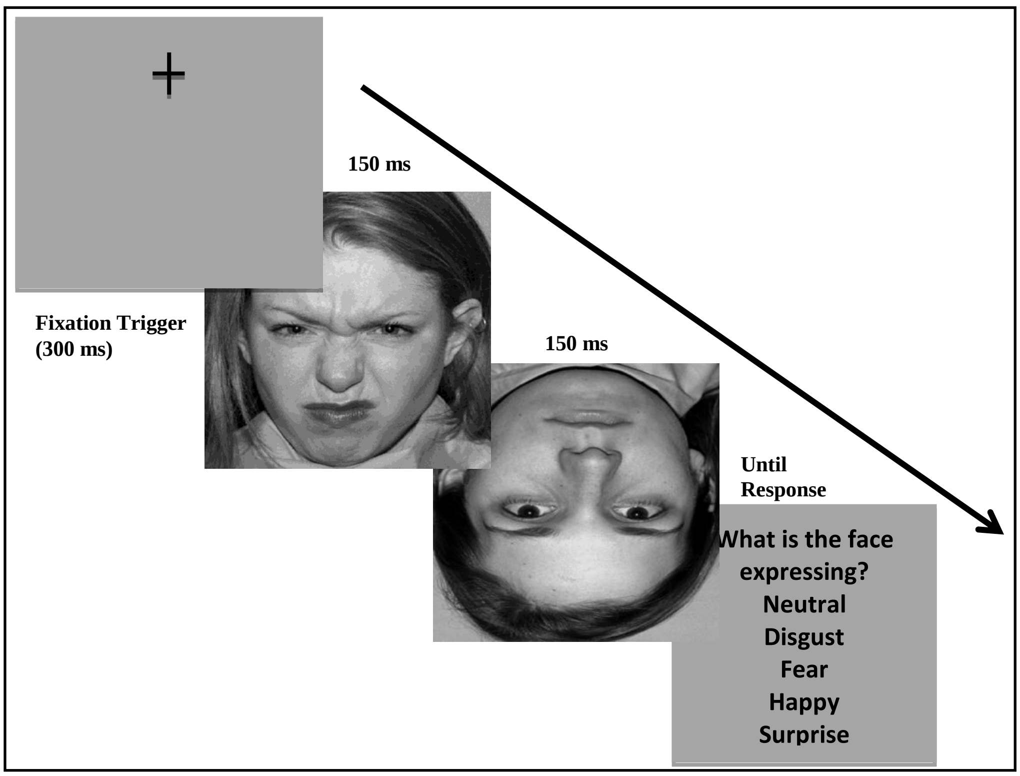



**Figure 2.2** Trial example with forehead fixation: Subjects were tested on 1200 trials organized as follows. First the fixation point was displayed on the screen jittered 1000-1500 ms with a fixation trigger of 300 ms. Then the grayscale picture was flashed for 150 ms, immediately followed by an inverted grayscale mask for 150 ms. Subjects had an unlimited amount of time to select the correct response using the click of the mouse on the corresponding word.

*Apparatus*

The stimuli were presented on a Viewsonic PS790 CRT 19-inch colour monitor driven by an Intel Corel Quad CPU Q6700 with a refresh rate of 60 Hz. Eye movements were recorded using a remote Eyelink 1000 eye-tracker from SR Research with a sampling rate of 1000 Hz. The eye-tracker was calibrated to each participant's dominant eye, but viewing was binocular. Calibration was done using a nine-point automated calibration accuracy test. Calibration was repeated if the error at any point was more than 1º, or if the average for all points was greater than 0.5 º. The participants' head positions were stabilized with a head and chin rest to maintain viewing position and distance.

*Materials and Procedure*

Participants were aware that their eye movements would be monitored during the entire experiment. They were explicitly told to fixate on the cross, and not to move their eyes from the fixation-cross location after it was removed. Before the experiment started, participants were given a practice session of eight trials. Each of the eight fixation-cross locations was presented so that participants became accustomed to moving their eyes to various locations on the screen. Participants were instructed to fixate on the center of the black fixation-cross in order to initiate the trial and to remain fixated on that specific location until the response screen appeared. Upon presentation of the response screen participants were able to look anywhere on the screen. In the experimental session a trial started with a black fixation-cross on a gray background jittered between 1000 and 1500 ms. For each trial the fixation-cross appeared at one of the eight fixation locations in an unpredictable fashion. Once participants focused on the center of the fixation-cross for 300 ms the target face was presented for 150 ms, and was immediately masked by one of the four inverted neutral face masks. The duration of the mask was always 150 ms (100 ms presentation times and greater have been shown to be effective masks, e.g., Esteves & Ohman, 1993). Immediately following the presentation of the mask a response screen appeared with instructions reading “Please choose the correct emotion” accompanied by a vertically presented list of the five emotions which remained until response (see Figure 2.2 for a trial example). The order of the emotions on the response screen was kept constant for all trials. Participants were instructed to respond as quickly and accurately as possible. The next trial was initiated following the response made using a mouse click. Testing was carried out in ten blocks separated by a self-paced break, during which the eye-tracker was re-calibrated. During each block, the presentation of 120 images was pseudo-randomized: each fixation-cross location was presented 15 times and at each fixation-cross location the five expressions were presented three times each such that all identities and emotions were presented across the 10 blocks. The order of the 10 blocks was counterbalanced across participants with a total of 1200 trials (30 trials for each emotion and fixation location condition).

Participants then completed the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree, MacLeod, French, & Locke). The STICSA is a Likert-scale questionnaire assessing cognitive and somatic symptoms of anxiety as they pertain to one’s mood in the moment (state; 21 items) and in general (trait; 21 items). This provided relief to participants from the computer task and allowed time for the experimenter to set up the final task. Anxiety was measured because it is known to interact with the processing of gaze and emotions (e.g., Fox, Calder, Mathews, & Yiend, 2007). Additionally, participants completed a demographic questionnaire assessing age, vision, gender, and ethnicity.

The last task served as a facial expression identification capability check without the manipulation of time, mask, or fixation location. Each of the 10 identities was presented once for each emotion, resulting in 10 trials per emotion. The same experimental procedure as the actual experiment was used except the fixation was always in the center of the screen and the target image was presented for 2 s. The participants' response, using the click of the mouse, initiated the start of the next trial. The entire experiment lasted approximately 120 minutes.

*Data Analysis*

Any trial with greater than one saccade and any participant with less than 20 trials per condition were removed from the analyses. This was to ensure that participants fixated on the specified location of the face during each trial and to ensure a similar number of trials per condition. Using this criterion, three participants were rejected in this experiment.

Expression accuracy performance was analyzed with signal detection methods similar to those used by Milders et al. (2008). The sensitivity measure *A'* was calculated for each emotion and each fixation-cross location. First, the number of responses for each expression and each fixation location were tabulated. For example, for happy expressions with a left eye fixation location, the possible responses were happy and non-happy (disgusted, fearful, neutral, or surprised). Next, the number of correct "happy" responses and non-happy response (i.e., "neutral", "disgusted", "fearful", or "surprised") were each divided by the number of presentations of happy plus non-happy (neutral, disgusted, fearful, surprised) stimuli. This provided conditional probabilities for each emotion at each fixation location. Hit rate (H) is the probability of correctly making a response given the corresponding stimulus. False alarm rate (FA) is the probability of making a particular response when the corresponding stimulus is absent. The probability of H and FA were entered into Equation 1 to determine the *A'* for conditions when H $\geq$ FA. For conditions when the FA $\geq$ H, Equation 2 was used. This procedure was followed for the other four expressions at each fixation location. For a discussion of the *A'* sensitivity index see Haase, Theios, and Jenison (1999), MacMillan and Creelman (1991), Maxwell and Davidson (2004), and Snodgrass and Corwin (1988).

**Equation 1**

$A' = 0.5 + (H\text{-}FA)(1 + H - FA)/[4H(1- FA)]$

**Equation 2**

$A' = 0.5 - (FA\text{-}H)(1 + FA - H)/[4FA(1- H)]$

The *A'* values were compared in a 5 (emotion) X 8 (fixation location) repeated measure Analysis of Variance (ANOVA). Further analyses of the interaction with separate ANOVAs for each emotion (comparing fixation locations) were completed.

In order to support the findings from the *A'* analyses the mean response times (RTs) were compared in a 5 (emotion) X 8 (fixation location) repeated measures ANOVA. Further analyses of the interaction with separate ANOVAs for each emotion (comparing fixation locations) were completed. Additionally, in order to look at individual data, the percentage of participants scoring at or below chance level ($A' \leq 0.5$) was calculated for each condition.

Response bias when FAs were made were analyzed using an 8 (fixation location) X 4 (incorrect emotion selection) repeated measure ANOVA for each emotion. Further analyses of the significant interactions with separate ANOVAs for each fixation location and incorrectly selected emotion were performed.

For ANOVA analyses <u>in all experiments</u>, the Greenhouse-Geisser correction to the degrees of freedom was used when sphericity was violated and Bonferroni corrections were used for multiple comparisons.

## 2.2 Results

*A'*

The average proportion of hits, false alarms (FAs), and *A'* values for each emotion and fixation location were calculated and are displayed in Figure 2.3. It is important to note that based on the equation, when the proportion of hits is high (as seen here) and the proportion of FA is low, *A'* becomes more equivalent to the proportion of hits. Therefore the lower the proportion of FA the more closely the *A'* value resembles the proportion of hits and vice versa. Analysis of these *A'* scores revealed a significant main effect of emotion (Figure 2.4) ($F(2.39, 33.49) = 31.95$, $p < .001$, partial $\eta^2 = .70$) with the highest *A'* scores for happy faces, followed by disgusted and neutral, then surprised, and lastly fearful expressions (all paired comparisons at $p < .05$ except for neutral and disgust which did not differ). The effect of fixation ($F\ (2.67, 37.39) = 5.58$, $p < .01$, partial $\eta^2 = .29$) was due to lower scores for the forehead (significantly compared to the left cheek, left eye and nose at $p < .05$). Although no emotion by fixation location interaction was found, Figure 2.4 suggests that the lower scores for the forehead were driven by fearful expressions only.

*Response Times (RTs)*

Analysis of the response time (RT) means revealed a main effect of emotion ($F(2.46, 34.54) = 25.27$, $p < .001$, partial $\eta^2 = .64$) with the fastest RT to happy and neutral faces (which did not differ), followed by disgust (which did not differ from neutral), and with the slowest RTs found for surprise and fear (which did not differ). There was no main effect of fixation location ($p = .11$) or an emotion by fixation location interaction ($p = .52$).

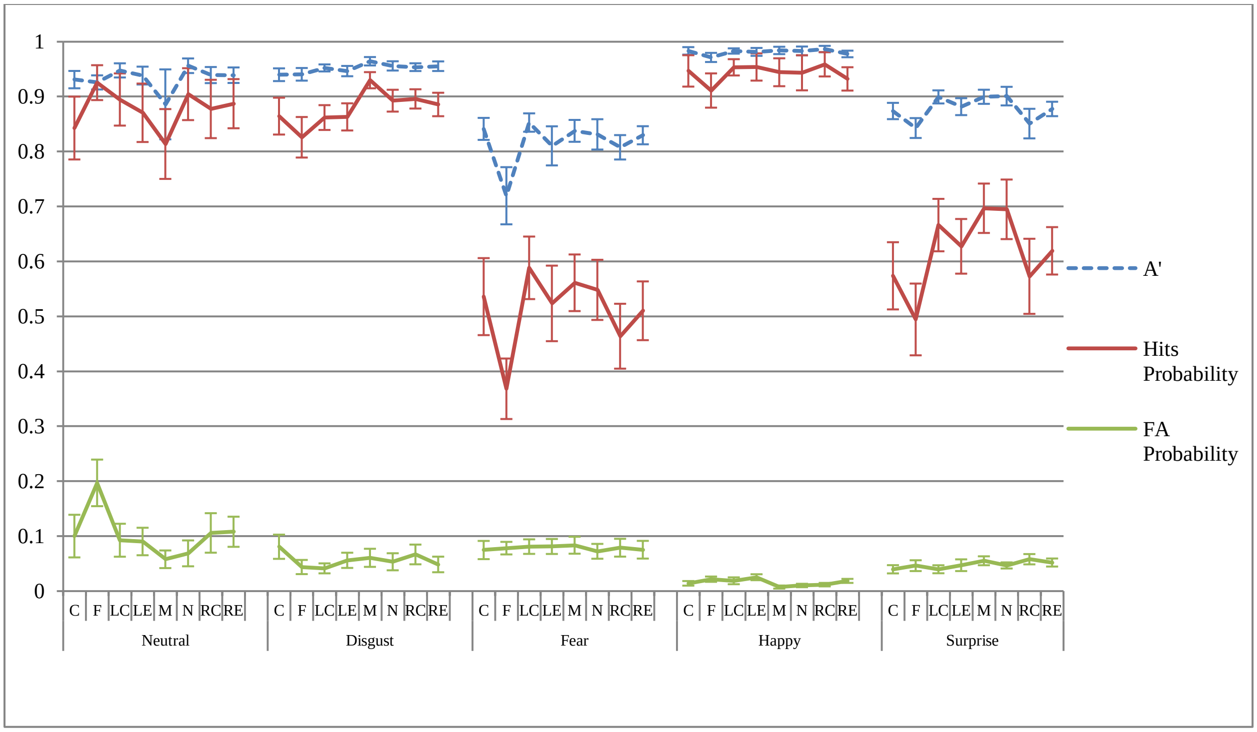



**Figure 2.3** Results of experiment 1 (target face presented for 150ms). Mean hits (correct) probability, FA probability, and sensitivity scores (*A'*) for neutral, disgusted, fearful, happy, and surprised expressions at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means. Note that the statistics reported in the text refer to the *A'* scores only.

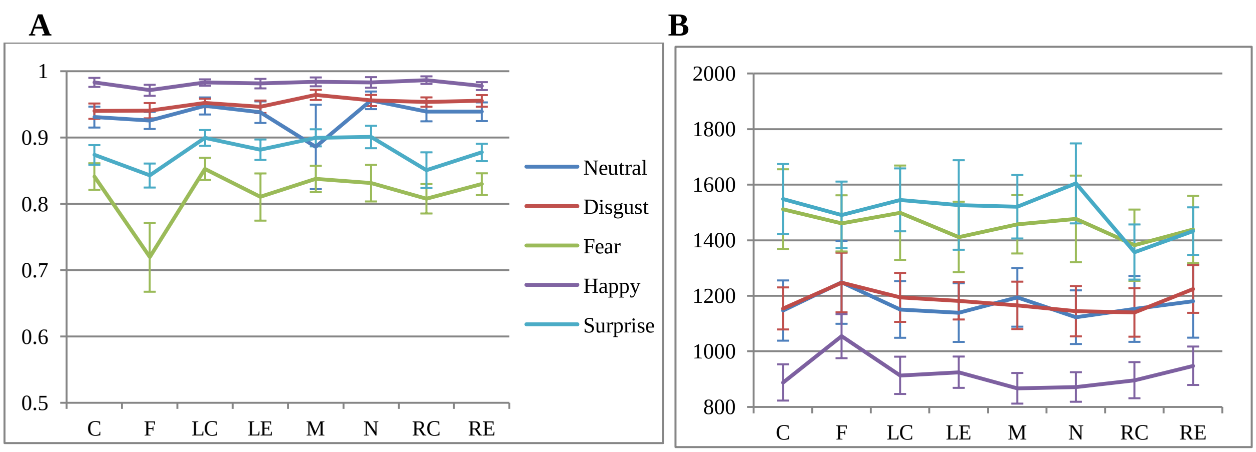



**Figure 2.4 A)** Mean *A'* values and **B)** Mean RTs (ms) for neutral, disgusted, fearful, happy, and surprised expressions presented for 150 ms.

*Percentage of Participants Scoring at or below Chance Level*

Table 2.1 displays the percentage of participants whose *A'* scores were at or below chance level ($A' \leq 0.5$). During the presentation of a disgusted, happy, or a surprised face for 150 ms all participants scored above chance level. For neutral faces a few participants scored below chance level but only when fixated on the mouth. This suggests 150 ms is sufficient time to accurately discriminate a neutral, disgusted, happy, and surprised facial expression. For fear, 20% of the participants scored below chance level in the forehead condition. Therefore, when fixated on the forehead during a 150 ms presentation, not all participants have enough time to accurately discriminate a fearful expression.

**Table 2.1** Percentage of participants scoring below chance level in experiment 1 (N = 15)

| | **Chin** | **Forehead** | **Left Cheek** | **Left Eye** | **Mouth** | **Nose** | **Right Cheek** | **Right Eye** |
|---|---|---|---|---|---|---|---|---|
| **Neutral** | 0 | 0 | 0 | 0 | 6.67% | 0 | 0 | 0 |
| **Disgust** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Fear** | 0 | 20% | 0 | 6.67% | 0 | 0 | 0 | 0 |
| **Happy** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Surprise** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Response Bias*

The percentage of errors in identifying each of the emotions were examined (Figure 2.5). The goal of this analysis was to determine whether the number of FAs made for each expression was distributed over the other four expressions equally or whether there were any systematic errors made preferentially to one or more of the other expressions and locations.

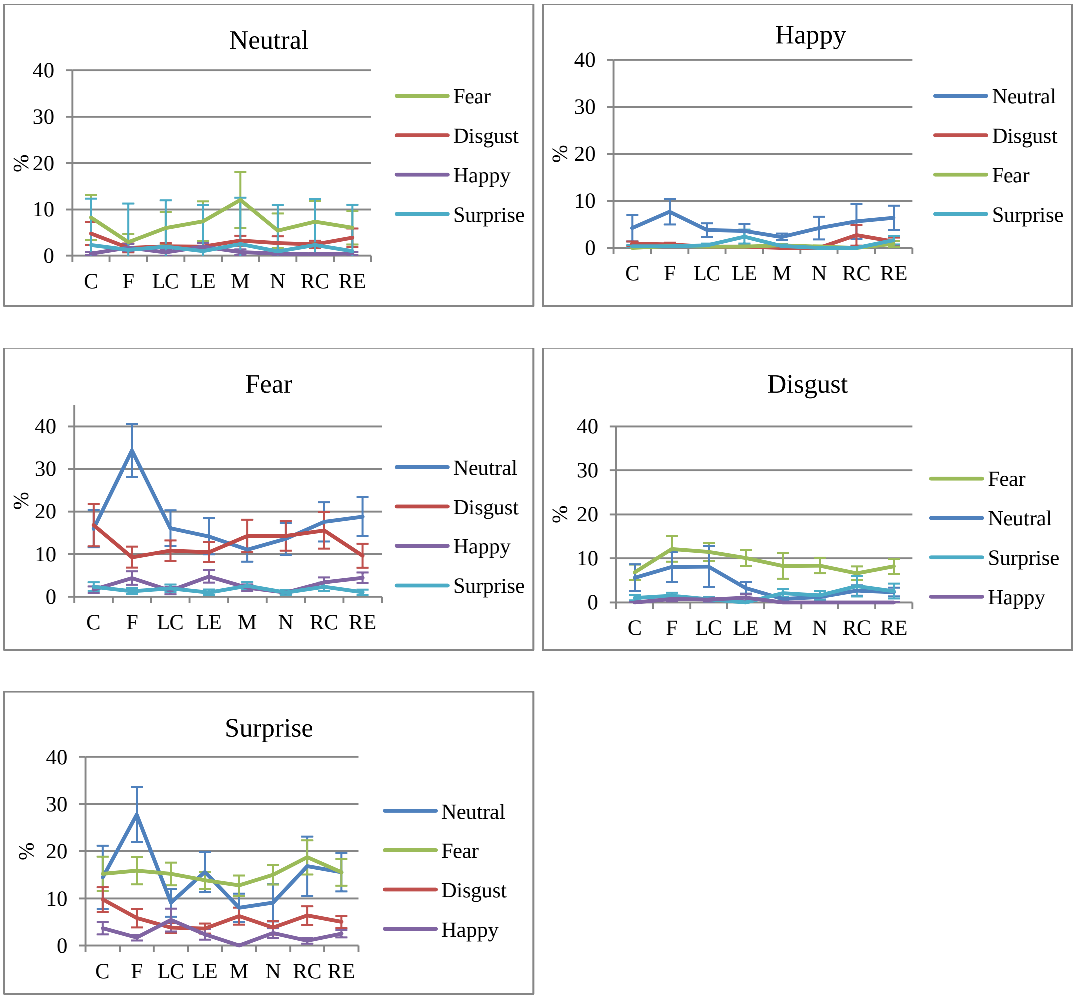



**Figure 2.5** Percentage of response bias to each emotion during a 150 ms presentation of a given emotion at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means.

When presented with a <u>neutral</u> face there was no effect of incorrect emotion selection ($p = .21$). There was an effect of fixation location ($F$ (3.37, 47.12) = 5.13, $p < .01$, partial $\eta^2 = .27$) revealing a trend for more incorrect selections when fixated on the chin and mouth than other fixation locations, however there were no significant pairwise comparisons. The interaction was not significant ($p = .15$).

When presented with a <u>happy</u> face there was an effect of incorrect emotion selection ($F$(1.04, 14.50) = 5.08, $p < .05$, partial $\eta^2 = .27$) due to a trend for choosing neutral more often than the other emotions, however no significant comparisons were found. No effect of fixation location ($p$ = .17) or an interaction ($p$ = .10) were found.

When participants were presented with a fearful expression, a main effect of incorrect emotion selection was found ($F(1.67, 5.66) = 4.85$, $p < .05$, partial $\eta^2 = .26$) indicating more overall incorrect selections to neutral and disgust than to surprise and happiness. The effect of fixation location, ($F(3.76, 52.69) = 7.73$, $p < .001$, partial $\eta^2 = .36$) was modulated by incorrectly selected emotion, as seen by a significant fixation location by emotion interaction, ($F(21, 294) = 5.97$, $p < .001$, partial $\eta^2 = .30$). The interaction revealed that when fixated on the right eye ($F(1.78, 24.90) = 3.87$, $p < .05$, partial $\eta^2 = .22$) and the forehead ($F(1.42, 9.86) = 10.12$, $p < .01$, partial $\eta^2 = .42$) only neutral was selected more than happiness and surprise.

When participants were presented with a disgusted expression, there was also a main effect of incorrect emotion selection ($F(2.08, 29.18) = 19.30$, $p < .001$, partial $\eta^2 = .58$) revealing that fear was incorrectly selected more often than the other emotions. A main effect of fixation location ($F(2.92, 40.93) = 3.97$, $p < .05$, partial $\eta^2 = .22$) was found although no clear pattern was seen. The interaction was not significant ($p$ = .28).

When presented with a surprised face there was an effect of incorrect emotion selection ($F(1.57, 21.97) = 6.33$, $p < .05$, partial $\eta^2 = .31$) due to more incorrect selections to fear and neutral (which did not differ) than disgust and happy (which did not differ). The effect of fixation location ($F(7, 98) = 9.37$, $p < .001$, partial $\eta^2 = .40$) was modulated by incorrectly selected emotion, as seen by a significant interaction between fixation location and incorrect emotion ($F(21, 294) = 4.02$, $p < .001$, partial $\eta^2 = .22$). The interaction revealed that when fixated on the forehead ($F(1.64, 22.97) = 11.87$, $p < .01$, partial $\eta^2 = .46$) neutral was incorrectly selected more than all emotions.

### 2.3 Discussion

As predicted, when faces were presented for 150 ms, facial expression discrimination performance varied as a function of emotion. The highest accuracy performance was seen for happy facial expressions followed by disgusted and neutral, then surprised, and was lowest for fearful expressions. The happy-superiority effect reported here is in line with previous results (e.g., Milders et al., 2008) however differences between the other emotions tested were also found. Therefore this is the first known study to report differences in accuracy performance beyond the happy-superiority effect within the backward visual masking literature and when using signal detection methods (*A'*) to evaluate responses. It should be noted that at a 150 ms presentation time, despite minor individual differences in the ability to discriminate fearful expressions, the majority of participants were able to discriminate the expressions above chance level. This is in line with the previous literature where participants discriminated angry, happy, neutral, and fearful faces above chance level at presentation times ranging between 20-50 ms (e.g., Maxwell & Davidson, 2004; Milders et al., 2008). It was expected that the differences between facial expression performances would be explained by the use of fixation on the suggested diagnostic facial features specific to each emotion. However, discrimination performance was not improved when fixated on the specific diagnostic facial feature compared to non-diagnostic facial features. Instead, overall performance was lower when fixated on the forehead. Fixation on the forehead during the presentation of a fearful expression was the only condition where participants scored below chance level. Therefore, 150 ms appears to be enough time to accurately discriminate facial expressions irrespective of fixation location (with the exception of the forehead for some participants). One possible explanation is that 150 ms is enough time to integrate all the internal features and discriminate the emotion, with accuracy varying as a function of emotion. Response time (RT) data were in support of the accuracy findings such that RTs varied as a function of emotion but not as a function of fixation location. Specifically, participants responded fastest to happy faces and slowest for fearful faces. Although the RT data go in the same direction as the accuracy results, they need to be taken cautiously given that the order of the emotions on the response screen was not randomized.

Analyses of the response bias data revealed that during the presentation of surprised and fearful expressions participants systematically incorrectly selected neutral when fixated on the forehead. This is most likely attributed to guessing when unable to discriminate the facial expression and is in line with lower performance overall for fixation on the forehead as measured by *A'*. For disgusted expressions, fear was systematically incorrectly chosen the most. Happy expressions did not show strong effects of incorrectly selected emotions and this is most likely due to the fact that overall few false alarms were made during the presentation of this emotion. For fearful expressions, disgust was also systematically incorrectly selected in addition to neutral. For surprised expressions, fear was incorrectly selected in addition to neutral. Therefore, surprise is mistaken for fear however the opposite is not true despite both expressions having characteristic eye widening and open mouths. Overall, the systematic effects of response bias are not strong beyond incorrectly selecting neutral most often. This is most likely due to high accuracy performance overall when presented with a facial expression for 150 ms.

**Chapter 3:** EXPERIMENT 2-100 ms

## 3.1 Method

*Participants*

Fifteen undergraduate participants (10 females), all with normal or corrected-to-normal visual acuity were recruited from the UW for course credit. The age range of the participants was 18-25 years ($M$ = 19.7). None of them took part in experiment 1.

*Materials and Procedure*

The materials and procedure were the same as used in experiment 1, except the target face was presented for 100 ms.

*Data Analysis*

Data analyses were the same as experiment 1 including Bonferroni and Greenhouse-Geisser corrections.

## 3.2 Results

*A'*

The average proportion of hits, FAs, and *A'* values for each emotion and fixation are displayed in Figure 3.1. Overall there is a low proportion of FA and a high proportion of hits, making *A'* values similar to proportion of hits. Comparison of these scores in a 5 (emotion) X 8 (fixation location) repeated measures ANOVA revealed a main effect of emotion ($F(2.17, 30.43) = 39.69$, $p < .001$, partial $\eta^2 = .74$) with the highest *A'* scores for happiness and disgust (which did not differ), followed by neutral, and the lowest scores for fear and surprise (which were not significantly different) (Figure 3.2). The effect of fixation location ($F$ (2.75, 38.58) = 13.35, $p < .001$, partial $\eta^2 = .49$) was due to lower performance when fixated on the forehead compared to all other fixation locations (paired comparisons at $p < .05$). There was no significant emotion by location interaction ($p = .19$).

*Response times (RTs)*

Analysis of the RT means revealed a significant main effect of emotion, ($F(1.60, 22.44) = 29.39$, $p < .001$, partial $\eta^2 = .68$) due to faster RTs for happy expressions than all other emotions (*p-values* < .05). In addition, RTs were faster to neutral expressions than fearful ($p < .001$) or surprised expressions ($p < .001$). Despite a non-significant main effect of fixation location ($p = .11$), there was a significant emotion by fixation location interaction ($F(6.75, 94.44) = 3.19$, $p < .001$, partial $\eta^2 = .19$) revealing that when fixated on the forehead the RTs did not differ between emotions (*p-values* > .05).

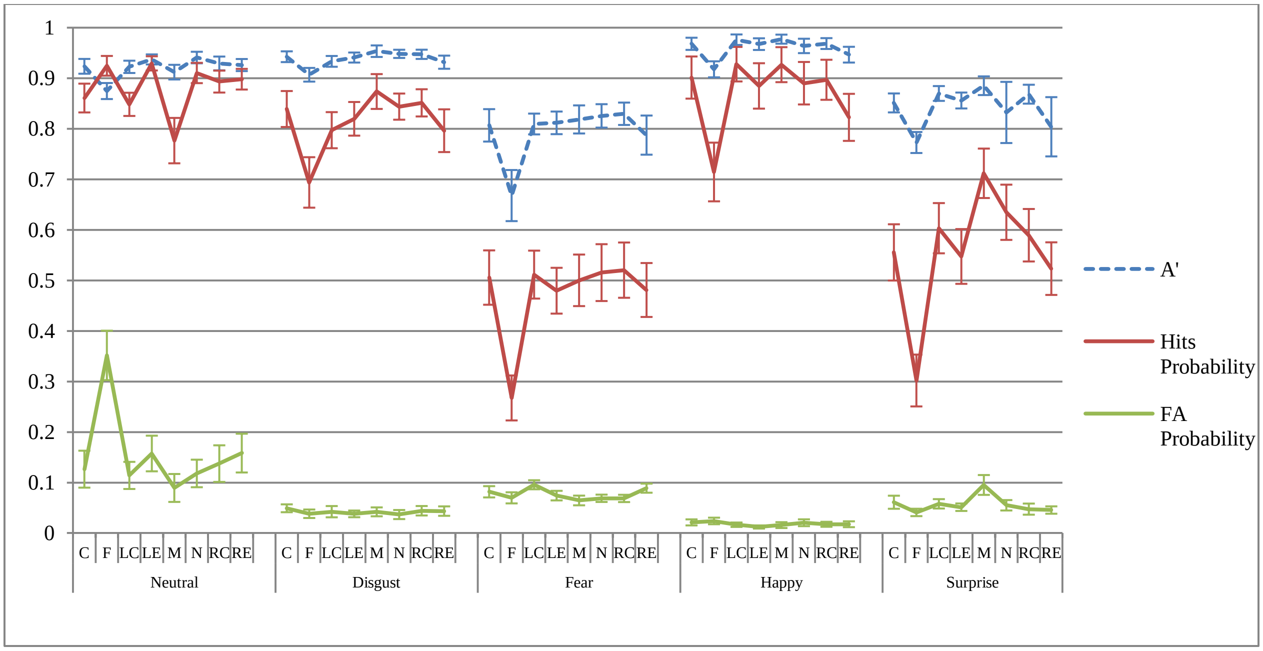
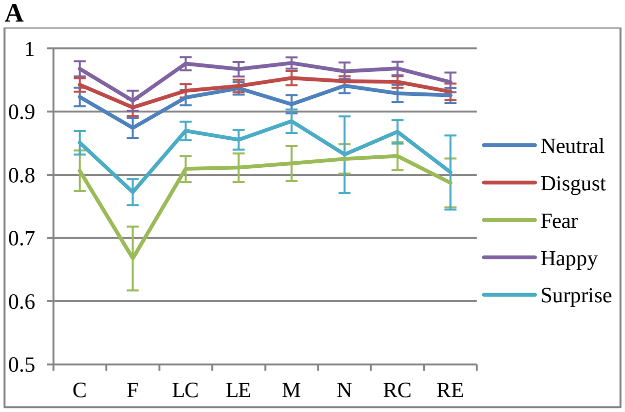



**Figure 3.1** Results of experiment 2 (target face presented for 150 ms). Mean hits (correct) probability, FA probability, and sensitivity scores (*A'*) for neutral, disgusted, fearful, happy, and surprised expressions at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means. Note that the statistics reported in the text refer to the *A'* scores only.

**A**




**B**

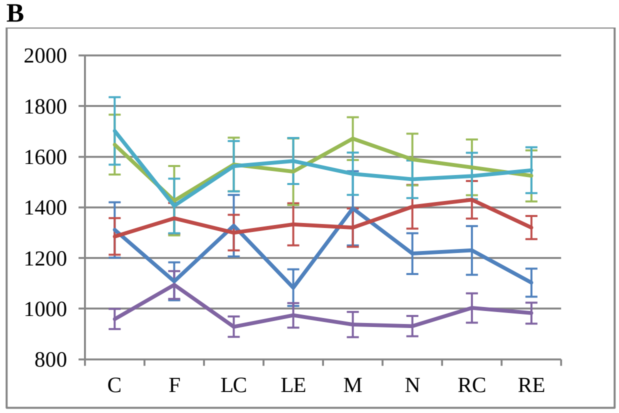



**Figure 3.2 A)** Mean A' values and **B)** Mean RTs (ms) for neutral, disgust, fear, happiness, and surprise presented for 100 ms.

*Percentage of Participants Scoring below Chance Level*

Table 3.1 displays the percentage of participants whose *A'* scores were at or below chance level (*A'* ≤ 0.5). When a neutral, disgusted, or happy facial expression was presented at 100 ms all participants scored above chance level. For fearful faces, some participants scored below chance level when fixated on the chin, forehead, and right eye. For surprised expressions, participants scored below chance when fixated on the right eye and nose. Therefore, 100 ms is enough time to accurately discriminate neutral, disgusted, and happy expressions above chance. However, when fixated on the chin, forehead, or right eye for fearful expressions and right eye and nose for surprised expressions performance is decreased.

**Table 3.1** Percentage of participants scoring below chance level in experiment 2 (N = 15)

| | **Chin** | **Forehead** | **Left Cheek** | **Left Eye** | **Mouth** | **Nose** | **Right Cheek** | **Right Eye** |
|---|---|---|---|---|---|---|---|---|
| **Neutral** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Disgust** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Fear** | 6.67% | 20% | 0 | 0 | 0 | 0 | 0 | 6.67% |
| **Happy** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Surprise** | 0 | 0 | 0 | 0 | 0 | 6.67% | 0 | 6.67% |

*Response Bias*

Percentage of errors in identifying each of the expressions of emotion were examined (Figure 3.3).

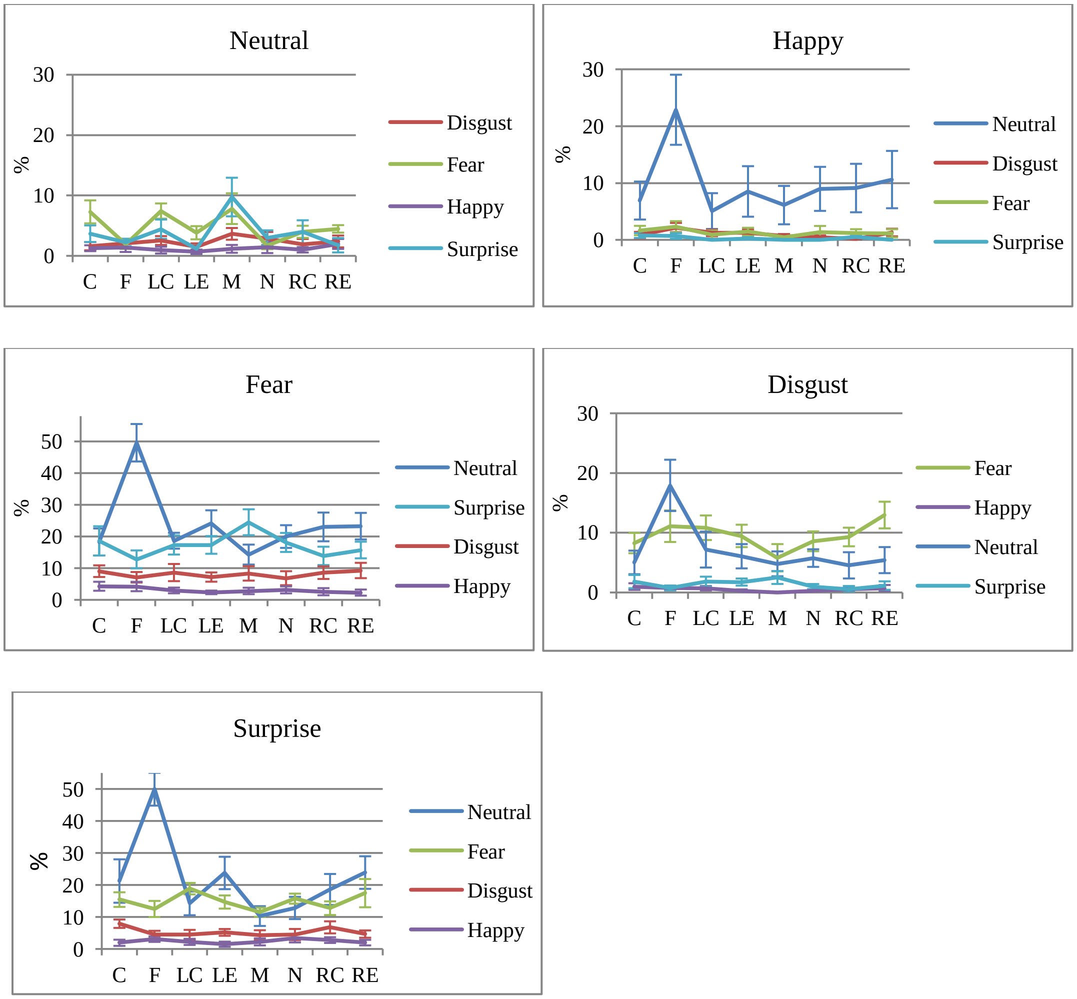



**Figure 3.3** The percentage of response bias to an emotion during a 100 ms presentation of a given emotion at each fixation location (C: chin, F: forehead, LC: left cheek, LE: left eye, M: mouth, N: nose, RC: right cheek, RE: right eye). Error bars represent standard error to the means. Note the scale changes for neutral, disgust and happy.

When presented with a neutral face, there was a main effect of incorrectly selected emotion ($F(2.04, 28.57) = 14.73$, $p < .001$, partial $\eta^2 = .513$) such that overall fear was selected more than all other emotions. There was no effect of fixation location ($p = .32$) however there was a significant interaction between incorrectly selected emotion and fixation location ($F(5.02, 70.28) = 3.23$, $p < .05$, partial $\eta^2 = .187$) such that fear was selected more often mostly in the chin, left cheek, and mouth fixation conditions.

When participants were presented with a happy expression, there was a main effect of incorrect emotion selection ($F(1.03, 13.42) = 5.35$, $p < .05$, partial $\eta^2 = .29$) due to more incorrect selections made to neutral expressions. The main effect of fixation location ($F(2.51, 32.61) = 7.58$, $p < .01$, partial $\eta^2 = .37$) was modulated by the significant interaction ($F(21, 273) = 4.58$, $p < .01$, partial $\eta^2 = .26$) revealing the effect of incorrect selection to neutral was stronger when fixated on the forehead ($F(1.08, 15.13) = 11.21$, $p < .05$, partial $\eta^2 = .45$) compared to the other fixation locations (*p-values* < .05).

When participants were presented with a fearful expression, there was a main effect of incorrect emotion selection ($F(1.90, 26.65) = 16.62$, $p < .001$, partial $\eta^2 = .54$) revealing more incorrect selections to neutral and surprised than happy and disgusted expressions. The effect of fixation location ($F(3.87, 54.30) = 6.10$, $p < .001$, partial $\eta^2 = .30$) was modulated by the interaction ($F(21, 294) = 9.76$, $p < .001$, partial $\eta^2 = .411$) such that neutral faces were especially selected more in the forehead condition.

When presented with a disgusted expression, a significant main effect of incorrect emotion selection ($F(1.81, 25.39) = 14.47$, $p < .001$, partial $\eta^2 = .51$) was found indicating that the most incorrect selections were to neutral and fear compared to happiness and surprise. The effect of fixation location ($F(3.09, 43.24) = 4.83$, $p < .01$, partial $\eta^2 = .26$) was modulated by the interaction ($F(21, 294) = 3.71$, $p < .01$, partial $\eta^2 = .21$) such that the selection of neutral and fearful faces was seen mostly in the forehead condition and not in the mouth condition.

When presented with a surprised expression, there was a main effect of incorrect selection ($F(1.36, 18.97) = 17.37$, $p < .001$, partial $\eta^2 = .55$) revealing more incorrect selections to neutral and fearful expressions compared to disgusted and happy expressions. An effect of fixation location ($F(2.94, 41.16) = 16.31$, $p < .001$, partial $\eta^2 = .54$) was modulated by the interaction ($F(21, 294) = 10.91$, $p < .001$, partial $\eta^2 = .44$) such that incorrect selection to neutral was mostly seen in the forehead condition.

### 3.3 Discussion

In experiment 1, accuracy performance varied as a function of emotion, however not as a function of fixation to diagnostic facial features specific to the emotion. Therefore, in experiment 2 the presentation time was decreased to 100 ms in order to search for this effect. Consistent with predictions and with the results seen in experiment 1, performance at 100 ms varied as a function of emotion such that the greatest performance was seen for happy and disgusted expressions, followed by neutral, and was lowest for both surprise and fear. Despite a non-significant difference between surprise and fear, the data were trending in the direction that identification performance was lowest for fear. Therefore, the differences beyond the happy-superiority effect are in the same direction as was seen in experiment 1, with accuracy ranging from highest to lowest in the following order: happiness, disgust, neutral, surprise, and fear. When looking at individual differences, participants scored above chance level during the presentation of neutral, disgusted, and happy expressions. For fear and surprise, participants scored below chance level when fixated on the forehead, chin, and right eye. However in line with the results seen in experiment 1, performance (as measured by *A'*) did not vary as a function of fixation on the proposed diagnostic facial features specific to an emotion. Instead, an effect of fixation location demonstrated decreased performance when fixated on the forehead compared to all other locations on the face, irrespective of emotion. Therefore, shortening the presentation time of the facial expressions led to more detrimental decreases in accuracy performance when fixating the forehead. At both 150 and 100 ms presentation times, fixation on the diagnostic facial features specific to an emotion did not provide an advantage for discrimination performance. Therefore, there was enough time for participants to integrate the internal features in order to accurately discriminate the emotions (except when fixating on the forehead). Response time (RT) data were in line with accuracy performance, displaying an effect of emotion with fastest RTs to happy faces and slowest to fear and surprise. Additionally, there was no main effect of emotion when fixated on the forehead. This too is in line with decreased accuracy performance when fixated on the forehead. RT results need to be taken cautiously though as the order of emotions on the response screen was not randomized.

Participants displayed response biases for happy and disgusted facial expressions that were not evident during the 150 ms presentation time. For both expressions as well as for fearful expressions, most incorrect selections were made to neutral, most often when fixated on the forehead (i.e., the location with decreased accuracy performance). Once again we see a stronger response bias to neutral and fear during the presentation of a surprised expression. Therefore, at 100 ms, surprise is taken for fear but fear is also taken for surprise.

**Chapter 4:** EXPERIMENT 3- 50 ms

## 4.1 Method

*Participants*

Nineteen undergraduate participants (12 female) all with normal or corrected-to-normal visual acuity were recruited from the UW for course credit. The age range of the participants were 18-25 years ($M$ = 20.52). None of the participants had taken part in experiment 1 or experiment 2. Four were rejected due to a low number of trials per condition (< 20) after removing saccade-contaminated trials, resulting in a final sample of 15 participants (9 female) aged 19- 23 ($M$ = 20.30) included in the analyses.

*Materials and Procedure*

The materials and procedure were the same as used in experiment 1 and 2, except that the target face was presented for 50 ms.

*Data Analysis*

Data analyses were the same as experiments 1 and 2 including Bonferroni and Greenhouse-Geisser corrections.

## 4.2 Results

*A'*

The proportion of hits, FAs, and *A'* values for each emotion and fixation are displayed in Figure 4.1. The Analysis of Variance revealed a significant main effect of emotion ($F(4, 56)$ = 54.18, $p < .001$, partial $\eta^2 = .80$) with the highest *A'* scores for happiness, followed by disgust, then neutral and surprise (which did not differ), and lastly fear (all significant pairwise comparisons $p < .05$) (Figure 4.2). There was also an effect of fixation location ($F(3.02, 42.25)$ = 16.36, $p < .001$, partial $\eta^2 = .54$) due to lower *A'* scores when fixated on the forehead compared to all locations and lower performance on the left eye (significantly at $p < .05$ compared to left cheek, mouth, nose, and right cheek). No significant interaction was found ($p = .08$), although it is appears from Figure 4.2 that the general decrease in performance for the left eye was driven by surprise.

*Response Times (RTs)*

Analysis of the RT means revealed a main effect of emotion ($F(2.93, 10.96) = 32.94$, $p < .001$, partial $\eta^2 = .70$) due to faster RTs to happy and neutral expressions compared to disgusted, fearful, and surprised expressions. The main effect of fixation location, ($F(1.99, 27.86) = 3.73$, $p < .05$, partial $\eta^2 = .21$) was modulated by the main effect of emotion as seen by the significant interaction ($F(3.75, 94.46) = 3.37$, $p < .01$, partial $\eta^2 = .19$). Separate analyses for each emotion revealed that for happy expressions ($F(2.93, 41.03) = 6.79$, $p < .01$, partial $\eta^2 = .33$) RTs were fastest when fixated on the mouth significantly compared to forehead, left cheek, and right cheek fixations ( *p-values* < .05).

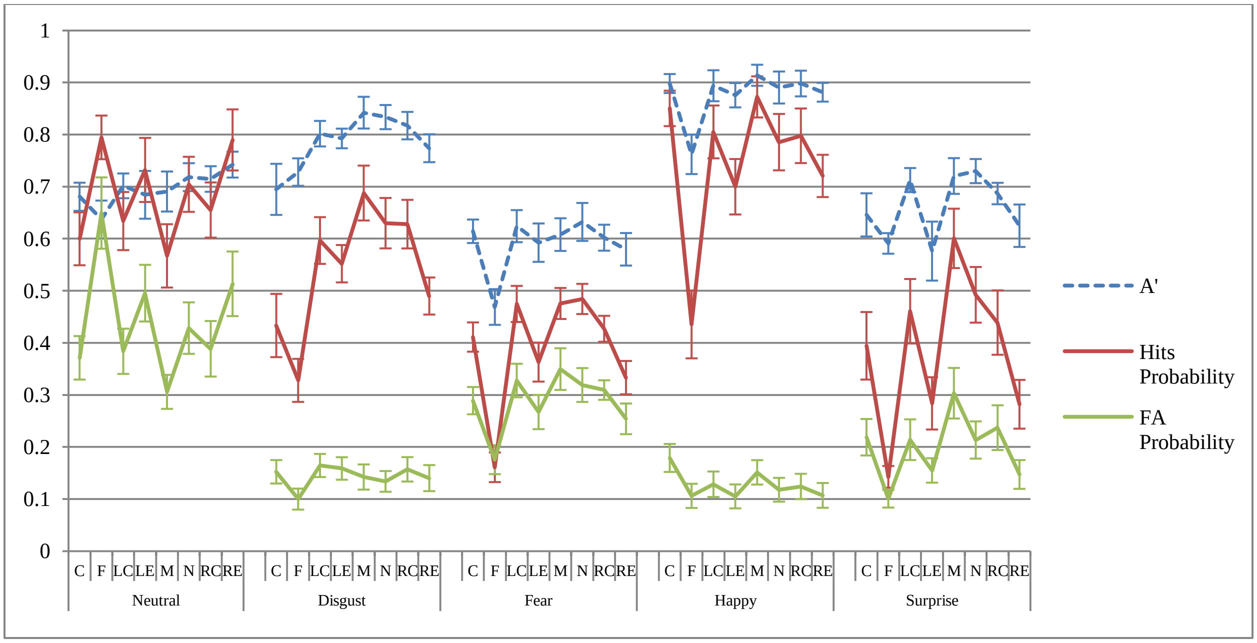



**Figure 4.1** Results of experiment 3 (target face presented for 50 ms). Mean hits (correct) probability, FA probability, and sensitivity scores (*A'*) for neutral, disgusted, fearful, happy, and surprised expressions at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means. Note that the statistics reported in the text refer to the *A'* scores only.

**A** **B**

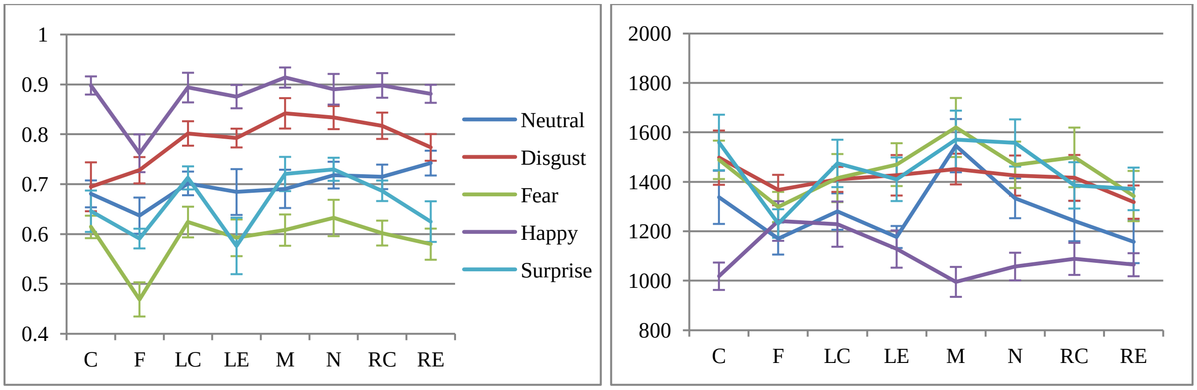



**Figure 4.2 A)** Mean *A'* values and **B)** Mean RTs (ms) for neutral, disgust, fear, happiness, and surprise presented for 50 ms.

*Percentage of Participants Scoring below Chance Level*

Table 4.1 displays the percentage of participants whose *A'* scores were at or below chance level (*A'* ≤ 0.5). Most participants scored above chance level when neutral, disgusted, and happy expressions were presented, although a few scored under chance level for a few fixation conditions. Fear was the only expression where at least some participants scored below chance level in every fixation location condition. Specifically, the mouth and chin conditions had the lowest percentage of participants scoring below chance level, whereas the forehead was the condition with the greatest percentage (close to 50%). For surprise, participants scored below chance level for all conditions except for the left cheek, right cheek, and nose; the greatest percentage of participants below chance level occurred when fixated on both eyes. Most conditions see an increase in the percentage of participants below chance level compared to both experiment 1 and 2.

**Table 4.1** Percentage of participants scoring below chance level in experiment 3 (N = 15)

| | **Chin** | **Forehead** | **Left Cheek** | **Left Eye** | **Mouth** | **Nose** | **Right Cheek** | **Right Eye** |
|---|---|---|---|---|---|---|---|---|
| **Neutral** | 0 | 6.67% | 0 | 13.33% | 13.33% | 0 | 0 | 0 |
| **Disgust** | 13.33% | 0 | 0 | 0 | 0 | 0 | 0 | 6.67% |
| **Fear** | 13.33% | 46.67% | 20% | 20% | 13.33% | 20% | 20% | 26.67% |
| **Happy** | 0 | 6.67% | 0 | 0 | 0 | 0 | 0 | 0 |
| **Surprise** | 13.33% | 13.33% | 0 | 20% | 13.33% | 0 | 0 | 20% |

*Response Bias*

Percent errors in identifying each of the expressions of emotions were examined (see Figure 4.3).

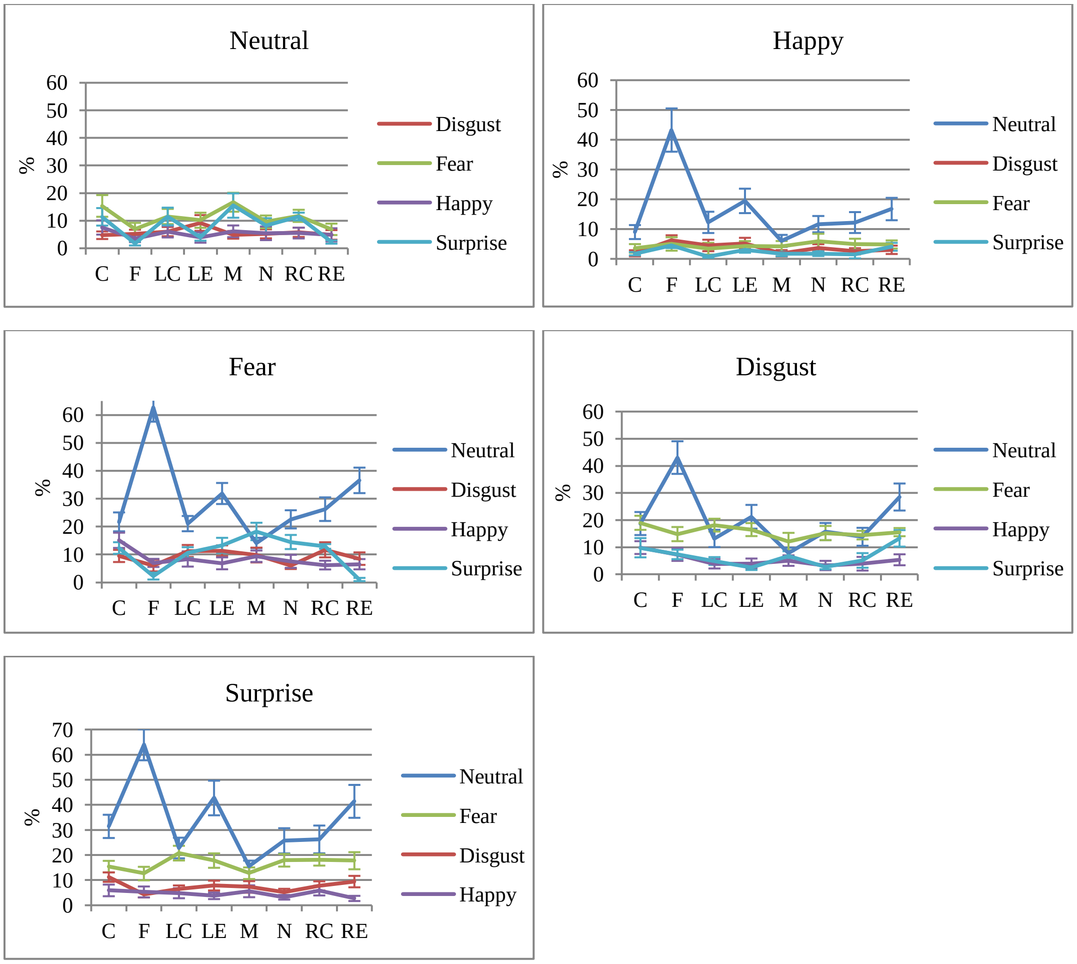



**Figure 4.3** The percentage of response bias to an emotion during a 50 ms presentation of a given emotion at each fixation location (C: chin, F: forehead, LC: left cheek, LE: left eye, M: mouth, N: nose, RC: right cheek, RE: right eye). Error bars represent standard error to the means. Note the scale changes for surprise.

When participants were presented with a <u>neutral</u> face there was no effect of incorrect emotion selection ($p = .07$). There was a main effect of fixation location ($F(3.42, 41.01) = 11.06$, $p < .001$, partial $\eta^2 = .48$) however no clear pattern was seen. There was no interaction between fixation location and incorrect emotion selection ($p = .07$).

When participants were presented with a <u>happy</u> expression, there was a main effect of incorrect emotion selection ($F(1.28, 16.57) = 14.05$, $p < .01$, partial $\eta^2 = .52$) due to more incorrect selections to neutral than all other emotions. There was also an effect of fixation location ($F(2.92, 37.94) = 24.63$, $p < .001$, partial $\eta^2 = .66$) modulated by the interaction with incorrect selection ($F(2.67, 34.72) = 12.09$, $p < .001$, partial $\eta^2 = .48$) such that the incorrect selection of neutral was more pronounced in the forehead condition.

When participants were presented with a <u>fearful</u> expression, there was a main effect of incorrect emotion selection ($F(1.80, 23.46) = 22.18$, $p < .001$, partial $\eta^2 = .63$) revealing more incorrect emotion selections to neutral than all other emotions. Again, the effect of fixation location ($F(7, 91) = 10.74$, $p < .001$, partial $\eta^2 = .45$) was modulated by the interaction ($F(7.07, 92.01) = 19.28$, $p < .001$, partial $\eta^2 = .60$), revealing that incorrect selection of neutral faces are more pronounced in the forehead and right eye conditions.

When participants were presented with a <u>disgusted</u> expression, there was a main effect of incorrect selection ($F(1.58, 20.54) = 11.54$, $p < .01$, partial $\eta^2 = .47$) with more incorrect selections to neutral and fear than happiness and surprise. The effect of fixation location ($F(7, 91) = 20.45$, $p < .001$, partial $\eta^2 = .61$) was modulated by incorrect emotion selection as seen by the significant interaction ($F(21, 273) = 7.35$, $p < .001$, partial $\eta^2 = .36$), such that neutral was incorrectly selected more than all emotions when fixated on the forehead ($F(1.28, 16.71) = 19.69$, $p < .001$, partial $\eta^2 = .60$).

When participants were presented with a <u>surprised</u> expression, there was a main effect of incorrectly selected emotion ($F(1.20, 15.58) = 24.75$, $p < .001$, partial $\eta^2 = .66$) due to the greatest number of incorrect emotion selections to neutral, then to fear, then disgust and happiness (which did not differ). The effect of fixation location ($F(4.23, 54.94) = 16.94$, $p < .001$, partial $\eta^2 = .57$) was modulated by incorrect emotion selection ($F(5.19, 67.48) = 12.40$, $p < .001$, partial $\eta^2 = .49$) such that neutral faces were incorrectly selected more often when fixation was on the forehead, left and right eye.

## 4.3 Discussion

Experiment 1 and 2 yielded a similar pattern of results with stronger effects seen at the reduced presentation time of 100 ms compared to 150 ms. Additionally no effect of fixation on diagnostic facial features was seen on accuracy performance. Therefore, in the search for differences in performance between fixation on diagnostic features versus non-diagnostic features the presentation time was decreased to 50 ms in experiment 3. In line with the previously reported happy-superiority effect, happy faces yielded the greatest accuracy scores, followed by disgust, neutral, surprise, and with the lowest performance seen for fear. In previous studies, during a 50 ms presentation time only a happy-superiority effect had been demonstrated with no differences between the other emotions tested (e.g., Milders et al., 2008). Therefore, this is the first study to replicate the happy-superiority effect and show accuracy differences between other emotions during a 50 ms presentation of masked facial expressions. Response time (RT) data revealed an effect of emotion with fastest RTs to happy and neutral expressions, supporting the effect of emotion seen for accuracy performance. Although the results go in the same direction as the accuracy scores, caution must be taken as the order of emotions on the response screen was not randomized. The patterns of results were thus consistent with experiments 1 and 2, however it should be noted that there was a marked decrease in the *A'* values (scores as low as .58). Comparing individual scores the data showed that overall more individuals scored below chance compared to both experiments 1 and 2. Participants were now scoring below chance level even during the presentation of neutral, disgusted, and happy facial expressions. Even with a 50 ms presentation time, performance was not improved when fixating on the putative diagnostic facial features specific to each emotion. Once again performance was lower during fixation on the forehead compared to all other locations on the face across all emotions. Therefore, by decreasing the presentation time performance varies according to emotion however not according to specific diagnostic facial features.

As seen in the previous experiments, the neutral expression was systematically selected when making an incorrect response for all emotions, with even more incorrect selections when fixated on the forehead. Additionally, fear was systematically chosen incorrectly during the presentation of a surprised expression while the opposite was not true during the presentation of a fearful face despite the similar feature characteristics (i.e., the widened eyes and open mouth).

**Chapter 5:** EXPERIMENT 4- 16.67 ms

## 5.1 Method

*Participants*

Fifteen undergraduate participants (6 female), all with normal or corrected-to-normal visual acuity were recruited from the UW for course credit. The age range was 18-25 years (*M* = 20.6). None of the participants had taken part in experiment 1, 2 or 3.

*Materials and Procedure*

The materials and procedure were the same as used in experiment 1, except the target face was presented for 16.67 ms. This experiment was added because *A'* values for happy and neutral were still above chance level during a 50 ms presentation time. In the current experiment the 60 Hz refresh rate of the monitor limited the lowest possible presentation time of the target emotional face to a duration of 16.67 ms.

*Data Analysis*

Data analyses were the same as the previous three experiments.

## 5.2 Results

*A'*

The average percentage of hits, FAs, and *A'* values for each emotion and fixation location was calculated and are displayed in Figure 5.1. Analysis of the scores using a 5 (emotion) X 8 (fixation location) ANOVA revealed a trend for *A'* values for happy faces to be higher than for the other emotions which did not differ (main effect of emotion, $F(1.39, 19.52) = 3.50$, $p = .07$) (Figure 5.2). There was neither a main effect of fixation location ($p = .56$) nor an interaction between emotion and location ($p = .98$).

*Response Times (RTs)*

Analysis of the RT means revealed a trend for faster RTs to happy expressions compared to all other emotions (main effect of emotion, $F(3.38, 47.27) = 2.63$, $p = .06$). There was no main effect of fixation location ($p = .15$) or an emotion by fixation location interaction ($p = .62$).

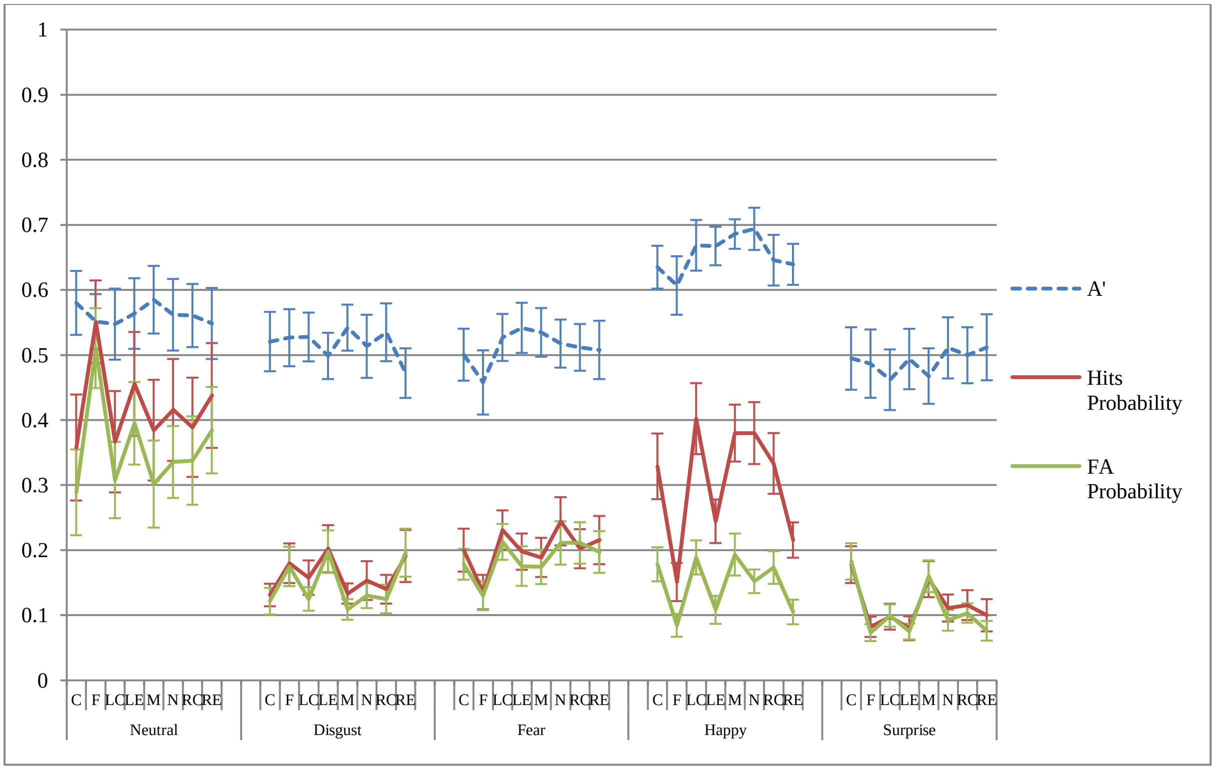



**Figure 5.1** Results of experiment 4 (target face presented for 16.67 ms). Mean hits (correct) probability, FA probability, and sensitivity scores (*A'*) for neutral, disgusted, fearful, happy, and surprised expressions at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means. Note that the statistics reported in the text refer to the *A'* scores only.

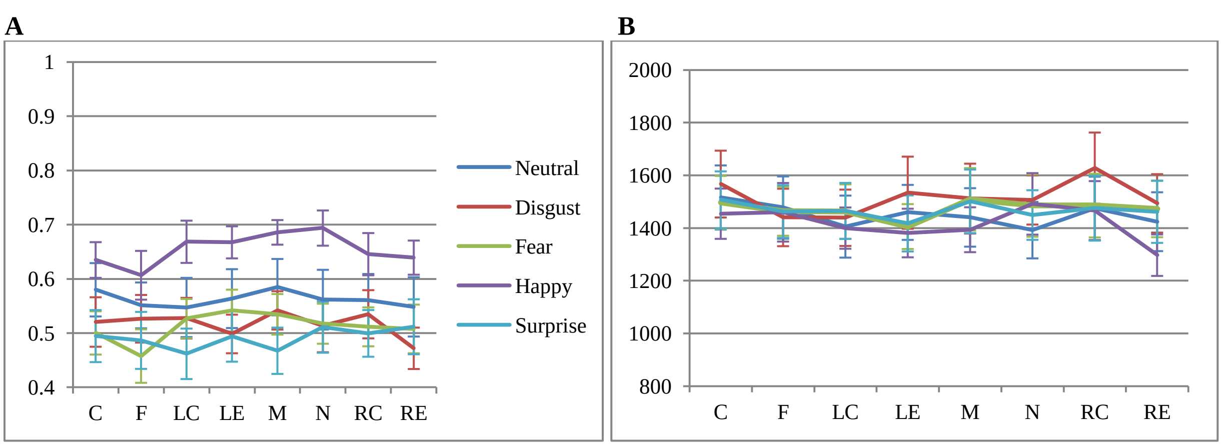



**Figure 5.2 A)** Mean *A'* and **B)** Mean RTs (ms) values for neutral, disgust, fear, happiness, and surprise presented for 16.67 ms.

*Percentage of Participants Scoring at or below Chance Level*

Table 5.1 displays the percentage of participants whose *A'* scores were at or below chance level ($A' \leq 0.5$). Participants scored below chance level in all conditions except for when a happy facial expression was presented with fixation to the mouth. Additionally when fixated on locations closest to the mouth (i.e., nose and chin) only 6.67% of participants scored below chance. In all other conditions at least 30% of the participants scored below chance level. For fear close to 50% of participants scored below chance level in five of the fixation conditions. Comparison of the nominal values in Tables (2.1, 3.1, 4.1, and 5.1) suggests that more participants are scoring below chance when the expression is presented for only 16.67 ms compared to when it is presented longer (experiment 1, 2, and 3).

**Table 5.1** Percentage of participants scoring below chance level in experiment 4 (N = 15)

| | **Chin** | **Forehead** | **Left Cheek** | **Left Eye** | **Mouth** | **Nose** | **Right Cheek** | **Right Eye** |
|---|---|---|---|---|---|---|---|---|
| **Neutral** | 26.67% | 46.67% | 40% | 33.33% | 26.67% | 33.33% | 33.33% | 46.67% |
| **Disgust** | 40% | 46.67% | 40% | 53.33% | 40% | 46.67% | 33.33% | 60% |
| **Fear** | 26.67% | 46.67% | 60% | 40% | 33.33% | 46.67% | 46.67% | 46.67% |
| **Happy** | 6.67% | 33.33% | 20% | 6.67% | 0% | 6.67% | 13.33% | 20% |
| **Surprise** | 53.33% | 40% | 53.33% | 53.33% | 46.67% | 40% | 40% | 40% |

*Response Bias*

Percent errors in identifying each of the expressions of emotions were examined (see Figure 5.3).

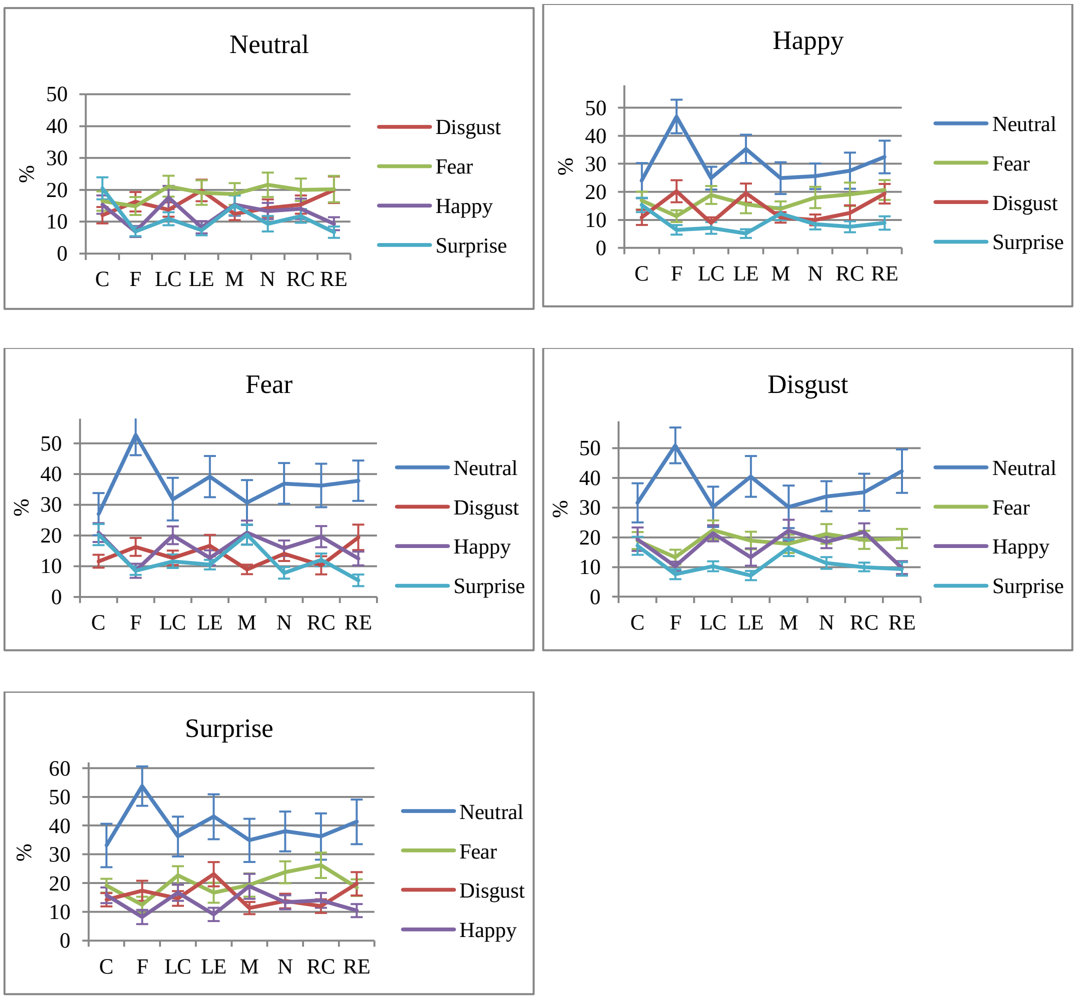



**Figure 5.3** The percentage of response bias to an emotion during a 16.67 ms presentation of a given emotion at each fixation location (C: chin, F: forehead, LC: left cheek, LE: left eye, M: mouth, N: nose, RC: right cheek, RE: right eye). Error bars represent standard error to the means. Note the scale changes for surprise.

When presented with a neutral face there was a significant main effect of incorrectly selected emotion ($F(2.54, 35.56) = 5.08$, $p < .01$, partial $\eta^2 = .27$) due to the most incorrect selections for fear. The effect of fixation location ($F(4.19, 58.70) = 7.50$, $p < .001$, partial $\eta^2 = .35$) was modulated by the interaction ($F(6.50, 91.02) = 3.06$, $p < .01$, partial $\eta^2 = .18$) such that disgust and fear were selected more than happiness and surprise in the left and right eye conditions.

When participants were presented with a happy expression, there was a significant main effect of incorrect emotion selection ($F$(1.17, 16.32) = 6.86, $p < .05$, partial $\eta^2 = .33$) revealing that more incorrect selections were made overall to neutral. The effect of fixation location ($F$(3.77, 52.82) = 8.79, $p < .001$, partial $\eta^2 = .39$) was modulated by the interaction ($F$(6.73, 234.59) = 5.51, $p < .001$, partial $\eta^2 = .28$) such that more incorrect selections to neutral were seen in the forehead condition.

When participants were presented with a fearful expression, there was a significant main effect of incorrect emotion selection ($F$(1.14, 16.01) = 7.47, $p < .05$, partial $\eta^2 = .35$) due to more incorrect selections to neutral than the other expressions. The effect of fixation location ($F$(3.76, 52.75) = 2.93, $p < .05$, partial $\eta^2 = .17$) was modulated by the interaction ($F$(7.00, 98.03) = 7.77, $p < .001$, partial $\eta^2 = .36$) such that the selection of neutral was seen mostly in the forehead condition.

When presented with a disgusted expression, there was a significant effect of incorrect emotion selection ($F$(1.23, 17.24) = 7.29, $p < .001$, partial $\eta^2 = .34$) revealing more incorrect selections to neutral than the other expressions and this was modulated by the interaction ($F$(7.41, 103.79) = 7.13, $p < .001$, partial $\eta^2 = .34$) such that neutral faces were especially more selected in the forehead condition. There was no main effect of fixation location ($p = .18$).

When presented with a surprised expression, there was a main effect of incorrect emotion selection ($F$(1.13, 15.81) = 6.22, $p < .05$, partial $\eta^2 = .31$) revealing that more incorrect selections were made overall to neutral expressions. The main effect of fixation location ($F$(3.82, 53.46) = 4.67, $p < .01$, partial $\eta^2 = .25$) was modulated by the interaction ($F$(5.64, 79.00) = 5.43, $p < .001$, partial $\eta^2 = .28$) such that more incorrect selections to neutral were in the forehead condition.

**5.3 Discussion**

When facial expressions were presented for 50 ms in experiment 3, we expected increased performance when participants fixated on the putative diagnostic features for given emotions. Once again, however, we failed to show any diagnosticity effects. In the hope of uncovering these effects in experiment 4 we lowered the presentation times of the target faces to 16.67 ms – the lowest possible presentation time allowed by the monitor. Once again, happy faces were the best identified expression compared to the other emotions, in line with Milders et al. (2008) and with the happy-superiority effect reported as early as 10 ms, although this effect only approached statistical significance at this extremely short presentation time.

In terms of the diagnostic feature predictions, by minimizing the presentation times to the smallest possible values (at least for the monitor that we employed) at last we begin to see support for the hypothesis that fixating on the diagnostic feature for happy faces helps for the emotion discrimination. When looking at the individual scores, not a single participants scored below chance level when attempting to identify a happy face while fixating the mouth (see table 5.1). Additionally, only 6.67% scored below chance when fixated on the chin and the nose, which are the closest locations relative to the diagnostic cue (i.e., the mouth).

Generally, more participants scored below chance level than was seen in the previous experiments. Specifically, a large proportion of subjects (~50%) scored below chance when identifying fearful and surprised expressions (at most locations). Therefore with a 16.67 ms presentation time the percentage of participants scoring above chance is lower for fear and surprise compared to the other emotions.

It is also important to note that *A'* values obtained with a 16.67 ms presentation time were much lower than the other three experiments (ranging from .46 to .69), demonstrating an overall decrease in performance. This will be addressed in further analyses comparing between experiments. Response time (RT) data demonstrated a trend for faster responses to happy expressions compared to all emotions despite a non-significant effect. This supports the results seen for accuracy performance (measured by *A'*), however must be interpreted with caution as the order of the emotions on the response screen was not randomized. As was seen in the accuracy results there was no effect of fixation location on speed of responses for any emotion.

Examination of response biases revealed that participants incorrectly selected neutral most often when fixated on the forehead for disgusted, fearful, happy, and surprised expressions. This demonstrates that neutral is the default choice when participants are unaware of the facial expression that was presented.

**Chapter 6:** BETWEEN GROUPS COMPARISON

In order to compare facial expression discrimination performance between presentation time groups, a 5 (emotion) X 8 (fixation location) X 4 (presentation time) mixed ANOVA was conducted (Figure 6.1). There was a significant main effect of emotion ($F(2.00, 111.94) = 20.31$, $p < .001$, partial $\eta^2 = .47$) such that for all studies *A'* values were highest for happiness, followed by neutral and disgust (which did not differ), then surprise, and were lowest for fear. There was also a main effect of fixation location ($F(5.07, 15.20) = 21.43$, $p < .001$, partial $\eta^2 = .28$) revealing the lowest *A'* values when fixated on the forehead and lower *A'* values when fixated on the right and left eye than when fixated on the nose. A main effect of presentation time ($F(3, 56) = 147.72$, $p < .001$, partial $\eta^2 = .89$) was found indicating the highest *A'* values at 150 ms and 100 ms presentation times (which did not differ), followed by 50 ms, and lowest *A'* scores for 16.67 ms. There were significant emotion by presentation time ($F(5.99, 111.94) = 3.33$, $p < .01$, partial $\eta^2 = .15$), fixation location by presentation time, ($F(15.20, 283.65) = 2.70$, $p < .01$, partial $\eta^2 = .13$), and emotion by fixation location ($F(12.76, 38.29) = 2.12$, $p < .05$, partial $\eta^2 = .04$) interactions. However, the emotion by presentation time by fixation location interaction was not significant ($p = .49$). In order to explore the presentation time by emotion interaction separate ANOVAs were conducted for each emotion. For fearful expressions, discrimination performance was lower for the 16.67 and 50 ms groups (which did not differ) compared to the 100 and 150 ms groups (which did not differ). All other emotions followed the pattern of the main effect of presentation time, with no difference between 150 ms and 100 ms, and a decrease in performance between 100 ms, 50 ms, and 16.67 ms (Figure 6.1).

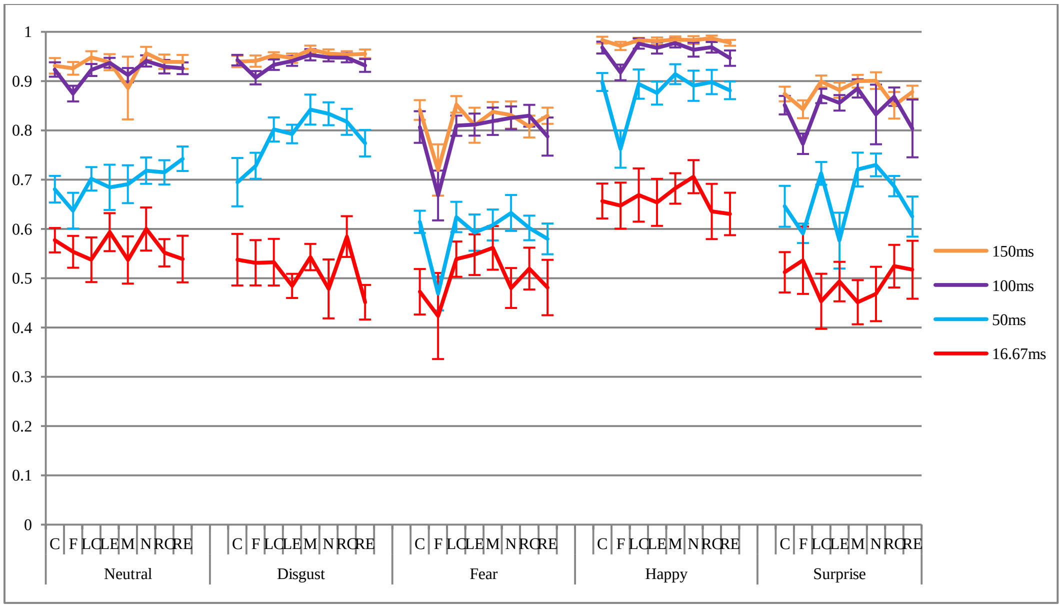



**Figure 6.1**. Results of the comparison between experimental groups (Exp. 1= 150 ms, Exp. 2 = 100 ms, Exp. 3 = 50 ms, Exp. 4 = 16.67ms). Sensitivity scores (*A'*) for neutral, disgusted, fearful, happy, and surprised expressions at each fixation location (C: chin; F: forehead; LC: left cheek; LE: left eye; M: mouth; N: nose; RC: right cheek; RE: right eye). Error bars represent standard errors to the means.

## **Chapter 7:** EMOTION DISCRIMINATION POST-TEST

An emotion discrimination post-test was conducted after each experiment in order to ensure participants could accurately discriminate the emotions above chance level without the manipulation of presentation time or fixation to features. Faces were fixated centrally and presented for 2000 ms (see details in the method section, chapter 2). The post-test *A'* scores were compared in a 5 (emotion) X 4 (experimental group) mixed ANOVA (Figure 7.1). There was a significant main effect of emotion ($F(2.44, 137.14) = 41.49$, $p < .001$, partial $\eta^2 = .43$) revealing higher scores for happiness, followed by neutral and disgust (which did not differ statistically), surprise, and lowest scores for fear. The main effect of experimental group ($F(3, 56) = 6.48$, $p < .01$, partial $\eta^2 = .26$) was modulated by the emotion by experimental group interaction ($F(7.35, 137.14) = 3.95$, $p < .001$, partial $\eta^2 = .18$). In the 16.67 ms group there were larger impairments for fear and surprise compared to the other groups (*p-values* < .05). This interaction involving experimental group was not expected given that the post-test was exactly the same for all groups (i.e., did not involve any SOA manipulations).

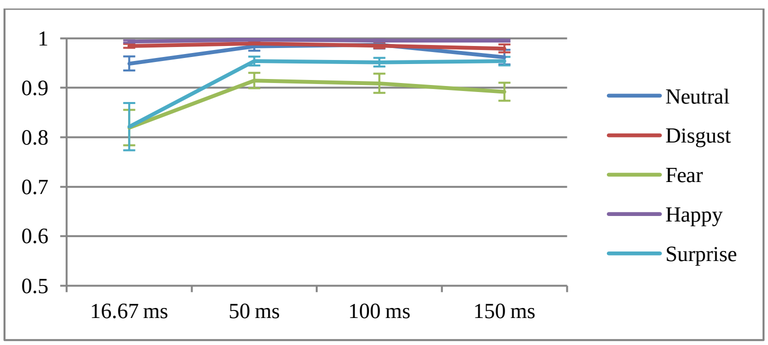



**Figure 7.1** Mean *A'* values for each experimental group (Exp. 1= 150 ms, Exp. 2 = 100 ms, Exp. 3 = 50 ms, Exp. 4 = 16.67ms). Separate lines represent neutral, disgusted, fearful, happy, and surprised expressions presented for 2000 ms (post-test).

No difference in discrimination performance was found between the 100 and 150 ms experimental groups. However, it remained unknown whether there would be differences in performance between a 150 and 2000 ms presentation of facial expressions. Consequently, *A'* scores from the nose fixation condition (closest to a central fixation) for the 150 ms group was used to compare with the 2000 ms post-test condition of that group (Figure 7.2). Only the nose condition (central fixation location) was selected for comparison as participants were centrally fixated on the target image during the post-test. A 5 (emotion) X 2 (target face presentation time: 2000 ms, 150 ms) ANOVA was conducted. There was a main effect of emotion ($F(2.46, 68.85) = 39.80$, $p < .001$, partial $\eta^2 = .59$) due to the highest *A'* scores seen for happiness, followed by neutral and disgust (which did not differ), followed by surprise, and the lowest scores seen for fear. There was a main effect of target face presentation time ($F(1, 28) = 4.51$, $p < .05$, partial $\eta^2 = .14$) due to slightly higher *A'* scores when the target image was presented for 2000 ms than when presented for 150 ms (in the nose condition). The interaction between target face presentation time and emotion was not significant ($p = .08$) although surprise and fear tended to show a larger increase in performance at 2000 ms presentation time than the other emotions.

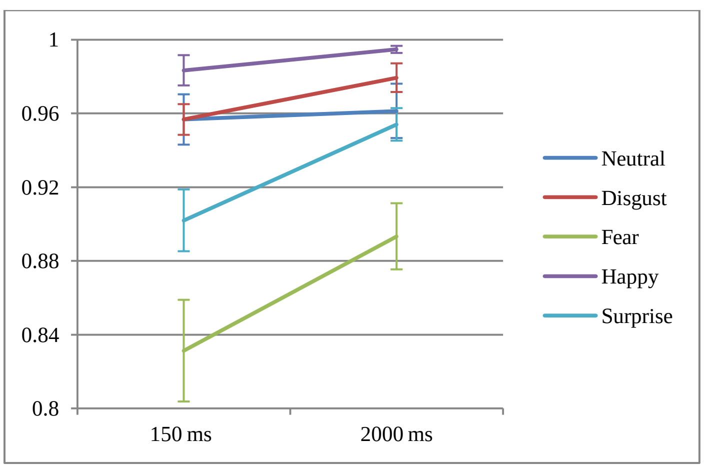



**Figure 7.2**. Mean *A'* scores for neutral, disgust, fear, happiness and surprise when presented for 150 ms (during fixation to the nose) and when presented for 2000 ms (central fixation). Data taken from experiment 1.

## **Chapter 8:** GENERAL DISCUSSION

The present studies investigated whether fixation on the diagnostic facial features, as suggested by Schyns et al. (2009), would affect discrimination accuracy performances, and whether this varied as a function of emotion. Eye-tracking was used in order to ensure fixation to eight different fixation locations (chin, forehead, left cheek, left eye, mouth, nose, right cheek, and right eye) on neutral, disgusted, fearful, happy, and surprised target expressions. In each study a different presentation time (150 ms, 100 ms, 50 ms, and 16.67 ms) of the target expressions was used followed by an inverted neutral masking stimulus to prevent further processing of the facial expression. This is the first study to use signal detection measures of accuracy performance while concurrently using eye movement monitoring to ensure fixation to specific locations during the brief presentation of the entire face.

Based on previous emotion discrimination studies using masked (Milders et al., 2008) and unmasked expressions (e.g., Rapesak et al., 2002; Palermo & Coltheart, 2004; Williams et al., 2009) it was predicted that happiness would be recognized with the greatest accuracy at all presentation times. The results supported this prediction. Superior discrimination performance was seen for happy facial expressions from 50 ms to 150 ms with a trend in the 16.67 ms group. Supporting this result, participants were also fastest to respond to a happy facial expression in all experiments (trending for 16.67 ms exposure time). Differences between the other emotions have been inconsistent with no clear pattern emerging in the masking literature while using signal detection methods to evaluate responses. Additionally, only neutral, angry, and fearful expressions had been tested. Therefore, the present results are novel as they included disgusted and surprised expressions. With a full range of expressions tested, happy expressions were best discriminated, followed by neutral and disgust, then surprise. Fearful expressions were the most poorly discriminated. This pattern was consistent across the 50 ms, 100 ms, and 150 ms presentation times. RT data also supported this pattern of results. It is therefore possible to conclude that facial expression discrimination varies as a function of emotion beyond the happy-superiority effect when brief presentations of the faces are used.

Based on the research reported by Schyns et al. (2009), greater discrimination performance was predicted when participants fixated on the specific diagnostic facial feature for a given expression, relative to non-diagnostic locations for that emotion. However, using the *A'* analyses, this hypothesis was not supported for any of the tested emotions during any of the presentation times. The analysis concerning the percentage of participants who were above chance showed only weak support for the diagnostic feature hypothesis, and only for happy expressions. The failure to find a clear and consistent mouth-fixation effect supporting the happy face discrimination advantage suggests that the robust happy-superiority effect seen in the present study is not due to using the smiling mouth as a shortcut. In terms of fixations, the only consistent finding was that discrimination performance was decreased when participants fixated on the forehead compared to the other fixation locations and this effect became stronger as the presentation time was decreased until 50 ms. It is possible that the internal features (i.e., the nose, mouth, eyes) are being integrated (holistic processing) in order to discriminate the emotions and the longer the presentation time the more accurate this integration is. Currently, the evidence regarding the role of configural and featural face cues in facial expression discrimination is somewhat mixed (see Bartlett, Searcy, & Abdi, 2003). In support of the view that facial expressions are processed holistically, Derntl et al. (2009) demonstrated that the discrimination of facial expressions (except neutral expressions) was affected by inversion. Additional support for the integration of internal features comes from earlier work by Ellison and

Massco (1997) demonstrating that emotion categorization occurs more efficiently when multiple face features convey consistent emotional signals compared to inconsistent features. Fixation on the forehead does not allow for the integration of these features. It is also important to note that participants incorrectly selected neutral most of the time, regardless of the target emotion, even more so when fixated on the forehead. In sum it appears that participants were simply guessing when selecting a response during the forehead fixation for all emotions, with the default guess being the neutral face. In support of the accuracy performance results there was also no effect of fixation location on RT performance. Based on the current results it appears that the differences in discrimination performance between emotions are not explained by the use of diagnostic facial features. However, it is important to note that this conclusion may not generalize beyond the current paradigm.

Comparisons between experiments (150, 100, 50, and 16.67 ms) were also conducted and it was predicted that there would be an increased discrimination performance with increased presentation time for all emotions. Results demonstrated that increasing exposure time did lead to increased performance up until 100 ms. There was no gain in performance seen from a 100 ms exposure time to a 150 ms exposure time for any emotion. Additionally, for the emotion of fear there was no improvement in accuracy performance seen between 16.67 ms and 50 ms exposure times, in contrast to the other emotions which did show improvements between 16.67 ms and 50 ms presentation times. It is therefore possible that the identification of fearful expressions requires additional time to integrate the internal features and subsequently identify the emotion correctly.

An emotion discrimination post-test was included at the end of each experimental condition in order to ensure that participants could accurately identify the emotions without experimental manipulations. Ten identities expressing each emotion were presented for 2000 ms without a backward mask and with fixation in the center of the face. Participants identified all emotions above chance level with the lowest accuracy seen for fear and surprise, consistent with the emotion discrimination literature of unmasked faces. Additionally, for the 150 ms group, results from the 2000 ms post-test were compared with the nose fixation condition of the experimental task to determine whether performance increased beyond a 150 ms presentation time. There was only a small increase in performance between the 2000 ms presentation time and the 150 ms presentation time. This increase did not vary significantly across the emotions although a trend for a larger increase was seen for fear and surprise compared to the other emotions. However, it is important to note the limitations when making this comparison. First, while there were at least 20 trials per condition in each of the experimental nose conditions there were only 10 trials per condition in the 2000 ms post-test. Additionally, the 2000 ms post-test did not include masking of the target images and therefore the small improvement may be due to the fact that participants were processing the facial expressions beyond 2000 ms.

As previously mentioned the results of this investigation did not support an effect of diagnostic facial features. It is important to consider two possible explanations for failing to find an effect. First, the results could be due to the parameters used in the current study. The current paradigm presented large faces in the same location on the screen for each trial. Therefore, participants could have pre-attended to other locations on the face despite the fovea being fixated on the featural location. However, this is unlikely to be the case as participants were never informed of which facial expression would appear next and would not know where to "pre-attend" on the face. If participants were pre-attending to the core features of the face we would not expect to see a decreased performance for the forehead fixation condition. This is because the cross was located at the top of the screen for the forehead condition and intuitively one would pre-attend to the middle of the screen in order to capture the most information; however, this was not reflected in the accuracy performance. Additionally, the results could be due to the nature of the masking stimuli used. Previous research investigating the minimum presentation time required for accurate discrimination of facial expressions has used an upright neutral masking stimulus (e.g., Milders et al., 2008). However, the current paradigm used an inverted neutral mask in order to avoid confusion with the neutral target stimuli. This presents a limitation of the present study making it possible that the mask was not as effective as the upright mask at stopping the processing of the target stimuli after the desired presentation time. Evidence from categorical face processing studies (sex categorization) suggests that during brief presentations there is an advantage for the extraction of feature-based cues whereas when given a longer time to view the faces, the featural advantage is attenuated (Martin & Macrae, 2007). It is therefore possible that effects of diagnostic facial features were not found because participants were processing the expressions longer than the presentation time due to an inefficient mask. Future studies are required to determine which type of mask is the most efficient at preventing further processing of facial expressions.

Another possible explanation is that fixation on Schyns et al. (2007) proposed diagnostic facial features does not improve discrimination accuracy performance. Estimates of the time course of emotion processing in the brain were derived from co-registering the *Bubbles* paradigm with event-related potentials (ERPs) (Schyns et al., 2009). The N170 has been shown to be a face-sensitive ERP (Bentin, Allison, Puce, Perez, & McCarthy, 1996) allowing the study of the time course of facial expressions. It remains controversial however what this component actually reflects -the structural encoding of faces or a response to the eyes (Bentin, Allison, Puce, Perez,

& McCarthy, 1996; Taylor, Edmonds, McCarthy, & Allison, 2001) - and whether it can be modulated by facial expressions (Batty & Taylor, 2003; De Hann, Nelson, Gunnas, & Tout, 1998; Eimer & Holmes, 2007). Schyns et al. (2007) demonstrated that the integration of facial information begins 50 ms before the N170 (~150 ms after face onset) starting with the eyes for all emotions, and peaks after the diagnostic facial features specific to the emotion have been integrated (e.g., the eyes in fear). Based on this finding, Schyns et al. (2009) reported that the distance from the eyes to the diagnostic features would determine the latency of the N170. According to this hypothesis, the integration of a fearful expression should occur earlier than a happy expression as the eyes are in fact the diagnostic facial feature for fear. However, in the present study, at all presentation times, fearful expressions had lower discrimination performance compared to the other expressions and elicited longer RTs. Therefore, the concept of diagnostic facial features for each emotion could be limited to the *Bubbles* paradigm. Here the entire face was presented for a brief presentation time while Schyns et al. (2009) revealed portions of the face until the emotion was recognized accurately above 75%. That is, holistic processing was still possible in the current studies while in Schyns et al. (2009) studies, featural processing was mandatory. It appears that their findings may not be generalizable to the current paradigm. Based on the current results accurate discrimination performance (in a behavioural task) for a given emotion may require the integration of all the internal facial features as a function of time rather than fixation on specific diagnostic facial features.

In summary, the present studies replicate the happy-superiority effect seen in previous signal detection tasks and are the first to report differences in accuracy performance between neutral, disgusted, fearful, and surprised facial expressions while using *A'* to evaluate responses. In contrast to the diagnostic feature predictions, accuracy performance was not improved during fixation to Schyns et al.’s (2009) suggested diagnostic facial features for all emotions and at all presentation times. Performance was only systematically decreased during fixation to the forehead, especially for fear and surprise, lending to the possibility that accuracy performance depends on the time available to integrate the internal features (holistically). If this were true, fear and surprise then require a longer presentation time to integrate the facial features than neutral, disgust, and happiness. Future studies are required to investigate whether these results were due to the parameters of the current paradigm or whether accuracy performance is truly not improved when fixated on specific diagnostic features. Before this conclusion can be made the current paradigm needs to be tested with upright neutral masking stimuli to rule out the possibility that the target faces were still being processed after the specified presentation time.

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