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Eye spy: The predictive value of fixation patterns in detecting subtle and extreme emotions from faces

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ABSTRACT

Successful social interaction requires recognizing subtle changes in the mental states of others. Deficits in emotion recognition are found in several neurological and psychiatric illnesses, and are often marked by disturbances in gaze patterns to faces, typically interpreted as a failure to fixate on emotionally informative facial features. However, there has been very little research on how fixations inform emotion recognition in healthy people. Here, we asked whether fixations predicted detection of subtle and extreme emotions in faces. We used a simple model to predict emotion detection scores from participants' fixation patterns. The best fit of this model heavily weighted fixations to the eyes in detecting subtle fear, disgust and surprise, with less weight, or zero weight, given to mouth and nose fixations. However, this model could not successfully predict detection of subtle happiness, or extreme emotional expressions, with the exception of fear. These findings argue that detection of most subtle emotions is best served by fixations to the eyes, with some contribution from nose and mouth fixations. In contrast, detection of extreme emotions and subtle happiness appeared to be less dependent on fixation patterns. The results offer a new perspective on some puzzling dissociations in the neuropsychological literature, and a novel analytic approach for the study of eye gaze in social or emotional settings.

1. Introduction

Day to day social situations require us to continuously interpret the emotional states of individuals with whom we interact. We use information from many sources in forming these interpretations, including body language, tone of voice and contextual factors (Barrett, Lindquist, & Gendron, 2007; Meeren, van Heijnsbergen, & de Gelder, 2005). The communication of emotional state through facial expressions has long been of particular interest, as stereotyped emotional expressions are well conserved across species and are thought to be universal among humans (Darwin, 1896; Ekman & Friesen, 1971).

Recognizing these basic emotions requires searching for and detecting the emotional content in a face. Expressive information is largely conveyed through dynamic changes in facial features such as the width of the eyes, position of the jaw, or the curving of the lips (Calder, Burton, Miller, Young, & Akamatsu, 2001). The distinct pattern of features involved in each expression suggests that sampling of information-rich features might be an effective strategy for distinguishing between facial emotions. Smith, Cottrell, Gosselin, and Schyns (2005) confirmed that individual features observed in isolation are more or less useful in distinguishing between basic emotional expressions (e.g. eyes were more useful for fear, mouth for happiness), by requiring participants to judge an emotional expression where only parts of the face were visible (Bubbles method;

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(Gosselin & Schyns, 2001)). Smith et al. (2005) demonstrated the sufficiency of specific facial features in conveying different emotions. However, it is not clear how sampling facial features informs emotion recognition in the more usual case, when we search for emotional content in a fully visible face.

Tracking eye movements while participants assess facial emotions provides information about which features are foveated, and thus processed with the greatest visual acuity and contrast sensitivity (Robson & Graham, 1981). Fixations to face stimuli are generally distributed within the central features: mostly the eyes, nose and mouth (Bindemann, Scheepers, & Burton, 2009; Haith, Bergman, & Moore, 1977; Janik, Wellens, Goldberg, & Dell'Osso, 1978; Yarbus, 1967). The pattern of gaze is functionally important for detecting emotional expressions: Asking healthy subjects to fixate away from the eye region worsens their ability to recognize facial emotions (Peterson & Eckstein, 2012; but also see Arizpe, Kravitz, Yovel, & Baker, 2012).

Studies of clinical populations impaired in detecting emotional expressions also commonly show disturbed gaze behavior. Patients with schizophrenia, autism and prosopagnosia demonstrate unusual fixation patterns while examining facial stimuli (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002; Schwarzer et al., 2007; Streit, Wolwer, & Gaebel, 1997). Adolphs et al. (2005) found that a patient with bilateral amygdala damage avoided fixating the eye region and was impaired at detecting fear in emotional faces. Asking this patient to directly fixate the eyes restored her recognition of fearful expressions to control levels. These findings suggest that orienting foveal vision to regions of the face with diagnostic emotional content has an important role in emotion recognition. The presence of altered fixation patterns in clinical populations, and evidence that normal variation in fixation patterns can be related to social functioning (e.g. autistic traits are associated with less frequent fixations to the eyes (Chen & Yoon, 2011; Freeth, Foulsham, & Kingstone, 2013)) imply an important mechanistic link between fixation patterns and emotion recognition.

Critically, abnormal fixation patterns in clinical populations do not disrupt detection of all emotions (Adolphs et al., 2005). Diagnostic emotional content of faces may not always reside in the eyes: The mouth, nose or brow may be important, depending on the emotion being examined (Blais, Roy, Fiset, Arguin, & Gosselin, 2012; Smith et al., 2005). The functional importance of the 'normal' pattern of fixations to face stimuli in emotion recognition is unknown. Eisenbarth and Alpers (2011) found a slightly greater preference for the mouth while viewing happy faces and an increased tendency to look toward the eyes of angry and sad faces in early fixations. This study suggested that fixations are somewhat biased to certain features, but did not assess if directing gaze to these regions benefitted emotion detection. Fixations may not necessarily reveal what visual information is being actively attended (Posner, 1980; Remington, 1980, although see Deubel & Schneider, 1996). Instead, we may fixate a point to maximize access to facial information using parafoveal vision rather than directly fixating the most informative features (Hsiao & Cottrell, 2008; Peterson & Eckstein, 2012).

These findings raise doubts about the importance of fixation patterns for emotion recognition, despite the circumstantial evidence from clinical populations. We suspect that task differences explain the inconsistent emphasis on fixation patterns in the literature: fixation to informative features might be more critical for recognizing subtle compared to extreme emotional expressions (Adolphs, 2002). While emotional changes in expression might require acute foveal vision when subtle, the emotional content of extreme expressions is visible at a parafoveal resolution.

In the current study we examined the role of fixations to facial features in emotion detection during free exploration of face stimuli by healthy participants. We developed a simple model to predict emotion detection scores using the weighted sum of participants' fixations to facial features. This model allowed us to examine how fixations to individual facial features contribute to emotion detection under different conditions. We hypothesized that directing fixations to features with greater diagnostic emotional content in high spatial frequencies would predict successful emotion recognition. We used an ideal observer analysis to determine the diagnostic emotional content of subtle and extreme emotional stimuli along a range of spatial frequencies. We predicted that the relevance of fixations to emotion detection would be greater in the recognition of subtle than extreme emotions, where the emotional content is present at lower frequencies, and might not require discrete foveal processing.

We also tested secondary questions, examining the effects of varying task demands (instructing participants to search for a specific emotion, or simply to categorize faces by emotion), emotional content (neutral versus afraid, disgusted, happy or surprised) and the signal strength of the expression (subtle versus extreme emotions) on fixation patterns.

2. Methods

2.1. Participants

Thirty-two participants volunteered for this study. Four were excluded either because they met exclusion criteria (history of psychiatric or neurological disease, head trauma, regular use of psychoactive drugs) or because eye-tracking data of sufficient quality could not be acquired. Of the remaining 28 participants, 18 were female, with a mean age of 24.57 years, *SD* = 4.8 years. The McGill University Research Ethics Board approved the study protocol and all participants gave written informed consent.

2.2. Apparatus

The experiment was programmed using E-Prime 1.2 (Psychology Software Tools, Inc., Pittsburgh, PA, USA). Participants' heads were stabilized using a headrest and stimuli were presented on a 19-inch monitor (Dell Inc., Round