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Face in profile view reduces perceived facial expression intensity: An eye-tracking study

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ABSTRACT

Recent studies measuring the facial expressions of emotion have focused primarily on the perception of frontal face images. As we frequently encounter expressive faces from different viewing angles, having a mechanism which allows invariant expression perception would be advantageous to our social interactions. Although a couple of studies have indicated comparable expression categorization accuracy across viewpoints, it is unknown how perceived expression intensity and associated gaze behaviour change across viewing angles. Differences could arise because diagnostic cues from local facial features for decoding expressions could vary with viewpoints. Here we manipulated orientation of faces (frontal, mid-profile, and profile view) displaying six common facial expressions of emotion, and measured participants' expression categorization accuracy, perceived expression intensity and associated gaze patterns. In comparison with frontal faces, profile faces slightly reduced identification rates for disgust and sad expressions, but significantly decreased perceived intensity for all tested expressions. Although quantitatively viewpoint had expression-specific influence on the proportion of fixations directed at local facial features, the qualitative gaze distribution within facial features (e.g., the eyes tended to attract the highest proportion of fixations, followed by the nose and then the mouth region) was independent of viewpoint and expression type. Our results suggest that the viewpoint-invariant facial expression processing is categorical perception, which could be linked to a viewpoint-invariant holistic gaze strategy for extracting expressive facial cues.

1 . Introduction

Facial expressions of emotion provide crucial visual cues for us to understand other people's emotional state and intention. The ability to recognize an individual's expression accurately and quickly, whilst at the same time assessing its intensity, plays a crucial role in our social communication and even survival (e.g., McFarland et al., 2013). Classical studies by Ekman and colleagues have suggested that each of six common facial expressions, such as happy, sad, fear, anger, disgust and surprise, represents one of our typical emotional states, is associated with distinctive pattern of facial muscle movements and is culturally similar (universal) among humans (Ekman & Friesen, 1976; Ekman & Rosenberg, 2005; see also Jack, Blais, Scheepers, Schyns, & Caldara, 2009). Our perception of facial expressions of emotion is therefore likely to be categorical, as we have a finite set of predefined expression classes and this category knowledge influences the perception (Ekman & Rosenberg, 2005). Similar to categorical colour and object perception, expression perception also demonstrates between-category advantage (Goldstone, 1994) with enhanced performance (e.g., accuracy, reaction time, discriminability) for discriminating expressive faces which span the categorical boundary compared to faces which do not cross the boundary (Fugate, 2013). An alternative to the categorical model is the continuous or dimensional model (Russell, 2003) in which each emotion is represented as a feature vector (e.g., pleasure–displeasure) in a multidimensional space given by some characteristics common to all emotions (e.g., arousal and valence). It is relatively easy for this model to justify the perception of less common expressions which share affective information, such as shame and confusion.

Considering that faces often appear under very different viewing conditions (e.g., brightness, viewing angle, or viewing distance), an invariant face representation in our visual system (within given limits) would be useful for efficient face perception and advantageous to our social interactions. Indeed, several recent psychological studies have demonstrated that varying resolution of face images (up to 10 × 15 pixels in which almost no useful local facial information is left for visual analysis; Du & Martinez, 2011), and manipulating presented face size to mimic viewing distance in typical social interactions (ranging from arm's length to 5 m; Guo, 2013), or changing face viewpoint from frontal view to profile view (Kleck & Mendolia, 1990; Matsumoto & Hwang, 2011; see also Hess, Adams, & Kleck, 2007; Skowronski, Milner, Wagner, Crouch, & McCanne, 2014) had little impact on expression categorization accuracy for the six common facial expressions,

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suggesting an invariant facial expression judgment under different viewing conditions.

These studies, however, only measured expression identification accuracy. It is unclear to what extent the perceived expression intensity is affected by viewing perspectives, such as from different viewing angles or viewpoints. Previous studies have clearly shown that different facial musculature patterns are associated with different facial expressions (Ekman & Friesen, 1976), and different local facial features transmit diagnostic information in recognizing different expressions (e.g., the eyes and mouth contain crucial cues for detecting angry and happy expressions, respectively) (Calvo & Nummenmaa, 2008; Smith, Cottrell, Gosselin, & Schyns, 2005). As the visible area of these facial musculature patterns and local facial features will vary according to horizontal viewing angles (e.g., frontal face may provide greater opportunity than profile face for detecting the lowering of inner eyebrows associated with angry expression), the perceived expression intensity could be sensitive to viewpoints.

Additionally, the expresser's head position can indicate focus of attention and consequently influence the interpretation of expressions in social context (Hess et al., 2007). For example, in comparison with profile view, we might be more sensitive to an angry face in frontal view because the associated aggression is more direct and consequently has a greater and imminent threat value to the viewer. Indeed, brain imaging studies have observed greater neural responses in amygdala to angry faces directed towards the observer compared with away (N'Diaye, Sandler, & Vuilleumier, 2009; Sato, Yoshikawa, Kochiyama, & Matsumura, 2004). Furthermore, given that different expressions could be associated with different functional value (e.g., angry and happy faces could signal threat and approachability, respectively) (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Hess et al., 2007), it is plausible they may show a different degree of vulnerability to viewpoints.

Taken together, the reported invariant facial expression perception could be due to categorical judgement of emotions, as the perceived facial structure differences across viewpoints may only affect expression intensity judgement rather than expression categorization. Alternatively, if facial expression perception can be accounted for by the continuous model (Russell, 2003) in which the expression intensity is intrinsically defined in the representation of emotion type, then both expression recognition accuracy and perceived expression intensity might be influenced by viewpoints, as expressive cues from local facial features could become ambiguous at some viewing angles (e.g., profile view) for both expression categorization and intensity judgement. This possibility will be systematically examined in this study.

At a close social distance, the faces falling in our visual field are large enough to elicit saccadic eye movements that provide a sensitive and real-time measure of visual processing. Coinciding with our behavioural sensitivity and expertise in processing facial expressions, our gaze pattern could reflect expert cognitive strategies for extracting diagnostic facial information in expression perception. When using full frontal expressive faces as stimuli, recent eye-tracking studies have observed that when categorizing facial expressions, participants tended to adopt a 'holistic' viewing strategy to integrate featural information from key internal facial features into a single representation of the whole face (Guo, 2012). Specifically, smaller faces would attract a stronger fixation bias to the central face region (e.g., nose area) to efficiently gather facial cues from surrounding features (e.g., eyes and mouth). For larger faces, if individual facial features were large enough to attract direction gaze, people would scan all key internal facial features (i.e. eyes, nose, and mouth) to extract and integrate expressive featural cues in order to reliably decode facial affects (Guo, 2012, 2013), but looked more often at local facial regions that are most characteristic for each facial expression, such as mouth in happy faces and eyes in angry faces (Eisenbarth & Alpers, 2011; Guo, 2012; Jack et al., 2009). It is unclear, however, whether this holistic but also expression-sensitive gaze pattern would also be viewpoint-invariant. If the holistic viewing behaviour is part of generic scanning strategy for general face processing (Guo, 2013), then viewpoint should not qualitatively affect our gaze distribution at key facial features. On the other hand, if the gaze allocation is mainly determined by current available local information (Eisenbarth & Alpers, 2011), then viewpoint-induced changes in visible area of internal facial features should systematically influence the amount of fixations directed at these features.

In this exploratory eye-tracking study we presented six common facial expressions of emotion (happy, sad, fearful, angry, disgusted, and surprised) at three different viewing angles (frontal, mid-profile, and profile view), and aimed to examine to what extent observers' expression categorization accuracy, perceived expression intensity, and associated gaze behaviour were affected by varying viewpoints. Built upon previous observation of emotion categorization at different viewing angles and gaze behaviour in processing expressive faces, we hypothesised there would be (1) an evident impact of viewpoint on expression judgement, at least on the perceived expression intensity; (2) an holistic face-viewing gaze distribution at all internal facial features with viewpoint quantitatively modifying the amount of fixations at each feature.

2 . Materials and methods

Thirty-two undergraduate students (11 male, 21 female), age ranging from 18 to 43 years old with the mean of 19.94 $\pm$ 4.34 (Mean $\pm$ SD), volunteered to participate in this study. All participants had normal or corrected-to-normal visual acuity. The Ethical Committee in School of Psychology, University of Lincoln approved this study. Written informed consent was obtained from each participant, and all procedures complied with the British Psychological Society Code of Ethics and Conduct and with the World Medical Association Helsinki Declaration as revised in October 2008.

Digitized grey-scale face images were presented through a ViSaGe graphics system (Cambridge Research Systems, UK) and displayed on a non-interlaced gamma-corrected colour monitor (30 cd/m^2 background luminance, 100 Hz frame rate, Mitsubishi Diamond Pro 2070SB) with the resolution of 1024 $\times$ 768 pixels. At a viewing distance of 57 cm, the monitor subtended a visual angle of 40° $\times$ 30°.

Western Caucasian face images were obtained from the Karolinska Directed Emotional Faces CD ROM (Lundqvist, Flykt, & Öhman, 1998). Five male and five female models were carefully chosen to ensure symmetrical distribution of internal facial features (i.e. eyes, nose, and mouth) on both hemifaces, and had no distinctive facial marks (e.g., moles) on each hemiface. Each of these models posed six high-intensity facial expressions (happy, sad, fearful, angry, disgusted, and surprised) at three different horizontal viewing angles: full-face frontal view, a left 45° mid-profile view, and a left profile view (see Fig. 1 for examples). As a result, 180 expressive face images (10 models $\times$ 6 expressions $\times$ 3 viewing angles) were generated for the testing session. Although they may have real-world limitations, and categorization performance for some expressions could be subject to culture influence, these well-controlled face images were chosen for their comparability and universality in transmitting facial expression signals, at least for our observer group (Western Caucasian adults). The faces were processed in Adobe Photoshop to ensure a homogenous grey background, brightness, and face size (369 $\times$ 500 pixels, 14.2° $\times$ 19.2°). As human vision follows an approximate gamma function, with greater sensitivity to relative luminance differences between darker tones than between lighter ones, these images were gamma corrected to ensure a natural shades appearance as seen by human eyes. During the testing, the face images were displayed once in a random order.

All of our participants were aware of 'universal' facial expressions. Before the testing, they were shown a PowerPoint presentation containing one male and one female model posing happiness, sadness, fear, anger, disgust, and surprise (sampled from Pictures of Facial Affect), and were asked to label each facial expression as carefully as possible