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ORIGINAL ARTICLE

Facial expression recognition in peripheral versus central vision: role of the eyes and the mouth

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Abstract This study investigated facial expression recognition in peripheral relative to central vision, and the factors accounting for the recognition advantage of some expressions in the visual periphery. Whole faces or only the eyes or the mouth regions were presented for 150 ms, either at fixation or extrafoveally (2.5° or 6°), followed by a backward mask and a probe word. Results indicated that (a) all the basic expressions were recognized above chance level, although performance in peripheral vision was less impaired for happy than for non-happy expressions, (b) the happy face advantage remained when only the mouth region was presented, and (c) the smiling mouth was the most visually salient and most distinctive facial feature of all expressions. This suggests that the saliency and the diagnostic value of the smile account for the advantage in happy face recognition in peripheral vision. Because of saliency, the smiling mouth accrues sensory gain and becomes resistant to visual degradation due to stimulus eccentricity, thus remaining accessible extrafoveally. Because of diagnostic value, the smile provides a distinctive single cue of facial happiness, thus bypassing integration of face parts and reducing susceptibility to breakdown of configural processing in peripheral vision.

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Introduction

This study investigated whether emotional facial expressions can be accurately identified in peripheral vision, how much recognition is impaired relative to central vision, and what mechanisms account for the recognition advantage of some expressions. In most of the prior studies, the face stimuli have been presented at fixation and thus available to foveal vision. However, little is known about facial expression processing in the visual periphery before the faces are fixated. This issue is theoretically important because it deals with the processing of social signals outside the focus of overt attention with the low-resolution peripheral retina, the extent to which expression encoding is affected by stimulus eccentricity, and how much recognition performance varies with type of expression under impoverished perceptual conditions. This issue has also practical implications because, in real-life social settings, faces often appear initially in the visual periphery, among other objects or within a group of people. It would thus be highly beneficial if the cognitive system could extract expression information before the eyes land on the face: This would facilitate early attentional selection, orienting to, and processing of the most relevant faces among the multiple, simultaneously occurring stimuli, and, as a consequence, allow viewers to react promptly with preparatory adaptive behavior to important social cues.

Despite coarse visual acuity, processing can be accomplished surprisingly accurately in extrafoveal vision (between 2.5° and 40° away from the current eye fixation; i.e., in parafoveal or peripheral vision; see Wandell, 1995).

A number of previous studies have shown that both semantic categorization and emotional evaluation (see Nummenmaa, Hyönä, & Calvo, 2010) can be performed when complex visual scenes, and pictures of objects and animals are presented extrafoveally, using behavioral (e.g., Kirchner & Thorpe, 2006; Calvo, Nummenmaa, & Hyönä, 2008), and neurophysiological (e.g., De Cesarei, Codispoti, & Schupp, 2009; Rigoulot et al., 2008) measures. There is also evidence of extrafoveal vision of emotional *facial expressions* using behavioral (Calvo, Nummenmaa, & Avero, 2010; Goren &Wilson, 2006) and neurophysiological (Bayle, Schoendorff, Henaff, & Krolak-Salmon, 2011; Rigoulot et al., 2011; Rigoulot, D'Hont, Honoré, & Sequeira, 2012; Stefanics, Csukly, Komlósi, Czobor, & Czigler, 2012) measures. Nevertheless, prior work has tested extrafoveal processing of only a limited number of emotional expressions (mainly, fearful and neutral), and often a foveal display condition was not included for comparison. In the current study, we extended prior research by assessing recognition speed and accuracy of all six 'basic 'emotional expressions (i.e., fear, anger, sadness, disgust, surprise, and happiness) under three stimulus eccentricity conditions encompassing central, parafoveal, and peripheral vision. This allowed us to quantify how much extrafoveal—relative to foveal—processing is impaired, depending on the type of expression.

Recognition advantage of happy faces in central vision

An advantage in the recognition of happy faces has been reported in prior research in categorization tasks: Happy expressions are identified more accurately and faster than all the other basic facial expressions of emotion (Calder, Young, Keane, & Dean, 2000; Calvo & Lundqvist, 2008; Leppänen & Hietanen, 2004; Loughead, Gur, Elliott, & Gur, 2008; Palermo & Coltheart, 2004; Svärd, Wiens, & Fischer, 2012; Tottenham et al., 2009). The advantage has been replicated with different stimulus sets, such as the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998; e.g., Calvo & Lundqvist, 2008), the Pictures of Facial Affect (Ekman & Friesen, 1976; e.g., Leppänen & Hietanen, 2004), the NimStim Stimulus Set (Tottenham, Borscheid, Ellersten, Marcus, & Nelson, 2002; e.g., Tottenham et al., 2009), and a combination of them (Palermo & Coltheart, 2004). This advantage also holds across different response systems (manual: Calvo & Lundqvist, 2008; verbal: Palermo & Coltheart, 2004; and saccadic: Calvo & Nummenmaa, 2009). Furthermore, happy faces can be recognized with shorter exposures than other expressions (Calvo & Lundqvist, 2008; Esteves & Öhman, 1993; Milders, Sahraie, & Logan, 2008), are less effectively pre- and/or post-masked (Maxwell & Davidson, 2004; Milders et al., 2008; Stone & Valentine, 2007), and have perceptual dominance during binocular rivalry (Yoon, Hong, Joorman, & Kang, 2009).

Affective information is not distributed uniformly in the face, and in general human observers use the mouth more than the eyes to discriminate facial expressions (Blais, Roy, Fiset, Arguin, & Gosselin, 2012). While there is some agreement that recognition of angry and fearful faces depends more on information in the eye region, that disgust is conveyed mainly by the mouth, and that sadness and surprise may be similarly recognizable from both regions, there is consensus that the smiling mouth is both necessary and sufficient for recognizing happy expressions (Calder et al., 2000; Calvo & Marrero, 2009; Kohler et al., 2004; Leppänen & Hietanen, 2007; Nusseck, Cunningham, Wallraven, & Bülthoff, 2008; Smith, Cottrell, Gosselin, & Schyns, 2005). This is highlighted in the Calder et al. (2000) study, which reported that happy expressions can be recognized from the bottom half of the face (with the mouth) as accurately (1 % of errors) as and even faster than when the whole face was shown, and that they are recognized more accurately than any other expression from either the top or bottom half. In contrast, recognition of happiness from the top half (with the eyes) was much less accurate (20 % of errors) and significantly slower. Nevertheless, although expressive changes in the eye region are not necessary or sufficient for the *categorization* of faces as happy, the eyes are important for the *affective* processing of a smile as positively valenced and for judging genuine happiness (Calvo, Fernández-Martín, & Nummenmaa, 2012; Johnston, Miles, & Macrae, 2010; McLellan, Johnston, Dalrymple-Alford, & Porter, 2010).

Mechanisms involved in a happy face recognition advantage

The happy face recognition superiority can be attributed to two properties of the smiling mouth: perceptual salience or visual conspicuousness, and categorical distinctiveness or diagnostic value. *Saliency* is a computationally derived index of the visual prominence of an image region in relation to its surroundings, and it is defined as a combination of physical image properties such as luminance, contrast, and spatial orientation (Borji & Itti, 2013; Itti & Koch, 2000; see also Torralba, Oliva, Castelhano, & Henderson, 2006). Calvo and Nummenmaa (2008) found that the smiling mouth is in fact more salient, and captures the viewers' initial fixation more likely, than any other region of happy and non-happy faces. In addition, local saliency differences between the smiling mouth and those of other expressions are more predictive of quick discrimination performance between happy and non-happy faces than differences in other properties such as global low-level image statistics, categorical information, and affective valence are (Calvo & Nummenmaa, 2011). Presumably, saliency makes the smiling mouth readily accessible to the visual system due to increased sensory gain, and the smiling mouth can thus successfully compete with other facial areas for early attentional capture and processing. In contrast, for non-happy faces, the lower saliency of the respective diagnostic features would allow for more attentional competition.

Categorical *distinctiveness* refers to the degree that a facial feature is unambiguously associated with a particular expression category. High distinctiveness, thus, allows viewers to accurately classify an expression into a specific category with minimal interference among various alternatives. The smile is systematically and uniquely associated with the expression of happiness, whereas other facial features overlap to some extent across different expression categories (Calvo & Marrero, 2009; Kohler et al., 2004). The smile becomes diagnostic of facial happiness because the smile implies (or leads observers to infer) that the expresser is happy (although being happy does not imply that the expresser should necessarily smile). Being a single diagnostic feature, the smile can be used as a shortcut for a quick and accurate feature-based categorization of a face as happy (Adolphs, 2002; Leppänen & Hietanen, 2007). In contrast, recognition of non-happy expressions would require configural processing of particular combinations of facial features, which would make the recognition process slower and more prone to errors. In sum, the visual saliency and distinctiveness of a smile would jointly yield a processing advantage of happy faces: An early attentional selection of the most diagnostic facial cue is first secured and subsequently enhanced by visual saliency of the smile.

The current study: facial expression recognition in peripheral vision

From the above review, we can predict that the recognition of happy expressions will be less impaired in peripheral relative to central vision than the other expressions. Furthermore, the relative recognition superiority of happy over non-happy faces will increase with stimulus eccentricity. The rationale is based on the two critical properties of the smile that we have considered. First, the high visual saliency and subsequent sensory amplification of the smile make it resistant to acuity degradation at eccentric locations of the visual field. As a result, smiles are expected to remain accessible to covert attentional processing in low-resolution extrafoveal vision. Second, the highly diagnostic value of the smile ensures that facial happiness can be recognized from a single expressive feature, without the need of configural processing of the whole face. Expression recognition in peripheral vision is thought to be impaired because of breakdown of configural processing mechanisms (Goren &Wilson, 2006), as the loss of visual acuity prevents the viewer from integrating facial components holistically. Accordingly, if the happy expression recognition depends on feature analysis of a diagnostic and salient mouth, the breakdown of configural processing should have minimal effects on happy face recognition in peripheral vision. In contrast, the recognition of other expressions will be more impaired depending on the extent that they lack a salient and diagnostic single feature and how much their processing relies on the configural mechanism.

We tested these predictions in two experiments. In Experiment 1, whole-face stimuli showing each of the six basic emotional expressions were presented either centrally (at fixation), parafoveally (2.5° away from fixation), or peripherally (6° away from fixation) for 150 ms, followed by a backward mask. In such conditions, only the central face can be foveally fixated (see Calvo et al., 2010). In a categorization task, a probe word appeared following the mask, and participants responded whether or not the word represented the preceding facial expression. This paradigm allowed us to compare the effects of eccentricity depending on the type of expression. Experiment 2 investigated the role of the eyes and the mouth in the recognition of facial expressions in peripheral vision. To this end, we presented *only* the *eye* or the *mouth* region, either at fixation or peripherally. To the extent that the recognition advantage of any expression (e.g., happy) depends on the eyes or the mouth, a lesser impairment will occur in peripheral relative to central vision when the eyes or the mouth regions are presented alone. In addition, we assessed the diagnostic value of eyes and the mouth by comparing recognition performance when each of these regions was presented alone relative to when the whole face was displayed. Finally, we computed the visual saliency of the eye and mouth regions to examine the hypothesis that the happy face advantage could be attributed to this perceptual property.

Experiment 1

Method

Participants

Eighty-one psychology undergraduates (19–24 years old; 65 female) at the University of La Laguna participated for course credit.

Stimuli

We selected 180 digitized color photographs from the KDEF (Lundqvist et al., 1998) stimulus set. The *target* face stimuli portrayed 30 individuals (15 females: KDEF nos. 01, 02, 03, 05, 07, 09, 11, 13, 14, 19, 20, 26, 29, 31, 33; and 15 males: KDEF nos. 03, 05, 06, 08, 10, 11, 12, 13, 22, 23, 25, 29, 31, 34, 35), each posing six expressions (happiness, anger, sadness, disgust, surprise, and fear). Each photograph was cropped: Non-facial areas (e.g., hair, neck, etc.) were removed by applying an ellipsoidal mask. Each face subtended a visual angle of 8.5° (height) × 6.4° (width) at a 60-cm viewing distance, and was presented against a black background.

In addition to the target face, a Fourier-phase scrambled neutral face was used to balance the visual display. This scrambled face was presented lateralized on each trial at the same time as the target face (see Fig. 1). Such a balanced display ensured that the mere abrupt onset of the target face in the extrafoveal presentation conditions did not serve as an exogenous singleton cue potentially attracting overt attention. In addition, the scrambled face was used as a backward mask.

Apparatus and procedure

The stimuli were presented on a SVGA 17″ monitor with a 100-Hz refresh rate connected to a computer. The E-Prime software controlled stimulus presentation and response collection. A forehead and chin rest was used at 60-cm viewing distance from the screen.

Each trial (see Fig. 1) began with a central fixation cross for 500 ms, followed by a target face for 150 ms. The target face appeared either at the center of the screen (foveal display condition) or to the left or the right (50 % on each side, both in the parafoveal and peripheral conditions). The scrambled face appeared (a) to the left or the right (50 % of trials on each side) of the central target face (foveal condition), or (b) in the opposite side of the parafoveal and the peripheral target faces (i.e., left visual field, if the target face was on the right, and vice versa). The target and the scrambled face were then replaced with a backward mask for 150 ms. Finally, a probe word was displayed at the center of the screen. The participant responded whether or not this word represented the expression conveyed by the prime face, by pressing one of two keys. Response latencies were time locked to the onset of the probe word.

Each participant was presented with 180 experimental trials in three blocks, randomly, after 24 practice trials. All the participants saw the 30 KDEF photographs of each of the six expressive categories, with 10 photographs of different individuals (5 females and 5 males) of each category per block. For all the participants, all the faces of all six categories appeared as primes followed by a probe word representing either the same expression (5 times per category and block) as the prime face or a different expression (5 times per category and block). Each participant was presented with 90 *same* prime-probe trials (i.e., happy face—'*happy*' word), and another 90 *different* prime-probe trials (i.e., happy face—'*angry*', etc., word). The *same* and the *different* trials were combined randomly for each participant. Responses on the *same* prime-probe trials served to measure hits; those on *different* prime-probe trials assessed false alarms.

Design and measures

We used a mixed experimental design where face *location* was manipulated between subjects and facial *expression* was a within-subject factor. Location involved three levels (foveal: at fixation; parafoveal: with the face inner edge

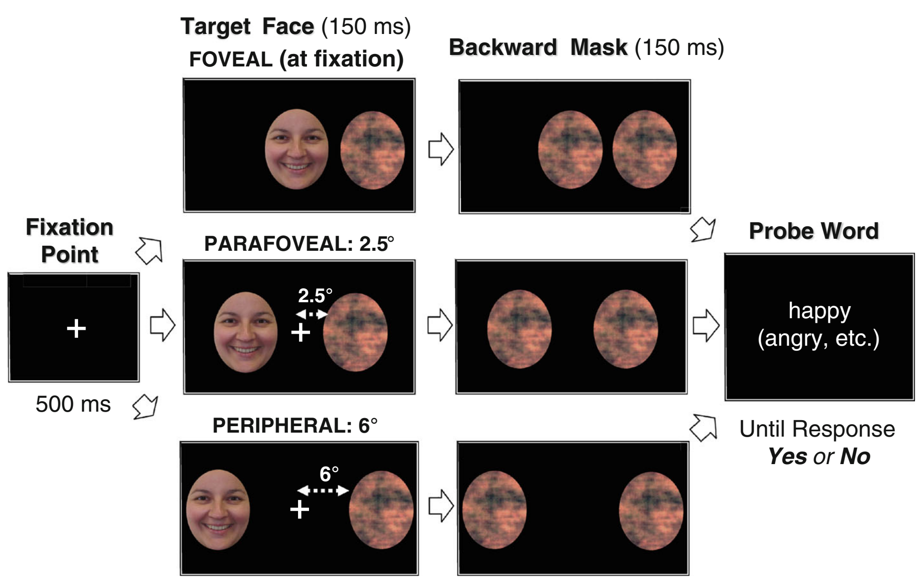

Fig. 1 Sequence of events and overview of basic characteristics of a trial in Experiment 1. For copyright reasons, a different face stimulus is shown in the figure, instead of the original KDEF pictures

located 2.5° away from the central fixation cross, i.e., 5.7° to the center of the face; and peripheral: with the face inner edge at 6° from fixation, i.e., 9.2° to the center of the face), and 27 participants at each level. Expression involved six categories (happy, angry, sad, disgusted, surprised, fearful). Prior eye-movement research using equivalent spatial and temporal (150 ms display) parameters has confirmed that, in such conditions, the parafoveal and peripheral faces cannot be fixated, although they remain extrafoveally available to covert attention (Calvo et al., 2010).[1]

Recognition accuracy measures and correct response reaction times were collected. The probability of hits (PH; correct recognition of the facial expression, e.g., responding "sad" when the face was sad) and false alarms (PFA; incorrect responses, e.g., responding "sad" when the face was fearful) were converted to the non-parametric A' index of sensitivity (see Snodgrass & Corwin, 1988), where $A' = 0.5 + (\mathrm{PH} - \mathrm{PFA}) \times (1 + \mathrm{PH} - \mathrm{PFA})/(4 \times \mathrm{PH}) \times (1 - \mathrm{PFA})$. A' scores vary from low to high sensitivity in a 0–1 scale, where 0.5 represents the chance level.

Assessment of perceptual attributes of face stimuli: global low-level image properties and local visual saliency

Various models have proposed that basic image properties and local visual saliency influence initial shifts of covert and overt attention (see Borji & Itti, 2013; Itti & Koch, 2001). Empirical work has confirmed that attentional orienting is affected by the image physical properties (e.g., luminance or energy: Calvo & Nummenmaa, 2011; Kirchner & Thorpe, 2006) and saliency weights (Calvo & Nummenmaa, 2008; Underwood & Foulsham, 2006). To examine potential differences between expressions, we first computed the global low-level image statistics of each face as a whole (mean and variance in luminance, RMS or root mean square contrast, skewness, kurtosis, and energy) with Matlab 7.0 (The Mathworks, Natick, MA). In addition, local visual saliency of three main face regions (eye, nose/cheek, and mouth; each region subtended 1.7°, vertically) was modeled by means of the iLab Neuromorphic Vision C+ Toolkit algorithm (e.g., Itti, 2006; Walther & Koch, 2006). Figure 2 illustrates how the face areas were defined for the computation of saliency.

[1] In the Calvo et al. (2010) study using a 150-ms display, saccades were *initiated* from the central fixation point towards the target face on 5.8 % of trials. This implies that most saccade latencies were longer than 150 ms. Crucially, the probability that a saccade actually *landed* on the face was negligible (0.2 % of trials), and there were no differences as a function of expression. This allows us to rule out the hypothesis that the effects found in the current study could be due to foveal fixations on the faces.

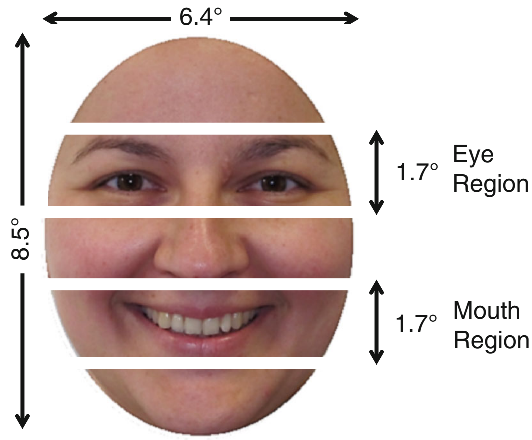

Fig. 2 Area covered by the eye region, the nose/cheek region, and the mouth region, of which the visual saliency was computed

Results

We conducted 3 (face location) × 6 (facial expression) ANOVA on A' scores and reaction times of correct responses. Given that the A' *sensitivity* index combines the proportion of hits and false alarms, we will only report the analysis of A' scores and reaction times (hit and false alarm rates will be presented in Table 1). Bonferroni corrections and alpha level of $p < 0.05$ were used for all post hoc multiple contrasts in this and the following experiment. The meaning of the main effects and the contrasts between experimental conditions is indicated in the tables and figures by means of letters attached to the average scores for each condition.

For A' *sensitivity scores,* the main effects of expression, $F(5,390) = 22.43$, $p < 0.0001$, $\eta_p^2 = 0.223$, and location, $F(2,78) = 26.28$, $p < 0.0001$, $\eta_p^2 = 0.403$, were qualified by an expression by location interaction, $F(10,390) = 2.35$, $p = 0.011$, $\eta_p^2 = 0.057$. One-way (location) ANOVA for each expression revealed a significant decrease in A' scores as a function of eccentricity for all (Fs ≥ 6.5, all ps < 0.01) except for happy faces ($F < 1$; see the contrasts in Fig. 3). Not only was sensitivity for happy faces significantly higher than for all the other expressions, but it was not reliably affected by eccentricity. One-way (expression) ANOVA for each location, followed by post hoc multiple contrasts (all ps < 0.05), revealed significantly higher scores for happy than for fearful, angry, and sad faces in the foveal condition, $F(5,130) = 11.08$, $p < 0.0001$, $\eta_p^2 = 0.299$, and higher scores for happy than for all the other expressions in both the parafoveal, $F(5,130) = 9.12$, $p < 0.0001$, $\eta_p^2 = 0.260$, and the peripheral condition, $F(5,130) = 8.82$, $p < 0.0001$, $\eta_p^2 = 0.253$. All the A' scores were above the 0.5 chance level (all ts > 2.4, $p < 0.025$). A significant linear relationship

Table 1 Mean probability of hits and false alarms (FAs), and reaction times of correct responses (RTs), as a function of type of emotional expression and face stimulus location, in Experiment 1

Variable	Type of expression						
	Happy	Surprised	Disgusted	Sad	Angry	Fearful	Mean
HITS							
Foveal	0.963	0.930	0.901	0.844	0.863	0.750	0.875a
Parafoveal	0.941	0.847	0.775	0.724	0.746	0.615	0.775b
Peripheral	0.913	0.774	0.673	0.629	0.623	0.549	0.695c
Mean	0.939a	0.851b	0.783bc	0.732c	0.746c	0.638d	
FAs							
Foveal	0.063	0.106	0.084	0.096	0.106	0.181	0.106a
Parafoveal	0.063	0.153	0.239	0.157	0.253	0.238	0.184b
Peripheral	0.059	0.231	0.254	0.218	0.283	0.282	0.221b
Mean	0.062a	0.163b	0.192bc	0.157b	0.214bc	0.234c	
RTs							
Foveal	685	859	960	924	924	1,066	903a
Parafoveal	738	941	1,060	1,002	1,038	1,120	983ab
Peripheral	774	997	1,110	1,078	1,100	1,182	1,040b
Mean	732a	932b	1,043c	1,001bc	1,021bc	1,123d	

Mean scores with a different letter (horizontally, for type of expression; vertically, for location) are significantly different; means sharing a letter are equivalent

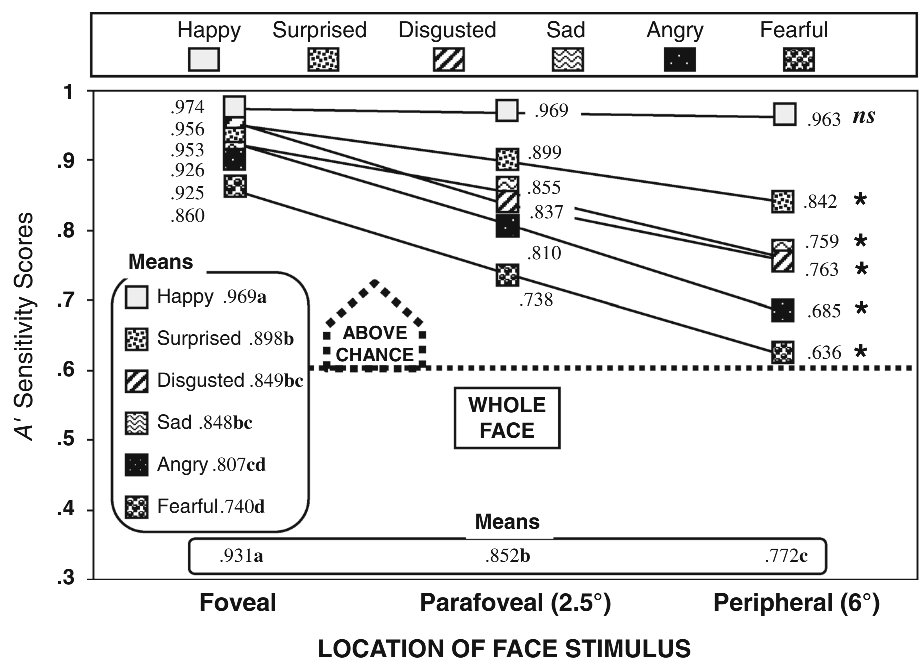

Fig. 3 Mean A' recognition sensitivity scores as a function of type of expression and presentation location in the whole-face condition. Letters *a* to *d* indicate the main effects of type of expression and location. Mean scores with a different letter are significantly different; means sharing a letter are equivalent. *Asterisk* vs. ns: significant vs. non-significant differences between foveal and peripheral location conditions for each expression

between eccentricity and A' scores—indicating a progressive recognition performance impairment—emerged for all the expressions (average: $R^2 = 0.192$, beta regression coefficient $= -0.435$, $t = 4.30$, $p < 0.0001$), except for happy faces ($R^2 = 0.014$, $\beta = -0.120$, $t = 1.07$, $p = 0.29$, ns). Mean scores and significant differences between conditions are shown in Fig. 3.

Reaction times for correct responses were influenced by expression, $F(5,390) = 57.65$, $p < 0.0001$, $\eta_p^2 = 0.424$, and location, $F(2,78) = 5.37$, $p < 0.01$, $\eta_p^2 = 0.121$, but not by the interaction ($F < 1$). As indicated in Table 1, responses to happy faces were the fastest, although they were affected by eccentricity in a similar fashion to that of the other expressions. To control for the effect of probe

Table 2 Mean low-level image statistics of the whole face, and visual saliency values of the mouth, nose/cheek, and eye regions for each facial expression

Variable	Type of Expression					
	Happy	Surprised	Disgusted	Sad	Angry	Fearful
Image statistics						
M luminance	71	69.8	68.2	69.6	70.2	68.9
SD luminance	58.3	57.7	56.2	56.8	57.2	56.8
RMS contrast	0.823	0.829	0.826	0.818	0.818	0.827
Skewness	0.625	0.623	0.636	0.606	0.597	0.628
Kurtosis	2.50	2.51	2.53	2.47	2.46	2.50
Energy ($\times 10^{-7}$)	2.279	2.292	2.180	2.177	2.193	2.214
Visual saliency						
Eye region	0.49b	2.94a	1.91a	2.73a	2.50a	2.71a
Nose/cheek region	0.10	1.11	0.91	1.12	1.15	0.89
Mouth region	8.33a	5.77b	5.59b	2.17c	3.69bc	4.12b

Mean scores with a different letter (horizontally, for type of expression) are significantly different; means sharing a letter (or no letter) are equivalent

words on the observed reaction times in the recognition of *facial expressions*, such words were presented alone (without the faces) in a separate experiment with 24 new participants performing a word–nonword lexical-decision task (see Calvo et al., 2010). No reaction time differences emerged as a function of type of word. This implies that the differences in recognition latencies across expressions in the current experiments were not due to differences in the processing of the probe words.

Analysis of global image statistics and local visual saliency

Table 2 shows the mean scores of global image properties of each face as a whole, as well as those of local saliency of the eye, nose/cheek, and mouth regions. The *low-level image* measures were analyzed by means of one-way (6: expression) ANOVA. The analyses showed no significant differences between expression categories in any of these image properties: Fs < 1, for mean luminance, RMS contrast, skewness, and kurtosis; $F(5,174) = 1.26$, $p = 0.28$, ns, for the variations (SD) in luminance; and, $F(5,174) = 2.01$, $p = 0.080$, ns (all ps > 0.36, after Bonferroni corrections) for energy.

A 6 (expression) × 3 (region) ANOVA on *visual saliency* values yielded main effects of expression, $F(5,145) = 5.56$, $p < 0.001$, $\eta_p^2 = 0.161$, and region, $F(2,58) = 74.31$, $p < 0.0001$, $\eta_p^2 = 0.719$, and an interaction, $F(10,290) = 11.63$, $p < 0.0001$, $\eta_p^2 = 0.286$. To decompose the interaction, separate one-way (expression) ANOVA was conducted for each region. For the *eye* region, effects of expression, $F(5,145) = 5.09$, $p < 0.001$, $\eta_p^2 = 0.149$, revealed that the eyes of happy faces were *less* salient than those of all the other faces, which were equivalent. No significant effects emerged on the *nose/cheek* region, $F(5,145) = 1.54$, $p = 0.20$, ns, with all the expressions being equivalent. For the *mouth* region, effects of expression, $F(5,145) = 17.19$, $p < 0.0001$, $\eta_p^2 = 0.372$, indicated that the mouth of happy faces was *more* salient than that of all the other faces. There were, in addition, some mouth saliency differences among the other expression categories, as indicated in Table 2.

Discussion

Experiment 1 yielded three major findings. First, recognition performance (A' *sensitivity* scores) was above chance level for all expressions and locations, which reveals that facial expressions can be recognized reasonably accurately in extrafoveal vision. Second, there was a linear decline in recognition performance as a function of increasing visual eccentricity. This confirms the validity of our location manipulation, and is consistent with the well-known fact that perceived object details progressively fade out as they appear farther apart from fixation. Third, A' scores were higher and reaction times were shorter for happy than for all the other expressions in peripheral (and also in parafoveal and foveal) vision. Importantly, such an advantage did not involve any reduction of A' scores for happy faces in peripheral relative to central vision, but rather an impairment for the other expressions.

The latter finding is specifically related to the aims and hypotheses of the current study. Why should happy faces have an even greater recognition advantage in peripheral relative to central vision? We have argued that resistance to impairment in peripheral vision can be due to their having a visually salient—thus more resistant to acuity degradation—single feature, which is also highly diagnostic—thus more resistant to configural processing disruption—of the happiness expression. The smiling mouth is assumed to be such a critical feature. In Experiment 1, the mouth of happy faces indeed proved to be especially salient. In contrast, there were no saliency differences between expressions in the eye or the nose/cheek region, or differences in basic image properties (luminance, energy, etc.) of the face as a whole.

Experiment 2

Having established the saliency-driven peripheral recognition advantage of happy faces in Experiment 1, we investigated the role of diagnostic value of smiles in Experiment 2. To this end, we examined how accurately facial expressions can be identified from the *mouth* or the *eyes alone*, relative to the whole face, in peripheral vs. central vision. As all the participants belonged to the same pool, and were randomly assigned, we could compare recognition performance in the whole-face (Experiment 1) and the eye- or mouth-only conditions (Experiment 2). If the smiling mouth is highly diagnostic of facial happiness, and the recognition advantage is due to such a diagnostic value, then, in peripheral vision (a) happy expressions will be recognized from the mouth better than other expressions are from the mouth or the eyes, and, (b) recognition performance will be minimally impaired in peripheral relative to central vision when the smiling mouth is presented alone, in comparison with the whole face.

Method

Participants

One hundred and eight (80 female) psychology undergraduates (aged from 19 to 24 years old) participated in this experiment.

Stimuli, design, procedure, and measures

The face stimuli used in Experiment 1 were modified as follows: Only the eye region or only the mouth region was presented. Each region subtended 1.7° in height (20 % of the whole face) by 6.4° in width (same size as in Experiment 1). Figure 4 illustrates how stimuli appeared in the eye and mouth displays. The procedure and measures were identical to those in Experiment 1 in all other respects. The experimental design involved a factorial combination of expression category (6: happy, surprised, disgusted, sad, fearful, and angry), stimulus location (2: central vs. peripheral) by face format (2: eyes vs. mouth), with expression as a within-subjects factor, and location and format as between-subjects factors (with 27 participants in each combination of conditions, randomly assigned).

Results

Overall ANOVA

A' scores and correct response reaction time data were initially analyzed by means of 6 (expression) × 2 (location) × 2 (format) ANOVA. Given the multiple significant effects on the various dependent variables, we will focus on the meaning of the interactions (as they qualify the main effects).

For the A' *sensitivity* index, in addition to effects of expression, $F(5,520) = 8.95$, $p < 0.0001$, $\eta_p^2 = 0.079$, location, $F(1,104) = 140.03$, $p < 0.0001$, $\eta_p^2 = 0.574$, and format, $F(1,104) = 4.34$, $p = 0.040$, $\eta_p^2 = 0.040$, and an expression by format interaction, $F(5,520) = 20.94$, $p < 0.0001$, $\eta_p^2 = 0.168$, the ANOVA revealed a three-way interaction, $F(5,520) = 6.30$, $p < 0.001$, $\eta_p^2 = 0.057$. For *reaction times*, effects of expression, $F(5,520) = 25.67$, $p < 0.0001$, $\eta_p^2 = 0.198$, and location, $F(1,104) = 15.35$, $p < 0.0001$, $\eta_p^2 = 0.129$, were qualified by an expression by format interaction, $F(5,520) = 39.40$, $p < 0.0001$, $\eta_p^2 = 0.275$. Tables 3 and 4 show the mean reaction times, in addition to the hit and false alarm scores. The three-way interaction on A' scores is shown in Figs. 5 and 6.

Analysis of the eye-only and the mouth-only conditions

To decompose the three-way interactions on A' scores and the two-way interaction on reaction times, 6

Fig. 4 Illustration of the different face stimulus format in the whole-face, eye region, and mouth region conditions

Table 3 Mean probability of hits, false alarms (FAs), and reaction times of correct responses (RTs), as a function of type of emotional expression and face stimulus location, in the eye region only condition (Experiment 2)

Variable	Type of expression						
	Happy	Surprised	Disgusted	Sad	Angry	Fearful	Mean
HITS							
Central	0.641	0.811	0.662	0.621	0.825	0.701	0.710a
Peripheral	0.393	0.658	0.452	0.393	0.666	0.526	0.509b
Mean	0.517c	0.734a	0.557bc	0.507c	0.745a	0.613b	
FAs							
Central	0.205	0.121	0.265	0.250	0.181	0.182	0.201a
Peripheral	0.315	0.254	0.327	0.335	0.210	0.287	0.288b
Mean	0.260c	0.187a	0.296cd	0.292cd	0.195ab	0.234bc	
RTs							
Central	890	813	974	952	828	911	895a
Peripheral	1,086	939	1,117	1,078	874	966	1,010b
Mean	988bc	876ab	1,045c	1,015c	851a	938b	

Mean scores with a different letter (horizontally, for type of expression; vertically, for location) are significantly different; means sharing a letter are equivalent

Table 4 Mean probability of hits, false alarms (FAs), and reaction times of correct responses (RTs), as a function of type of emotional expression and face stimulus location, in the mouth region only condition (Experiment 2)

Variable	Type of expression						
	Happy	Surprised	Disgusted	Sad	Angry	Fearful	Mean
HITS							
Central	0.961	0.804	0.811	0.755	0.676	0.562	0.762a
Peripheral	0.891	0.700	0.642	0.595	0.423	0.356	0.601b
Mean	0.926a	0.752b	0.726bc	0.675b	0.549c	0.459c	
FAs							
Central	0.098	0.128	0.141	0.181	0.279	0.197	0.171a
Peripheral	0.144	0.182	0.276	0.225	0.430	0.320	0.263b
Mean	0.121a	0.155ab	0.208bc	0.203bc	0.354d	0.258cd	
RTs							
Central	603	792	904	866	976	1,111	875a
Peripheral	693	879	1,005	957	1,227	1,262	1,004b
Mean	648a	835b	954c	911bc	1,101d	1,186d	

Mean scores with a different letter (horizontally, for type of expression; vertically, for location) are significantly different; means sharing a letter are equivalent

(expression) $\times$ 2 (location) ANOVA was conducted for each format separately.

In the *eye* format condition, for A' *sensitivity*, effects of expression, $F(5,260) = 8.22$, $p < 0.0001$, $\eta_p^2 = 0.137$, and location, $F(1,52) = 50.90$, $p < 0.0001$, $\eta_p^2 = 0.495$, emerged, with no significant interaction ($F = 2.00$, $p = 0.098$). A' scores were higher for surprised and angry faces than for most of the other expressions, and impairments in A' *sensitivity* occurred in peripheral relative to central vision for all expressions. One-sample t tests indicated that scores were above the 0.5 chance level for angry, surprised, and fearful faces (all $ts > 2.6, ps < 0.025$), but not for the others. See the mean A' scores in Fig. 5. For *reaction times*, only the effects of expression, $F(5,260) = 8.61$, $p < 0.0001$, $\eta_p^2 = 0.142$, and location, $F(1,52) = 7.71$, $p = 0.008$, $\eta_p^2 = 0.129$, reached statistical significance. Responses were faster when the eye region was displayed in central than in peripheral vision conditions, and were faster for angry eyes than for all the others, except the surprised eyes. See the mean RT scores in Table 3.

In the *mouth* condition, for A' *sensitivity* scores, the effects of expression, $F(5,260) = 22.49$, $p < 0.0001$,

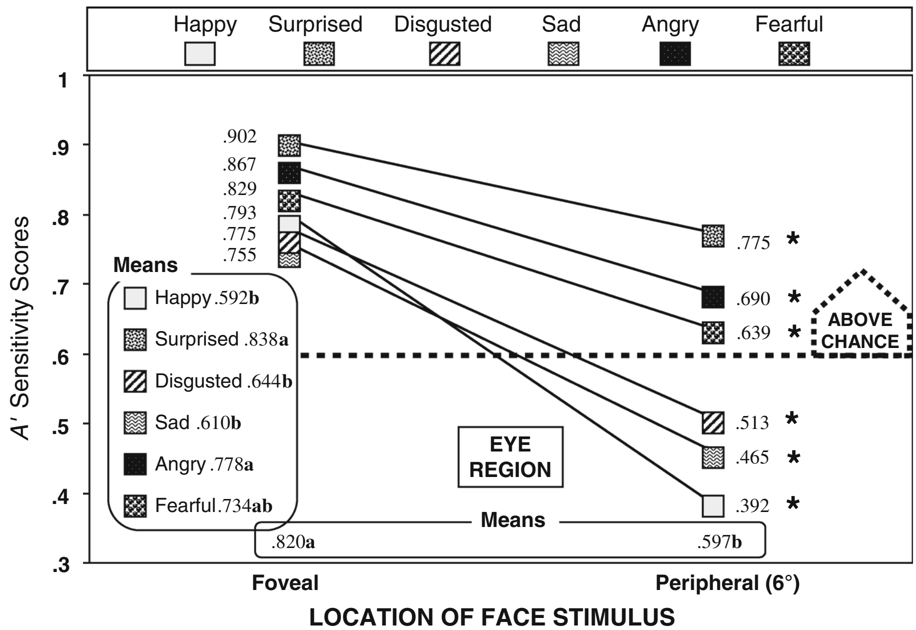

Fig. 5 Mean A' recognition sensitivity scores as a function of type of expression and presentation location in the eye region condition. Letters *a* and *b* indicate the main effects of type of expression and location. Mean scores with a *different letter* are significantly different; means sharing a letter are equivalent. *Asterisk* indicates significant differences between the foveal and the peripheral condition for each expression

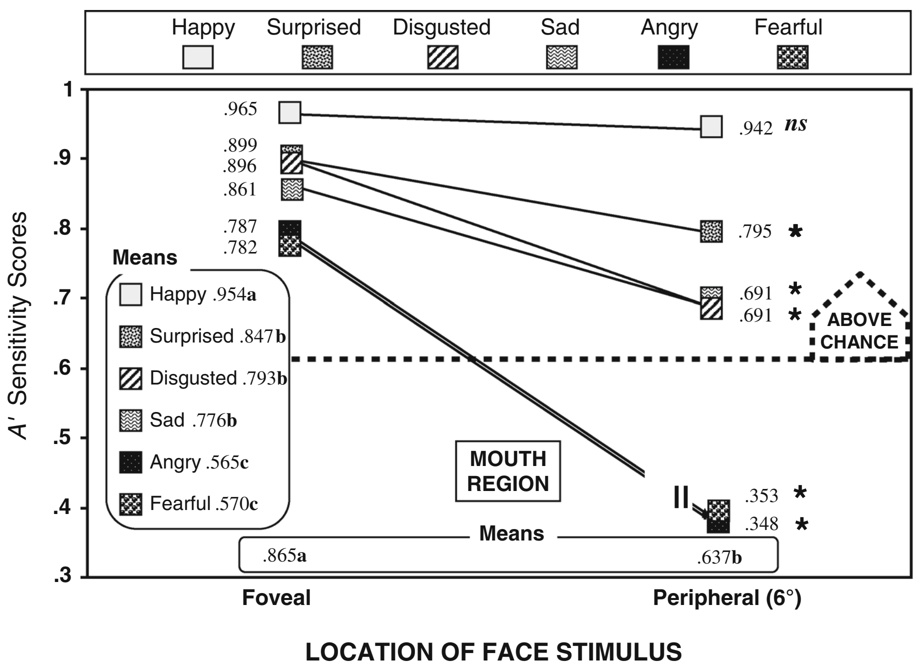

Fig. 6 Mean A' recognition sensitivity scores as a function of type of expression and presentation location in the mouth region condition. Letters *a* to *c* indicate the main effects of type of expression and location. Mean scores with a *different letter* are significantly different; means sharing a letter are equivalent. *Asterisk* vs. ns: significant vs. non-significant differences between the foveal and the peripheral condition for each expression

$\eta_p^2 = 0.302$, and location, $F(1,52) = 120.79$, $p < 0.0001$, $\eta_p^2 = 0.699$, were qualified by an interaction $F(5,260) = 6.84$, $p < 0.001$, $\eta_p^2 = 0.116$. Planned contrasts between the central and the peripheral condition revealed A' reductions in peripheral relative to central vision for all expressions (all ts > 3.1, ps < 0.01), except happy faces ($p = 0.10$, ns). One-sample t tests indicated that A' scores were above the 0.5 chance level for happy, surprised, disgusted, and sad faces (all ts > 3.7, ps < 0.001), but not for angry and fearful faces. See the mean A' scores in Fig. 6. For *reaction times*, only the effects of expression, $F(5,260) = 59.79$, $p < 0.0001$, $\eta_p^2 = 0.535$, and location, $F(1,52) = 7.68$, $p = 0.008$, $\eta_p^2 = 0.129$, reached statistical significance ($p = 0.13$, ns, for the interaction). Responses were faster when the mouth region was displayed in central than in peripheral vision conditions, and were faster for happy and slower for angry and fearful mouths, relative to all the other expressions. See the mean RT scores in Table 4.

Joint analysis of Experiments 1 and 2

To determine how much the perception of each facial expression in peripheral vision relies on the eyes and the mouth, we compared the whole-face condition (Experiment 1) with the eye-only and the mouth-only conditions (Experiment 2). In general, the less is performance impaired in peripheral relative to central vision when the eyes or the mouth are presented alone, in comparison with when the whole face is presented, the more the peripheral recognition of an expression depends on the eyes or the mouth. A' scores and the reaction times for correct responses were analyzed in a 6 (expression) × 2 (location: central vs. peripheral) × 3 (format: whole face vs. eyes vs. mouth) ANOVA.

For A' *sensitivity* scores, there were effects of expression, $F(5,780) = 16.01$, $p < 0.0001$, $\eta_p^2 = 0.093$, location, $F(1,156) = 184.01$, $p < 0.0001$, $\eta_p^2 = 0.541$, and format, $F(2,156) = 34.45$, $p < 0.0001$, $\eta_p^2 = 0.306$, as well as interactions of expression by format, $F(10,780) = 14.12$, $p < 0.0001$, $\eta_p^2 = 0.153$, expression by location, $F(5,780) = 4.04$, $p = 0.002$, $\eta_p^2 = 0.025$, and a three-way interaction, $F(10,780) = 4.41$, $p < 0.0001$, $\eta_p^2 = 0.054$. To decompose the three-way interaction, difference scores were computed between the central and the peripheral condition for each expression (i.e., peripheral–central). These scores were subsequently compared with one-way (3: face format) ANOVA to examine (a) how much A' *sensitivity* is impaired in the peripheral relative to central condition for each expression, and, (b) the relative amount of impairment for the eyes and the mouth regions, in comparison with the whole face. Format effects emerged for happy, $F(2, 78) = 13.48$, $p < 0.0001$, $\eta_p^2 = 0.257$, fearful, $F(2, 78) = 2.99$, $p = 0.055$, $\eta_p^2 = 0.068$, and angry, $F(2, 78) = 4.17$, $p < 0.01$, $\eta_p^2 = 0.097$, but not for surprised, disgusted, and sad expression (Fs ≤ 1). Results of all the post hoc contrasts are shown in Fig. 7. Essentially, A' *sensitivity* was lower for the eyes but not for the mouth of happy expressions, relative to the whole face. In contrast, sensitivity was lower for the mouth but not for the eyes of angry and fearful faces. Importantly, however, sensitivity was impaired for all expressions and formats in peripheral vision, except for the mouth region and the whole face of happy expressions.

For *reaction times*, the ANOVA yielded effects of expression, $F(5,780) = 55.14$, $p < 0.0001$, $\eta_p^2 = 0.261$, location, $F(1,156) = 29.96$, $p < 0.0001$, $\eta_p^2 = 0.138$, and an expression by format interaction, $F(10,780) = 23.75$, $p < 0.0001$, $\eta_p^2 = 0.233$, but the three-way interaction did not reach statistical significance, $F(10,780) = 1.57$, $p = 0.11$, ns. To decompose the expression by format interaction, separate one-way (3: format) ANOVA was conducted for each expression. Effects were significant for happy, $F(2,159) = 45.24$, $p < 0.0001$, $\eta_p^2 = 0.363$, fearful, $F(2,159) = 13.50$, $p < 0.0001$, $\eta_p^2 = 0.145$, and angry, $F(2,159) = 13.55$, $p < 0.0001$, $\eta_p^2 = 0.146$, expressions. In contrast, the borderline effects for sad expressions, $F(2,159) = 3.02$, $p = 0.052$, $\eta_p^2 = 0.037$, were no longer significant after Bonferroni corrections, nor for surprised and disgusted, expression (ps ≤ 0.12). All the post hoc multiple contrasts are indicated in Fig. 8. Essentially, regardless of face location, for happy faces, correct responses were slower for the eyes but not for the mouth region, in comparison with the whole face. In contrast, for angry and fearful faces, responses were slower for the mouth but not the eye region, in comparison with the whole face.

Discussion

A major finding emerged from the comparison of *peripheral* versus *central* recognition of the eye-only and the mouth-only displays: When the eye region was shown

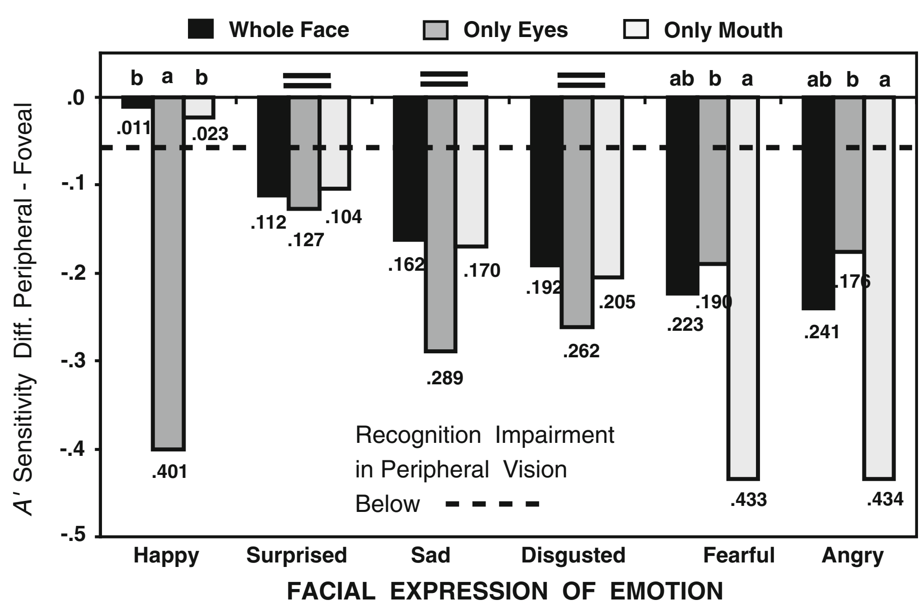

Fig. 7 A' sensitivity mean difference scores between the peripheral and the central vision conditions (i.e., peripheral minus foveal), as a function of facial expression and face format (whole, eyes, mouth). Within each expression category, a different letter (*ab*) indicates significant differences between format types (means with the same letter or the = sign are equivalent)

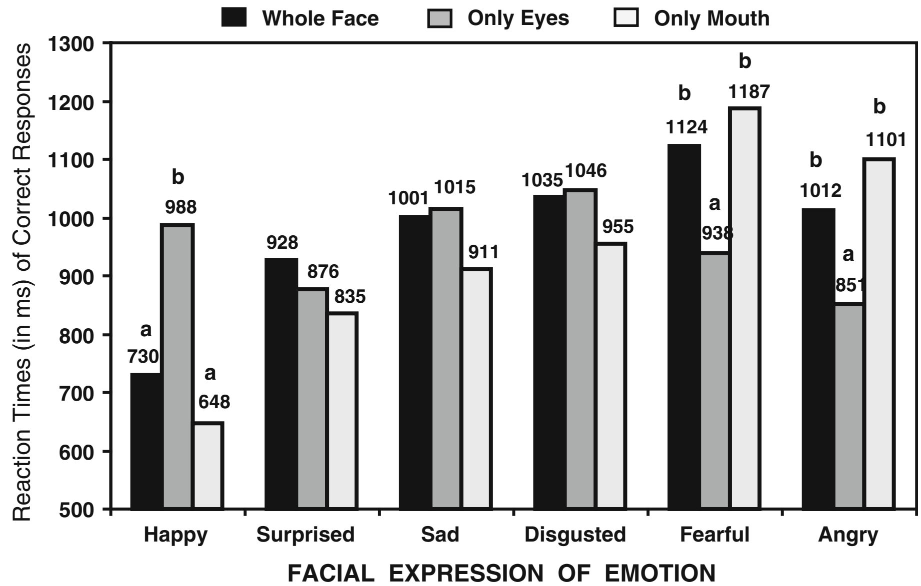

Fig. 8 Mean reaction times of correct responses as a function of type of expression and face format (whole, eyes, mouth). Within each expression category, a different letter (*ab*) indicates significant differences between format types (means with the same letter or no letter are equivalent)

alone in peripheral vision, performance was poorer (lower A' sensitivity and longer reaction times) than in central vision for all the expressions. In contrast, when the mouth region was presented alone, recognition was impaired for all expressions except happy faces. A second set of findings is concerned with the comparison of recognition performance in the *whole-face* versus the *eye* or *mouth* displays in peripheral vision. Recognition sensitivity was equivalent, and responses were even faster, when the happy mouth was shown alone relative to the whole-face display, whereas performance decreased when only the happy eye region was shown. Regarding the other expressions, performance was generally poorer for part versus whole-face formats, although the eyes facilitated the recognition of fearful and angry expressions.

These findings suggest that the reliable recognition of peripherally seen, whole-face happy expressions is due to the smiling mouth. Not only was performance for the mouth-only condition equivalent in peripheral and central vision, but performance was equivalent or even better than for the whole face. This reveals that the smiling mouth is a highly diagnostic feature of facial happiness. In contrast, the eyes make a significant contribution to the recognition of fear and anger, yet they are not diagnostic (or salient) enough as to become impervious to the detrimental effects of peripheral vision. Recognition of disgust, sadness, and surprise seems to rely similarly on the eyes and the mouth, although none is sufficient to preserve recognition in peripheral vision.

General discussion

This study investigated (a) the extent to which emotional facial expressions can be recognized in peripheral vision and how much recognition is impaired relative to central vision, (b) whether the typical advantage of happy faces over the other expressions in central vision also holds or is even increased in peripheral vision, and (c) which properties of the eyes and the mouth can account for any potential recognition advantage. Results revealed that all six basic expressions were recognized in the visual periphery above chance level. Nevertheless, there was a clear advantage of happy faces: They were recognized more accurately and faster than the others and were minimally impaired in peripheral relative to central vision, whereas recognition of other expression deteriorated significantly. This demonstrates that the *relative* superiority of happy expressions is in fact *increased* in peripheral vision. Furthermore, such an effect remained when only the smiling mouth was presented. Given the higher visual saliency and distinctiveness of the smiling mouth, we propose a saliency-distinctiveness model to account for the advantageous recognition of happy faces.

A happy face recognition superiority in peripheral vision

Prior research in which face stimuli were presented at fixation has demonstrated that happy faces are recognized more accurately and faster than the other basic expressions (Calder et al., 2000; Calvo & Lundqvist, 2008; Juth, Lundqvist, Karlsson, & Öhman, 2005; Leppänen & Hietanen, 2004; Loughead et al., 2008; Palermo & Coltheart, 2004; Svärd et al., 2012; Tottenham et al., 2009). In two studies, the faces were shown in extrafoveal locations of the visual field (Calvo et al., 2010; Goren & Wilson, 2006), and both also found support for the happy face advantage. Goren and Wilson (2006) observed that the recognition accuracy of computer-generated facial expressions in peripheral (5.5° from fixation to the innermost edge of face; 110 ms display) versus central vision was impaired for sad, angry, and fearful but not for happy faces. Calvo et al. (2010) presented the face stimuli in parafoveal vision (2.5°; 150 ms), while preventing overt attention to the stimuli by means of gaze-contingent foveal masking. Recognition sensitivity for all six basic expressions was above chance level, although happy faces were recognized faster than the others.

A limited number of neurophysiological studies (Bayle, Henaff, & Krolak-Salmon, 2009; Liu & Ioannides, 2010; Rigoulot et al., 2011; Wijers & Banis, 2012) have also addressed the issue of facial expression processing in extrafoveal vision. Electrophysiological studies (Rigoulot et al., 2011; Wijers & Banis, 2012) have established that fearful faces result in ERP (event-related potential) modulations between 160 and 300 ms from stimulus onset relative to neutral faces. Relatedly, magnetoencephalographic studies (Bayle et al., 2009; Liu & Ioannides, 2010) have found increased amygdala activation around 100 ms post stimulus in response to fearful relative to neutral faces. Nevertheless, in most of these studies only fearful expressions were included, and therefore it is not possible to determine whether all expressions can be recognized extrafoveally and whether (and why) some of them are processed more efficiently. Liu and Ioannides (2010) included happy faces in addition to fearful and neutral expressions and, interestingly, early amygdala activation also differentiated happy from fearful and neutral faces. There was also some evidence of an earlier separation in the activation patterns of happy faces from those of the other expressions, which Liu and Ioannides interpreted as a happy face processing advantage.

The current study extends prior research in four ways. First, we used three eccentricity levels, whereas other studies used only one or two, sometimes without a central vision condition. This allowed us to reveal a linear decline in recognition as a function of eccentricity for all except happy expressions. Second, we tested recognition of all six basic expressions of emotion, whereas most of the other studies used only one or two, except Goren and Wilson (2006) and Calvo et al. (2010). Such a wider range of expressions is important to examine potential differences across emotions. Third, we used photographic real faces from a large sample of 30 individuals, instead of the limited stimulus sample in most previous studies. Representativeness and external validity requires within-category variability of exemplars, given the enormous variation across individuals and situations in real life (Krumhuber & Scherer, 2011; Scherer & Ellgring, 2007). Fourth, and most importantly, we have considered the role of the mouth and the eyes, as well as physical (e.g., saliency) and semantic (i.e., diagnostic value) properties of these regions, in facilitating extrafoveal processing.

The role of the smile saliency and distinctiveness

To account for the recognition of facial expressions in peripheral vision, and the advantage of happy faces, we propose a mechanism involving perceptual saliency and categorical distinctiveness of the eyes or the mouth. Distinctiveness of a specific facial feature makes it a diagnostic cue of the expression category, to the extent that it is not shared by other categories. This allows an expression to be recognized from a single cue without the need of whole-face integration, thus bypassing configural analysis and saving processing time. If configural encoding breaks down in peripheral vision (Goren & Wilson, 2006), feature-based recognition of expressions with highly diagnostic features—thus less dependent on configural analysis—will be less impaired than those with less diagnostic ones. Nevertheless, in our theoretical account, categorical distinctiveness must be associated with high visual saliency to enable detection of the diagnostic cues in low-resolution peripheral vision: High visual saliency makes a facial feature easily accessible to perception because of sensory gain and resistance to acuity degradation at eccentric locations of the visual field. As a result, such a feature can successfully compete with others for attentional selection, and thus ensure early cognitive processing. Accordingly, accurate recognition of facial expressions in peripheral vision depends on their having highly distinctive *and* salient features.

We determined the role of distinctiveness by comparing performance when the eye or the mouth regions were presented alone relative to when the whole face was shown. The less expression recognition is impaired when a single region is presented, the higher its diagnostic value is assumed to be. Prior research has demonstrated that the diagnostic value of the eyes and the mouth varies as a function of expression: Changes in the mouth are important for happy and disgusted faces, whereas anger and fear rely mainly on the eye region, and sadness and surprise depend on the eyes and the mouth in a more balanced way (Calder et al., 2000; Calvo & Marrero, 2009; Kohler et al., 2004; Nusseck et al., 2008; Smith et al., 2005). The smiling mouth is, nevertheless, the sole feature that is both necessary and sufficient for expression categorization, and is thus highly diagnostic of facial happiness. Consistent with this, the current study established that recognition of happy expressions depends on the mouth, as both sensitivity scores and reaction times were similar when only the mouth region and when the whole face were presented. We also found evidence of the diagnostic value of the eyes of anger and fear, as shown by the faster recognition of these expressions from the eye region alone, relative to the mouth or the whole face. As for disgust, sadness, and surprise, comparable sensitivity and reaction times in the whole, eye-only, and mouth-only conditions indicate that no region was particularly diagnostic.

The role of local visual saliency—as a purely bottom-up, sensory-driven factor—in expression recognition was determined by means of computational modeling, using the iNVT algorithm (Itti & Koch, 2000; Itti, 2006). Visual saliency has been proposed to facilitate covert and overt attentional orienting (see Borji & Itti, 2013). Data from human observers have confirmed many predictions of such models (Calvo & Nummenmaa, 2008; Parkhurst, Law, & Niebur, 2002; Underwood & Foulsham, 2006).[2] The current study corroborated that the most visually salient feature of all expressions was the smiling mouth. It is thus possible that the greater recognition advantage and the minimal impairment of happy expressions in peripheral vision are due to their having a highly diagnostic mouth which is *also* highly salient. In contrast, although the angry and the fearful eyes were clearly diagnostic, they did not facilitate the recognition of the respective expressions because they were not salient enough as to be accessed in peripheral vision. As for the other expressions, the eyes and the mouth were either not salient or diagnostic enough, or both. Accordingly, saliency and distinctiveness must act in combination to facilitate expression recognition in peripheral vision.

Alternative explanations: role of teeth and the affective uniqueness of happy expressions

The recognition advantage effects attributed to the saliency and distinctiveness of happy faces are not merely due to their having an open mouth and exposed teeth. In *visual search* tasks, teeth may serve as singleton cues facilitating effective search (Horstmann, Lipp, & Becker, 2012), although Calvo and Nummenmaa (2008) showed that the role of teeth varies as a function of type of expression. For the face stimuli used in the current study in a *recognition* task, the expression-wise proportions of faces with an open mouth and exposed teeth, respectively, were as follows: happy (100 and 100 %), fearful (100 and 83 %), surprised (100 and 50 %), disgusted (73 and 73 %), angry (50 and 30 %), and sad (0 and 0 %). Fearful expressions were the most poorly recognized, yet they were similar to happy faces in their having an open mouth and exposed teeth, and were more likely to have these features than most of the other categories. Conversely, sad faces had no open mouths or exposed teeth, yet their recognition performance was similar to that of the surprised, disgusted, or angry expressions with open mouths. Accordingly, an open-mouth/exposed-teeth explanation is unlikely to account for the effects found in the current study.

An affective processing explanation of the happy face recognition advantage in peripheral vision must also be considered, as happy faces were the only expressions conveying positive affect, whereas most of the others were negatively valenced. Such an affective uniqueness could have made the happy faces easily discriminable from the others, which, in contrast, would have been subjected to mutual competition and interference, thus reducing their discriminability. While this affective explanation makes sense, it can be significantly downplayed. First, surprised expressions are affectively ambiguous (Mendolia, 2007), given that surprise can occur as a reaction to something unexpected that is positive or negative. Yet, in spite of their being ambiguous, the recognition pattern of surprised faces was equivalent to that of the negative expressions in our study. Second, the happy eyes have proved to be important for *affective* assessment of a smile as conveying genuine happiness (Calvo et al., 2012; Johnston et al., 2010; McLellan et al., 2010). Yet the happy eyes did not facilitate recognition in our study, which suggests that the categorization of facial happiness in peripheral vision is not dependent on affective processing. Third, the affective valence account cannot explain the *greater*—rather than equivalent—happy face advantage in peripheral relative to central vision (why should affective value *increase* in peripheral vision?). Accordingly, similar recognition differences between happy and non-happy faces in central and peripheral vision should occur, which was not the case.

Our own saliency-distinctiveness explanation is, nevertheless, not incompatible with the one involving affective discrimination, but qualifies it by focusing on local expressive sources rather than the whole face, and by emphasizing the role of perceptual content as the factor supporting expression recognition in peripheral vision. In our view, featural distinctiveness of the smile, rather than emotional distinctiveness of the whole expression, underlies the happy face advantage. Importantly, in parafoveal vision, affective priming by happy faces emerges later (750 ms; Calvo et al., 2010) than categorical discrimination driven by the saliency of the smiles (180–280 ms; Calvo & Nummenmaa, 2009, 2011). Even in central vision, affective priming with facial expressions occurs later than perceptual priming (>500 vs. <170 ms, respectively; Calvo

[2] We used relatively simple visual stimuli such as faces from which, in addition, some aspects—not relevant to expression— such as hair, etc., had been removed. With more complex stimuli and naturalistic scenes, the predictive power of saliency as a purely sensory-driven factor in guiding attention may be limited (Tatler, Hayhoe, Land, & Ballard, 2011), and task demands can override the effects of saliency (Einhäuser, Rutishauser, & Koch 2008). Consequently, saliency models probably work best on simple stimuli with clear saliency peaks and when top-down goals are minimal.

et al., 2012). Accordingly, the perceptual saliency of a diagnostic feature, i.e., the smile, could produce a recognition advantage before an affective representation is formed. Saliency would make a distinctive feature resistant to visual acuity degradation, and featural distinctiveness could thus bypass configural processing. This would lead happy faces to *increase* their relative recognition superiority in peripheral vision, in comparison with faces with less salient—hence more susceptible to acuity degradation—and less distinctive—hence requiring configural integration—features.

Conclusions

Basic facial expressions of emotion can be reliably recognized in parafoveal and near peripheral vision, although recognition is impaired relative to central vision for all expressions more than for happy faces. The advantage of happy faces is increased in peripheral vision and remains when only the mouth region is presented. Such an advantage can be attributed to the visual saliency and diagnostic value of the smiling mouth. Due to saliency, sensory gain control can counteract visual acuity degradation and thus keep the mouth accessible extrafoveally. Due to distinctiveness, the mouth provides a unique diagnostic cue from which the expression could be inferred, without the need of integration of the various face parts, thus minimizing configural processing breakdown. In general, our findings favor a perceptual rather than an affective account of expression recognition in peripheral vision.

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