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Recognition advantage of happy faces in extrafoveal vision: Featural and affective processing

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Happy, surprised, disgusted, angry, sad, fearful, and neutral facial expressions were presented extrafoveally (2.5° away from fixation) for 150 ms, followed by a probe word for recognition (Experiment 1) or a probe scene for affective valence evaluation (Experiment 2). Eye movements were recorded and gaze-contingent masking prevented foveal viewing of the faces. Results showed that (a) happy expressions were recognized faster than others in the absence of fixations on the faces, (b) the same pattern emerged when the faces were presented upright or upside-down, (c) happy prime faces facilitated the affective evaluation of emotionally congruent probe scenes, and (d) such priming effects occurred at 750 but not at 250 ms prime–probe stimulus–onset asynchrony. This reveals an advantage in the recognition of happy faces outside of overt visual attention, and suggests that this recognition advantage relies initially on featural processing and involves processing of positive affect at a later stage.

Keywords: Affective priming; Attention; Emotion; Facial expression; Recognition.

In recognition studies, happy faces are typically identified more accurately and rapidly than other basic facial expressions. This has been shown in

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expression categorization tasks for separate comparisons of happiness versus sadness (Kirita & Endo, 1995), happiness versus disgust (Leppänen & Hietanen, 2004), happiness versus anger (Juth, Lundqvist, Karlsson, & Öhman, 2005; Leppänen, Tenhunen, & Hietanen, 2003), and happiness versus fear (Juth et al., 2005). Furthermore, in three studies (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004; Tottenham et al., 2009), the recognition of all six basic emotional facial expressions (fear, anger, disgust, sadness, surprise, and happiness; Ekman & Friesen, 1976) was compared. A consistent pattern of findings appeared in all three studies, even though different face databases were used: Recognition accuracy was highest and speed was fastest for happy expressions (speed was not assessed in Tottenham et al., 2009). The accuracy advantage held both for open- and for closed-mouth faces (Tottenham et al., 2009). In addition, Calvo and Lundqvist (2008) found that the relative recognition advantage of happy faces over the other expressions increased linearly when stimulus display duration was reduced. Only minimal impairment in the recognition of happy expressions was observed, as display duration decreased from unlimited time to 500, 250, 100, 50, and 25 ms, whereas recognition of all the other emotional expressions was substantially impaired.

Nevertheless, the perceptual and affective mechanisms responsible for the happy face recognition advantage are not well understood. In general terms, the facilitated processing of happy expressions can be related to their functional value in the initiation and maintenance of social interactions and bonds (Tomkins, 1962). Such an advantage would be instrumental in maximizing the receipt of reward from other people and establishing alliance and collaboration. Alternatively, it is possible that the more efficient recognition of happy expressions is due to their being more familiar, as happy faces are encountered in everyday social environments more frequently than other emotional expressions (see Bond & Siddle, 1996). In this second view, the happy face recognition advantage would not be contingent on the affective or communicative value of the expressions. Beyond these general accounts, however, the current study focuses on the specific cognitive mechanisms underlying the identification or recognition advantage of happy expressions.

To this end, we investigated three issues. First, in prior research, the happy face advantage has been demonstrated for foveally presented faces, i.e., when they appear at fixation. It remains to be determined whether the superior recognition of happy faces also occurs when they are presented extrafoveally. This issue is theoretically important because it deals with the question of whether facial expressions of emotion can be recognized outside the focus of visual attention. It is also important at a more practical level because in real life faces often appear initially in the visual periphery (e.g., among other objects or within a group of people). Hence, it would be highly beneficial if the cognitive system could rapidly recognize the expressions in extrafoveal vision, prior to bringing them to foveal vision with a saccade. Second, the recognition advantage of happy faces might rely on the processing of single facial features to a significant extent. Even though facial expression recognition requires processing of the meaning or category of a target face, it is possible that it relies on single features rather than involving the whole facial configuration, and that featural analysis accounts for the faster recognition of happy expressions. And, third, if features are responsible for the happy face recognition advantage, there is the issue of whether and, if so, when positive affect is also extracted from such expression, beyond the mere encoding of some prominent and distinctive physical cue (e.g., mouth shape) that can be accessed rapidly in extrafoveal vision.

The findings from visual search studies (see reviews and discrepancies about a happy vs. an angry face detection advantage in Calvo & Nummenmaa, 2008, and Frischen, Eastwood, & Smilek, 2008) are relevant to our first issue, i.e., processing of facial affect outside the focus of overt attention, because in such studies the target face typically appears *away* from the initial fixation point within an array of other faces. Eyetracking studies have confirmed that detection of facial expressions occurs to some extent prior to landing a fixation on the faces (Calvo, Nummenmaa, & Avero, 2008). Eyetracking studies have also shown that happy faces are more likely than other expressions to attract the first fixation from the onset of the display (when the target face is still in parafoveal or peripheral vision), and that the time taken to localize (i.e., fixate) the target face is shorter for happy faces than for other emotional faces (Calvo & Nummenmaa, 2008; Calvo et al., 2008). As the search and detection advantage involves faster overt visual *localization*, and as shifts of covert attention generally precede saccades (see Awh, Armstrong, & Moore, 2006; Findlay & Gilchrist, 2003), these results suggest that (a) face processing begins in extrafoveal vision and (b) happy faces are processed more efficiently than others *before* they are fixated; otherwise no bias in eye movements would be observed.

Nevertheless, *detection* in visual search tasks does not necessarily involve *recognition*, categorization, or identification of the emotional expressions. In visual search tasks, generally, viewers must decide whether there is any target face that is *different* from the others in an array of otherwise identical (typically, neutral) distracter faces, rather than decide *which* kind of expression it is. As visual discriminability between the target and the distracters is the major determinant of visual search performance (Duncan & Humphreys, 1989), detection of the target face could be accomplished on the basis of mere physical or visual differences between the target and the distractors, without recognition of the target expression or its affective meaning. To test whether physical features could account for the happy face detection superiority, Calvo and Nummenmaa (2008) employed a computational model of visual attention (iNVT; developed by Itti & Koch, 2000) to estimate the visual (i.e., purely physical) saliency of different expressive faces within an array of neutral faces. They found that happy faces were more salient than the other emotional faces (see also Mermillod, Vermeulen, Lundqvist, & Niedenthal, 2009, for a related view), and that the most salient facial region was the mouth of happy faces. Furthermore, computationally modelled saliency was greatest for the faces (happy) and regions (mouth) that human observers fixated earlier and detected faster in a subsequent experiment. In addition, there was close correspondence between the onset of the modelled initial saliency peak and the time at which observers first fixated the faces. Calvo and Nummenmaa concluded that visual saliency of specific facial features—especially the smiling mouth—accounts for initial orienting towards happy faces, which subsequently facilitates detection. Accordingly, the advantageous detection of happy faces in visual search tasks can be accounted for by featural processing.

This raises the issue of whether the processing of happy expressions in extrafoveal vision involves identification of emotional *meaning* rather than mere detection of *physical features*. What information is accessed when perception of a physically salient facial feature (e.g., the mouth) leads to facilitated processing of a happy face outside the focus of overt attention? Does the salient physical cue serve as a short-cut for efficient matching of the perceptual input and the stored long-term visual representation of the expression, or does the happy mouth provide a short-cut for accessing the affective valence of the face, or both? Put it simply, do we automatically perceive a warm-hearted smile in a happy face or just a visually salient mouth? This contrast between a perceptual and an emotional account of facial expression recognition is a critical issue in research on emotional face processing (Calder & Young, 2005).

In the current study, first, to determine whether expression recognition can be accomplished in the absence of fixations on the faces, we presented them parafoveally for 150 ms (Experiments 1 and 2) while foveal viewing was prevented by means of gaze-contingent masking (Experiment 1): A moving black circle with a diameter of 3.5° accompanied the viewer's gaze position changes, thus allowing for only extrafoveal viewing of the faces. If foveal vision (i.e., overt attention) is required, no face recognition and no advantage for happy faces will occur in such conditions. In contrast, if recognition can be accomplished in extrafoveal vision (i.e., by covert attention), the happy face advantage will remain.

Second, to examine the role of configural and featural processing, we presented face stimuli upright and upside-down in Experiment 1. Face inversion disrupts the analysis of configural information, while that of featural information is impaired to a lesser extent (Farah, Tanaka, & Drain, 1995; Maurer, LeGrand, & Mondloch, 2002). If the superior recognition of happy faces relies on a quick analysis of single distinctive features such as a smiling mouth, inversion will impair the recognition advantage of happy faces minimally. In contrast, inversion will be more detrimental for recognition of the expressions that require configural processing, and therefore the happy face relative advantage should be even greater for inverted faces.

Third, to investigate the processing of emotional meaning of the faces, we used an affective priming paradigm in Experiment 2. A to-be-ignored prime face (happy, neutral, or sad) was followed by a probe scene (either unpleasant or pleasant, e.g., a battered female or a romantic couple). The participants responded whether the probe scene was unpleasant or pleasant. If the affective valence of the prime face is encoded, responses to the probes will be faster when there is prime–probe congruence in valence (e.g., happy prime → pleasant probe) than when there is incongruence (e.g., sad prime → pleasant probe) or when there is no affective relationship (e.g., neutral prime → pleasant or unpleasant probe).

EXPERIMENT 1

This experiment was aimed at investigating (a) whether emotional expressions can be recognized in the absence of foveal vision (i.e., without fixating them), (b) the potential recognition superiority for some expressions in these conditions, and (c) whether such an advantage is due to processing of single facial features. Emotional and neutral faces were presented extrafoveally (2.5° away from fixation) for 150 ms, followed by a probe word for recognition. The faces appeared either upright or upside-down. Eye movements were recorded and gaze-contingent masking prevented foveal viewing of the faces.

Method

Participants. Forty-eight psychology undergraduates (19–24 years old; 36 female) at the University of La Laguna participated for course credit.

Stimuli. We selected 210 digitized colour photographs from the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998) stimulus set. The *target* face stimuli portrayed 30 individuals (15 females: KDEF no. 01, 02, 03, 05, 07, 09, 11, 13, 14, 19, 20, 26 29, 31, 33; and 15 males: KDEF no. 03, 05, 06, 08, 10, 11, 12, 13, 14, 17, 22, 23, 29, 31, 34), each posing seven expressions (neutral, happiness, anger, sadness, disgust, surprise, and fear). Each photograph was cropped: Nonfacial areas (e.g., hair, neck, etc.) were removed by applying an ellipsoidal mask. Each face subtended a visual angle of 6.6° (height) × 5.0° (width) at a 60 cm viewing distance, and was presented against a black background.

In addition to the target faces, a *scrambled* version of the corresponding target face was presented simultaneously on each trial. The faces were lateralized to opposite sides of the screen (see Figure 1). This balanced display ensured that the mere onset of the target face did not serve as an exogenous singleton cue potentially attracting covert and overt shifts of attention. Scrambling was done by dividing the inner region of each face into a 6 × 6 matrix of square tiles and then randomly rearranging these tiles. This disrupted the global face structure and configuration; hence, the scrambled faces were devoid of any meaning about emotional expression. A Fourier phase scrambled neutral face was used as a *backward mask* following the target and the scrambled face.

Apparatus and procedure. The stimuli were presented on a 21-inch monitor with a 120 Hz refresh rate. A forehead-and-chinrest was used, at 60 cm viewing distance. Participants' eye movements were recorded with an EyeLink II tracker (SR Research Ltd., Mississauga, Ontario, Canada) at a 500 Hz sampling rate and < 0.5° spatial resolution in pupil tracking mode.

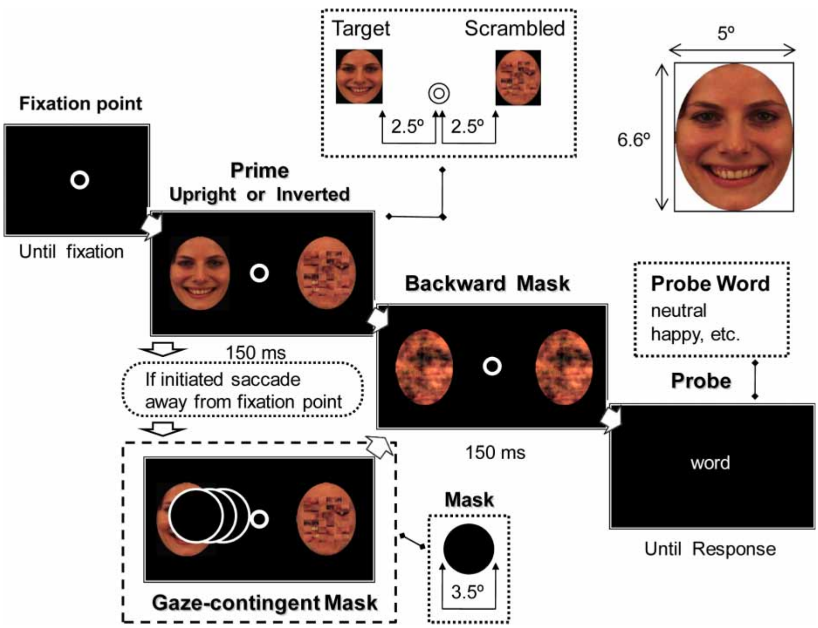

Figure 1. Sequence of events and overview of basic characteristics of a trial. To view this figure in colour, please see the online issue of the Journal.

Each participant was presented with 186 experimental trials in three blocks, randomly, in addition to 16 practice trials. Across participants, all faces of all seven categories were presented as primes followed by a probe word representing the same expression as the prime. In addition, all faces were followed by a probe word *not* representing (i.e., different) the expression of the prime. Each participant was presented with 84 *same* prime–probe trials (i.e., neutral-neutral, and emotional-emotional; 1/7 of each expression), and another 84 *different* prime–probe trials (i.e., emotional-neutral, and neutral-emotional). An additional 18 emotional-emotional trials in which the prime face (e.g., happy) was different from the probe word (e.g., angry) were interspersed among the "same" and the "different" trials. These additional trials encouraged participants to pay attention to differences among emotional expressions rather than merely discriminating between emotional and neutral expressions.

Each trial (see Figure 1) began with a central drift correction circle (0.5°). When the participant fixated this circle, a target and a scrambled face appeared for 150 ms in a prime period. The distance between the inner edge of each of these stimuli and the fixation point was 2.5°. During the prime period, a gaze-contingent foveal mask prevented fixations on the faces. A moving black circle (3.5°) was contingent on the changes in the participant's gaze direction and thus masked foveal vision (see Calvo & Nummenmaa, 2007). Participants were free to move their eyes, but if they saccaded away from the central fixation point, foveal vision was blocked with the mask. Participants were not told about the mask, in order not to discourage them from making saccades towards the face stimuli. Following the prime period, two backward masks replaced the target and the scrambled face for 150 ms. Finally, the masks disappeared and a probe word appeared at the centre of the screen. The participant responded whether or not this word represented the expression of the target face, by pressing one of two keys, and response latencies were time-locked to the presentation of the probe word. Responses on the "same" prime–probe trials were used to measure hits; those on "different" prime–probe trials assessed false alarms.

Design. The experimental design involved one between-subjects factor: Orientation of the faces (upright vs. inverted; with 24 participants at each level), and two within-subjects factors: Expression (neutral, happy, angry, sad, disgusted, surprised, fearful) and visual field (left vs. right) of the target face.

Eye movement measures. To demonstrate processing of facial expressions in the absence of overt attention, it is imperative that the faces are *not* fixated. We thus measured the probability that a saccade was initiated towards the target face during and after the prime period, the saccade latency, and the probability that saccades landed on the face (i.e., that a fixation was made) during the 150 ms prime display. Saccade latencies were time-locked to the onset of the prime face.

Recognition performance measures. Accuracy and reaction times for correct responses in the recognition task were collected. The probability of hits (PH; correct recognition of the facial expression) and false alarms (PFA; incorrect responses) were converted to the nonparametric A' index of sensitivity (see Snodgrass & Corwin, 1988), where $A' = 0.5 + (\text{PH} - \text{PFA}) * (1 + \text{PH} - \text{PFA})/(4 * \text{PH}) * (1 - \text{PFA})$. A' scores vary from low to high sensitivity in a 0–1 scale, where .5 represents the chance level.

Results

We conducted 2 (orientation) × 7 (facial expression) × 2 (visual field) repeated-measures ANOVAs on each dependent measure. Bonferroni corrections ($p < .05$; for six comparisons, i.e., those between each expression and the other six expressions) were used for all post hoc multiple contrasts.

Eye movements. Neither the probabilities nor the latencies of saccades were affected by facial expression (Fs < 1). During the 150 ms prime period, the probability that a saccade was *initiated* from the central fixation point towards the target face ($M = 0.058$, i.e., on 5.8% of trials, $SE = 0.015$, in the upright condition; $M = 0.041$, $SE = 0.015$, in the inverted condition), and the probability that a saccade *landed* on the face ($M = 0.002$; 0.2% of trials, $SE = 0.001$, in the upright condition; $M = 0.001$, $SE = 0.001$, in the inverted condition) were negligible. A considerable number of saccades (on 18.4% of trials) were initiated towards the target face location *after* the prime face offset, with mean latency being 296 ms for both the upright and the inverted condition. These data thus confirm that there were no fixations on the faces. Only an effect of visual field emerged for saccade probabilities, $F(1, 46) = 15.14$, $p < .001$, $\eta_p^2 = .25$ (left, $M = 0.211$, $SE = 0.020$; right, $M = 0.158$, $SE = 0.017$), and latencies, $F(1, 46) = 12.92$, $p < .001$, $\eta_p^2 = .22$ (left, $M =$ 267 ms, $SE = 14.80$; right, $M = 325$ ms, $SE = 19.58$).

Recognition performance: A' sensitivity scores (see Figure 2). The ANOVA revealed main effects of expression, $F(6, 276) = 39.90$, $p < .0001$, $\eta_p^2 = .46$, and orientation, $F(1, 46) = 121.59$, $p < .0001$, $\eta_p^2 = .73$ (upright, $M = 0.907$; inverted, $M = 0.716$), as well as an expression by orientation interaction, $F(6, 276) = 12.44$, $p < .0001$, $\eta_p^2 = .21$. Face inversion impaired A' scores (i.e., reduced accuracy in the inverted vs. the upright condition) for all expressions, although the impairment was greater (ps < .05) for some

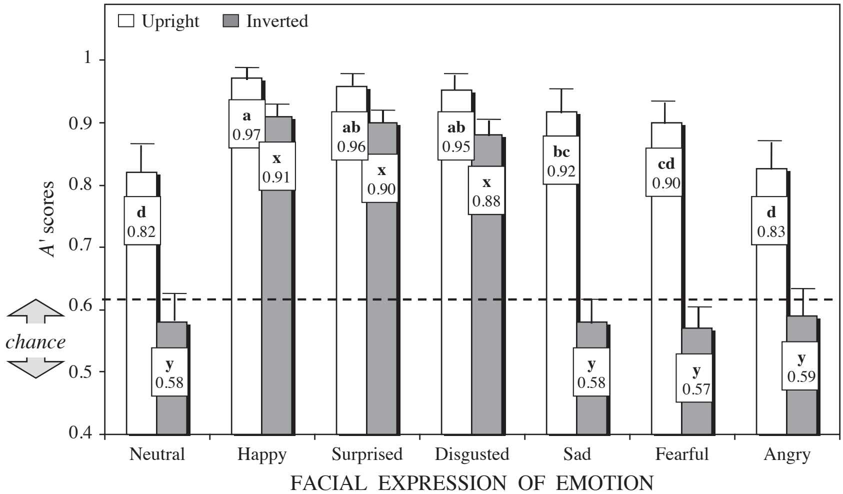

Figure 2. Mean A' sensitivity scores and standard errors, as a function of type of facial expression, in the upright and the inverted spatial orientation conditions. Mean scores with a different superscript are significantly different (a, b, c, d for the upright condition; x, y, for the inverted condition); means sharing a superscript are equivalent. Scores below the dashed line do not exceed the chance level.

faces (sad: –.33; fearful: –.33; angry: –.24; and neutral: –.24) than for others (happy: –.06; surprised: –.06; and disgusted: –.07).

In the upright condition, an effect of expression, $F(6, 138) = 22.95$, $p < .0001$, $\eta_p^2 = .50$, showed higher A' scores for happy than for sad, fearful, angry, and neutral faces. One-sample t-tests were used to compare the A' scores for each expression against the .50 chance level. All scores were above chance, $t\text{s} > 13$, $p < .0001$. In the inverted condition, a similar expression effect, $F(6, 138) = 26.67$, $p < .0001$, $\eta_p^2 = .54$, revealed higher A' scores for happy, surprised, and disgusted faces than for sad, fearful, angry, and neutral faces. However, only the happy, surprised, and disgusted faces exceeded the chance level, $t\text{s} > 20$, $p < .0001$.

Reaction times (see Figure 3). Response latencies were affected by expression, $F(6, 276) = 47.30$, $p < .0001$, $\eta_p^2 = .51$, visual field, $F(1, 46) = 5.70$, $p < .025$, $\eta_p^2 = .11$ (left: $M = 1170$ ms, $SE = 26.36$; right: $M = 1207$ ms, $SE = 30.47$), and orientation, $F(1, 46) = 5.25$, $p < .05$, $\eta_p^2 = .10$ (upright: $M = 1126$ ms, $SE = 38.73$; inverted: $M = 1251$ ms, $SE = 38.73$), and there was an expression by orientation interaction, $F(6, 276) = 2.62$, $p < .025$, $\eta_p^2 = .05$. Inversion slowed down recognition for all faces, although the increase in response times was greater ($p\text{s} < .05$) for some expressions (angry: 203; fearful: 171; sad: 146; and disgusted: 141 ms) than for others (surprised; 69; and happy: 87 ms). Main effects of expression in the upright,

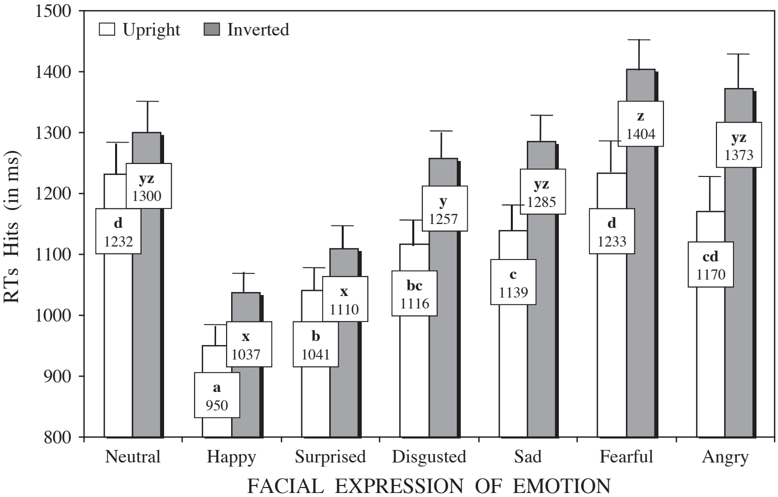

Figure 3. Mean reaction times and standard errors (in ms) for correct responses, as a function of type of facial expression, in the upright and the inverted spatial orientation conditions. Mean scores with a different superscript are significantly different (a, b, c, d, for the upright condition; x, y, z, for the inverted condition); means sharing a superscript are equivalent.

$F(6, 138) = 29.72$, $p < .0001$, $\eta_p^2 = .56$, and the inverted condition, $F(6, 138) = 22.78$, $p < .0001$, $\eta_p^2 = .50$, showed faster responses for happy faces than for all the other faces (upright; ps $< .05$), and faster responses for happy, and also surprised, faces than for all the other faces (inverted; ps $< .05$).

To control for the effect of probe *words* on the observed reaction times in the recognition of *facial expressions*, these words were presented alone (without the faces) in a separate experiment with 24 new participants. The words representing each facial expression were included in a lexical-decision task (i.e., deciding whether letter strings were meaningful words or not). Each facial-expression word was presented once, one at a time, interspersed with 144 expression-unrelated words and 72 pseudowords. A seven (word) one-way ANOVA, followed by Bonferroni corrections for multiple contrasts, was performed on lexical-decision times, $F(6, 138) = 7.34$, $p < .0001$, $\eta_p^2 = .24$, with significant differences only between the word neutral ($M = 715$ ms; $SE = 21.71$) and all the other words (except surprised; all ps $< .05$; happy: $M = 630$, $SE = 19.34$; surprised: $M = 633$, $SE = 19.82$; disgusted: $M = 632$, $SE = 17.21$; angry: $M = 618$, $SE = 17.55$; sad: $M = 602$, $SE = 16.66$; fearful: $M = 604$, $SE = 18.45$), which did not differ from each other (all ps $= 1$). This implies that the differences in recognition latencies across expressions were not due to differences in the processing of the probe words.

Discussion

When face stimuli were presented in the canonical upright orientation, recognition performance was above the chance level for all expressions. As this occurred in conditions where there were no eye fixations on the extrafoveally presented faces, we conclude that facial expression recognition can be accomplished to a significant extent outside the focus of overt attention. Nevertheless, it must be noted that there was a happy face advantage, as happy expressions were recognized faster than all the other expressions.[1] In addition, although inversion impaired the recognition of all expressions, the pattern of differences between them generally remained similar to that in the upright condition. Most importantly, the recognition of happy (and also surprised and disgusted) faces was less affected by inversion than that of angry, sad, fearful, and neutral faces, which did not exceed the chance level. If we assume that face inversion disrupts the processing of configural or holistic information more than that of individual parts or face features (e.g., Maurer et al., 2002; though see Rhodes, Hayward, & Winkler, 2006), these results imply that the recognition of happy (and also surprised and disgusted) faces relies on the analysis of single facial features.

Accordingly, the happy face recognition advantage may be accounted for in terms of featural processing. Happy expressions are identified faster because their recognition relies to greater extent on single features the processing of which would take less time than that required for the integration of several features involved in configural processing. The mouth of happy faces has been found to be a highly salient visual feature (Calvo & Nummenmaa, 2008). Visual saliency would make the mouth especially accessible to extrafoveal analysis, and thus the mouth could

[1] As an alternative interpretation of the happy face recognition advantage, a reviewer suggested that such an advantage might not be due to face recognition per se, but to the relative ease or difficulty in *matching* the face and the word. Essentially, because there is one category of positively valenced words and faces (happy), whereas there are several subcategories of negatively valenced faces and words (angry, sad, etc.), the process of matching word and face might be easier for the positive than for the negative faces. Against this hypothesis, (a) the general agreement in using each of the six words for each of the six basic expressions in daily life, (b) the familiarization with examples of faces and words shown to the participants during the instructions prior the experiment, as well as the practice trials, and (c) the repeated presentation of experimental trials, lead us to think that such word–face matching is/was overlearned and it should have been accomplished easily for all the expression categories. More importantly, (d) the happy face advantage remained when scenes (Experiment 2), rather than words (Experiment 1), were used as probes. Furthermore, in Experiment 2 *only one* negative (i.e., sad) expression category was used, which should have reduced or eliminated the competition between different negative-valence expressions.

serve as a cue that guides the quick identification of happy faces outside of overt attention (i.e., in the absence of fixations). There is, however, the question of whether the conspicuity of single physical features simply leads to rapid categorization or whether the happy face advantage also involves rapid *affective* evaluation of the expression. This was investigated in Experiment 2.

EXPERIMENT 2

A major aim of Experiment 2 was to investigate whether positive affect is perceived from extrafoveally presented happy faces, rather than merely physical features devoid of any emotional meaning. To this end, an affective priming paradigm was used in which happy, sad, or neutral faces primed photographs of emotional scenes. The participants were instructed to ignore the prime faces and assess the emotional valence of the probe scenes. If *affective significance* is extracted from the prime faces, there will be faster affective evaluation of probe scenes that are congruent in affective valence (i.e., happy face—pleasant scene, or sad face—unpleasant scene), in comparison with when there is no prime–probe affective relatedness (i.e., neutral–pleasant, or neutral–unpleasant) or when there is affective incongruence (i.e., happy–pleasant, or sad–pleasant). Furthermore, the priming effect will be greater for the happy than for the sad face primes.

We also examined the time course of affective priming. To this end, the stimulus–onset asynchrony (SOA) between the prime and the probe was varied. This enabled us to determine whether the advantage in the processing of happy faces takes place automatically. It is possible that affective content is extracted, but not immediately. The superior recognition of happy faces might involve quick detection of the visually salient mouth shape, which would be matched with the representation of a happy face, and then *followed* by the recognition of the affect associated with the expression. That is, the *initial* perception of the salient physical feature would be used to infer positive affect at *later* processing stages. The choice of SOAs (250 vs. 750 ms) was motivated by prior studies showing that affective priming effects with SOAs of 300 ms or less reflect automatic priming, whereas priming effects resulting from strategic processing would require at least 500 ms (Hermans, Spruyt, & Eelen, 2003). Automaticity generally involves a continuum rather than a dichotomy for many cognitive processes and tasks, and the various empirical criteria to define automaticity do not always covary (see Moors & de Houwer, 2006). In this context, the 250 versus 750 ms SOA operationalization of two ends of the automatic–strategic continuum provides a time course view of when affective content can be extracted from emotional prime faces.[2]

Method

Participants. Forty-eight psychology undergraduates (38 female) at La Laguna University participated for course credit. All were aged between 18 and 24 years old.

Stimuli. As *prime* faces, we selected 96 digitized colour photographs from the KDEF (Lundqvist et al., 1998) stimulus set. The face stimuli portrayed 32 individuals (those used in Experiment 1 plus models F30 and M25), each posing three expressions (neutral, happiness, and sadness). Each face subtended a visual angle of 8.4° (height) × 6.4° (width) at a 60 cm viewing distance, and was presented against a black background. In addition, as in Experiment 1, a *scrambled* version of the prime face was presented simultaneously for 150 ms, each lateralized to opposite sides of the screen (see Figure 4). Also, a Fourier phase scrambled neutral face was used as a *backward mask*.

As *probes*, we selected 32 pleasant and 32 unpleasant scenes from the IAPS (International Affective Picture System; Lang, Bradley, & Cuthbert, 2005; see the Appendix). The size of the probes was 13° (height) × 11° (width). A one-way ANOVA (valence category: Unpleasant vs. pleasant) on valence and arousal ratings (in 9-point scales; Lang et al., 2005) showed main effects of valence category on valence scores, $F(1, 63) = 1513.78$, $p < .0001$ (M *unpleasant* $= 2.15$, $SE = 0.10$; M *pleasant*: 7.74, $SE = 0.08$) and arousal scores, $F(1, 63) = 50.79$, $p < .0001$ (M *unpleasant* $= 6.52$, $SE = 0.16$; M *pleasant*: 4.85, $SE = 0.16$).

Apparatus and procedure. The stimuli were presented on a 17-inch SVGA monitor, connected to a Pentium-IV 2.8 GHz computer. The E-Prime software controlled stimulus presentation and response collection. A forehead-and-chinrest was used. Nevertheless, no eyetracker was used in Experiment 2, given that in Experiment 1 there were few saccades and practically no fixations on the prime faces. Each participant was presented with 192 experimental trials in two blocks, randomly, and 18 practice trials.

[2] In this paradigm, it is likely that processing of the prime ceases with the onset of the probe, given that (processing and responding to) the probe is the critical task-relevant event. Nevertheless, such an assumption is not necessary for the logic underlying the assessment of the time course of affective processing of the prime. Rather, the important point is that priming (i.e., either facilitation or interference with probe processing) will occur *when* an affective representation of the prime has reached a certain activation level, be it *prior to* the onset or *during* the presentation of the probe.

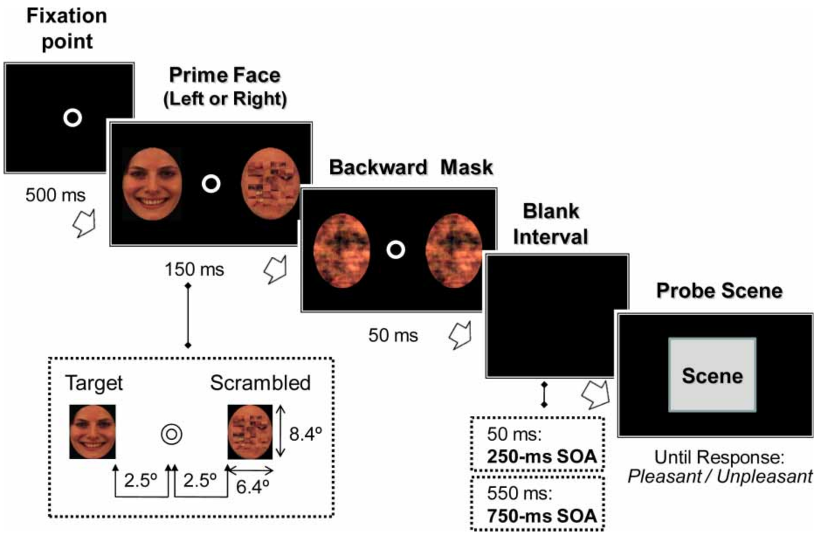

Figure 4. Sequence of events and overview of basic characteristics of a trial in Experiment 2. To view this figure in colour, please see the online issue of the Journal.

Each trial (see Figure 4) began with a central fixation circle for 500 ms. This was followed by a prime face display for 150 ms, in which a target face appeared on one side of the screen (either left or right) and the corresponding scrambled face on the other. The distance between the inner edge of the faces and the central fixation circle was 2.5°. Following the prime display, a backward mask appeared for 50 ms. Next there was a blank interval of either 50 or 550 ms, resulting in a 250 or a 750 ms prime–probe SOA. Finally, the probe scene was displayed at the centre of the screen until the participant responded whether it was unpleasant or pleasant, by pressing a key with the left or the right finger. Assignment of keys was counter-balanced. Response accuracy and latencies were collected.

Design. There were three within-subjects factors: Prime face expression (happy vs. neutral vs. sad), probe scene valence (pleasant vs. unpleasant), and prime visual field (left vs. right). Prime–probe SOA (250 vs. 750 ms) was a between-subjects factor, with 24 participants assigned to each SOA condition. The combination of prime and probe represented affective congruence (happy/pleasant, or sad/unpleasant), incongruence (happy/un-pleasant, or sad/pleasant), and no affective relatedness (neutral/pleasant or unpleasant). Each participant was presented with a neutral, a happy, and a sad face of each poser once in the right and once in the left visual field, followed by a pleasant or an unpleasant probe. Each probe was presented three times (once following a neutral, a happy, or a sad prime face). Similarly for each SOA level, the prime–probe pairs were established randomly within each prime condition, and each participant was presented with different prime–probe pairs.

Results

A 3 (prime expression) × 2 (probe valence) × 2 (prime visual field) × 2 (SOA) ANOVA was conducted on response accuracy and reaction times for correct responses. For response *accuracy*, the only significant effect involved probe valence, $F(1, 46) = 4.25$, $p < .05$, $\eta_p^2 = .09$, with a higher proportion of correct responses for pleasant ($M = 0.984$; $SE = 0.004$) than for unpleasant scenes ($M = 0.970$; $SE = 0.005$). For response *latencies*, a main effect of probe valence, $F(1, 46) = 10.55$, $p < .01$, $\eta_p^2 = .19$, was qualified by an interaction of prime expression by probe valence, $F(2, 92) = 6.74$, $p < .01$, $\eta_p^2 = .13$, and a three-way interaction involving prime expression by probe valence by SOA, $F(2, 92) = 4.61$, $p < .025$, $\eta_p^2 = .09$. Mean scores and contrasts are shown in Figure 5.

To decompose the three-way interaction, we conducted ANOVAs separately for each SOA condition. At 250 ms SOA, no significant effects appeared. In contrast, at 750 ms SOA, a main effect of probe valence,

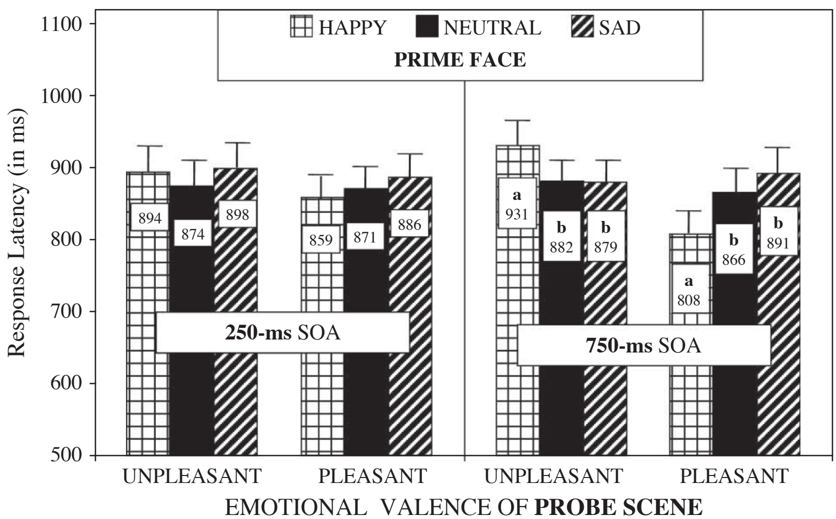

Figure 5. Mean reaction times and standard errors (in ms) for correct responses to probe scenes, as a function of prime face expression and probe scene valence in the 250 ms and the 750 ms SOA conditions. Mean scores with a different superscript are significantly different within each probe valence condition; means sharing a superscript are equivalent.

$F(1, 23) = 6.92$, $p < .025$, $\eta_p^2 = .23$, was qualified by a reliable interaction between prime expression and probe valence, $F(2, 46) = 13.76$, $p < .0001$, $\eta_p^2 = .37$. Subsequent one-way (prime expression) ANOVAs were conducted for each probe condition. The effect of prime expression was significant for both unpleasant, $F(2, 46) = 5.56$, $p < .01$, $\eta_p^2 = .20$, and pleasant, $F(2, 46) = 9.54$, $p < .0001$, $\eta_p^2 = .29$, probes. Post hoc multiple contrasts with Bonferroni corrections (for two comparisons) indicated that correct responses to unpleasant probes were *slower* following a happy prime than following both a neutral and a sad prime (both ps < .05). Conversely, correct responses to pleasant probes were *faster* following a happy prime than following both a neutral and a sad prime (both ps < .05). Importantly, differences between the neutral and the sad prime conditions were never significant. Given that probe scenes in the unpleasant category were more arousing than those in the pleasant category (see previous Stimuli), we examined the possible role of arousal in affective priming. The scenes of each valence category were separated into two groups (above and below the median arousal, according to their original IAPS ratings), and the affective priming scores were reanalysed. No main effect of arousal or interactions with other variables emerged (Fs < 1). The priming effect of happy faces occurred regardless of arousal.

Discussion

A reliable prime face expression by probe scene valence interaction revealed that happy faces facilitated the affective processing of pleasant scenes and inhibited the processing of unpleasant scenes, whereas sad faces had no effect. The fact that priming varied as a function of affective in/congruence between the happy prime faces and the probe scenes indicates that positive *affect* was extracted from happy faces, while negative affect was not from sad faces. Given that the task involved affective evaluation of the probe scenes, facilitation of responses for congruent pleasant scenes—and, consistently, inhibition for incongruent unpleasant scenes—implies that positive emotional valence was processed from happy faces, and that such priming occurred as a function of affect rather than merely visual appearance. Nevertheless, the priming effects emerged at 750 ms but not at 250 ms prime–probe SOA. This suggests that the affective representation responsible for the priming effects was not activated immediately upon perceiving the happy face, but took some time to develop. Next we discuss the hypothesis that perceptual salience is processed first and then affect is extracted from salient and distinctive features with delay.

GENERAL DISCUSSION

The current study investigated (a) whether emotional facial expressions can be recognized without overt visual attention in extrafoveal vision, (b) whether the happy face recognition advantage depends on featural processing, (c) whether it involves affective assessment rather than merely perceptual analysis, and (d) the time course of such affective processing in comparison with featural processing.

Recognition of facial expressions of emotion in extrafoveal vision

Although participants made virtually no fixations on extrafoveally presented, upright faces, sensitivity scores showed that all emotional expressions were recognized well above chance level. Nevertheless, happy faces were recognized faster than all the other expressions. This advantage occurred in conditions where the probability of landing a fixation on the face was negligible (0.2% of trials), and even those rare fixations were blocked with a gaze-contingent foveal mask. Neither the recognition of emotional expressions in extrafoveal vision nor the superiority of happy faces in such conditions have been reported previously, as faces were typically presented at fixation in prior studies (Calvo & Lundqvist, 2008; Juth et al., 2005; Leppänen & Hietanen, 2004; Palermo & Coltheart, 2004; Tottenham et al., 2009). Our findings reveal that the advantageous recognition of happy expressions begins with covert attentional processing, before the faces are overtly attended to. This is consistent with results obtained by Goren and Wilson (2006), who found that the recognition accuracy of computer-generated facial expressions in peripheral vision (8.1° to centre of face) was impaired—relative to central vision—for sad, angry, and fearful faces, but not for happy faces. As faces were presented for 110 ms, it is unlikely that they were fixated. We have extended this finding to real faces and to recognition latencies, and verified that this occurs under conditions that strictly prevent overt attention to the face stimuli.

The role of featural processing in the happy face recognition advantage

The recognition superiority of happy expressions is due to featural processing. Although inversion impaired recognition for all expressions, the pattern of A' and response time (RT) differences generally remained the same as in the upright condition. Furthermore, the recognition of happy (and surprised) faces was less affected by inversion than that of other faces. As face inversion disrupts the analysis of configural or holistic information more than that of individual parts or face features (Maurer et al., 2002), the present results imply that the superior recognition of happy faces is due to their processing relying heavily on single features. Consistently with this view, two prior studies using Pictures of Facial Affect stimuli (Ekman & Friesen, 1976), rather than KDEF stimuli (current study), have shown no (McKelvie, 1995) or only minimal (Leppänen & Hietanen, 2007) impairment of happy face recognition as a function of inversion (when the faces were presented within central—rather than extrafoveal—vision).

Within a featural account, we can consider the role of teeth exposure and an open mouth for expression recognition, as the proportion of faces with exposed teeth and open mouths was greater for happy than for other expressions in our stimulus sample (probably because these are *typical* features of smiles). Two types of data are relevant to address this issue. First, with the same face stimuli, Calvo and Nummenmaa (2008) found that low-level image properties such as luminance were not greater for the mouth region of happy faces than for other expressions. Furthermore, the effect of teeth exposure on face detection varied as a function of expression. Teeth exposure facilitated detection of happy, angry, and disgusted faces similarly, but had no effect on fearful faces and produced interference for surprised faces. Second, Tottenham et al. (2009) compared recognition accuracy for closed- and open-mouth versions of all expressions (except surprise). Happy, angry, and fearful, but not disgusted, faces resulted in higher recognition scores with open mouths, whereas sad expressions were identified more accurately with a closed mouth. Importantly, happy expressions were identified more accurately than all the other expressive faces not only with open mouths but *also* with closed mouths. This implies that the recognition advantage of happy faces cannot be attributed merely to their showing teeth or having an open mouth. Rather, a particular mouth *shape* (e.g., upturned lip corners) may be a critical feature. In any case, teeth exposure and an open mouth are significant features of expressions rather than trivial low-level confounds.

Is there an automatic processing of affect in happy faces?

Does the featural analysis underlying the recognition advantage of happy faces involve affective evaluation? Our affective priming findings revealed that positive affect was extracted from happy faces. This was inferred from the fact that happy face primes facilitated the evaluation of probe scenes that were congruent in emotional valence, and interfered with incongruent scenes. Nevertheless, these priming effects did not appear immediately (within a 250 ms prime–probe SOA), but with delay (750 ms SOA). Accordingly, affective processing of extrafoveal happy faces does not fulfil one major criterion (namely, rapidity) for automaticity (see Moors & de Houwer, 2006). Using the same stimuli and eccentricity as in the current study, and taking saccade latencies in a two-alternative forced-choice paradigm as an index of recognition time course (see Kirchner & Thorpe, 2006), Calvo and Nummenmaa (2009) found that the categorization of happy expressions began between 160 and 180 ms from stimulus onset (with median latencies of 284 ms). This implies that visual expression recognition starts earlier than affective assessment, and that affect would be unlikely to account for the happy face recognition advantage, as affective priming occurred later than expression categorization.

Some previous studies have also used affective priming paradigms to investigate whether and when facial affect is perceived, with faces as primes and pictures (faces or scenes) or words as probes (Aguado, García-Gutiérrez, Castañeda, & Saugar, 2007; Banse, 2001; Carroll & Young, 2005; Lipp, Price, & Tellegen, 2009; Nummenmaa, Peets, & Salmivalli, 2008). Priming was found in all these studies even when the SOA was 300 ms or less (except in Nummenmaa et al., 2008, in which priming appeared only after 450 ms SOA). The present experiments make a contribution in two respects. First, in all the prior studies the prime faces were presented within central vision. We have shown that affective processing of faces in parafoveal vision may have a time course cost, as priming appeared later (750 ms SOA) than in the previous studies. Second, happy faces were not specifically compared with other expressions in prior research (except in the Lipp et al., 2009, study). Rather, neutral faces of *liked* or *disliked* people were presented as primes (Banse, 2001; Nummenmaa et al., 2008); or various emotional expressions were used as primes, but comparisons between different emotions were not carried out (Aguado et al., 2007; Carroll & Young, 2005). We have shown that *happy* expressions produce genuine affective priming.[3]

[3] Lipp et al. (2009) have also reported affective priming for happy faces, as well as for angry, fearful, and sad faces, as primes (when presented at fixation, rather than extrafoveally), using positively and negatively valenced probe words. However, Lipp et al. did not use a neutral prime face condition. As a result, it was difficult to determine the relative magnitude of the priming effects as a function of prime emotional valence: More specifically, whether the congruent versus incongruent prime–probe differences (e.g., happy prime vs. angry prime, for pleasant probes) reflected facilitation due to congruent valence (e.g., happy–pleasant) or inhibition due to incongruent valence (e.g., happy–unpleasant). The use of a comparison condition (neutral prime face) in the current study revealed both positive and negative priming for happy faces.

From featural to affective processing

How can positive affect be extracted from happy expressions extrafoveally, albeit with delay? Our explanation involves a two stage visual-affective mechanism. The first stage involves a quick featural detection through perceptual analysis of visually salient regions. The minimal impairment of both detection (Calvo & Nummenmaa, 2008) and recognition (Leppänen & Hietanen, 2007; McKelvie, 1995) of happy faces suggests that their initial processing can be accomplished by featural analysis. Furthermore, the mouth region is a particularly salient feature in happy faces. Calvo and Nummenmaa (2008) computed the saliency of five horizontal segments (forehead, eyes/eyebrows, nose/cheeks, mouth, and chin) of the faces used in the current study, by means of a neuromorphic model of visual attention (iNVT) developed by Itti and Koch (2000). In this model, visual saliency is defined by a combination of purely physical image properties devoid of meaning (local contrast, spatial orientation, and energy). Calvo and Nummenmaa found that the mouth of happy faces was more salient than any other region and the mouth of the other expressions. Presumably, such a high visual saliency would make the mouth easily accessible to extrafoveal vision (see Goren & Wilson, 2006) and then attract attention (Calvo & Nummenmaa, 2008). The happy face recognition advantage would thus start with automatic selective covert attention to (followed by overt orienting, if there is enough time for saccades; see Calvo & Nummenmaa, 2008) and facilitated detection of a salient feature, i.e., the mouth region.

In the second stage, salient features would be used for expression recognition and affect retrieval. Two characteristics of happy faces would facilitate these processes: Distinctiveness and diagnosticity. Expression information can be easily and reliably extracted from the happy mouth shape because it is a perceptually distinctive feature that is uniquely and systematically associated with happy expressions. Calvo and Marrero (2009) assessed 16 action units (Ekman, Friesen, & Hager, 2002) of the same faces used in the current study. The only unit that appeared on more than 75% of the exemplars of a given emotional expression *and* that was not shared by any other expression (hence unique, distinctive, and reliably associated) was the upper lips raised of happy faces. All other units (e.g., frown, wide open eyes, teeth exposed, etc.) were not consistently and exclusively associated with any expression. The mouth has indeed been found to be the most important element in the recognition of happy faces (Kontsevich & Tyler, 2004; Smith, Cotrell, Gosselin, & Schyns, 2005). The expressive changes in the mouth region are sufficient for a face to be classified as happy (Leppänen & Hietanen, 2007) without resorting to configural processing. The smiling mouth shape could thus be used as a diagnostic cue to retrieve the affective associations of the recognized expression, and would then serve as a shortcut to infer the emotional significance of happy faces.

Within the described mechanism, the process that leads from perception of the physical appearance of the mouth to the emotional significance of the face would take time. The rapid identification of happy faces would initially rely on some visual features, from which affective meaning would be extracted later. Some features regularly linked to particular facial expressions may have acquired their affective properties through a process of associative learning. As a consequence, when we detect the feature, affective meaning could be retrieved even before the whole facial configuration is processed. For example, facial expressions of fear involve an increase of the amount of visible sclera, and amygdala response (often associated with fear processing; see Adolphs, 2002) is greater for large versus small eye whites presented in isolation (Whalen et al., 2004). Alternatively, even if the salient features do not convey affective meaning themselves, they can serve as cues that allow viewers to infer such meaning strategically. As proposed by Adolphs (2006), perception of facial emotion does not occur instantaneously as a single process and through a single neurological and cognitive route. Rather, perception of emotion is an active, inferential process, whereby we go from the visual appearance of an emotional face to its social meaning.

CONCLUSIONS

The recognition of facial expressions of emotion begins before the faces are fixated, thus showing that recognition can be performed to some extent outside the focus of overt attention. In the absence of eye fixations, happy faces are not only the fastest expressions to be recognized, but also positive affect can be extracted from them. As the happy face recognition advantage occurs even when faces are presented upside-down, it can be attributed to the processing of highly salient and distinctive facial features—most likely in the mouth region—that can be perceived in the visual periphery. Due to visual saliency, the happy mouth region would be easily accessed extrafoveally. Due to distinctiveness, the mouth region would allow viewers to recognize the happy expression unambiguously with reduced processing demands. The salient smile would provide a diagnostic cue from which an inference of positive affect would be drawn. Viewers can thus perceive a warm-hearted smile (rather than just a salient mouth) in a happy face when it is still outside of foveal vision. Nevertheless, the affective processing of happy expressions occurs with some delay and is unlikely to be responsible for the happy face recognition advantage. Such an advantage would be initially driven by the analysis of visually prominent facial features.

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APPENDIX
IAPS identification number of the pictures used as unpleasant and pleasant probes in Experiment 2

Unpleasant scenes

2095, 2141, 2455, 2700, 2703, 2710, 2799, 2800, 2900, 3180, 3181, 3225, 3300, 3350, 6212, 6243, 6313, 6530, 6550, 6560, 6838, 6840, 8010, 8231, 9040, 9250, 9254, 9400, 9410, 9421, 9429, 9921.

Pleasant scenes

2040, 2057, 2070, 2071, 2154, 2160, 2165, 2170, 2260, 2311, 2332, 2340, 2530, 2540, 2550, 2565, 4572, 4599, 4623, 4626, 4641, 4653, 4660, 4687, 4695, 4700, 5831, 5836, 7325, 8032, 8200, 8461.