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Perceptual, categorical, and affective processing of ambiguous smiling facial expressions

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ABSTRACT

Why is a face with a smile but non-happy eyes likely to be interpreted as happy? We used blended expressions in which a smiling mouth was incongruent with the eyes (e.g., angry eyes), as well as genuine expressions with congruent eyes and mouth (e.g., both happy or angry). Tasks involved detection of a smiling mouth (perceptual), categorization of the expression (semantic), and valence evaluation (affective). The face stimulus display duration and stimulus onset asynchrony (SOA) were varied to assess the time course of each process. Results indicated that (a) a smiling mouth was visually more salient than the eyes both in truly happy and blended expressions; (b) a smile led viewers to categorize blended expressions as happy similarly for upright and inverted faces; (c) truly happy, but not blended, expressions primed the affective evaluation of probe scenes 550 ms following face onset; (d) both truly happy and blended expressions primed the detection of a smile in a probe scene by 170 ms post-stimulus; and (e) smile detection and expression categorization had similar processing thresholds and preceded affective evaluation. We conclude that the saliency of single physical features such as the mouth shape makes the smile quickly accessible to the visual system, which initially speeds up expression categorization regardless of congruence with the eyes. Only when the eye expression is later configurally integrated with the mouth, will affective discrimination begin. The present research provides support for serial models of facial expression processing.

1. Introduction

In a categorical approach to facial affect, emotional expressions are conceptualized as discrete entities that can be subsumed under six basic categories: fear, anger, sadness, happiness, disgust, and surprise (Ekman, 1994). Although this conceptualization is not devoid of its own limitations (see critical reviews in Barrett (2006) and Barrett, Gendron, and Huang (2009)), it has been widely adopted by prior research on the recognition of facial expressions, and studies have generally used prototypical examples of the six categories as stimuli. In real life, however, there is an enormous idiosyncrasy and variability across individuals and social contexts, where ambiguous expressions are frequently encountered (Carroll & Russell, 1997; Scherer & Ellgring, 2007). For example, Ekman (2001) identified at least 18 different types of smiles, and proposed that there may be as many as 50 in all. However, the evidence regarding the perception, categorization, and affective processing of non-prototypical expressions has remained elusive. In the present study we examined whether the processing of ambiguous expressions with a smile, but non-happy eyes, involves the same mechanisms and stages as that of the prototypical expressions.

To investigate the recognition of ambiguous expressions, studies have used genuine blends (Nummenmaa, 1988), hybrids (Schyns & Oliva, 1999), morphed (Calder,

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Rowland, et al., 2000), and composite (Calder, Young, Keane, & Dean, 2000) face stimuli. In composite faces, the top half of a face conveying one expression is fused with the bottom half of another expression. The resulting facial configuration is thus a blend of two expressions and therefore becomes ambiguous. In the current study we employed this approach by aligning the bottom half of a happy face with the top half of non-happy faces (either angry, sad, fearful, disgusted, surprised, or neutral) of the same individual. This produced blended expressions with a smiling mouth but non-happy eyes. For comparison, we also used intact faces conveying prototypical happy or non-happy expressions, in which the eye region was congruent with the mouth region, as both belonged to the same category (and individual), and therefore these expressions were genuine and unambiguous. With this approach, we explored (a) the extent to which the presence of a smile—even though incongruent with other facial components—can bias the recognition of an expression as happy, (b) whether featural or configural processing is involved in the categorization and affective evaluation of blended expressions, and (c) how such bias develops over time for the extraction of perceptual, categorical, and emotional information.

1.1. Role of a smile in facial expression processing

From a theoretical standpoint, smiles provide a useful and well-established model for studying the processing of blended facial expressions. First, happy faces are recognized more accurately and faster than all the other basic expressions (Calder, Young, et al., 2000; Calvo & Lundqvist, 2008; Calvo & Nummenmaa, 2009; Juth, Lundqvist, Karlsson, & Öhman, 2005; Leppänen & Hietanen, 2004; Loughead, Gur, Elliott, & Gur, 2008; Milders, Sahraie, & Logan, 2008; Palermo & Coltheart, 2004; Tottenham et al., 2009). Facial happiness is also the most consistently identified expression across different cultures (Russell, 1994). Second, the smile is a critical feature supporting the recognition advantage of happy faces. Whereas a smiling mouth is a necessary and sufficient criterion for categorizing faces as happy, the eye region makes only a modest contribution (Calder, Young, et al., 2000; Kontsevich & Tyler, 2004; Leppänen & Hietanen, 2007; Nusseck, Cunningham, Wallraven, & Bülthoff, 2008; Smith, Cottrell, Gosselin, & Schyns, 2005). Third, the importance of the smile in facilitating expression recognition has been attributed to its high visual saliency and diagnostic value (Calvo & Nummenmaa, 2009; Calvo, Nummenmaa, & Avero, 2010). Because the smiling mouth is a salient or conspicuous feature, the smile attracts the first eye fixation more likely than any other region of the six basic expressions (Calvo & Nummenmaa, 2008). In addition, because of its distinctiveness or diagnostic value, the smile is systematically associated with facial happiness and is absent in all other expression categories (Calvo & Marrero, 2009). Such a single diagnostic feature can thus be used as a shortcut for a quick categorization of a face as happy.

By assuming the contribution of the saliency and distinctiveness of a smile, we addressed two questions. First, is the smiling mouth so salient and distinctive that it overrides the processing of other facial components, such as the eye region, even when these are inconsistent in meaning with the smile? If so, the presence of a smiling mouth would bias viewers towards judging blended facial expressions as happy, regardless of other expressive sources. This issue has obvious theoretical and practical importance, as in many everyday situations people smile without necessarily being happy. The smile is a complex, multifunctional signal, which can also reflect mere politeness or even conceal negative motives (embarrassment, dominance, etc.), depending on the combination with other facial signals (see Ambadar, Cohn, & Reed, 2009; Niedenthal, Mermillod, Maringer, & Hess, 2010). It is, nevertheless, possible that, because of its saliency and distinctiveness, a smiling mouth "dazzles" the viewers and prevents them from noticing less salient yet informative facial cues such as frowns, which would be necessary to interpret the smile accurately and react with adaptive behavior in time.

Second, does the categorization of an ambiguous, as well as a genuine, smiling face involve only perceptual processing—either single feature detection or configural pattern recognition—of a salient mouth, or also extraction of positive affect? Furthermore, can affect be obtained from feature analysis or does it require configural analysis, and what is the relative time course of these processes? There is considerable evidence that faces (Richler, Mack, Gauthier, & Palmieri, 2009) and facial expressions (Calder, Young, et al., 2000) are processed configurally or holistically, that is, coded as unitary objects, in an integrated representation that combines the different face parts. Studies have, nevertheless, also shown that the category of an emotional expression can be inferred from the separate analysis of single distinctive facial components (Ellison & Massaro, 1997; Fiorentini & Viviani, 2009). Probably, both views are complementary, with some expressions being more dependent on holistic and others relying more on analytic processing (Tanaka, Kaiser, Butler, & Le Grand, in press). In any case, for both the configural and the featural conceptualization, it is possible that expression recognition is performed solely on the basis of some perceptual pattern or a single visual cue from the face image, without retrieving any affective meaning. It remains unresolved whether emotional representations are also activated during perceptual processing and used for expression categorization, and how this applies to blended facial expressions.

1.2. The current study

To investigate whether a smiling mouth can overshadow other facial regions and override their processing even when these are incongruent with the smile, we used composite faces (Calder, Young, et al., 2000; Leppänen & Hietanen, 2007; Tanaka et al., in press), in which non-happy (e.g., angry) eyes were combined with a smiling mouth, thus conveying blended expressions. These faces were then compared with intact faces conveying prototypical expressions (happy, angry, etc.) in several tasks. In Experiment 1, we used a categorization task in which participants responded whether each face looked happy or not. To determine the role of configural and featural processing, the face stimuli were presented upright or spatially inverted. In Experiments 2 and 3, we aimed to distinguish between affective and perceptual processes. To this end, we used priming tasks in which happy, neutral, or blended face primes were followed by an emotional probe scene. Participants responded whether the scene was pleasant or unpleasant (affective priming task) or whether there was any person smiling in the probe scene (perceptual priming task). Depending on the emotional congruence and the visual similarity between the prime and the probe, priming effects (i.e., faster responding to the probe following the happy or the blended prime, relative to the neutral prime) allowed us to tease apart affective and perceptual processing of the genuine and the blended expressions. Finally, in Experiment 4, we directly compared the performance on all three tasks (perceptual, categorization, and affective) within the same experimental design.

A major aim of this study was to investigate the relative time course of perceptual, categorical, and affective processing of blended and prototypical expressions. To examine when discrimination between genuinely happy and blended expressions with a smile occurs, in Experiments 2 and 3, we varied the stimulus onset asynchrony (SOA; 170, 340, 550, and 800 ms) between a prime face and a probe scene. The lower boundary of 170 ms was motivated by the earliest event-related potential (ERP; N170 component) that reflects facial structural encoding (i.e., differentiation between faces and non-face objects), about which there is a debate on whether it is also sensitive to emotional expression (i.e., differentiation of emotional from non-emotional faces; see Eimer & Holmes, 2007; Schacht & Sommer, 2009). Discrimination among emotional expressions is likely to start later, as reflected in the N300 and P300 (from 250 to 500 ms) ERP components (Luo, Feng, He, Wang, & Luo, 2010). Similarly, conscious recognition of basic expressions can be accomplished in ~300 ms (Calvo & Nummenmaa, 2009, 2011), which thus represents a critical time point for comparison with blended expressions. Finally, affective retrieval is predicted to occur later than categorization. In fact, affective priming by happy or liked faces has been found between 300 and 750 ms from face onset (Calvo et al., 2010; Lipp, Price, & Tellegen, 2009; Nummenmaa, Peets, & Salmivalli, 2008). Our 550- and 800-ms SOA conditions will thus explore a possible delay for blended expressions. In a complementary approach to estimate the processing time course, in Experiment 4, we varied the display duration of the face stimuli (20, 40, 70, and 100 ms), while participants judged whether or not (a) the mouth was smiling (perceptual), (b) the face was happy (categorization), and (c) the expression was pleasant (affective).

2. Experiment 1

Face stimuli were presented in their normal upright position or upside-down, and displayed until participants responded whether a face looked happy or not. Expressions were either (a) genuinely happy (henceforth, happy), with a smiling mouth that was congruent with the eye expression, (b) genuinely non-happy (henceforth, non-happy; i.e., angry, sad, and so forth, with matching eyes and mouth), or (c) blended, with non-happy eyes (e.g., angry, neutral, etc.) and a smiling mouth. We also modeled the visual saliency of the eye and the mouth regions of the face stimuli. This served to explore the extent to which the smile remained highly salient in the blended expressions and could thus bias their categorization as happy.

The manipulation of spatial orientation (upright or inverted) of the face stimuli was relevant to determine how much the categorization of blended expressions relies on featural vs. configural processing. Face inversion is believed to disrupt the analysis of configural information, while that of featural information is impaired to a lesser extent (Farah, Tanaka, & Drain, 1995; Maurer, Le Grand, & Mondloch, 2002). If the distinctive smiling mouth remains salient in blended expressions, it will probably promote feature-based categorization, and so the processing of these expressions will not be impaired by inversion: They will be judged as *happy* with equal likelihood and latency when displayed upright or inverted. In contrast, to the extent that configural integration of the smiling mouth with the inconsistent non-happy eyes is required, performance impairment will occur: The correct judgment of blended expressions as *not happy* will take longer in the inverted than in the upright condition.

2.1. Method

2.1.1. Participants

Fifty psychology undergraduates (36 female) participated in the experiment. As in the following experiments, all the participants were psychology undergraduates at La Laguna University, between 18 and 25 years of age, who gave informed consent and received course credit for their participation.

2.1.2. Stimuli

We selected 168 digitized photographs from the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998) stimulus set. The face stimuli portrayed 24 individuals (12 females: KDEF no. 01, 02, 07, 11, 14, 19, 20, 22, 26, 29, 31, 35; and 12 males: KDEF no. 03, 05, 06, 10, 11, 12, 22, 23, 24, 25, 31, 35), each posing seven basic expressions (neutral, happiness, anger, disgust, sadness, fear, and surprise). In addition to these intact faces with *genuine* expressions faces taken from the KDEF, we constructed six *composite* faces with *blended* expressions of each of the 24 selected models, thus producing 144 new face stimuli. To this end, we combined the upper half of each non-happy face and the lower half of the happy face of the same individual, by cutting each face along a horizontal line through the bridge of the nose and smoothing the junction by Adobe® Photoshop® CS5. In the resulting composite stimuli, the two halves of a face—each with a different expression—were always spatially aligned. The following blended expressions were produced: Neutral eyes + Happy smile (NEHA), Angry eyes + Happy smile (ANHA), Disgusted eyes + Happy smile (DIHA), Sad eyes + Happy smile (SAHA), Fearful eyes + Happy smile (FEHA), and Surprised eyes + Happy smile (SUHA) (see Fig. 1). Nonfacial areas (e.g., hair, neck, etc.) were removed by applying an ellipsoidal mask. Each face subtended a

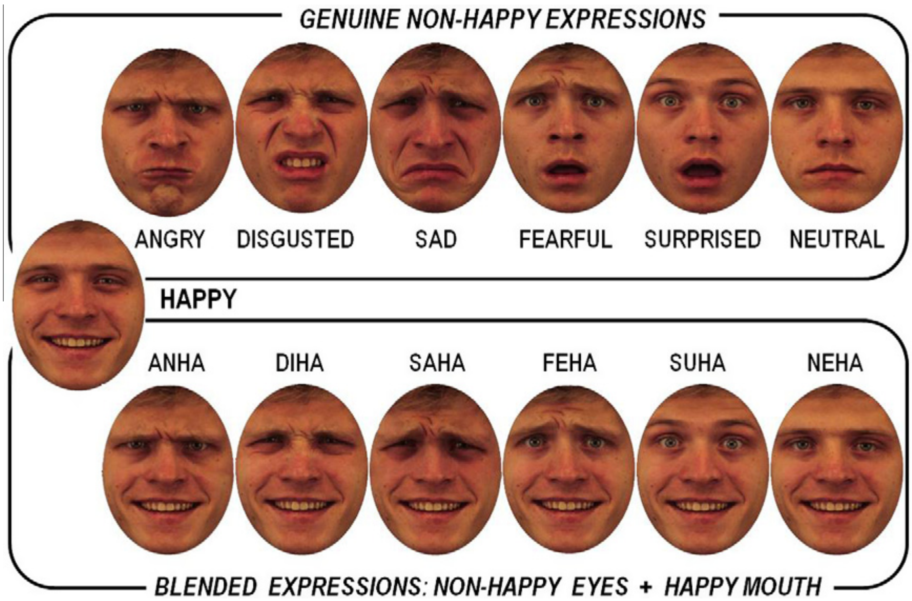

Fig. 1. Sample face stimuli with happy, non-happy, and blended expressions used in Experiments 1–4. Blended expressions: ANHA: angry eyes + smile (i.e., angry upper part of face with happy lower part of face); DIHA: disgusted eyes + smile; SAHA: sad eyes + smile; FEHA: fearful eyes + smile; SUHA: surprised eyes + smile; NEHA: neutral eyes + smile.

visual angle of 8.4° (height) × 6.4° (width) at a 60-cm viewing distance.

A distinction has been made between "genuine" smiles conveying positive affect and "fake" (also called "social", "polite", or "masking") smiles, with several morphological and dynamic differences between them (e.g., Krumhuber & Manstead, 2009; Miles & Johnston, 2007). Both types of smiles involve contraction of the *zygomaticus major* muscle, with lip corners turned up and pulled backwards, often accompanied by a raised upper lip and exposed teeth. There is, however, another component, called the Duchenne marker, which is typically associated with genuine smiles but frequently absent in fake smiles. It involves recruitment of the *orbicularis oculi*, *pars lateralis* muscle, with raised cheeks, bulges below the eyes, crow's feet wrinkles at the outer corners of the eyes, a lowering of the eyebrows and a narrowing of the eye aperture. To ensure that our original models were conveying facial expressions of genuine happiness, we selected the KDEF models that included both morphological components of smiles. All the smiles, both for the happy and the blended expressions, involved an open mouth and exposed teeth.

2.1.3. Assessment of visual saliency

We obtained the saliency values of two horizontal segments of each face, corresponding to the eye and the mouth regions, by means of the iLab Neuromorphic Vision C++ Toolkit (iNVT; Itti & Koch, 2000; see also Walther & Koch, 2006). This algorithm simulates which features in a given image attract attention as a function of physical image properties (local contrast, orientation, and energy), by mimicking the response properties of retinal neurons, lateral geniculate nucleus, thalamus, and V1. Such features are then integrated for a neural saliency map that is a graded representation of the visual conspicuity of each pixel in the image. In our face stimuli, both the eye region and the mouth region subtended vertical visual angles of 1.6° each, for every face stimuli (see Fig. 2). To preserve the face configuration intact, saliency was computed for each predefined region integrated within the whole face, rather than in isolation. This implies that the relative saliency of a given region (e.g., the eyes) can vary depending on the saliency of the other regions in a face (e.g., the mouth).

2.1.4. Procedure and design

The stimuli were presented against a black background on a SVGA 17″ CRT monitor (with a 100-Hz refresh rate, at a resolution of 800 × 600 pixels) by means of the E-Prime (Version 2.0) experimental software. Each participant received 312 experimental trials (24 of each expression category) in four blocks, randomly. Each trial began with a central fixation circle for 500 ms, followed by a target face in the center of the screen. The face stimulus was shown until the participant responded that it looked "happy" or "not happy", by pressing one of two keys. The participants were not informed that there were composite faces with blended expressions. The intertrial interval was 1500 ms. The probability of responding whether a face was happy or not, as well as response latencies from the onset of the face, were collected.

The experimental design involved facial expression category (13: 7 genuine and 6 blended; see Section 2.1.2), as a within-subjects factor, and spatial orientation of face stimuli (2: upright or inverted), as a between-subjects factor, with 25 participants (18 female) in each type of display condition. As indicated in the introduction, the manipulation of spatial orientation was used to distinguish between configural and featural processing.

2.2. Results

2.2.1. Categorization performance

We conducted four types of analyses. First, the probability that faces were *categorized as "happy"* was analyzed

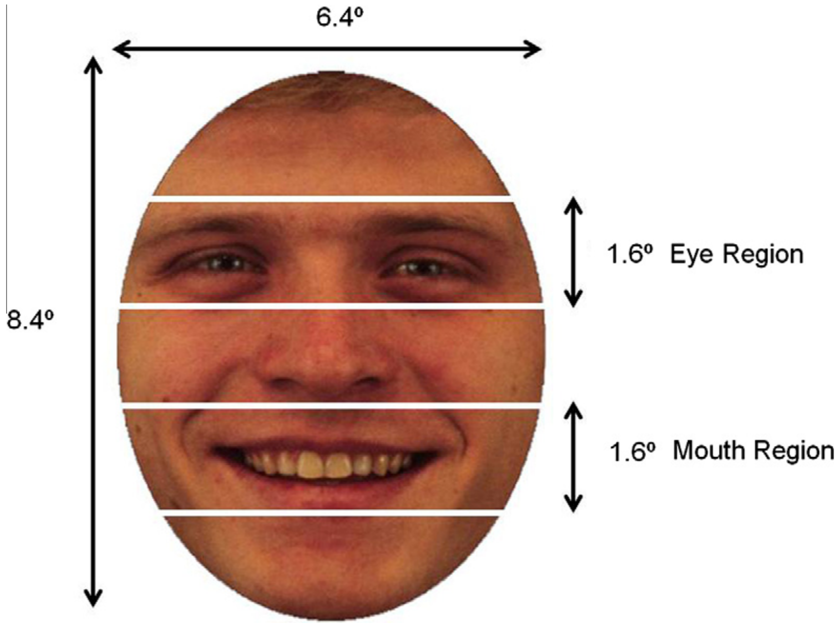

Fig. 2. Area covered by the eye region and the mouth regions, of which the visual saliency was computed.

in a 13 (expression category) × 2 (spatial orientation) ANOVA. This revealed the tendency to confuse blended expressions as happy. Second, we used single-sample *t* tests to compare the *probability of correct responses* for each expression category against the 0.5 chance level. To this end, "yes, happy" responses to prototypical happy faces were correct, whereas "no, not happy" responses to blended expressions and prototypical non-happy faces were considered as correct. Third, *reaction times* of *correct responses* were analyzed in a 13 (category) × 2 (orientation) ANOVA to determine the processing demands of the accurate recognition of expressions. Finally, the *reaction times* of "*yes, happy*" (incorrect) *responses* to the blended expressions were compared with "*no*" (correct) responses to them, and with "*yes*" (correct) responses to truly happy faces. In combination with spatial orientation, this served to assess the extent to which configural or featural analysis is involved in the processing of blended expressions (see Section 2.3).

For all the ANOVAS, and given that there were multiple experimental conditions (i.e., expression categories) to be compared, we used Bonferroni corrections with an alpha level of $p < .05$ for all the multiple comparisons in this and the following experiments, to control for type I error. Tables 1 and 2 show the probability of categorizing faces as "happy" and the reaction times for correct responses for each facial expression category, as well as the corresponding contrasts among categories. Figs. 3 and 4 show the mean happy face scores, as well as the average scores for the non-happy and the blended expressions.

First, in a 13 (expression) × 2 (orientation) ANOVA on the *probability* that faces were *categorized as "happy"*, main effects of expression appeared, $F(12,576) = 550.57$, $p < .0001$, $\eta_p^2 = .920$. As indicated in Table 1 and Fig. 3, for both the upright and the inverted conditions, (a) scores were higher for the happy faces than for all the other categories, (b) scores were lower for each non-happy face (e.g., angry) than the corresponding blended expression (e.g., angry eyes + happy smile), (c) there were no significant differences among the various genuinely non-happy faces, and (d) the ANHA and the NEHA faces were less and more likely, respectively, to be judged as happy than most of the other expressions. The main effects of orientation were not significant ($F < 1$), but there was a reliable

Table 1
Mean probability of responding "happy" to a face, as a function of facial expression and spatial orientation, in Experiment 1.

Non-happy	Facial expression category						
	Angry	Disgusted	Sad	Fearful	Surprised	Neutral	Happy
Upright	01^b	$.02^b$	$.01^b$	$.02^b$	$.09^b$	$.03^b$	$.96^a$
Inverted	$.02^b$	$.04^b$	$.03^b$	$.05^b$	$.11^b$	$.05^b$	$.85^a$
Blended	ANHA	DIHA	SAHA	FEHA	SUHA	NEHA	Happy
Upright	$.33^d$	$.39^d$	$.40^{cd}$	$.41^c$	$.44^{bc}$	$.49^b$	$.96^a$
Inverted	$.32^d$	$.38^d$	$.38^{cd}$	$.41^c$	$.43^{bc}$	$.48^b$	$.85^a$

Note: ANHA: Angry eyes with a smile (i.e., angry upper part of face with happy lower part of face); DIHA: disgusted eyes with a smile; SAHA: sad eyes with a smile; FEHA: fearful eyes with a smile; SUHA: surprised eyes with a smile; NEHA: neutral eyes with a smile. Means with a different superscript horizontally are significantly different; means with the same superscript or no superscript are equivalent. Differences between non-happy and blended expressions were always significant.

Table 2
Mean reaction times for correct responses ("happy", to happy faces; "not happy", to non-happy and to blended-expression faces), as a function of facial expression and spatial orientation, in Experiment 1.

Facial expression category							
Non-happy	Angry	Disgusted	Sad	Fearful	Surprised	Neutral	Happy
Upright	540	564	533	563	550	537	529
Inverted	611[c]	648[bc]	614[c]	649[bc]	644[bc]	615[c]	693[ab]
Blended	ANHA	DIHA	SAHA	FEHA	SUHA	NEHA	Happy
Upright	779[a]	803[a]	794[a]	787[a]	803[a]	838[a]	529[b]
Inverted	952[a]	988[a]	974[a]	964[a]	997[a]	1,039[a]	693[b]

Note: ANHA: Angry eyes with a smile; DIHA: disgusted eyes with a smile; SAHA: sad eyes with a smile; FEHA: fearful eyes with a smile; SUHA: surprised eyes with a smile; NEHA: neutral eyes with a smile. Means with a different superscript horizontally are significantly different; means with the same superscript or no superscript are equivalent. Differences between non-happy and blended expressions were always significant.

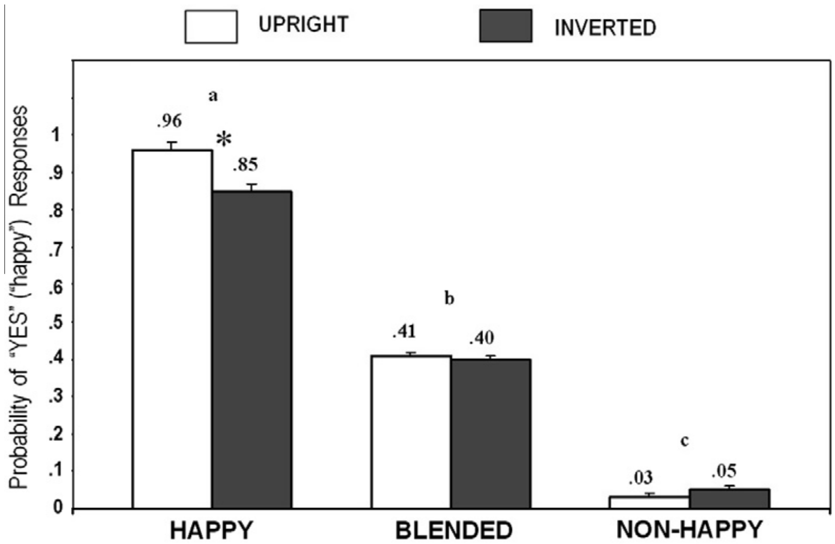

Fig. 3. Mean probability of "yes" ("happy") responses for happy, blended, and non-happy facial expressions, in the upright and the inverted display conditions, in Experiment 1. Asterisks indicate significant differences between the upright and the inverted condition. Means with a different superscript are significantly different between expression categories across the upright and the inverted condition.

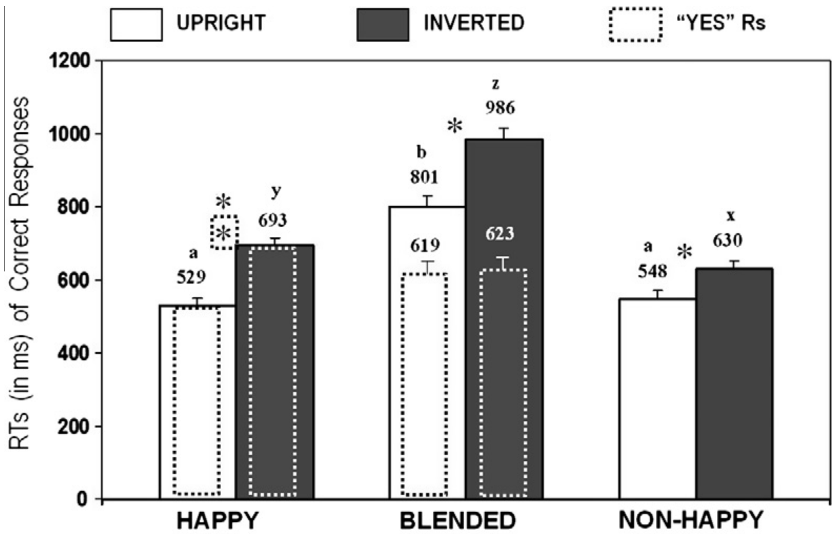

Fig. 4. Mean reaction times of correct responses (and of "yes, happy" responses, shown by dotted-line boxes) for happy, blended, and non-happy facial expressions, in the upright and the inverted display conditions, in Experiment 1. Asterisks indicate significant differences between the upright and the inverted condition. Means with a different superscript (a, b, c, for the upright condition; x, y, z, for the inverted condition) are significantly different; means with the same superscript are equivalent.

interaction, $F(12,576) = 2.08$, $p < .025$, $\eta_p^2 = .042$. The interaction reflected the fact that the probability of categorizing the happy faces as happy was lower in the inverted than in the upright condition, $t(48) = 5.57$, $p < .0001$, whereas inversion did not affect the blended or the non-happy faces.

Second, the single-sample t tests of the *probability* that *correct responses* exceeded the 0.5 chance level revealed that scores were significantly greater than expected by chance for the happy and all the non-happy faces in both the upright and the inverted condition ($ts \geqslant 22$, $p < .0001$). All the blended expressions exceeded the chance level (all $ts \geqslant 2.34$, $p < .05$) except those with neutral eyes and a smiling mouth (NEHA; $t < 1$, $p = .39$), in both the upright and the inverted condition.

Third, for *reaction times* of *correct responses*, the 13 (category) × 2 (orientation) ANOVA yielded main effects of expression, $F(12,576) = 266.78$, $p < .0001$, $\eta_p^2 = .848$, orientation, $F(1,48) = 14.29$, $p < .0001$, $\eta_p^2 = .229$, and an interaction, $F(12,288) = 7.47$, $p < .0001$, $\eta_p^2 = .135$. As indicated in Table 2 and Fig. 4, post hoc contrasts showed that, (a) in the upright condition, response latencies for the happy faces were equivalent to those of all the non-happy faces, but shorter than those of all the blended expressions, which were longer than those of the corresponding non-happy expressions; (b) in the inverted condition, differences were significant among all three categories. Also, reaction times were longer in the inverted than in the upright condition for all the categories (all $ts \geqslant 2.19$, $p < .05$). The interaction reflected the fact that the effect of inversion was greater for the happy $t(48) = 5.14$, $p < .0001$, $d = 1.48$, $r = .60$, and the blended, $t(48) = 4.17$, $p < .0001$, $d = 1.20$, $r = .52$, expressions than for the non-happy expressions $t(48) = 2.67$, $p < .01$, $d = 0.77$, $r = .36$, as revealed by the corresponding Cohen's d and effect-size r values: While the percentage in reaction times that was accounted for by orientation was 35.5% for the happy faces, and 26.5% for the blended faces, it was only (though still significant) 12.9% for the non-happy faces.

Finally, *reaction times* for "*yes*" (incorrect) responses to blended expressions were first compared with "*no*" (correct) responses in a 6 (blended category) × 2 (orientation) × 2 (type of response) ANOVA (see Fig. 4). Main effects of orientation, $F(1,48) = 4.81$, $p < .05$, $\eta_p^2 = .091$, and type of response, $F(1,48) = 7{,}857.46$, $p < .0001$, $\eta_p^2 = .994$, were qualified by an interaction, $F(1,48) = 872.79$, $p < .0001$, $\eta_p^2 = .948$. The interaction reflected the significant difference between the upright and the inverted condition for "no" responses (as reported above), whereas reaction times for "yes" responses were nearly identical in both orientation conditions (all $ts < 1$, $ps \geqslant .90$). In addition, "yes" responses were compared for the blended and the happy expressions in a 7 (expression) × 2 (orientation) ANOVA (see Fig. 4). An interaction, $F(6,288) = 11.10$, $p < .05$, $\eta_p^2 = .188$, confirmed that inversion slowed down response latencies for the happy expressions (see above), whereas it did not affect the time to judge the blended expressions as happy.

2.2.2. Analysis of visual saliency

A 2 (facial expression: non-happy vs. blended) by 6 (eye expression: angry, disgusted, sad, fearful, surprised, and neutral) ANOVA was conducted on the saliency values of the eye and the mouth regions. In addition, the eye and the mouth saliency scores for happy faces were compared with those for the non-happy or the composite faces in separate one-way (7: face category) ANOVAS. See the mean scores for each expression category in Table 3. The average scores for the non-happy, the blended, and the happy expressions are presented in Fig. 5.

For the *mouth* region, effects of facial expression, $F(1,287) = 269.09$, $p < .0001$, $\eta_p^2 = .494$, revealed that the mouth was more salient in the blended ($M = 8.81$) than in the non-happy faces ($M = 4.17$). These effects were qualified by an interaction with type of eyes, $F(5,276) = 6.60$, $p < .0001$, $\eta_p^2 = .107$. In the comparison of the non-happy and the happy faces, effects of face category emerged, $F(6,161) = 17.53$, $p < .0001$, $\eta_p^2 = .395$. The mouth of happy faces was more salient than that of all the non-happy faces. In contrast, in the comparison of blended expressions and happy faces, all the categories with a smile had equivalent saliency.

For the *eye* region, main effects of facial expression, $F(1,287) = 58.24$, $p < .0001$, $\eta_p^2 = .174$, on saliency scores revealed that the eyes were less salient in the blended ($M = 0.59$) than in the non-happy faces ($M = 2.52$). No

Table 3
Mean visual saliency values of the mouth and the eye regions for each facial expression.

Eye region	Facial expression category						
Genuine	Angry	Disgusted	Sad	Fearful	Surprised	Neutral	Happy
	2.21^{ab}	2.32^{ab}	2.82^{a}	2.51^{ab}	3.47^{a}	1.81^{ab}	0.35^{b}
Blended	ANHA	DIHA	SAHA	FEHA	SUHA	NEHA	
	0.52	0.49	0.42	0.73	0.68	0.71	0.35
Mouth region	Facial expression category						
Genuine	Angry	Disgusted	Sad	Fearful	Surprised	Neutral	Happy
	3.74^{bc}	6.06^{b}	2.10^{c}	4.36^{bc}	5.93^{b}	2.52^{c}	8.89^{a}
Blended	ANHA	DIHA	SAHA	FEHA	SUHA	NEHA	
	8.83	8.87	9.02	9.05	8.60	8.62	8.89

Note: ANHA: Angry eyes with a smile; DIHA: disgusted eyes with a smile; SAHA: sad eyes with a smile; FEHA: fearful eyes with a smile; SUHA: surprised eyes with a smile; NEHA: neutral eyes with a smile. Means with a different superscript horizontally are significantly different; means with the same superscript or no superscript are equivalent.

Fig. 5. Mean visual saliency of the eye and the mouth regions for happy, blended, and non-happy facial expressions. Means with a different superscript (a and b, for the mouth region; x and y, for the eye region) are significantly different; means with the same superscript are equivalent.

effects of type of eyes or an interaction emerged ($Fs \leqslant 1$). In the comparison of the non-happy and the happy faces, effects of face category, $F(6,161) = 3.26$, $p < .01$, $\eta_p^2 = .108$, showed lower saliency for happy than for surprised and sad faces. In contrast, in the comparison of blended faces and happy faces, no significant difference appeared.

2.3. Discussion

Blended expressions with a smiling mouth but non-happy eyes were less likely to be classified as happy than truly happy faces with congruent eyes and mouth, thus showing discrimination. This is consistent with reports that viewers are sensitive to the differences between genuine and fake smiles (see Ambadar et al., 2009; Johnston, Miles, & Macrae, 2010; Krumhuber & Manstead, 2009; Miles & Johnston, 2007). However, such discrimination was limited, as revealed by four types of findings. First, all the blended expressions were classified as happy with a relatively high ($M = 40\%$) likelihood. Second, the blended expressions were more likely to be judged as happy than the respective non-happy faces with the same eyes but no smile. Third, reaction times in responding that faces looked "not happy" were longer for blended than for non-happy expressions. Fourth, the composite faces with neutral, non-expressive eyes (and a smile) were equally likely to be categorized as "happy" and "not happy". Accordingly, as the non-happy and the blended expressions shared the eyes but not the mouth, whereas the happy and the blended expressions shared the mouth but not the eyes, our findings imply that the smiling mouth played a critical role in whether or not the faces were perceived as happy.

The contribution of the mouth was corroborated by the visual saliency analyses: The smiling mouth of both the happy and the blended expressions was more salient than the (non-smiling) mouth of non-happy expressions, whereas this pattern was reversed for the eye region. In addition, the mouth was equally salient in the happy and the blended expressions, and always much more salient than the eyes. Given that the smile is a highly diagnostic feature that is unequivocally associated with happy faces (e.g., Calvo & Marrero, 2009; Kohler et al., 2004), our results suggest that saliency underlies the bias towards interpreting ambiguous expressions as happy. Saliency ensures early and selective allocation of attention to the smiling mouth (Calvo & Nummenmaa, 2008), which thus becomes the dominant cue that is used for the categorization decision (see Fiorentini & Viviani, 2009). This view on the role of the smile saliency in the happy face *recognition* superiority is consistent with the view held by Mermillod, Vermeulen, Lundqvist, and Niedenthal (2009) about the role of perceptual factors in the *visual search* advantage of happy faces.

The role of the smile saliency is related to another major finding: The tendency to judge blended facial expressions with a smile as "happy" (i.e., *incorrect* "yes" responses) was not influenced by face inversion. Equivalent probability scores and reaction times were observed in the upright and the inverted condition. The lack of an inversion effect (e.g., Maurer et al., 2002) suggests that the tendency to judge blended expressions as happy is due to *featural* analysis of the smile. In contrast, the *correct* discrimination of blended expressions as "not happy", as well as the correct identification of truly happy faces, depends on *configural* analysis, as suggested by the performance impairment (i.e., longer response latencies) in the inverted vs. the upright condition. According to Fiorentini and Viviani (2009), reliance on single facial components becomes crucial when coherence is compromised because of some features being absent or contradictory, as is the case in blended expressions. In such cases, the decision about the expression category can be based on the most diagnostic feature. For blended expressions with a smile but non-happy eyes, conflict would be dealt with by relying on the most distinctive cue, that is, the salient mouth. When such a processing strategy is used, quick but erroneous decisions lead to consider the blended expressions as if they were happy. Only with configural integration of the smiling mouth and the non-happy eyes, would blended expressions be correctly judged as "not happy".

Given the role attributed to the mouth, we can further ask about *what* kind of information is obtained from blended expressions with a smile, and *when*. Presumably, such information underlies the tendency to categorize the blended expressions as happy for the first 800 ms (as shown by the mean time required to respond that they are "not happy"; Table 2). The categorization task ("happy" vs. "not happy") could be performed with purely *perceptual* criteria; that is, using some salient features such as teeth surrounded by lips with upturned corners. If so, it is possible that no *emotional* information associated with the face stimulus is retrieved when categorizing the faces. Categorization could be performed on the basis of some visual pattern—involving either single or integrated visual features—of the face image. Such perceptual processing could be linked directly to language networks of the brain to retrieve the name of the expression category, without engaging any emotional meaning (see Adolphs, 2002). This distinction has important implications when we consider that the neural pathways thought to underlie facial expression recognition indeed include the ventral visual stream, but also the amygdalo-striatal pathways involved in early processing of emotional information (e.g., Adolphs, 2002; Calder & Young, 2005). The question is, therefore, *whether* and, if so, *when* affective—relative to perceptual—information is activated during the recognition of ambiguous expressions.

3. Experiment 2

To determine whether emotional information is extracted from blended expressions with a smile, we used an affective priming protocol (see Fazio & Olson, 2003). Participants were presented with a prime face followed by an emotional probe scene photograph, and responded whether the scene was pleasant or unpleasant. The prime faces conveyed either neutral, happy, or blended expressions. The blended expressions with (a) angry eyes + smile, (b) sad eyes + smile, or (c) neutral eyes + smile were chosen because they showed better, intermediate, or poorer discrimination, respectively, from happy expressions in Experiment 1. The probe scenes depicted either pleasant or unpleasant situations, and were thus congruent or incongruent in affective valence with the primes. If positive affect is extracted from the happy and the blended-expression primes, response latencies to pleasant probes will be shorter following these primes than following neutral face primes. Variations in the SOA between the prime face and the probe scene (170, 340, 550, or 800 ms) allowed us to estimate the time point at which the affective representations were activated.

In addition, we wanted to examine how much affective processing itself depends on perceptual stimulus properties. To this end, we used pleasant probe scenes that were either visually dissimilar (no people smiling) or similar (one or more persons smiling) to the prime smiling faces. The 'smiling' and 'non-smiling' probe scenes were equivalent in rated pleasantness (see below; Section 3.1.2), and thus affective valence was orthogonal with visual similarity. If priming effects are due to perceptual rather than to affective processing of the prime smiling face, response facilitation will occur only when the probe scene is visually similar to the prime in the key ingredient (i.e., presence of a smile). On the contrary, genuine affective priming will involve facilitation when there is affective prime–probe congruency in the absence of visual similarity.

3.1. Method

3.1.1. Participants

Eighty psychology undergraduates (64 females) participated in this experiment.

3.1.2. Stimuli

Two types of experimental stimuli were presented: prime faces and probe scenes. As *primes*, we selected a subset of the face stimuli in Experiment 1, with 24 KDEF models of the following categories: neutral, truly happy, neutral/happy (NEHA), sad/happy (SAHA), and angry/happy (ANHA). As *probes*, we used 24 pleasant and 24 unpleasant scenes from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008; see the Appendix). Of the 24 pleasant scenes, 12 portrayed people smiling and 12 portrayed people not smiling. The 24 unpleasant scenes depicted (non-smiling) people in situations involving threat, physical injuries, etc. A scene category (pleasant with smile vs. pleasant without smile vs. unpleasant) one-way ANOVA on valence and arousal ratings (in 9-point scales; Lang et al., 2008) showed significant differences between both types of pleasant scenes and the unpleasant scenes in valence scores, $F(2,45) = 809.70$, $p < .0001$ (*M pleasant/smile* = 7.72; *M pleasant/no-smile* = 7.57; *M unpleasant* = 2.12) and arousal scores, $F(1,45) = 24.26$, $p < .0001$ (*M pleasant/smile* = 5.05; *M pleasant/no-smile* = 4.94; *M unpleasant* = 6.62). The pleasant scenes with and without smiles did not differ from one another.

Filler trials were added to reduce familiarity with the experimental probe scenes. For those trials, we selected 72 *filler faces*, 24 of each of the following categories: disgust, fear, and surprise (the same as in Experiment 1). These were paired with 24 IAPS *filler scenes*, of which 12 were pleasant and 12 were unpleasant. Thus there were 72 filler trials, with 12 faces of each category being followed by a pleasant scene and another 12 followed by an unpleasant scene.

3.1.3. Procedure

Participants were instructed to ignore the prime face and pay attention and respond to the probe scene. Each participant was presented with 240 experimental trials with a prime and a probe, in three blocks, randomly, with 72 interspersed filler trials. Each trial (see Fig. 6) began with a fixation circle for 500 ms, followed by a prime face for 150 ms. After the prime display, a backward mask (a Fourier phase scrambled neutral face) appeared for 20 ms. Next there was a blank interval of either 0, 170, 380, or 630 ms, resulting in SOAs of 170, 340, 550 or 800 ms, respectively. Finally, the probe scene was

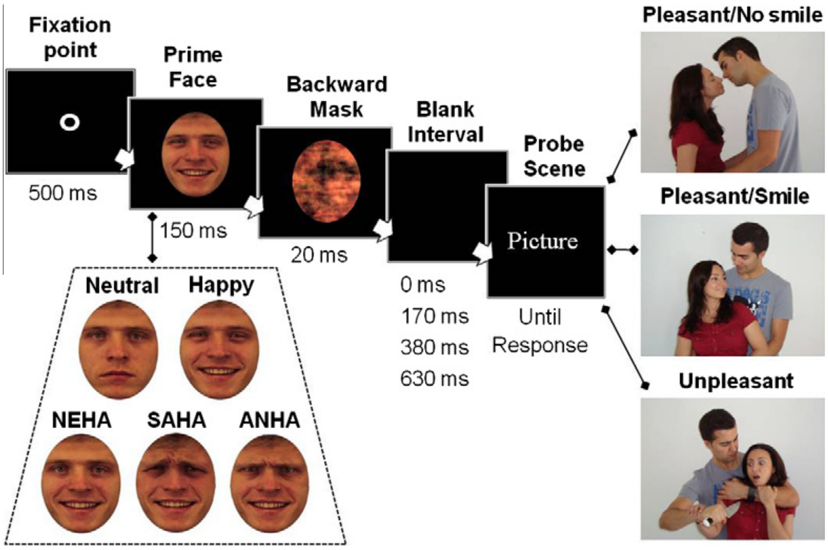

Fig. 6. Sequence of events and overview of basic characteristics of a trial in Experiments 2 and 3. ANHA: angry eyes + smile; SAHA: sad eyes + smile; NEHA: neutral eyes + smile. For copyright reasons, different examples of probe scenes are shown in the figure, instead of the original IAPS pictures.

displayed until the participant responded whether it was unpleasant or pleasant, by pressing a key with the left or the right forefinger. Assignment of keys was counterbalanced. Response accuracy and latencies were collected.

3.1.4. Design

The experimental conditions were combined in a mixed factorial design, with prime face expression (5: neutral, happy, neutral/happy, sad/happy, and angry/happy) and probe scene valence (3: pleasant/smile, pleasant/no-smile, and unpleasant) as within-subjects factors, and SOA (4: 170, 340, 550, and 800 ms) as a between-subjects factor, with 20 participants at each SOA level. The neutral prime condition was the baseline against which the other four prime conditions were compared. Each participant was presented with a neutral, a happy, a neutral/happy, a sad/happy, and an angry/happy prime face of each of 24 posers twice: once preceding a pleasant probe scene (12 with a smile; 12 with no smile); and once preceding an unpleasant probe scene (24). Each probe appeared five times, once following each prime face category. The prime–probe pairs were established randomly.

3.2. Results

A 5 (prime expression) × 3 (probe valence) × 4 (SOA) ANOVA was conducted on response accuracy and reaction times for correct responses. The analysis of response *accuracy* yielded no significant effects. The probability of correct responses was comparable for the different probe scenes (pleasant/no-smile, $M = .963$; pleasant/smile, $M = .941$; unpleasant $M = .954$). For response *latencies*, there were main effects of prime expression, $F(4,304) = 6.60$, $p < .0001$, $\eta_p^2 = .080$, probe valence, $F(2,152) = 144.79$, $p < .0001$, $\eta_p^2 = .656$, and SOA, $F(3,76) = 3.75$, $p < .025$, $\eta_p^2 = .129$, which were qualified by a prime by probe interaction, $F(8,608) = 6.90$, $p < .0001$, $\eta_p^2 = .083$, and a three-way interaction, $F(24,608) = 1.54$, $p < .05$, $\eta_p^2 = .057$. Mean scores for each condition are shown in Table 4.

To break down the interactions, *priming scores* were calculated by subtracting reaction times in each emotional prime condition (i.e., happy, neutral/happy, sad/happy, and angry/happy) from those in the neutral prime condition. Positive scores thus indicate response facilitation and negative scores response inhibition in the emotional priming condition, relative to the neutral priming condition. As indicated in Fig. 7, in the *pleasant/no-smile* probe condition, priming scores were significant only following happy primes at both 550-ms, $t(19) = 3.92$, $p < .001$, and 800-ms, $t(19) = 4.99$, $p < .0001$, SOAs. In the *pleasant/smile* probe condition, scores were significant following happy primes at 340-ms, $t(19) = 4.87$, $p < .0001$, 550-ms, $t(19) = 6.13$, $p < .0001$, and 800-ms, $t(19) = 4.78$, $p < .0001$, SOAs. In this condition, scores also reached significance following neutral/happy primes at 550-ms, $t(19) = 3.74$, $p < .001$, and 800-ms, $t(19) = 2.29$, $p < .05$, SOAs, as well as following sad/happy primes at 550-ms SOA, $t(19) = 2.40$, $p < .05$. In the *unpleasant* probe condition, no priming score was statistically significant.

3.3. Discussion

Two major findings appeared in Experiment 2. First, only truly happy face primes produced genuine affective priming. Response facilitation in the evaluation of affectively congruent probe scenes occurred even when they were visually dissimilar from the primes and did not include smiling people. This rules out the potential influence of merely visual characteristics on priming. Rather, this suggests that positive affect was extracted from happy expressions, and that the affective congruence between a prime and a probe resulted in the observed priming effect. In contrast, however, blended expressions with a smile but non-happy eyes did not produce any affective priming when the prime and the probe were affectively congruent

Table 4
Mean reaction times (in ms) to the pleasant/no-smile, the pleasant-smile, and the unpleasant probe scenes, as a function of the expression of the prime face, at each SOA condition, in the affective priming task, in Experiment 2.

Probe	Facial expression of prime				
Pleasant/no-smile	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	762	768	764	766	759
320-ms SOA	748	733	741	747	749
550-ms SOA	730	688	713	729	737
800-ms SOA	701	651	680	702	712
Probe Pleasant/smile	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	727	722	731	726	724
320-ms SOA	709	663	679	692	701
550-ms SOA	701	638	655	669	674
800-ms SOA	680	617	643	658	655
Probe Unpleasant	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	779	772	779	776	785
320-ms SOA	765	773	773	758	761
550-ms SOA	750	766	759	747	735
800-ms SOA	728	750	732	734	710

Note: NEHA: Neutral eyes with a smile; SAHA: sad eyes with a smile; ANHA: angry eyes with a smile.

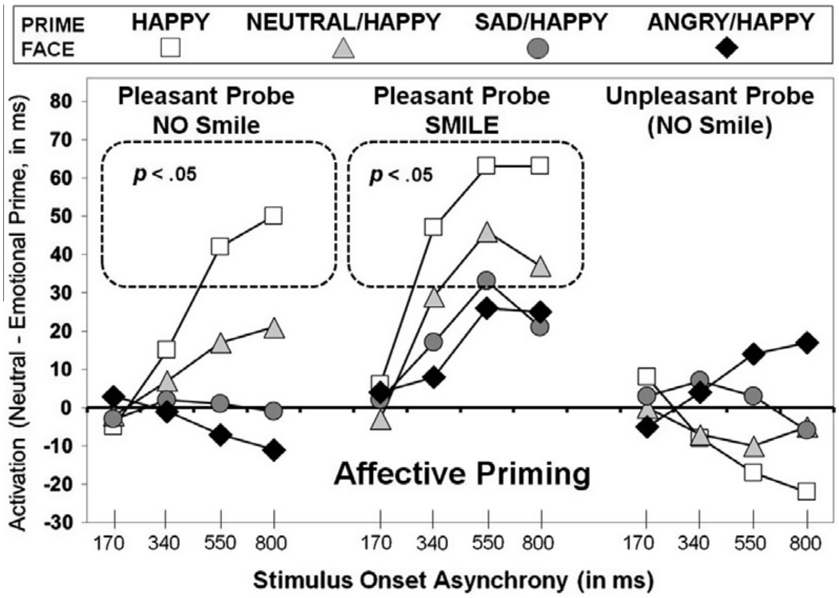

Fig. 7. Affective priming scores (i.e., RTs following the neutral prime face minus RTs following the emotional prime faces) for each probe and SOA condition, as a function of type of prime face, in Experiment 2. Squares within the dotted-line rectangle represent priming scores significantly different from the neutral prime, zero baseline.

but visually dissimilar. Only when there was visual similarity (with both the prime and the probe including smiling people), did priming effects emerge for the neutral–happy blends, and the same tendency appeared for the sad–happy and angry–happy blends. This shows that the visual representation of the smile was indeed activated when perceiving the blended expressions, yet it was not sufficient for activating an affective representation of pleasantness in the observer.

The second major finding is concerned with the time course of affective processing. Affective priming uncontaminated by visual similarity emerged for happy expressions 550 ms from face stimulus onset (compared to 340 ms under visual prime–probe similarity). In contrast, for blended expressions, priming effects appeared later (550 ms post-stimulus), and only with prime–probe visual similarity, which suggests that the effect was dependent on perceptual matching rather than affective congruence.

Therefore, while a smiling mouth in an otherwise non-happy face can lead viewers to categorize the face as happy to a significant extent (Experiment 1), such smile is not enough to convey and subsequently trigger positive affect in the observer (Experiment 2). The tendency to categorize the blended expressions as happy in Experiment 1 was probably driven by perceptual processing and reliance on the visually salient and distinctive shape of a smiling mouth, rather than by affective processing and the use of positive affect conveyed by the smile. Until affective processing develops later, the judgment of facial expressions would be guided by the earlier active perceptual criteria. To address this issue more directly, we conducted Experiment 3.

4. Experiment 3

In this experiment, we investigated the time course of perceptual priming of the smile in blended expressions. This served to determine whether an early perceptual processing of the smiling mouth underlies the tendency to evaluate such faces as happy and delays their correct rejection as "not happy". With the same stimuli and SOAs as in Experiment 2, the perceptual priming task in Experiment 3 involved responding whether or not there were some people smiling in the probe scene, instead of whether or not the scene was un/pleasant (Experiment 2). Thus the visual pattern of the smiling mouth, rather than its affective content, was task-relevant. While affective priming would be based on the prime–probe emotional congruence, perceptual priming would rely on the prime and the probe sharing a common visual feature, that is, a U-shaped mouth. If perception of a salient smile in the prime face is responsible for categorizing the whole face as happy, then (a) all the smiling prime faces (both happy and blended expressions) will similarly facilitate the detection of such a facial feature in the probe scene, and (b) this perceptual priming will occur at an earlier stage than the affective priming observed in Experiment 2.

4.1. Method

4.1.1. Participants

Eighty psychology undergraduates (62 female) participated in this experiment.

4.1.2. Stimuli, procedure, and design

The stimuli, procedure, and design were the same as in Experiment 2, with one important exception. Instead of evaluating the affective valence (un/pleasantness) of probe scenes following prime faces, the perceptual priming task involved detecting the presence vs. absence of a smiling face in the probe scene. Such a task does not require explicit affective processing of the scene (unlike in Experiment 2), but the mere detection of a single visual feature in a face.

4.2. Results

A 5 (prime expression) $\times$ 3 (probe valence) $\times$ 4 (SOA) ANOVA was conducted on response accuracy and reaction times for correct responses. There were no significant effects on response *accuracy* (all Fs < 1). The probability of correct responses was comparable for all probe scenes (pleasant/no-smile, $M = .932$; pleasant/smile, $M = .933$; unpleasant $M = .945$). For response *latencies*, effects of probe valence, $F(2,152) = 583.47$, $p < .0001$, $\eta_p^2 = .885$, were qualified by a prime by probe interaction, $F(8,608) = 9.27$, $p < .0001$, $\eta_p^2 = .110$, which was decomposed by means of separate ANOVAs for each type of probe. No effects of prime appeared in the *pleasant/no-smile* or the *unpleasant* probe conditions. In contrast, a reliable prime effect emerged in the *pleasant/smile* condition, $F(4,304) = 17.51$, $p < .0001$, $\eta_p^2 = .187$. See the mean response latency scores in Table 5.

As in Experiment 2, we computed and analyzed *priming scores* (i.e., reaction times in the neutral prime condition minus those in each emotional prime condition—happy, neutral/happy, sad/happy, and angry/happy). Positive scores show response facilitation following the emotional relative to the neutral prime whereas negative scores reveal inhibition by the emotional primes. As indicated in Fig. 8, neither for *pleasant/no-smile* probes nor for *unpleasant* probes were the scores statistically significant. In contrast, for *pleasant/smile* probes, priming scores were significant following all the emotional primes at 170-ms (all $ts(19) \geqslant 3.10$, $p \leqslant .01$), at 320-ms (all $ts(19) \geqslant 3.13$, $p \leqslant .01$), and at 550-ms SOA (all $ts(19) \geqslant 2.29$, $p < .05$). At 800-ms SOA, the scores reached statistical significance for happy, neutral/happy, and sad/happy primes (all $ts(19) \geqslant 2.65$, $p \leqslant .025$), but not for angry/happy primes ($p = .18$).

4.3. Discussion

Perceptual priming of smile detection in probe scenes occurred similarly for the happy and the blended expressions. In comparison with neutral prime faces, all the prime faces with a smile facilitated the detection of smiling people in the probe scenes. As this happened regardless of whether the prime smile was affectively congruent (genuine happy faces) or not (blended expressions) with the eyes, it demonstrates that featural recognition of a smile is automatically accomplished even when the configural representation of the face does not reflect genuine happiness. Importantly, however, it must be noted that the smiles in the prime faces and those in the probe scenes were not identical; rather, they differed in size, shape, orientation, color, surrounding facial features, etc. Despite this, significant priming effects were observed, thus implying that a perceptual *pattern* or a *conceptual* representation of the smile was activated, rather than a mere visual representation of the specific sensory properties of each single smile.

The perceptual priming effects in Experiment 3 appeared very early for all the expressions with smiles, i.e., at 170-ms SOA, and remained for at least 800 ms. In contrast, the affective priming uncontaminated by visual similarity was not observed in Experiment 2 until much later (550-ms SOA). This implies that, for at least the first 550 ms following the onset of a smiling face, the perceptual criterion in judging the facial expression must have been dominant. This would explain the tendency to categorize the blended expressions as happy until after ~800 ms (in Experiment 1). We can thus conclude that perceptual information (probably an abstract pattern) about the shape of a salient smiling mouth is extracted and used earlier than information about the smile significance. Presumably, such an early dominant perceptual cri-

Table 5
Mean reaction times (in ms) to the pleasant/no-smile, the pleasant-smile, and the unpleasant probe scenes, as a function of the expression of the prime face, at each SOA condition, in the perceptual priming task, in Experiment 3.

Probe	Facial expression of prime				
Pleasant/No-smile	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	821	820	824	823	826
320-ms SOA	810	830	828	825	821
550-ms SOA	800	821	817	814	811
800-ms SOA	789	808	805	807	802
Probe Pleasant/smile	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	721	676	677	681	682
320-ms SOA	709	660	663	667	670
550-ms SOA	700	654	652	663	670
800-ms SOA	693	641	648	660	667
Probe Unpleasant	Neutral	Happy	NEHA	SAHA	ANHA
170-ms SOA	760	765	764	757	762
320-ms SOA	751	748	757	749	745
550-ms SOA	740	746	737	735	732
800-ms SOA	725	734	728	723	721

Note: NEHA: Neutral eyes with a smile; SAHA: sad eyes with a smile; ANHA: angry eyes with a smile.

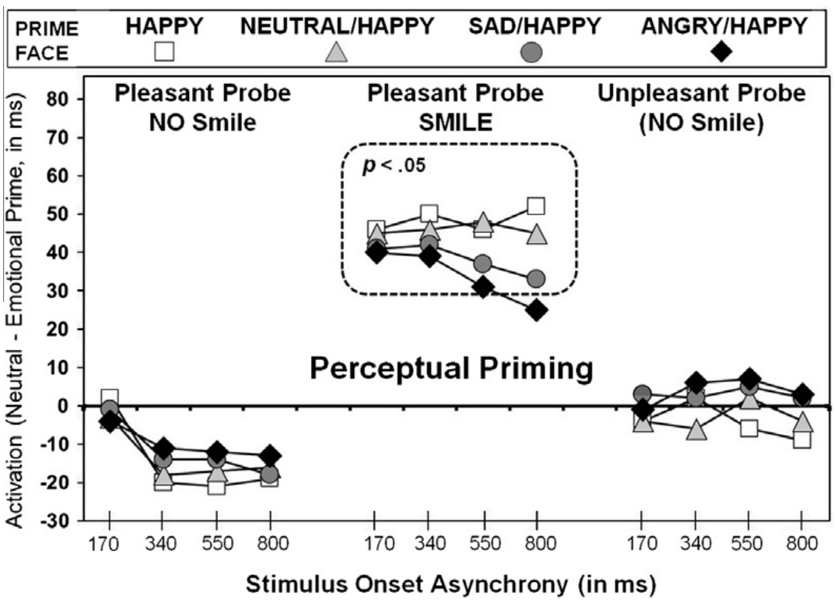

Fig. 8. Perceptual priming scores (i.e., RTs following the neutral prime face minus RTs following the emotional prime faces) for each probe and SOA condition, as a function of type of prime face, in Experiment 3. Squares within the dotted-line rectangle represent priming scores significantly different from the neutral prime, zero baseline.

terion would temporarily inhibit the development and later use of an affective criterion, thus leading to errors or to delays in correctly rejecting the ambiguous smiling faces as "not happy".

5. Experiment 4

In Experiments 2 and 3, we found that perceptual priming by a happy face occurred earlier than affective priming. Furthermore, whereas there was perceptual and affective priming for happy faces with congruent smiling mouth and eyes, perceptual but not affective priming appeared for blended expressions with a smile but not happy eyes. This suggests that the perceptual detection of a smiling mouth occurs in advance and regardless of the affective evaluation of the expression as pleasant. In addition, in Experiment 1, blended expressions with a smile but non-happy eyes were likely to be categorized as happy. These data suggest that semantic categorization of facial expressions depends on the perception of facial features rather than on the extraction of affective content of the expressions themselves.

This view of the time course of facial expression processing—where perceptual and semantic analysis precede affective evaluation—is in contrast with conceptualizations of affective primacy (Bargh, 1997; Murphy & Zajonc, 1993; Zajonc, 2000), which posit that the encoding of affective valence of stimuli can precede object identification. A number of psychophysiological studies on facial expression processing have indeed shown that subliminally presented (typically for 20–30 ms and backwardly masked) emotional faces can evoke affect-dependent electrodermal (Esteves, Dimberg, & Ohman, 1994) and electromyographic responses (Dimberg, Thunberg, & Elmehed, 2000), as well as hemodynamic changes in the brain regions involved in emotional processing (Morris, Öhman, & Dolan, 1999). The evidence from the subliminal presentation studies would thus suggest that emotional information is processed rapidly outside of awareness (but see Pessoa, Japee, Sturman, and Ungerleider (2006) who noted that amygdala responses to facial expressions can depend on visual awareness), which would be compatible with the affective primacy hypothesis.

Nevertheless, the studies reviewed above did not test whether perceptual and semantic (e.g., expression categorization) encoding occurred as well. Accordingly, to *compare* the time course of perceptual, semantic, and affective processing with direct measures of these processes, in Experiment 4, we asked participants to perform corresponding tasks under the same constrained visual presentation conditions. Sandwich-masked emotional facial expressions were displayed for 20, 40, 70, and 100 ms, and viewers had to discriminate whether the mouth was smiling or not (perceptual), to categorize the face as happy or not (semantic), and to evaluate the expression as pleasant or not (affective). This paradigm allows us to directly contrast the affective vs. the perceptual and cognitive primacy hypotheses. As masking interrupts visual processing (Breitmeyer & Ogmen, 2000), performance should be better (as reflected in higher response accuracy and shorter reaction times) for a given stimulus duration in the task (perceptual, semantic, or affective) that can be accomplished earlier, and differences will decrease as exposure duration increases.

5.1. Method

5.1.1. Participants

Sixty psychology undergraduates (46 females) participated in this experiment.

5.1.2. Stimuli

We selected 24 happy faces and 24 non-happy faces (8 angry; 8 fearful; 8 disgusted) of the KDEF models listed in Experiment 1. All the face stimuli portrayed prototypical or genuine expressions. Importantly, all the happy, angry, fearful, and disgusted faces showed an open mouth and clearly visible teeth; sad faces were excluded because none of them fulfilled this condition. By choosing only this type of faces, we wanted to avoid the possibility that participants could simply perform the tasks by relying on the mere presence vs. absence of an open mouth with teeth. This obliged the viewers to discriminate patterns of features (at least the different shapes of the mouth showing teeth) to perform the tasks.

5.1.3. Procedure

The stimuli were presented on 17″ monitors. The E-Prime (Version 2.0) experimental software controlled stimulus presentation and response collection. Following 24 practice trials, each participant was presented with 192 target trials and 72 interspersed filler trials in four blocks of 66 trials each, randomly. Each trial began with a central fixation asterisk for 750 ms, followed by a (a) pre-mask for 150 ms, (b) a face in the center of the screen (target trials) or displaced upwards vertically (filler trials), with variable exposure duration (20, 40, 70 or 100 ms), and (c) a post-mask that remained visible until the participant responded (see Fig. 9). The masks were Fourier-phase scrambled, thus effectively removing any expressive information, but retaining low-level image properties of the face stimulus. A question mark at the center of the post-mask served as a prompt for responding. The participants were informed that faces would be presented quickly and that, immediately following each face, they should respond—depending on the assigned task—whether (a) the mouth was smiling or not (perceptual judgment), (b) the face looked happy or not (categorization task), or (c) the expression was pleasant or not (affective evaluation).

Filler trials with vertically displaced faces were included to encourage participants to maintain gaze position at the central fixation point. As the mouth appeared sometimes below (target trials) and sometimes above (filler trials) the fixation point, the viewer could not predict where the mouth was going to appear (above or below), thus looking at the central fixation point would be the optimal strategy. If faces had been presented only centrally on all trials, participants could have tended to (pre)look below the central fixation asterisk (where the mouth was) most of the times, as the mouth was probably the major informative source of the face expressiveness. Such a control was particularly important in the perceptual task, where the viewers could automatically look at the location of the mouth even before the face appeared, and completely ignore the rest of the face. In the filler trials, the mouth was at the same distance from the central fixation point as in the target trials.

5.1.4. Design

The experimental design involved facial expression category (2: happy vs. not happy—angry, disgusted, and fearful) and face display duration (4: 20 vs. 40 vs. 70 vs. 100 ms) as a within-subjects factor, and task or type of judgment (3: perceptual vs. categorical vs. affective; see Section 5.1.3), as a between-subjects factor, with 20 participants in each condition. One-fourth of the trials in each of four blocks belonged to each of the display duration conditions, with random assignment. Each participant was presented with all the 24 happy faces and all the 24 non-happy faces (eight angry, eight disgusted, and eight fearful). For each participant, each face was presented four times, once in each of the four display duration conditions.

5.2. Results

Response accuracy and reaction times from the onset of the post-mask were analyzed for target trials. To make the

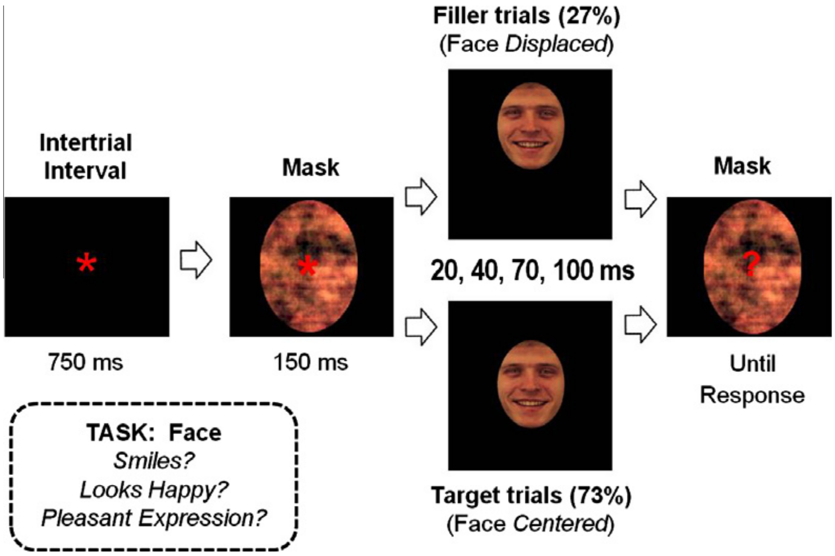

Fig. 9. Sequence of events and overview of basic characteristics of a trial in Experiment 4.

three tasks comparable, YES responses were considered as accurate in all three tasks if the face was happy, and NO responses were considered as accurate in all three tasks if the face was angry, fearful, or disgusted. Response accuracy scores and reaction times for correct responses were analyzed in 2 (expression: happy vs. non-happy) × 3 (task) × 4 (display duration) ANOVAs. The mean scores are shown in Figs. 10 and 11. Single-sample *t* tests were used to compare the probability of correct responses for each expression category against the .5 chance level. Scores were significantly greater than expected by chance for both the happy and the non-happy faces in all four display conditions and for all three tasks (all $ts \geqslant 6.85$, $p < .0001$).

5.2.1. Response accuracy

The ANOVA on response accuracy scores showed main effects of task, $F(2,57) = 11.82$, $p < .0001$, $\eta_p^2 = .293$, with accuracy being higher for both the perceptual ($M = .951$) and the categorization ($M = .936$) tasks than for the affective task ($M = .873$). Also, main effects of display duration emerged, $F(3,171) = 12.51$, $p < .0001$, $\eta_p^2 = .180$, with significant differences between the 20-ms condition ($M = .873$) and all the other displays (40 ms = .918; 70 ms = 939; 100 ms = .950), and between the 40- and the 100-ms display. These effects were qualified by a task by display duration interaction, $F(6,171) = 3.14$, $p < .01$, $\eta_p^2 = .100$.

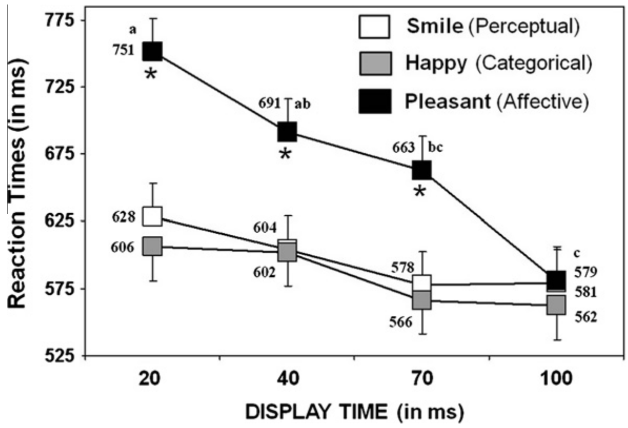

Fig. 11. Mean correct response times in the perceptual, categorization, and affective tasks across display duration conditions, in Experiment 4. Asterisks indicate significant differences between the perceptual/categorization conditions and the affective condition. Means with a different superscript are significantly different across display duration conditions.

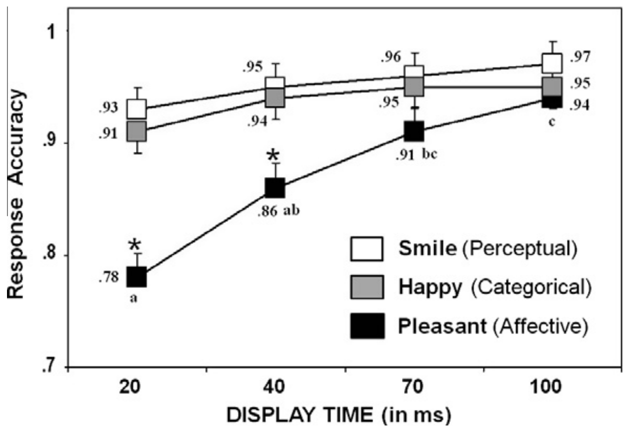

Fig. 10. Mean probability of correct responses in the perceptual, categorization, and affective tasks across display duration conditions, in Experiment 4. Asterisks indicate significant differences between the perceptual/categorization conditions and the affective condition. Means with a different superscript are significantly different across display duration conditions.

To decompose the interaction, we first conducted a one-way (3: task) ANOVA for each display duration condition separately. An effect of task appeared in the 20-ms, $F(2,57) = 12.31$, $p < .0001$, $\eta_p^2 = .302$, and the 40-ms, $F(2,57) = 10.25$, $p < .0001$, $\eta_p^2 = .265$, display conditions, with better performance in both the perceptual and the categorization tasks than in the affective task. In contrast, no significant differences emerged between tasks in the 70-ms, $F(2,57) = 2.34$, $p = .10$, *ns*, and the 100-ms ($F < 1$), conditions. Secondly, a one-way (4: display duration)

ANOVA for each task condition revealed an effect in the affective task, $F(3,57) = 9.89$, $p < .0001$, $\eta_p^2 = .342$, with significant differences between the 20-ms display and both the 70- and the 100-ms displays, and between the 40- and the 100-ms display (see Fig. 10). In contrast, there were no reliable differences in the perceptual and the categorization tasks after correcting for multiple comparisons.

5.2.2. Reaction times of correct responses

The ANOVA yielded main effects of task, $F(2,57) = 6.68$, $p < .01$, $\eta_p^2 = .190$, with faster responses in both the perceptual ($M = 597$ ms) and the categorization ($M = 584$) tasks than in the affective task ($M = 671$). Main effects of display duration, $F(3,171) = 11.97$, $p < .0001$, $\eta_p^2 = .174$, revealed significant differences between the 20-ms condition and the 70- and the 100-ms condition, and between the 40- and the 100-ms condition (20 ms = 662; 40 ms = 633; 70 ms = 602; 100 ms = 574). These effects were qualified by a task by display duration interaction, $F(6,171) = 2.50$, $p < .025$, $\eta_p^2 = .081$.

To decompose the interaction, we first conducted a one-way (3: task) ANOVA for each display duration condition. An effect of task appeared in the 20-ms, $F(2,57) = 9.33$, $p < .0001$, $\eta_p^2 = .247$, the 40-ms, $F(2,57) = 4.45$, $p < .025$, $\eta_p^2 = .135$, and the 70-ms, $F(2,57) = 4.38$, $p < .025$, $\eta_p^2 = .133$, display durations, with faster responses in both the perceptual and the categorization tasks than in the affective task. In contrast, no significant differences emerged in the 100-ms condition ($F < 1$). Secondly, a one-way (4: display duration) ANOVA for each task condition revealed an effect in the affective task, $F(3,57) = 11.08$, $p < .0001$, $\eta_p^2 = .368$, with significant differences between the 20-ms display and both the 70- and the 100-ms display, and between the 40- and the 100-ms display (see Fig. 11). In contrast, there were no reliable effects in the perceptual task ($F = 1.46$, *ns*) and the categorization task ($F = 2.72$, $p = .09$, *ns*).

5.3. Discussion

Performance accuracy was above chance for the perceptual, the semantic, and the affective tasks across all display duration conditions. Thus, even for sandwich-masked face stimuli shown for only 20 ms, enough information can be obtained that is relevant for smile discrimination, expression categorization, and affective evaluation. Obviously, if we take the stimulus presentation time and the processing time distinction into account (see VanRullen, 2011), this finding does not imply that all these processes can be performed within 20 ms, but that a 20-ms stimulus exposure was sufficient for them to start, whereas the time to complete the processes was considerably longer (>500 ms). Differences in the time course of these three processes allow us to estimate the extent to which each of them precedes the others and their mutual dependence: (a) smile detection and expression categorization were performed better than affective evaluation at the 20-, 40- and even 70-ms display conditions, as shown by the higher accuracy and/or shorter response latencies; (b) while affective evaluation was impaired by reductions in stimulus display duration, smile detection and expression categorization were not; (c) performance accuracy and response times were equivalent for the smile discrimination and the expression categorization tasks across all display duration conditions. These findings are relevant to address two important issues.

First, our results are not consistent with the affective primacy hypothesis. Rather, they support the view that perceptual identification and possibly semantic recognition of critical visual features are necessary to later judge an object's affective valence (see Nummenmaa, Hyönä, & Calvo, 2010). This does not deny the fact that facial affect can be detected very early and automatically (outside of awareness and unintentionally; Dimberg et al., 2000; Esteves et al., 1994; Morris et al., 1999; Murphy & Zajonc, 1993). Rather, our results confirm that some perceptual (e.g., a salient mouth) and semantic (e.g., a distinctive smile) attributes are *also* extracted with minimal stimulus evidence at an early processing stage. It is possible that either affective valence is obtained in parallel with respect to perceptual and semantic information, or that affective valence is contingent upon perceptual and semantic evidence. In neither case, however, would affective processing precede some kind of perceptual and semantic recognition of the facial expression. Our findings would thus be more consistent with models of postattentional processing of affective significance (Cave & Batty, 2006; Storbeck, Robinson, & McCourt, 2006; see Calvo & Nummenmaa, 2007). Storbeck et al. (2006) argued that the features of objects must first be integrated, and the objects themselves identified, prior to affective analysis. Cave and Batty (2006) argued that only low-level perceptual features of visual stimuli can be encoded preattentively, which can, through practice, be associated with affective meaning. In general, this implies that perceptual and semantic distinctions are required before affective associations can be retrieved, and before decisions are taken about whether an object (or a face) is good or bad.

It could, nevertheless, be argued that our findings might apply only to information that is accessible to awareness and can be verbally coded (e.g., as "pleasant" or "not pleasant"). It may still be possible that non-conscious processes lead to extraction of an affective impression prior to it being verbally coded and prior to obtaining a semantic representation of visual stimuli (see Calvo, Avero, & Nummenmaa, 2011; Lieberman et al., 2007). Against this view, however, it should be noted that even our implicit measures (hence not involving intentional processing of the prime face) of affective and perceptual priming (Experiments 2 and 3) indicated that the analysis of facial features preceded affective analysis. Though the SOA (in Experiments 2 and 3) and the prime display duration (Experiment 4) manipulations probably do not reflect the *absolute* timing estimates of each process, both converge in revealing their *relative* timing, with affective processing taking place later.

The second issue is concerned with the comparable response accuracy and time course pattern for the perceptual and the categorization tasks. This finding suggests that the happy vs. not happy categorization is contingent on the detection of a smiling mouth. If categorization depended on the integration of expressive sources, i.e., the eyes and the mouth, it should have required additional processing or display time, compared with the smile detection task. This was not the case, and therefore the happy vs. not happy categorization was probably made on the basis of a salient and diagnostic smiling mouth. That is, the categorization task could be performed with a purely perceptual criterion, and no affective criterion is used. This feature-based processing may seem inconsistent with the fact that the categorization of truly happy (and truly non-happy) faces was impaired by inversion in Experiment 1, thus suggesting that they were holistically processed. The discrepancies can, however, be explained as a function of the tasks, the stimuli, and the display time. In Experiment 4, smile detection (feature-based analysis) was sufficient to solve the "happy" categorization (and also the "pleasant" evaluation), as there were only smile vs. no-smile faces (which matched the happy vs. not happy, and the pleasant vs. unpleasant faces). In such conditions, and given the very short stimulus display, an economical processing strategy would involve relying on the presence vs. absence of a smile as a single feature, and using it as a shortcut for all the processes. In contrast, in Experiment 1, blended expressions were also presented, in addition to the truly happy and truly non-happy faces. In such conditions, the smile was not diagnostic enough, as it could appear in non-happy-eyed faces. To perform the categorization task, considerable holistic processing was thus required, involving the integration of the eyes and the mouth.

6. General discussion

This study highlighted the considerable influence of the smile on the processing of ambiguous facial expressions with non-happy eyes. First, a smiling mouth proved to be visually highly salient, regardless of its congruence or incongruence with the eye region expression. Second, the presence of a smile increased the probability of judging blended expressions as happy and delayed their categorization as "not happy", relative to faces with the same eyes but no smile. Third, the categorization (probability and reaction times) of blended expressions as happy was equivalent for upright and inverted faces. Fourth, while genuinely happy faces triggered positive affect in the observers, as revealed by affective priming effects, blended expressions with a smile did not. Finally, the visual discrimination of smiles began approximately at the same time as the semantic categorization of the expression, with both smile detection and expression recognition starting earlier than the extraction of positive affect. These findings reveal the mechanisms underlying perception, categorization, and evaluation of ambiguous facial expressions, and why a smile can lead viewers to wrongly accept them as happy.

6.1. Contribution of the smile and the eyes to facial expression processing

Prior research on prototypical facial expressions of emotion has demonstrated that happy faces are recognized more accurately and faster than other expressions (e.g., Palermo & Coltheart, 2004), and that the smile is the critical expressive component responsible for this advantage (e.g., Calder, Young, et al., 2000), due to its high visual salience (Calvo & Nummenmaa, 2008) and distinctiveness (Calvo & Marrero, 2009). However, in real-life situations, we often encounter non-prototypical, blended—hence ambiguous—yet socially relevant facial expressions. Given the ubiquitous use of the smile for multiple functions in social contexts and its morphological variability (Ambadar et al., 2009; Ekman, 2001), the question arises about its effects when the smile appears as a part of an ambiguous expression in a face with non-happy eyes. Is the smiling mouth so salient and distinctive that it overrides the processing of other facial components, even when these are inconsistent in meaning with the smile?

The response to this question depends on the type of cognitive process that is considered: perception, categorization, or affective evaluation. First, the contribution of the mouth to *perceptual processing* is greatest, with the eye region being overshadowed by the smiling mouth. The detection of a smile in the probe scenes of Experiment 3 was primed rapidly by a smiling prime face, and this effect was equivalent in magnitude and time course regardless of the eye expression. Second, the mouth plays a lesser but still important role in *categorization*. In Experiment 1, a smile biased viewers towards judging around 40% of the blended expressions as happy, and this occurred similarly for upright and inverted faces. The comparable time course for smile detection and expression categorization in Experiment 4 further suggests that the visual recognition of the mouth underlies the identification of the expression. Nevertheless, the categorization effects of the smile are modulated to some extent by the eye expression, as they varied depending on the eyes in Experiment 1. Third, the smile alone exerts minimal influence on *affective evaluation*, which is strongly dependent on the processing of the facial configuration. In Experiment 2, a prime face produced affective priming only when the smiling mouth appeared with congruent happy eyes, but not when combined with non-happy eyes. In Experiment 4, when explicit affective evaluation of the face had to be made (thus requiring integration of the eyes and the mouth), performance was greatly dependent on display duration, whereas this did not occur for smile detection (for which only the mouth was needed). Altogether this suggests that, although perception of smiles, and to a lesser extent categorization of expressions as happy, rely on feature analysis (Fiorentini & Viviani, 2009), affective processing requires configural integration of other facial cues, most critically the eyes (Niedenthal et al., 2010).

Prior studies investigating the viewers' sensitivity to genuine vs. non-genuine smiles are relevant to our distinction between categorization and affective evaluation. Viewers can differentiate genuine and fake smiles when judging the affective state of the people smiling (Miles & Johnston, 2007). Also, observers report more pleasure when they see genuine compared to posed smiles, and facial EMG responses also differentiate between neutral expressions and genuine but not posed smiles (Surakka & Hietanen, 1998). Moreover, such sensitivity impacts subsequent approach behavior (e.g., co-operation) of the observers (Johnston et al., 2010; Peace, Miles, & Johnston, 2006). Interestingly, these differences occur when the task involves judging "the emotion being *felt*" by the expresser; in contrast, when judging "the emotion being *shown*", such sensitivity is significantly reduced or disappears (McLellan, Johnston, Dalrymple-Alford, & Porter, 2010). This pattern matches perfectly with our findings. In the explicit categorization task of Experiment 1, only the "emotion *shown*" criterion was needed, with the smiling mouth as the dominant cue, which led to poor discrimination between happy and blended expressions. In contrast, when an implicit measure of affective evaluation was employed in Experiment 2, the "emotion *felt*" criterion was required, which increased sensitivity to genuine facial happiness.

6.2. Time course in the processing of genuine and ambiguous smiles

Prior research using the priming paradigm has shown that affect is obtained from emotional face primes, as revealed by their impact upon the processing of subsequent pleasant or unpleasant probe words or visual scenes, depending on the prime–probe congruence in affective valence (Carroll & Young, 2005). More specifically, happy as well as liked faces produce affective priming between 300 and 750 ms from face stimulus onset (Calvo et al., 2010; Lipp et al., 2009; Nummenmaa et al., 2008; but see McLellan et al. (2010) for earlier effects). Consistent with this, the findings from our Experiment 2 demonstrated affective priming effects of truly happy faces between 340 ms (with prime–probe visual similarity) and 550 ms (without visual similarity) following face onset. This confirms that positive affect was automatically extracted from the truly happy face primes. The process can be conceptualized as automatic in the sense of not being intentionally (i.e., strategically) driven, as participants were told to ignore the prime face and focus on the valence of the probe scene. In contrast, genuine affective priming by blended expressions was not observed. For these expressions, priming was restricted to conditions where the affective prime–probe congruence was contaminated by prime–probe visual similarity.

These affective priming time course data can be examined in the light of neurophysiological research using ERP measures during emotional face processing (for reviews, see Eimer & Holmes, 2007, and Palermo & Rhodes, 2007). Three stages with distinct neural underpinnings have been established (Debruille, Brodeur, & Hess, 2011; Luo et al., 2010; Paulmann & Pell, 2009). The first stage is sensitive to physical stimulus factors and may include detection of negatively valenced stimuli and fearful expressions with distinct visual features such as the white sclera in the fearful eyes, as shown by N1 and P1 ERP components (within a 100–200-ms latency range). During the second stage, the brain can distinguish almost all expressive faces from neutral faces, in addition to performing facial structural encoding, as reflected in N170 and vertex positive potential (VPP, 150–280 ms), and also encompassing N2 and EPN (200–400 ms) components. The third stage is sensitive to motivational and affective significance, and discrimination between different emotional expressions is made, as indexed by N300 and P300 (250–500 ms), and LPP (300–700 ms) components. Interestingly, differences between prototypical emotional expressions and ambiguous grimaces have been found at N400 (350–450 ms; Paulmann & Pell, 2009). For ambiguous faces with minor expressive changes, electrocortical activity has shown an additional delay, as reflected in SPWs (>700 ms; Debruille et al., 2011).

The ERP data thus suggest that facial properties conveying affect are coded within a time range of 250–500 ms post-stimulus. Although ERPs do not reveal *which* type of affective *meaning* is extracted, these findings are in line with our behavioral measures. Compared with affective priming, perceptual priming occurred much earlier (170 ms post-stimulus, at least, and remained until 800 ms, at least). Furthermore, the magnitude and time course of perceptual priming were equivalent for happy and blended expressions. Thus, the earlier perception of the smile physical features, relative to its affective significance, would account for the tendency to categorize ambiguous faces as happy. The smiling mouth was the same in the happy and the blended expressions, with equivalent visual saliency and the same perceptual time course. It is, therefore, reasonable that the mouth was similarly used to categorize both types of faces as happy. It is also understandable that such a biasing influence remained for at least 550 ms, until the affective information would reach sufficient activation as to compete with the perceptual representation. At that time, the meaning added by the affective content would allow viewers to discriminate between truly happy smiles and incongruent smiles.[1]

6.3. Conclusions

A smiling mouth is visually much more salient than the eyes, both for genuine expressions of happiness and blended expressions with non-happy eyes. Saliency makes purely physical features such as the smiling mouth shape easily accessible and attention-capturing. As a result, featural analysis of the mouth rather than configural analysis of the face establishes a perceptual representation very early (<170 ms; as shown by the perceptual priming effects of the smile, regardless of eye expression). Such an early analysis of the mouth biases the categorization of the expression while the eye region only marginally influences this process. In contrast, affective significance is extracted considerably later (>500 ms). This would occur when the less salient eyes reach attention and a configural, coherent representation of all the major expressive sources in the face is formed. This implies that, for at least 500 ms, the interpretation of a facial expression with a smile relies on a perceptual rather than an affective criterion, and so, in the mean time, all faces with a smile will be seen "as

[1] VanRullen (2011) has identified some limitations in common experimental paradigms used to determine the moment at which a visual recognition process is completed, or the order in which various processes come into play. In our view, such limitations mainly affect the estimates of the absolute time course points of a given process. The contribution of the current study is concerned with the relative—rather than the absolute—time course of perceptual, categorical, and affective processing in the recognition of facial expressions.

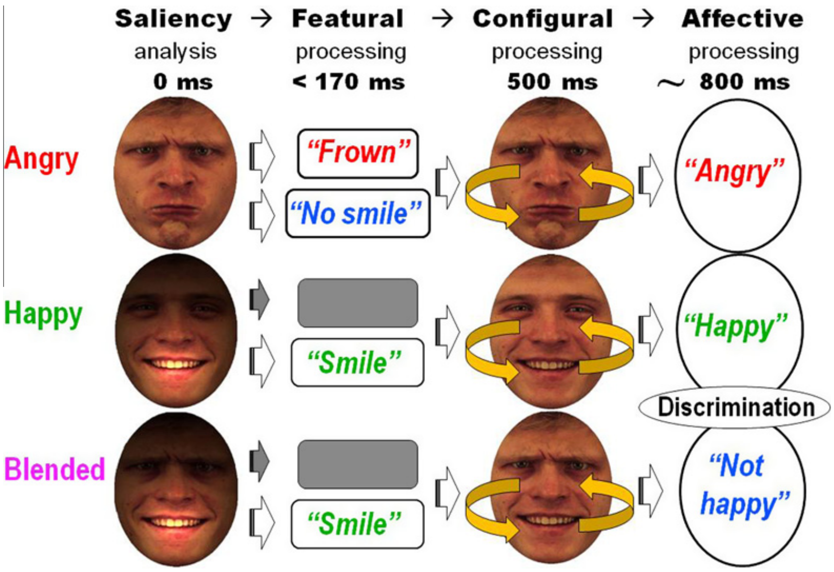

Fig. 12. Graphical summary of the major conclusions of the current study. The frown in angry faces (for example) could be encoded as a feature by 170 ms because it is sufficiently salient—and therefore attention-capturing—in the absence of a smile. In contrast, the same angry eyes and frown in blended faces, as well as the happy eyes in truly happy faces, would be less likely to be processed at such an early stage because the presence of a salient smile would reduce their saliency.

happy". A graphical summary of these conclusions is shown in Fig. 12.

At a more general level, we propose that the information extracted from a face accumulates over at least 800 ms from face onset, with highly salient information of single features (e.g., the mouth shape) being accessed first—which can be immediately used for expression categorization—and more complex affective information being analyzed last. Thus the present research provides support for a serial model of facial expression processing, where the initial perceptual analysis of single facial features is followed by their configural integration, which is then required for an even slower extraction of affective content. Importantly, the information obtained in the earlier stages biases processing in the later stages, thus resulting in potentially erroneous categorization of blended expressions based on "first impressions". As a smile is a highly diagnostic feature, viewers will tend to rely on it until clearly contrary evidence stemming from other sources is recruited. This framework is useful to explain why an ambiguous face with a smile is likely to be interpreted as happy at first sight and takes time to be discriminated from a truly happy face, and therefore why social smiles without genuine affective involvement can, nevertheless, be so effective, at least temporarily.

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Appendix A. IAPS number of pictures used as unpleasant and pleasant probes in Experiments 2 and 3

PLEASANT SCENES WITH SMILING FACES: 2040, 2165, 2340, 2347, 2530, 4572, 4599, 4626, 4641, 4700, 7325, 8461. PLEASANT SCENES WITH **NO** SMILING FACES: 2057, 2160, 2170, 2260, 2332, 2655, 4597, 4653, 4660, 5836, 8032, 8200. UNPLEASANT SCENES (with no smiling faces): 2691, 2700, 2799, 2900, 3181, 3300, 3350, 3530, 6212, 6243, 6313, 6550, 6560, 6838, 9040, 9075, 9250, 9254, 9400, 9410, 9413, 9421, 9429, 9921.

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