Short Title: Overshadowing and Priming by a Smile

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Misperception of non-Happy Facial Features:

Overshadowing and Priming by a Smiling Mouth

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Misperception of non-Happy Facial Features:

Overshadowing and Priming by a Smiling Mouth

Abstract

A smile underlies the well-known recognition advantage of prototypical happy faces. However, a smiling mouth also has side effects: It biases a tendency to incorrectly judge as "happy" *blended* expressions with non-happy eyes (neutral, sad, etc.). This reveals interference with the processing of such mixed-smile expressions, which are otherwise ubiquitous in social settings (hence its practical importance). To account for this effect, we investigated two mechanisms: Perceptual overshadowing driven by the smile visual saliency, and categorical priming driven by the smile diagnostic value. In Experiment 1, we obtained diagnostic values for the mouth and eye regions of facial expressions of emotion. In Experiment 2, facilitation and interference effects of prime mouths on probe eyes were examined as a function of such values. In Experiment 3, overshadowing and priming were compared. Results showed, first, a high diagnostic value of the smiling mouth, followed by disgusted, sad, and angry mouths. Second, in correspondence with such values, the mouth expressions facilitated the recognition of congruent eyes. Importantly, the presence of a smiling mouth especially impaired the accurate recognition of non-happy eyes. This supports the categorical priming hypothesis. And, third, the smiling mouth still caused some (albeit limited) interference with the processing of facial information unrelated to expression (masculine/feminine appearance of the expresser). This is consistent with an overshadowing-inattentional blindness hypothesis. An alternative affective priming hypothesis is discussed.

Word count: 224

Keywords: smile; overshadowing; priming; blended expressions; diagnostic value.

Introduction

The issue under investigation and its relevance

The smile is a powerful tool in social relationships. In general, a smile on a face predisposes viewers to perceive surrounding stimuli and situational contexts favorably, in a way that is congruent with the positive emotion presumably conveyed by the smile (Calvo et al., 2012; Day et al., 2023; Lipp et al., 2009; Peace et al., 2006). Also, smiling individuals are judged as more attractive (e.g., Sutherland et al., 2017) and more trustworthy (e.g., Centorrino et al., 2015). Consequently, they elicit approach behaviors and are more likely to receive social attention (Nikitin & Freund, 2019; Phaf et al., 2014). All this makes observers more receptive to people who smile.

Smiles can indeed convey good feelings and intentions. However, as communicative signals with multiple social functions, smiles are often used to influence other people rather than as conveyors of affect (Barrett et al., 2019; Durán & Fernández-Dols, 2021; Krumhuber & Kappas, 2022). Thus smiles can be mere displays of politeness, and they can also serve as a means of concealing less benevolent thoughts and motives (mockery, contempt, arrogance, malicious joy, cheating, embarrassment, etc.). Indeed, individuals frequently smile without experiencing genuine happiness (or enjoyment or friendliness). This results in ambiguous facial expressions (Ambadar et al., 2009; Niedenthal et al., 2010). Such blends with *mixed smiles* (Harris & Alvarado, 2005; i.e., a smiling mouth with non-happy eyes) may actually be more common than ‘prototypical’ happy faces (a congruent smile with truly happy eyes) in social settings (Fernández-Dols & Crivelli, 2013; Scherer & Ellgring, 2007).

Ekman (2001; see also Shor, 1978) identified at least 18 different types of smiles, and there are possibly many more, even if they are categorized within three major groups depending on social function: reward, affiliation, and dominance (see

Martin et al., 2017; Wood et al., 2022). This can render the distinction between genuine and non-genuine smiles challenging. It is therefore important to be able to differentiate truly happy smiles from those hiding other emotions and intentions, for obvious adaptive reasons. In social interaction, of course, smiling occurs in conjunction with other informative cues. Within the face, a relevant source is in the eye region. In order to obtain reliable information, observers could focus attention on the eyes of the expressers (Niedenthal et al., 2010). The critical question, however, is whether the impact of a smiling mouth is so strong, and occurs so early in facial expression processing, that it can override the contribution of other sources, including the eyes.

The facts and the proposed explanation

Prior research has shown that the presence of a smiling mouth in a face with *incongruent* non-happy eyes *interferes* with the accurate recognition (i.e., more errors and/or slower correct responses) of the facial expression *as a whole* (Calvo, Gutiérrez-García et al., 2013; Calvo et al., 2012) and even the actual *eye expression* itself (Calvo & Fernández-Martín, 2013; Calvo, Fernández-Martín et al., 2013). This happens when the mouth is looked at before the eyes. Calvo, Gutiérrez-García et al. (2013) observed that the probability of incorrectly judging blended expressions with a smile, but non-happy eyes, as happy was higher when the mouth was fixated prior to the eyes than when these were fixated earlier. This bias persists even when only the eyes are directly looked at while the mouth remains in parafoveal vision (Calvo & Fernández-Martín, 2013; Calvo, Fernández-Martín et al., 2013).

A mechanism can be put forth to account for these findings. It is proposed that an observer may be “dazzled” or “blinded” by viewing a smile at an early stage of face processing. This could then result in the observer either skipping or missing other informative sources, or processing them as if they showed happiness. This mechanism is comprised of two pathways. One pathway engages *perceptual* processes, whereby initial *overshadowing* by the smile leads to *inattentional blindness* for other facial cues. This would be driven by the high *visual saliency* of the smiling mouth. The other pathway engages semantic or *conceptual* processes, which involve *categorical priming*, i.e., preparedness to expect a specific expression. This would be driven by the high *diagnostic value* or distinctiveness of the smiling mouth regarding the expression of happiness. The perceptual process would precede and inform the conceptual process: Visual saliency would make a diagnostic smiling mouth readily available for selective and preferential attention. Electrocortical research (for a review, see Calvo & Nummenmaa, 2016), has provided evidence regarding the time course and neural signatures for the visual saliency and the conceptual distinctiveness of the smile: That is, their respective (i.e., saliency and distinctiveness) brain ERPs (Event Related Potentials; N1: 90‑130 ms post-stimulus onset, and P3b: 350-450 ms), and sources (left infero-temporal [IT, MTG] cortex, and the right IT [FG] and dorsal cingulate [CC]).

The role of each component in the processing of smiling faces can be analyzed separately. Table 1 provides a schematic comprehensive overview comparing the perceptual saliency-driven hypothesis and the conceptual distinctiveness-driven hypothesis.

INSERT TABLE 1 ABOUT HERE

Firstly, regarding the *perceptual hypothesis*, the smiling mouth is in fact more *visually salient* than the eyes in genuinely happy faces (Calvo & Nummenmaa, 2008), more salient than non-happy eyes (fearful, angry, etc.) in blended expressions (with a smile), and more salient than the mouth of non-happy faces (angry, sad, etc.; Calvo et al., 2012). Visual saliency has been operationalized in terms of physical image properties (Borji & Itti, 2013), and is indeed a major factor in the attentional advantage of happy faces (Entzmann et al., 2021). The high visual saliency of the smiling mouth can then result in the overshadowing or eclipsing of other facial regions, including the eyes, which may subsequently go unnoticed, at least temporarily, by an observer. Therefore, the visually salient smile, by accruing selective attention, could cause *inattentional blindness* for other informative, yet less salient, facial cues. If so, the observer would be inclined to judge the facial expression as happy, based on the conspicuous presence of the smiling mouth.

Secondly, with regard to the *conceptual hypothesis*, the smiling mouth is highly *distinctive* or *diagnostic* of (i.e., uniquely associated with) facial happiness, whereas the facial features associated to the other emotions (fear, anger, etc.) exhibit some degree of overlap across categories (Kohler et al., 2004). Such a single feature can then be used as a rapid categorization shortcut for a smiling face as happy (Leppänen & Hietanen, 2007). The high distinctiveness of this feature enables viewers to accurately classify an expression as belonging to a specific category (i.e., happiness) with minimal competition from alternatives. Indeed, faces are categorized as happy as likely and even faster from the bottom half of a face (with the smiling mouth) as/than from the whole face (Calder et al., 2000). As a consequence, the presence of a distinctive smile would *prime* and bias *recognition* towards happiness, i.e., lead viewers to wrongly accept non-happy eyes as happy, or to delay their correct identification as not happy.

In sum, the smiling mouth is visually prominent from an early processing stage and is regarded as a highly indicative feature of facial happiness. Due to saliency, the mouth would prevail over less salient sources in a face (e.g., the eyes). This implies that, upon glancing at the mouth, the viewer may become temporarily unable to accurately perceive the details of expressive changes in the eyes or other areas. Due to distinctiveness, the smiling mouth would automatically evoke a mental representation of a happy expression. Once activated, such a representation would prompt the viewer to categorize the eye expression as indicative of happiness (even in the absence of objective evidence or in contradiction to it).[1]

The current study

From this theoretical framework, straightforward predictions can be made. A *general* prediction of both hypotheses posits *interference* (i.e., more errors and slower responses) with the recognition of any cues in a smiling face, when the cues are *not congruent* with the smile. However, *specific* predictions associated with each hypothesis differ. Within the *visual saliency* approach: (1) overshadowing would be detrimental (i.e., *interference*) for the recognition of *any* other facial cues (either expression-relevant or irrelevant) in a face with a smiling mouth; and (2) even the recognition of congruent happy eyes could be compromised (e.g., delayed). In contrast, the *distinctiveness* or diagnostic value approach suggests that: (3) *no interference* would occur if the target is expression-irrelevant (e.g., sex of the expresser); and (4) *facilitation* would occur if the target is expression-congruent with the smiling mouth (e.g., happy eyes).

To test these predictions, a paradigm can be employed in which a *prime* stimulus is presented initially, comprising the lower half of either (a) a smiling happy face, (b) a non-happy face (with an angry, sad, etc., mouth), or (c) a scrambled face with no discernible mouth. Subsequently, a *probe* is presented, comprising the upper half of a face with eyes that are either (a) congruent with the mouth (i.e., exhibiting the same mouth-eye expression; prototypical expression), (b) incongruent (i.e., non-happy eyes but a smiling mouth; blended expression), or (c) a control condition with no mouth. The participants are required to categorize the probe eye expression as happy or not. Interference (i.e., reduced accuracy and longer response times) is expected in the incongruent condition, relative to the control condition; facilitation (i.e., greater accuracy and faster responses), in the congruent condition.

Our principal objective was to test the categorical priming mechanism while considering the perceptual overshadowing mechanism. To this end, in a first step, Experiment 1 was conducted to obtain measures of the diagnostic value of the mouth and the eye regions of all six basic facial expressions of emotion. Then, in Experiment 2, interference and facilitation effects in expression categorization were investigated in relation to diagnostic values. Finally, Experiment 3 compared overshadowing and priming: While priming should affect only the processing of *expressive* information (i.e., the facial expression category), overshadowing could also affect *non-expressive* facial information (e.g., the masculine/feminine appearance of the expresser).

Experiment 1

In this experiment, the diagnostic value of the eyes and the mouth regions was determined for the face stimuli that were then used in Experiments 2 and 3. Diagnostic value refers to the distinctiveness of a facial feature (e.g., furrowed eyebrows or upturned lips, etc.) in relation to a specific expression category (e.g., anger or happiness, etc.): In other words, the extent to which a feature is uniquely associated with, or specific to, a given expression, and is not shared with others; and, therefore, the ease with which an expression can be identified from the feature at issue.

The following approach was used: Expression recognition performance was compared when the eye or the mouth regions were presented individually (i.e., in either the upper or the lower half of the face) relative to when the entire face was displayed. The underlying rationale is that the lower the degree of recognition impairment when a single region is presented, the higher the diagnostic value of that region must be. A high diagnostic value indicates that an expression can be recognized as accurately and rapidly (or even better or faster) from the eyes or the mouth separately as (or than) from the entire face.

Importantly, by obtaining the diagnostic values of the eyes and the mouth for happy and also for non-happy expressions, we can examine the generalization of the categorical priming hypothesis (see Introduction) beyond the smile. If this hypothesis is correct, *other* mouth expressions (in addition to the smile) would also cause the predicted facilitation and interference effects, *to the extent* that the mouth expressions are diagnostic of their own expressive categories.

Method

Participants

In this and the following experiments, psychology undergraduates from the University of La Laguna (aged between 19 and 25 years) provided informed consent and received course credit for their participation. A total of 30 participants (21 female) took part in Experiment 1. Participants were different in the three experiments. The study (Experiments 1, 2, and 3) was approved by the University of La Laguna ethics committee (CEIBA, protocol number 2017-0227), and conducted in accordance with the WMA Declaration of Helsinki 2013.

A priori power analysis using G*Power 3.1.9.7 (see Faul et al., 2007) determined that a sample size of 30 participants was sufficient to detect a medium effect size of $f = 0.25$ (Cohen's $d = 0.5$), at $\alpha = 0.05$, with statistical power P (1 - β err prob) = 0.95, for an F test repeated-measures ANOVA in an experimental design involving two within-subjects factors (3 × 6: face format and eye expression). (It must, nevertheless, be noted that, for within-subject designs, this calculation might overestimate the actual power. Therefore, the computed power should be increased (from 0.80 to ≥ 0.90) and robust statistical effects should be obtained; Brysbaert, 2019).

Stimuli

We selected 144 digitized color photographs from the KDEF (Lundqvist et al., 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 six prototypical, basic expressions (original KDEF: happiness, anger, disgust, sadness, fear, and surprise). Nonfacial areas (e.g., hair, neck, etc.) were obscured. The stimuli were presented in three formats: the entire face, the upper half, and the lower half, in different experimental conditions. A total of 432 stimuli were used (144 of each format).

Apparatus, design, procedure, and measures

All the experiments (1, 2, and 3) were conducted within individual cabins in a laboratory setting. The face stimuli were presented on a screen connected to a computer. The E-Prime 2.0 Professional software (Schneider et al., 2002) controlled stimulus presentation and response collection. For all the experiments, the stimuli were presented on a 21" monitor with a 120-Hz refresh rate. The size of each whole face stimulus was 13-cm wide by 17-cm high, equalling a visual angle of 9.3° (horizontal) × 12.1° (vertical) at a viewing distance of 80 cm. This approximates the retinal projection of a real face during typical everyday conversation. The eye region and mouth regions subtended a vertical visual angle of 2.6° each.

Each participant was presented with the stimuli in six blocks of 72 trials. Each block comprised 24 trials of each face stimulus format. This entailed a within-subjects 3 (Format: whole face vs. top half vs. bottom half) by 6 (Expression: happy, angry, sad, fearful, disgusted, and surprised) experimental design. Trial order for each participant was randomized within each block and block order was counterbalanced.

Participants were required to identify the emotional expression depicted in each image promptly and accurately. The face image appeared in the centre of the screen and remained until the participant responded by pressing one of six buttons, labelled as 'happy', 'angry', 'sad', 'fearful', 'disgusted', or 'surprised'. Response accuracy and reaction times were collected. There was a 1,500-ms interval between trials. A button was randomly assigned to each emotion category, and the location of the emotion labels was counterbalanced across participants.

Results

Recognition accuracy and the latencies of correct responses were analyzed by means of 3 (Face format) × 6 (Facial expression) ANOVAs. In both cases, an interaction appeared. This indicates that the contribution of the eye and the mouth region differs for the various expressions. To decompose the interaction, separate one-way (3: Format) ANOVAs were conducted for each expression, followed by Bonferroni-corrected ($p < .05$) multiple comparisons. Importantly for the specific aims of the current study, this would serve to establish the respective diagnostic values of the eyes and the mouth. The primary criterion was based on the accuracy of recognition performance, which was generally convergent with response latencies for correct responses (see Figure 1). If performance in the condition of the face's upper or lower half is equivalent or superior to that of the entire face, this implies that the eye or mouth region is a highly diagnostic feature. Table 2 presents the categorization accuracy scores and the correct response times.

In addition, the H_u unbiased hit rate (see Table 2) was computed from the frequencies of hits and confusions (Wagner, 1993). Importantly, H_u and recognition accuracy (hit rates) were significantly correlated (Spearman rho, ρ; and coefficient of determination, R^2): For the whole face format ($\rho = 1, p < .001, n = 6; R^2 = .856, p = .008$), the upper-half face ($\rho = .829, p = .042, n = 6; R^2 = .644, p = .05$), and the lower-half face (ρ = .943, p = .005, n = 6; R^2 = .859, p = .008). The response frequency data from which H_u was calculated are available in Supplemental Dataset S1; the hit and confusion matrices are in Supplemental Information S4.

INSERT TABLE 2 ABOUT HERE

Recognition accuracy

The 3 (Format) × 6 (Expression) ANOVA yielded main effects of format, $F(2, 58) = 28.57$, $p < .0001$, $\eta_p^2 = .496$, and expression, $F(5, 145) = 7.20$, $p < .0001$, $\eta_p^2 = .199$, which were qualified by an interaction, $F(10, 290) = 14.21$, $p < .0001$, $\eta_p^2 = .329$. The follow-up separate one-way (3: Format) ANOVAs showed effects for happiness, $F(2, 58) = 117.68$, $p < .0001$, $\eta_p^2 = .802$, disgust, $F(2, 58) = 17.19$, $p < .0001$, $\eta_p^2 = .372$, anger, $F(2, 58) = 14.56$, $p < .0001$, $\eta_p^2 = .334$, fear, $F(2, 58) = 11.89$, $p < .0001$, $\eta_p^2 = .291$, and surprise, $F(2, 58) = 6.05$, $p < .01$, $\eta_p^2 = .173$, but they did not reach statistical significance for sadness, $F(2, 58) = 2.69$, $p = .079$ (*ns*), $\eta_p^2 = .085$.

The results of the comparisons across the three formats within each expression category are presented in Figure 1. Essentially, for happiness and disgust, accuracy rates were similarly high when the mouth region was displayed and when the entire face was shown, and higher than when the eye region was presented. In contrast, for anger and fear, accuracy was similarly high when the eye region was presented and when the whole face was presented, and higher than when the mouth region was shown. In the case of sadness and surprise, the pattern was not clear-cut, with no significant differences between the eyes and the mouth.

INSERT FIGURE 1 ABOUT HERE

Response latencies

The 3 (Format) × 6 (Expression) ANOVA showed effects of format, $F(2, 58) = 10.54$, $p < .0001$, $\eta_p^2 = .267$, expression, $F(5, 145) = 90.89$, $p < .0001$, $\eta_p^2 = .758$, and an interaction, $F(10, 290) = 43.13$, $p < .0001$, $\eta_p^2 = .598$. The follow-up separate one-way (3: Format) ANOVAs for each expression, revealed effects for happiness, $F(2, 58) = 305.83$, $p < .0001$, $\eta_p^2 = .913$, anger, $F(2, 58) = 8.92$, $p < .01$, $\eta_p^2 = .235$, fear, $F(2, 58) = 9.21$, $p < .001$, $\eta_p^2 = .241$, and surprise, $F(2, 58) = 6.72$, $p < .01$, $\eta_p^2 = .188$, but not for disgust, $F(2, 58) = 2.08$, $p = .13$, and sadness, $F(2, 58) = 1.86$, $p = .16$.

The results of the multiple comparisons across the three formats within each expression category are illustrated in Figure 1. Essentially, for happiness, latencies were shorter when the mouth region was displayed than when the whole face or the eye region were shown. In the case of disgust, the three formats yielded equivalent latencies. In contrast, for anger and fear, latencies were equivalent when the eye region and the whole face were presented, and shorter than when the mouth region was shown. The pattern for sadness and surprise was less straightforward, with no significant differences between the eyes and the mouth.

Discussion

We determined the diagnostic value of the mouth and the eye expression by comparing the recognition performance when the lower or the upper face halves were presented, relative to when the whole face was displayed. Firstly, the *mouth* region of *happy* faces was found to be highly diagnostic in terms of both accuracy and time. Secondly, the *mouth* region of *disgusted* faces was also highly diagnostic, although to a lesser extent than for happy faces. For instance, recognition performance for the mouth region of happy faces was superior, and response times were shorter, than those for disgusted faces. Thirdly, in contrast, for *angry* and for *fearful* expressions, the *eye* region was highly diagnostic, and more than the mouth region. And, fourthly, for *sad* and *surprised* faces, the mouth and the eyes exhibited similarly low diagnostic values.

The current results are aligned with those of prior research using different face stimuli and databases (Calder et al., 2000; Kohler et al., 2004; Nusseck et al., 2008; Smith et al., 2005). They are also, in principle, consistent with the categorical priming hypothesis regarding smiling (see Introduction). The mouth region of happy faces had the greatest diagnostic value, in comparison with the eye and mouth regions of all the other expressions. It is thus understandable that the smiling mouth can bias the categorization of (any) eye expressions towards happiness. A significant question that arises is whether comparable effects are elicited by other (non-happy) mouths in a manner that is *proportional* to their diagnostic value for the respective expression, or whether such effects are unique to the smiling mouth.

To this end, we conducted Experiment 2. In light of the findings of Experiment 1 regarding diagnostic values, it can be anticipated that the biasing effects (i.e., facilitation and interference) on the recognition of eye expressions (a) will be greatest when a smiling mouth is presented, (b) followed by those of a disgusted mouth, whereas (c) those of a sad or surprised mouth will be less pronounced or non-existent, and definitely (d) there will be no effects of angry or fearful mouth expressions.

Experiment 2

A *prime* mouth region (lower face half) was followed by a *probe* eye region (upper face half) in three conditions: (a) congruence (same prime-probe expression), (b) incongruence (different expression), and (c) control (no-mouth mask). Participants judged the probe eye expression. Facilitation (correct and faster recognition) should occur in the congruent relative to the control condition. Conversely, interference (incorrect and slower recognition) should be observed in the incongruent condition.

The mouth (prime) and the eyes (probe) were presented in sequence, rather than simultaneously. This was done to control or minimize the role of visual saliency (and therefore perceptual overshadowing). The rationale is straightforward: The relative saliency of a spatial region is *contingent upon* the visual stimulus as a whole; thus, when considered separately, the different mouths (smiling or otherwise) could be no more or less salient in relation to the eyes. This allowed us to isolate the effects of the diagnostic value (and therefore semantic priming) of the mouth.

The mouth expressions exhibited varying degrees of diagnostic value (DV), as determined in Experiment 1: a happy smiling mouth (*high* DV); a disgusted mouth (*moderate* DV); a sad mouth (*low* DV and *equivalent* to that of the eyes); and an angry mouth (*low* DV and *lower* than the eyes). In correspondence, in Experiment 2, there were four categorization tasks: Viewers judged the probe eyes as either “happy or not”; or “disgusted or not”; or “sad or not”; or “angry or not”. This enables us to ascertain whether effects on expression recognition vary in accordance with the degree of DV.

The following predictions were made: If the diagnostic value of the prime (mouth) biases recognition of the probe (eyes), then facilitation and interference will be greater for smiling mouths than for disgusted mouths, which will be greater than for sad mouths, which will be greater than for the angry mouth. It is likely that minimal, if any, effects will be observed for sadness and anger, given the low DV of the respective mouths.

Method

Participants

Forty-eight psychology undergraduates (33 female) served as participants. A priori power analysis using G*Power 3.1.9.7 (see Faul et al., 2007) determined that a sample of 30 participants was sufficient to detect a medium effect size of $f = 0.25$ (Cohen's $d = 0.5$), at $\alpha = 0.05$, with statistical power P ($1 - \beta$ err prob) = 0.92, for an *F* test repeated-measures ANOVA in an experimental design involving two within-subjects factors (2 × 4: type of mouth and eye expression).

Stimuli

The same 24 KDEF models as in Experiment 1 were used as stimuli, albeit there was an important difference. Instead of presenting the entire face, only the lower half containing the mouth and the upper half containing the eyes were presented in sequence, serving as the prime and the probe, respectively. In addition, a scrambled (a Fourier-phase mask) bottom-half face was used as a no-mouth control condition. Figures 2 and 3 illustrate the nature of the half-face stimuli. (For examples of *whole* face *blends*, see Calvo & Fernández-Martín, 2013; Calvo et al., 2012; Calvo, Gutiérrez-García et al., 2013).

The experimental use of composite faces with blended expressions has proven to be a valuable methodological tool (e.g., Calder et al., 2000; Tanaka et al., 2012; Valt & Stürmer, 2018). Furthermore, blended expressions are very common in social contexts (e.g., Calvo et al., 2014; Fernández-Dols & Crivelli, 2013; Krumhuber & Scherer, 2011). Also, people can indeed experience mixed emotions or feelings at any given time or within very short intervals (see Larsen, 217; Larsen & McGraw, 2014), which is likely to lead to mixed facial expressions.

The low-level image properties (luminance, root-mean square RMS contrast, skewness, kurtosis, energy, and signal-to-noise SNR ratio) of the stimuli had been assessed previously (Del Líbano et al., 2018), using Matlab 7.0 (The Mathworks, Natick, MA). These measures were obtained from the entire face, as well as from each face half, and also the eye region and the mouth region, separately. No significant low-level difference was observed for any facial area (all Fs < 1; ps ≥ 0.90) as a function of expression. Therefore, potential differences in recognition in the current study could not be attributable to confounding physical stimulus factors.

Procedure and measures

The stimuli were displayed on a computer screen by means of E-Prime software. Each participant was presented with 384 trials, distributed across four counterbalanced blocks, with 96 randomly ordered trials per block. Figure 2 provides an overview of the procedure.

INSERT FIGURE 2 ABOUT HERE

On each trial, a central 500-ms fixation point, followed by a 250-ms visual cue (a rectangle), appeared in the location where the mouth was scheduled to appear in the subsequent *prime period*. This prime period consisted of the presentation of either the bottom half of an intact or a scrambled face for 300 ms. The 300-ms display was selected based on previous studies, which have indicated that the average duration of a functional fixation in face recognition is approximately 300 ms (Henderson et al., 2005; Hsiao & Cottrell, 2008). Subsequently, the *probe period* started, during which the upper half of the face was displayed, with the eye region occupying the same position as the mouth region in the preceding period. The probe remained visible until the participant judged the eye region expression, by pressing ("as quickly and accurately as possible") a "Yes" or a "No" option on the keyboard. There was a 1,500-ms interval between trials.

In each of the four blocks of trials, the target task (i.e., the target eye expression) was different (happy, angry, sad, or disgusted). The term "target" refers to the criterion against which the eyes should be judged. At the beginning of each block, the target was pre-defined: Participants were to respond either whether the eyes were (a) happy or not (i.e., Happiness target task), or (b) angry or not (i.e., Anger target task), or (c) sad or not (i.e., Sadness target task), or (d) disgusted or not (i.e., Disgust target task). The probability of correctly identifying whether the eye expression corresponded to the predefined target, and the reaction times for accurate responses, were recorded.

Experimental design

To determine the relative influence of the happy, angry, sad, and disgusted mouths (hereafter referred to as "primes") on the evaluation of the eye expression (hereafter, "probe"), we used two complementary approaches. One assessed the influence of mouth expressions that were *congruent* with the eyes, as is the case for prototypical expressions. This approach was used to determine the *facilitation* effects of the mouth on the eye expression. The other was concerned with the influence of the mouth when it was *incongruent* with the eyes, as is the case for blended expressions. This approach served to determine *interference* effects.

For the first approach, the experimental conditions were combined in a Target Eye Expression (4: happy, disgusted, sad, angry) by Type of Mouth (2: *congruent* with eyes vs. no-mouth control) within-subjects factorial design. For the second approach, the conditions were combined in a Target Eye Expression (4: happy, disgusted, sad, angry) by Type of Mouth (2: *incongruent* with eyes vs. no-mouth control) within-subjects factorial design. (For a graphical illustration and details, see S5 Supplemental Information_Experimental Conditions in Experiment 2).

It should be noted that some of the (probe) eye expressions were necessarily different for the *congruent* and the *incongruent* approaches. For instance, happy eyes could not be used as probes in the incongruent conditions of the Happiness target task (as they would become actually congruent); or angry eyes in the Anger target task; and so on. Instead, for some trials, fearful, surprised, and neutral eyes (in addition to the other non-happy, or non-angry, etc., probe eyes) were used as replacement (see S5 Supplemental Information). This precluded a direct comparison between the congruent and the incongruent conditions. Importantly, however, *within* each approach, the eye expressions were *identical* in the control (no mouth) condition and the experimental condition (either congruent or incongruent), thereby enabling a strict comparison.

Results

Categorization of eye expressions as the predefined target expression: Facilitation

To assess facilitation effects, a 4 (Target eye expression: happy, angry, sad, disgusted) × 2 (Mouth: *congruent* vs. no mouth) ANOVA was conducted on the probability of *correctly* responding that the actual eye expression corresponded to the target expression, and on reaction times (see Table 3).

For *response accuracy*, main effects of target, $F(3, 141) = 12.50$, $p < .0001$, $\eta_p^2 = .210$, and mouth, $F(1, 47) = 101.85$, $p < .0001$, $\eta_p^2 = .684$, were qualified by an interaction, $F(3, 141) = 12.68$, $p < .0001$, $\eta_p^2 = .213$. Planned contrasts were conducted between the congruent and the no-mouth condition for each expression. Correct recognition performance was higher in the congruent than in the no-mouth condition for happy faces, $t(47) = 8.30$, $p < .0001$, and disgusted faces, $t(47) = 4.48$, $p < .0001$, but not for sad, $t(47) = 1.73$, $p = .09$, or angry ($t < 1$) faces.

INSERT TABLE 3 ABOUT HERE

Following the interaction, *difference scores* (i.e., congruent – no mouth) were computed for each expression. A one-way ANOVA (4: Target expression) with Bonferroni corrections ($p < .05$) for multiple comparisons, $F(3, 141) = 12.68$, $p < .0001$, $\eta_p^2 = .213$, revealed that the congruent condition advantage was greater for happy faces than for all the others, and that it was greater for disgusted faces relative to angry faces, which did not differ from sad faces (see Figure 3).

INSERT FIGURE 3 ABOUT HERE

For *reaction times*, main effects of target, $F(3, 141) = 7.46$, $p < .0001$, $\eta_p^2 = .137$, and mouth, $F(1, 47) = 13.57$, $p < .001$, $\eta_p^2 = .224$, emerged, with no interaction (*p*

> .30). Bonferroni-corrected multiple comparisons (p <.05) across expressions indicated that response latencies were significantly shorter for happy (M = 1,032 ms) and angry (M = 1,029 ms) faces than for sad (M = 1,133 ms) and disgusted (M = 1,169 ms) faces. *Difference scores* (i.e., congruent – no mouth) reached statistical significance only for the happy, $t(47) = 2.80$, $p < .01$, and the disgusted, $t(47) = 2.02$, $p < .05$, target expressions, whereas those for sad and angry targets showed only a non-significant trend (both ps ≥ .25) (see Figure 4).

INSERT FIGURE 4 ABOUT HERE

Categorization of eye expressions as the predefined target expression: Interference

To determine interference effects, a 4 (Target eye expression: happy, angry, sad, disgusted) × 2 (Mouth: *incongruent* vs. no mouth) ANOVA was conducted on the probability of *incorrectly* responding that the actual eye expression matched the target, and on reaction times of correct rejection responses (see Table 4).

For *response probability*, the main effects of target, $F(3, 141) = 4.69$, $p < .01$, $\eta_p^2 = .091$, and mouth, $F(1, 47) = 37.83$, $p < .0001$, $\eta_p^2 = .446$, were qualified by an interaction, $F(3, 141) = 5.89$, $p < .001$, $\eta_p^2 = .111$. Planned contrasts were conducted between the incongruent and the no-mouth condition for each expression. Incorrect recognition performance was higher in the incongruent condition for happy faces, $t(47) = 7.41$, $p < .0001$, but not for disgusted, sad, or angry faces (all ts ≤ 1.95, ps ≥ .06).

INSERT TABLE 4 ABOUT HERE

Difference scores (i.e., incongruent – no mouth) were computed for each expression. A one-way ANOVA (4: Target expression) with Bonferroni corrections (p < .05), $F(3, 141) = 5.89$, $p < .001$, $\eta_p^2 = .111$, revealed that the incongruent condition impairment was greater for happy faces than for all the other expressions, which did not differ from one another (see Figure 3).

For *reaction times* of correct rejection responses, main effects of target, $F(3, 141) = 4.84$, $p < .01$, $\eta_p^2 = .093$, and an interaction, $F(3, 141) = 4.85$, $p < .01$, $\eta_p^2 = .094$, emerged, with no effect of mouth ($p = .10$). Planned contrasts indicated that latencies were longer in the incongruent than in the no-mouth condition for happy faces, $t(47) = 4.48$, $p < .0001$, but not for sad, disgusted, or angry faces (all ts < 1, ps ≥ .48). After Bonferroni corrections for multiple comparisons ($p < .05$), $F(3, 141) = 4.85$, $p < .01$, $\eta_p^2 = .094$, *difference scores* between the incongruent and the no-mouth conditions were greater for happy faces than for all the other expressions, which did not differ from one another (see Figure 4).

Discussion

In comparison with a no-mouth control condition, a prime smiling mouth *facilitated* the recognition of congruent probe happy eyes, as evidenced by enhanced response accuracy and reduced reaction times. A similar effect was observed with a prime disgusted mouth for disgusted eyes. A comparable trend for sad mouths did not attain statistical significance, nor for angry mouths. Therefore, facilitation occurred in direct correspondence with the diagnostic values of the different mouth expressions. This confirmed our predictions, in support of the categorical priming hypothesis.

In the same vein, a smiling mouth *interfered* with the recognition of incongruent non-happy eyes, as evidenced by an increased number of errors and slower responses. In contrast, no such effects were observed in the case of mouths expressing disgust, sadness or anger. This lack of interference can be attributable to the diagnostic value *magnitudes* of these expressions, which were significantly lower than for the smiling mouth (in Experiment 1). For interference to occur, a certain diagnostic level must be reached, whereas facilitation is a relatively straightforward process.

These findings demonstrate that the smile has a unique or special capacity to influence the viewers' evaluation of eye expressions. We have proposed that the smile 'dazzles' the viewer through perceptual overshadowing (due to visual saliency) *and* categorical priming (due to diagnostic value). To keep their contributions apart, we varied the diagnostic value while controlling for visual saliency. The influence of *spatial* visual saliency was ruled out by presenting the mouth and the eye regions separately and in sequence, rather than simultaneously and within an entire face. But is it possible that visual saliency also projects to *immediately following* stimuli that appear in the same location? In such a scenario, it could be argued that the saliency of a smiling mouth prime could result in *transtemporal* overshadowing, thus keeping attention engaged *until after* the eye region probe is presented.

If so, other facial features may also be affected by a reduction in attention, if they appear in close spatial and temporal proximity to the smiling mouth. In this case, visual saliency might underlie the special interference effects of the smile. Accordingly, they could be attributed to either diagnostic value or visual saliency, or a combination of both. In order to distinguish between these alternatives, and to separate the proposed categorical priming effect from the unlikely (albeit potential) transtemporal overshadowing effect of the smile, we conducted Experiment 3.

Experiment 3

We aimed to distinguish the influence of visual saliency on overshadowing from that of categorical distinctiveness (or diagnostic value) on semantic priming. To this end, the effects of the smile, as a prime, were investigated for *non-expressive* features in a face, namely, the sex of the expresser, as a probe. Participants were instructed to indicate whether the probe stimulus corresponded to a male or female face, rather than judging the eye expression. Masculine/feminine appearance was task-relevant, with no diagnostic value in terms of emotional expression. Sex and expression were orthogonal, meaning that the prime expression could not be used as a clue to judge the probe.

Two different predictions can be made. If the visual saliency of the smiling mouth prime causes perceptual *overshadowing* (and hence inattentional blindness) on the probe, then *interference* (e.g., longer correct response latencies) will be observed following a smile prime, relative to other expressions (angry, etc.) and to the no-mouth prime condition. In contrast, if solely categorical *priming* is engaged, then *no interference* effects of the smile should occur, as the smile would be irrelevant (i.e., with no diagnostic value) in assessing the male/female appearance of the probe expresser. In either case, *no facilitation* is expected.

Method

Participants

Forty-eight psychology undergraduates (37 female) served as participants. To prevent the repetition of stimuli in a within-subjects design, 24 participants were presented with half of the stimuli in a same-sex (i.e., man-man or woman-woman) prime-probe condition, and the other half of the stimuli in a different-sex (i.e., woman-man or man-woman) condition; and the reverse was done with the other 24 participants.

A priori power analysis using G*Power 3.1.9.7 (see Faul et al., 2007) determined that a sample of 24 participants was sufficient to detect a medium effect size of $f = 0.25$ (Cohen's $d = 0.5$), at $\alpha = 0.05$, with statistical power P ($1 - \beta$ err prob) = 0.9, for an F test repeated-measures ANOVA and the current experimental design involving within-subjects factors (6 × 6, mouth expression by eye expression).

Stimuli, procedure, and design

The same stimuli used in Experiment 2 were employed, along with neutral faces. However, the top and bottom face halves were combined differently (see below). The procedure was also equivalent, except for a critical difference: In Experiment 3, participants categorized the sex (rather than the eye expression) of the individual depicted in the top-half face probe. The probability of correct responses and reaction times were measured. Figure 5 shows an overview of the procedure.

INSERT FIGURE 5 ABOUT HERE

In 50% of trials, the prime and the probe face halves corresponded to individuals of the same sex (both female or both male), yet always of different personal identities. In the remaining 50% of trials, the prime and the probe corresponded to individuals of different sex (and identities). This ensured that the prime stimulus did not provide any information about the probe face sex.

The experimental design involved three within-subjects factors: 6 (Prime mouth expression: happy, angry, disgusted, sad, neutral, and no-mouth) by 6 (Probe eye expression: happy, angry, disgusted, sad, neutral, and fearful) by 2 (prime-probe Sex Congruence: same vs. different sex).

To avoid repetition of stimuli across all the 64 experimental combinations of the three experimental factors, each participant was presented with only two different KDEF (out of the 24) models in each combination, thus totaling 128 experimental trials per participant (plus 24 practice trials).

Results

Sex categorization accuracy

Single-sample *t* tests were initially employed to compare the probability of correct responses for each combination of the experimental conditions against the 0.5 chance level. All scores were found to be higher than expected by chance (*t*-values exceeding 3.5, with *p*-values < 0.001). The mean accuracy scores ranged from 71.9% to 92.7%. Table 5 shows the mean scores as a function of prime and probe expression.

A 6 (Prime mouth expression) × 6 (Probe eye expression) × 2 (prime-probe Sex

Congruence) ANOVA yielded only a significant effect of sex congruence, $F(1, 47) = 10.50$, $p < .0001$, $\eta_p^2 = .183$. This revealed that, when the individual depicted in the prime and the probe images belonged to the same sex category, responses were more accurate ($M = 85.4$) than when sex was different ($M = 81.5$). The effects of prime mouth expression ($F < 1$), probe eye expression, $F = 1.28$, $p = .28$, and their interaction ($F = 1.40$, $p = .11$), did not reach statistical significance.

INSERT TABLE 5 ABOUT HERE

Reaction times of correct responses

The 6 × 6 × 2 ANOVA yielded only a significant effect of mouth expression, $F(5, 235) = 3.59$, $p < .01$, $\eta_p^2 = .071$. Multiple comparisons (Bonferroni-corrected, $p < .05$) across the prime mouth expressions indicated that it took longer to recognize the sex of the probe person following a smiling mouth prime than following a no-mouth prime, with both conditions being equivalent to all the others (see Table 5). The effects of eye expression ($F = 1.40$, $p = .23$) and prime-probe sex congruence ($F = 1.08$, $p = .37$) were not significant.

Discussion

The study examined whether viewing a smile affects the processing of surrounding *non-expressive* facial information. This approach allows us to compare an overshadowing vs. a priming mechanism. The results yielded a significant effect: The male/female appearance of the person depicted in the probe stimuli (upper face half) was identified more slowly following a smiling mouth prime (lower face half) than in a no-mouth control condition. It is noteworthy that this effect did not occur for any of the non-happy mouths (i.e., angry, disgusted, sad, and neutral mouths). It was only observed for the smile.

Although limited in strength, this *interference* effect is consistent with the hypothesis that viewing a smiling mouth can overshadow other facial features, even if they are irrelevant to emotional expression. It appears that the prior, immediate observation of a smile may capture and distract the viewer's attention, resulting in a temporary inability to process other information (i.e., inattentional blindness). The effect is not so pronounced as to impair the probability of correct sex recognition (in the upper face half), but it can *delay* the process.

The limited effect of the smile here cannot be attributed to a lack of sensitivity of the paradigm. Firstly, the effect of sex congruence was significant: Recognition accuracy was greater when the prime and the probe belonged to the same sex category. Secondly, recognition accuracy ranged between 72% and 93% (i.e., no 'floor' or 'ceiling' effects). This suggests that the task was neither very difficult nor very easy. Thirdly, mean reaction times ranged between 900 and 1,000 ms. This means that responses were not 'automatic' (i.e., around or less than 500 ms), but rather required controlled attentional resources.

Prior research has shown that observers associate anger more with male faces and happiness with female faces (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Aguado, García-Gutiérrez, & Serrano-Pedraza, 2009; Harris, Hayes-Skelton, & Ciaramitaro, 2016; Korb et al., 2023). Our study was not designed to investigate this association. Nevertheless, taking the prior research into account and given that women actually smile more than men (see a meta-analysis by LaFrance, Hecht, & Paluk, 2003), an alternative interpretation can be considered regarding the current smile effect in delaying sex recognition in Experiment 3: It could be argued that a *smile* prime could bias viewers to expect a *female* probe more likely than a male. If so, when, following a female smiling prime, a *less expected* male appears as a probe, such expectation would be disconfirmed, which would slow down correct sex identification. However, female and male probes were, actually, *equally likely*. Therefore, any potential interference (i.e. when a male probe appeared) should be *compensated for* with facilitation (i.e. speeding up correct identification) when a more predictable female probe appeared. Consequently, opposing effects would cancel each other out. It is then improbable that this alternative hypothesis explains the observed interference.

General Discussion

A smiling mouth on a face is typically perceived by viewers as an indication of happiness. Nevertheless, the smile is a social instrument that can be voluntarily used for a wide range of purposes (see Martin et al., 2021; Wood et al., 2022). Not all smilers are happy, and people can be happy without smiling. Friends smile as a means of greeting. But foes smile too, with less transparent intentions. In between, the smile is often just an expression of politeness.

This prompts us to consider the extent to which the impression conveyed by a smile reflects the actual state and traits of the expresser (Krumhuber & Kappas, 2022). In the present study, we addressed an implication of this view: To what extent does a smile prevent observers from perceiving (or cause them to disregard) other informative facial features (apart from deeper motives and intentions), at least temporarily? Given that the eye region is a primary source of facial information, the question concerns the effect of observing a smiling mouth on the perception of the eye expression: Does the smile make non-happy eyes (e.g., in blended facial expressions) look happy, thereby inhibiting or interfering with the accurate recognition of their actual meaning? Moreover, is this effect of the smile unique or special (i.e., more pronounced than for other emotional faces)?

The perceptual overshadowing and the categorical priming hypotheses

We have put forward a mechanism to predict and explain two effects of a smile:

(a) facilitation (i.e., correct and rapid identification) in the processing of congruent facial cues, particularly the eye expression; and (b) interference (i.e., incorrect responses and slowed correct identification) for incongruent, and even for expression-irrelevant, facial cues. Briefly, first, due to its *high visual saliency*, the smile captures the viewer's attention. As a result, other facial regions would be overshadowed, which would have a detrimental effect on their processing. This is anticipated to occur both for incongruent and irrelevant information, and might also manifest to a lesser extent for congruent information. Second, due to its *high diagnostic value*, the smile would elicit a dominant mental representation of a happy expression, which would then guide and prime the categorization of other face regions as happy. Consequently, recognition would be enhanced for expressive information that aligns with the primed representation (i.e., happiness), whereas it would be hindered for information that is incongruent with it, and would have no impact on non-relevant information.

This conceptualization is particularly pertinent for blended or ambiguous expressions, e.g., faces with a smiling mouth but non-happy eyes. This is important in practical terms because, in social contexts, such expressions are more prevalent than prototypical ones (Calvo et al., 2014; Fernández-Dols & Crivelli, 2013; Scherer & Ellgring, 2007). To accurately interpret a smile in such expressions, viewers must be able to detect a lack of coherence between the smile and the eyes. However, the mechanisms activated by the smile may prevent viewers from obtaining and using precise information from the eyes. If so, a smile may lead observers to misinterpret the non-happy eyes as happy. In general, the processing of discrete facial components (e.g., the mouth shape) becomes crucial when coherence is reduced because some other facial features (e.g., in the eye region) are absent or incongruent (Fiorentini & Viviani, 2009). In such instances, the most salient and diagnostic feature (i.e., the smiling mouth) would play a prevailing role in the categorization decision.

Our results revealed, first, facilitation effects of a smiling mouth on the recognition of congruent happy eye expressions, and interference with the recognition of incongruent non-happy eyes. Second, both these effects were greater in the case of a smiling mouth than for disgusted, sad, and angry mouths. Third, the strength of these effects was in correspondence with the level of diagnostic value of the smile and, to some extent, the disgusted mouth, in comparison with the sad and angry mouths. Fourth, when the relative visual saliency of the mouth and the eye regions were controlled (via separate stimulus displays), and diagnostic value was task-relevant, the aforementioned effects remained. Fifth, in contrast, when diagnostic value was not relevant to the task (i.e., not requiring expression identification), interference was significantly reduced, albeit it did not disappear. The first and the second groups of findings extend those obtained by Calvo, Fernández-Martín et al. (2013), and Calvo and Fernández-Martín (2013), using different experimental techniques and face halves as stimuli instead of whole faces. The remaining groups of results were entirely new.

In sum, the evidence is generally supportive of the (a) diagnostic value → categorical/semantic priming hypothesis, rather than (b) the visual saliency → perceptual overshadowing/inattentional blindness hypothesis (which is, nevertheless, consistent with the data to some extent). Thus, first, when there was expressive *congruence* between the prime smiling mouth and the probe eyes, recognition facilitation occurred (as predicted by (a)), rather than interference or no effects (as predicted by (b)). Further evidence in favor of the categorical priming hypothesis comes from the fact that facilitation emerged in correspondence with the levels of diagnostic value of the smiling mouth, the disgusted mouth, the sad mouth and, finally, the angry mouth. Second, under conditions of expression *incongruence* between the smiling mouth and the non-happy eyes, both hypotheses predict interference, which was indeed observed. Interference generally occurred when facial expression was task-relevant, i.e., judging the eye expression. In contrast, the interference caused by the smiling mouth was weak (yet significant) when facial expression was task-*irrelevant*, specifically when judging masculine/feminine appearance.

Alternative emotional explanation, and extensions

Thus far, we have proposed a two-pathway mechanism to account for the smiling mouth influence on the recognition of eye expressions. One engages *perceptual* processes; the other, *conceptual* processes. There is, nevertheless, an alternative *emotional* pathway. In addition to being perceptual stimuli with semantic information, smiles and other expressions often convey emotional content with a certain affective quality (valence: pleasantness/unpleasantness) and level of intensity (arousal: calmness/tension) as basic dimensions (e.g., Russell, 2003). It is likely that such emotional properties grab underlying processes that then influence recognition of the eye expression. Essentially, the smiling mouth pleasantness would facilitate recognition of (congruent) pleasant eyes through an *affective priming* process. Similarly, the unpleasantness of disgusted, etc., mouths would facilitate recognition of (congruent) unpleasant non-happy eyes. Conversely, affective priming would result in interference when the mouth and the eyes are incongruent in valence. No effect of valence is expected when the probe stimulus (or the task) is irrelevant to the prime un/pleasantness. With regard to arousal, general interference can be expected for all facial information, due to attentional distraction.

The current findings agree with predictions from the affective priming view with respect to valence, but not regarding arousal. In prior research, happy faces, when used as primes, have in fact been found to produce affective priming to a greater extent than other expressions. This has been observed using words (Lipp et al., 2009; McLellan et al., 2010) and scenes (Calvo et al., 2012) as probes. Moreover, for the six basic facial expressions of emotion, and across a range of methodologies (from self-reports to neurophysiological measures; for a review, see Calvo & Nummenmaa, 2016), happy faces are the only ones that convey positive affect (i.e., pleasant valence), while the others share unpleasant affect (with surprise being ambiguous). Accordingly, given the *affective uniqueness* of happy faces, it is reasonable to expect that the smile would produce greater effects than the other mouth expressions. In contrast, affective priming would be lower or null for mouths of disgust, sadness, or anger due to their mutual *affective competition*. This is consistent with the results in the current study, and can be related to the affective realism hypothesis (Gao et al., 2024; Wormwood et al., 2019).

Therefore, it is possible that also affective priming underpins the biasing effects of the smile. It should, however, be noted, first, that previous research on valence, arousal, and affective priming, used *whole*-face stimuli. It remains to be determined whether this is also the case with *half-face* stimuli (such as those in the current study). It seems implausible that the upper or the lower face halves, when viewed separately, convey the same degree of affect, and therefore act as affective primers to the same extent as the entire face does. And yet, in the current study, such half-face stimuli did have an effect on expression recognition. This implies that other (i.e., non-affective) face properties and processing mechanisms must have been involved. Secondly, even if affective priming were involved, this would not preclude the possibility of categorical or semantic priming, nor of perceptual overshadowing. Indeed, all three processes are compatible with one another, rather than mutually exclusive. The extraction of perceptual, categorical, and affective information from facial expressions occurs at different time points, with each contributing to expression recognition (see Calvo &

Nummenmaa, 2016).[2]

Conclusions

A smiling mouth prime (i.e., the initial viewing of a smile) biases the subsequent interpretation of probe eye expressions towards happiness: The smile facilitates the recognition of congruent happy eyes, while it impairs the accurate recognition of incongruent non-happy eyes. Importantly, this means that the presence of a smiling mouth makes viewers perceive non-happy eyes as happy. Such effects occur to a greater extent for smiling mouths than for non-happy (i.e., disgusted, sad, and angry) mouths. The interference effect is particularly intriguing and warrants further investigation: This phenomenon entails erroneous assessments of non-happy eye expressions as if they were happy, in addition to slower accurate rejections of such eyes as not happy. These effects can be primarily attributed to a categorical priming mechanism, which is driven by the high diagnostic value of the smile. Nevertheless, it is plausible that complementary perceptual overshadowing and affective priming processes may also be involved.

Data Availability Statement

The data obtained and analyzed for the current study are available in Supplementary Datasets S1 (Supplemental Dataset_Experiment 1), S2 (Supplemental Dataset_Experiment 2), and S3 (Supplemental Dataset_Experiment 3).

Additional information is provided in S4 (Supplemental Information_Matrices of Frequencies of Hits and Confusions in Experiment 1), S5 (Supplemental Information_Experimental Conditions in Experiment 2), and S6 (Supplemental Information_Summary of Hypotheses and Evidence).

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Footnotes or Endnotes

[1]It should be noted that, for the purposes of this argument, no assumption is required regarding the correspondence between external expression and internal emotion (see Durán & Fernández-Dols, 2021), but just between a particular facial feature, i.e., a smiling mouth, and an expression category, i.e., facial happiness. The experience of positive affect is neither necessary nor sufficient for smiling (Krumhuber & Kappas, 2022).

[2]A comparison of the three complementary explanations (perceptual, conceptual, and emotional), and the respective empirical support for each, is schematically shown in S6 Supplemental Information_Summary of Hypotheses and Evidence.

Table 1. Summary of Hypotheses and Predictions.

A. Perceptual Hypothesis

(a) **STIMULUS Properties**: Visual Saliency of the Smile

(b) **Cognitive PROCESSES**: Perceptual Overshadowing and Inattentional Blindness

(c) **Predicted EFFECTS**. *Recognition* of concurrent or immediately following Target stimuli:

- No Facilitation
- Interference, if Target Congruent in Expression
- Interference, if Incongruent in Expression
- Interference, if Irrelevant to Expression

B. Conceptual Hypothesis

(a) **STIMULUS Properties**: Distinctiveness or Diagnostic Value of the Smile

(b) **Cognitive PROCESSES**: Categorical or Semantic Priming of Expression

(c) **Predicted EFFECTS.** *Recognition* of concurrent or immediately following Target stimuli:

- Facilitation, if Target Congruent in Expression
- Interference, if Incongruent in Expression
- No effect, if Irrelevant to Expression

Table 2. Mean hit probability (in %) and H_u (unbiased hit rate), and standard errors (*SE*) of recognition of each expression, and mean reaction times (in ms) and standard errors of correct responses, as a function of face stimulus format, in Experiment 1.

Facial Expression

Recognition Performance

	Happy	Disgusted	Angry	Fearful	Sad	Surprised
Whole Face						
M hit	96.4	89.4	88.5	79.8	82.1	91.4
H_u	.932	.785	.758	.624	.747	.795
SE	1.21	2.86	2.27	3.32	3.10	2.35
Eye Region						
M hit	61.9	64.2	84.4	75.7	71.6	79.7
H_u	.474	.462	.593	.495	.527	.663
SE	2.92	3.64	3.35	4.07	3.53	3.69
Mouth Region						
M hit	97.8	83.0	67.0	57.3	74.7	79.9
H_u	.940	.623	.462	.432	.471	.664
SE	1.24	3.31	3.54	4.25	3.18	2.91

Reaction Times

	Happy	Disgusted	Angry	Fearful	Sad	Surprised
Whole Face						
M	1,291	1,871	1,785	1,949	1,836	1,779
SE	31	37	42	35	38	44
Eye Region						
M	1,902	1,886	1,703	1,845	1,874	1,914
SE	35	47	30	41	41	30
Mouth Region						
M	1,178	1,796	1,891	2,054	1,792	1,894
SE	29	46	44	50	43	41

Table 3. Mean probability (in %) and standard errors (*SE*) of **correct** responses, and reaction times, for each target eye expression and mouth **congruence** condition, in Experiment 2. **Facilitation Effects**.

	Target Eye Expression			
Mouth Expression	Happy	Disgusted	Sad	Angry
Probability of Response				
Congruent				
M	88.99	76.04	80.03	85.93
SE	1.78	2.37	2.17	1.74
No Mouth				
M	66.14	65.27	75.17	84.89
SE	2.55	2.58	2.73	1.80
Reaction Times				
Congruent				
M	975	1,135	1,114	1,114
SE	41	40	41	45
No Mouth				
M	1,089	1,202	1,153	1,043
SE	42	42	37	40

Table 4. Mean probability (in %) and standard errors (*SE*) of **incorrect** responses, and reaction times (for correct rejections), for each target eye expression and mouth **incongruence** condition, in Experiment 2. **Interference Effects**.

	Target Eye Expression			
Mouth Expression	Happy	Disgusted	Sad	Angry
Probability of Response				
Incongruent				
M	13.54	14.59	14.93	14.76
SE	0.99	1.35	1.38	1.18
No Mouth				
M	5.29	12.93	12.67	12.50
SE	0.93	1.46	1.38	1.08
Reaction Times				
Incongruent				
M	1,047	1,093	1,063	1,047
SE	37	36	35	32
No Mouth				
M	974	1,099	1,050	1,057
SE	36	36	29	32

Table 5. Mean probability (in %) and standard errors (*SE*) of correct (sex categorization) responses, and reaction times (RTs, in ms), as a function of prime mouth and probe eye expression, in Experiment 3.

		Prime Mouth Expression					
		Happy	Disgusted	Sad	Angry	Neutral	No-mouth
Probability	*M*	83.59	83.94	83.42	82.90	82.73	84.11
	SE	1.41	1.52	1.43	1.67	1.74	1.72
RTs	*M*	964[a]	912[ab]	917[ab]	920[ab]	914[ab]	900[b]
	SE	19	22	21	19	23	22
		Probe Eye Expression					
		Happy	Disgusted	Sad	Angry	Neutral	Fearful
Probability	*M*	83.25	83.07	83.42	81.25	85.24	84.46
	SE	1.37	1.50	1.55	1.34	1.70	1.63
RTs	*M*	905	913	935	930	922	920
	SE	21	20	21	17	19	21

Note. Horizontally (across expressions), means with a different superscript letter are significantly different. Means with the same letter (or no superscript) are equivalent.

Figure Captions

Figure 1. Pairwise comparisons (after Bonferroni correction for three possible contrasts) for recognition accuracy and reaction times of correct responses, across face format within each facial expression, in Experiment 1. Statistically significant differences are shown by means of a > or a < symbol (meaning higher or lower accuracy scores, respectively; or longer or shorter response latencies) within each pair (e.g., mouth vs. whole face). The = symbol indicates no significant differences.

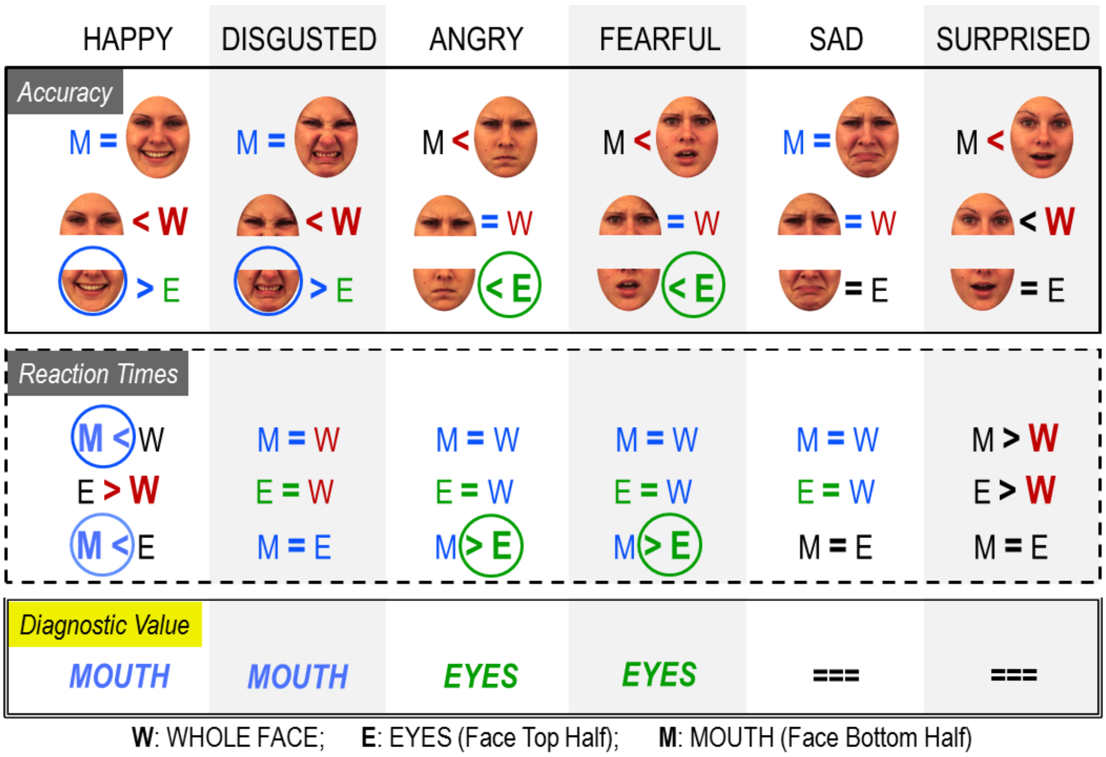

Figure 2. Sequence of events on a trial in Experiment 2. Faces obtained, adapted, and reprinted from the Karolinska Directed Emotional Faces Database. Copyright by Daniel Lundqvist, Anders Flykt, and Arne Öhman. Reprinted with permission.

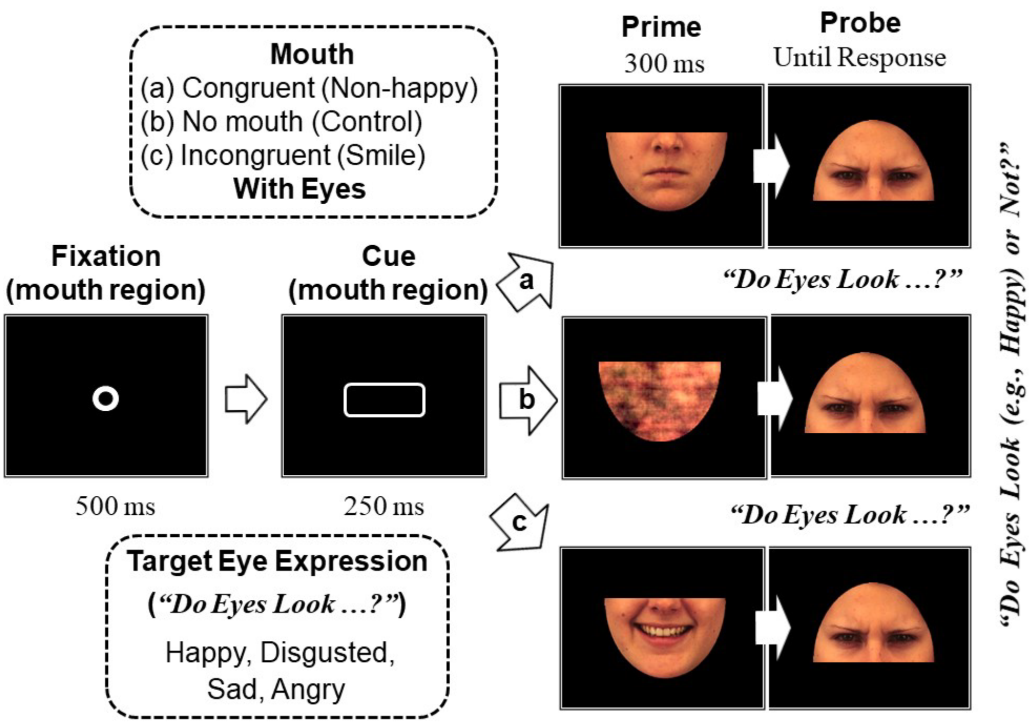

Figure 3. *Recognition Accuracy*. Facilitation (i.e., higher recognition accuracy in the congruent than in the no-mouth condition) or interference (impaired recognition in the incongruent condition) as a function of type of mouth expression, in Experiment 2. Different letters indicate significant differences across mouth expressions (same letters indicate equivalent performance). Asterisks indicate significant differences relative to the baseline control (i.e., no mouth) condition. HA: Happy: DI: Disgusted; SA: Sad; AN: Angry

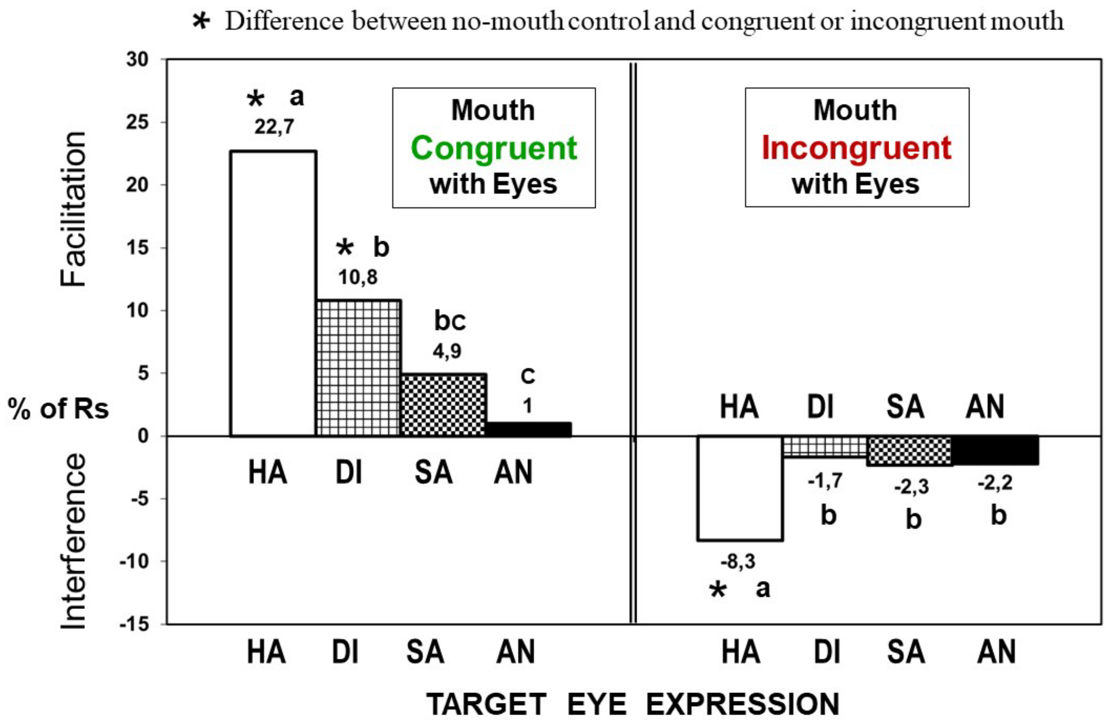

Figure 4. *Reaction Times.* Facilitation (i.e., faster recognition performance in the congruent condition than in the no-mouth condition) or interference (i.e., slower responses in the incongruent condition) as a function of type of mouth expression, in Experiment 2. Different letters indicate significant differences across mouth expressions (same letters indicate equivalent performance). Asterisks indicate significant differences relative to the baseline control (i.e., no mouth) condition. HA: Happy: DI: Disgusted; SA: Sad; AN: Angry

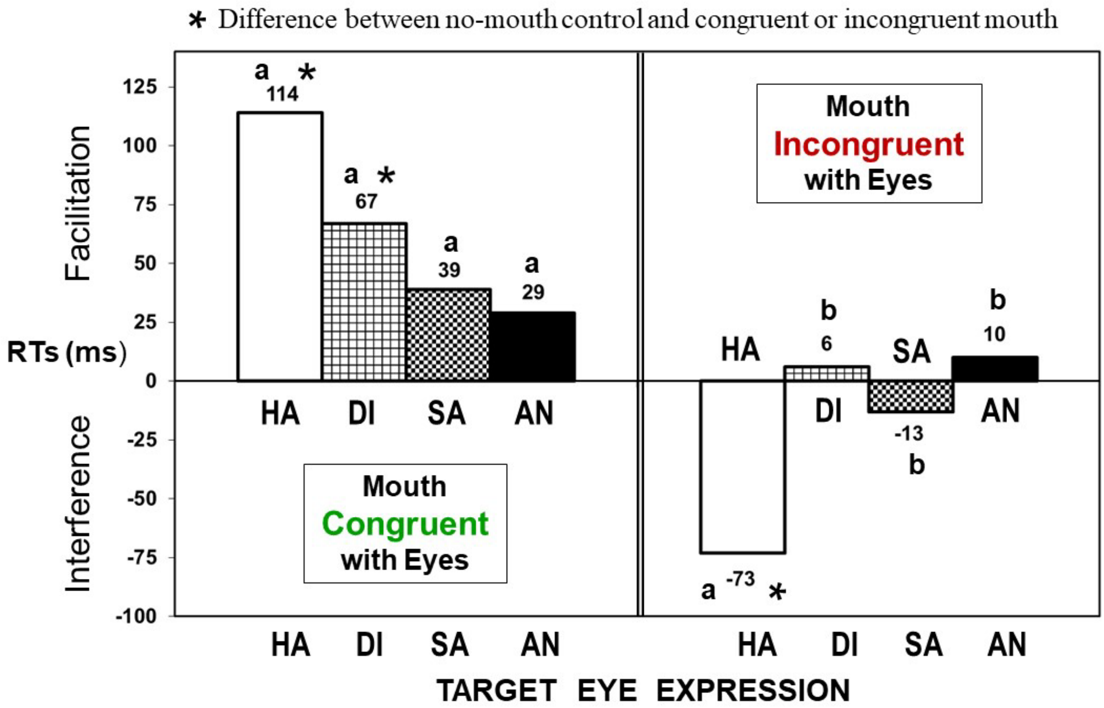

Figure 5. Sequence of events on a trial in Experiment 3. Faces obtained, adapted, and reprinted from the Karolinska Directed Emotional Faces Database. Copyright by Daniel Lundqvist, Anders Flykt, and Arne Öhman. Reprinted with permission.