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Long-lasting effects of subliminal affective priming from facial expressions

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ABSTRACT

Unconscious processing of stimuli with emotional content can bias affective judgments. Is this subliminal affective priming merely a transient phenomenon manifested in fleeting perceptual changes, or are long-lasting effects also induced? To address this question, we investigated memory for surprise faces 24 h after they had been shown with 30-ms fearful, happy, or neutral faces. Surprise faces subliminally primed by happy faces were initially rated as more positive, and were later remembered better, than those primed by fearful or neutral faces. Participants likely to have processed primes supraliminally did not respond differentially as a function of expression. These results converge with findings showing memory advantages with happy expressions, though here the expressions were displayed on the face of a different person, perceived subliminally, and not present at test. We conclude that behavioral biases induced by masked emotional expressions are not ephemeral, but rather can last at least 24 h.

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1. Introduction

The influence of affective information on behavior is notable because it can sometimes occur without conscious awareness of the affective input (e.g., Whalen et al., 1998; Zajonc, 1980, 1984). Demonstrations that subliminal processing of sensory input can influence how we immediately evaluate consciously perceived stimuli (e.g., Higgins, 1996; Li, Zinbarg, Boehm, & Paller, 2008; Murphy & Zajonc, 1993; Stapel, Koomen, & Ruys, 2002) are particularly intriguing because such findings highlight the remarkable extent to which human behavior is not necessarily in agreement with subjective intentions and experiences.

Given the immense amount of information in typical environments that people process without awareness, it is critical to understand the extent to which such processing influences conscious experience and behavior. In particular, if affective priming remains operative for many hours, such influences on people's preferences and social behavior may be much more pervasive than commonly assumed. The goal of the present investigation was thus to determine if unconscious emotional processing has long-lasting effects in addition to previously described short-term effects.

Investigations of unconscious processing often include procedures that allow experimenters to assess the degree to which aspects of an unseen *prime* stimulus are incorporated into a judgment regarding a consciously perceived *target* stimulus (Higgins, 1996). This subliminal assimilation is particularly effective with emotional stimuli such as facial expressions. Presumably, the affect from a subliminal stimulus is diffuse in the sense that it can spill-over onto a temporally adjacent stimulus. For example, subliminally presented smiling and scowling faces positively and negatively shift evaluative judgments of subsequently presented, affectively neutral Chinese ideographs (Murphy & Zajonc, 1993). In some paradigms, this spill-over appears to require a lack of awareness of quickly flashed primes, because primes presented for longer durations produce

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contrast effects in which ambiguous target stimuli are judged as opposite in valence from the primes (Murphy & Zajonc, 1993; Stapel et al., 2002), analogous to effects observed during recognition testing (Jacoby & Whitehouse, 1989).

Emotionally ambiguous facial expressions, such as surprise, derive their affective valence primarily through context. For example, a face with a surprise expression can appear positive in the context of a surprise birthday party or negative in the context of a grisly murder in a horror film. This emotional ambiguity makes surprise expressions especially susceptible to modulations of affective judgment (Kim et al., 2004), and thus suitable for use as targets in subliminal priming paradigms. In a recent study from our lab, for example, emotionally ambiguous surprise faces preceded by subliminally presented happy faces were judged to be more positive than those preceded by subliminally presented fearful faces (Li et al., 2008).

Although subliminal affective priming in these cases may be regarded as a transient phenomenon manifested only in fleeting perceptual changes, here we question the tacit assumption that such phenomena are short-lived. Might unconscious affective processing also have long-lasting effects? Memory for emotional faces is a natural avenue through which to study potential long-lasting effects of subliminal affective priming.

Unconscious affective processing is often thought to be mediated by a subcortical neural system that does not necessarily produce conscious affective sensations (Damasio, 1994; Winkielman, Zajonc, & Schwartz, 1997). This neural system has been described as implementing a “quick and dirty” analysis of visual threat through visual pathways from the thalamus to the amygdala, bypassing visual cortex (LeDoux, 1996). Several studies have demonstrated that subliminally presented fearful faces elicit greater amygdala activation than neutral faces, suggesting that the amygdala is involved in unconscious processing of threat (Breiter et al., 1996; Whalen, 1998; Williams et al., 2006). In addition to its role in coarsely-tuned threat detection (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Vuilleumier, Armony, Driver, & Dolan, 2003), the amygdala can function to narrow attention toward facial features critical for emotion recognition (Adolphs et al., 2005) and to enhance memory for emotional details (Adolphs, Tranel, & Denburg, 2000). One prediction might thus be that memory would be superior for surprise faces subliminally primed by fearful faces.

Alternatively, other findings have documented superior memory storage associated with processing happy faces. For example, after viewing happy and sad faces in an expression-classification procedure, participants were more accurate at recognizing faces with happy expressions than sad expressions when presented with the same images 5 min later (Ridout, Astell, Reid, Glen, & O’Carroll, 2003). Similarly, participants were more accurate at recognizing faces that had earlier been encoded showing happy rather than angry expressions, even though only faces with neutral expressions were used for memory testing (D’Argembeau & Van der Linden, 2007; D’Argembeau, Van der Linden, Comblain, & Etienne, 2003). In addition, when recall of the original facial affect was tested, also using neutral versions of the same faces, memory was superior for faces originally seen with happy expressions (D’Argembeau et al., 2003; Shimamura, Ross, & Bennett, 2006). When participants learned faces with neutral instead of emotional expressions, those learned in the context of a happy story were subsequently remembered better, when tested with the same facial images as shown during learning, than neutral faces learned in the context of a sad story (Bridge, Chiao, & Paller, *accepted for publication*). Similar results have also been demonstrated with non-face stimuli, such that neutral words encoded with a positive context are recalled better than neutral words encoded with a neutral or negative context (Erk et al., 2003). These results foster the prediction that faces subliminally primed by happy expressions might be remembered best.

In the present study, we examined the short- and long-lasting effects of unconscious affective processing by: (1) assessing the degree to which exposure to subliminal primes influenced immediate affective evaluations of surprise faces, and (2) assessing the degree to which both this unconscious processing and the affective evaluation influenced memory for the same surprise faces after a 1-day delay. Subliminal primes portrayed either a fearful, happy, or neutral expression. Our predictions were that assimilation of primes into perceptual processing of the surprise faces would, in accord with the affective valence of prime expressions, influence affective evaluations of surprise faces and subsequent memory for those same faces.

2. Method

2.1. Participants

Forty-three undergraduate students at Northwestern University gave informed consent to participate for course credit. All had normal or corrected-to-normal visual acuity, and all were enrolled in an introductory psychology course. Participants were tested individually in a dimly lit room on two consecutive days (Day 1 and Day 2).

2.2. Stimuli

We selected four categories of faces from the Karolinska Directed Emotion Face Set (Lundqvist, Flykt, & Öhman, 1998) according to their emotional expressions: 70 surprise faces (48 of which were used in the priming phase and 22 as foils in the memory test), as well as 8 fearful faces, 8 happy faces, and 8 neutral faces used as primes. Due to the limited size of the face set, the identities of the primes also appeared in surprise faces during the priming phase (20 matching identities) and as foils during the memory test (four matching identities). However, no surprise face was ever paired with a prime of the same identity. All faces were color photographs (half women and half men).

We validated these emotional categories in a preliminary experiment by requiring 11 participants to rate the faces using a 6-point scale, ranging from 1 (most negative) to 6 (most positive). The mean valence ratings were 3.36 ($SD = 0.46$) for surprise faces, 1.69 ($SD = 0.29$) for fearful faces, 5.53 ($SD = 0.07$) for happy faces, and 3.40 ($SD = 0.10$) for neutral faces. Although a single negative-to-positive dimension was used to obtain these ratings, this does not imply unidimensionality for fear and happiness. Surprise faces used in the priming phase were divided into three groups of 16 faces for counterbalancing with the three categories of primes. These groups were matched on mean valence (3.36, $SD = 0.49$; 3.36, $SD = 0.46$; and 3.43, $SD = 0.45$) and mean attractiveness (based on attractiveness ratings of corresponding neutral versions also made in the preliminary experiment using a 6-point scale that yielded mean ratings of 3.39, $SD = 0.52$; 3.25, $SD = 0.87$, and 3.30, $SD = 0.62$). In addition, the mean valence of the 48 surprise faces used in the priming phase (3.38, $SD = 0.45$) was similar to that of the 22 new surprise faces used only in the memory test (3.30, $SD = 0.49$).

Each face was cropped using an elliptical stencil to exclude hair, which can distract participants from emotionally relevant facial features (Tyler & Chen, 2006). Faces were then scaled to be approximately the same size with respect to the length between the hairline and chin and cheek to cheek. Each face subtended 2.75° by 3.95° of visual angle. Faces were embedded in a rectangular background of Gaussian noise subtending 2.98° by 4.24° of visual angle.

2.3. Priming phase (Day 1)

Visual stimuli were presented on a CRT monitor at a viewing distance of 115 cm. In each trial, an affective prime face was backward-masked by a surprise face. In each block of trials, only one category of prime facial affect was used. In each of the first three blocks, the prime expression was either fearful, happy, or neutral, with order counterbalanced across participants. The order of the three conditions was repeated in the next three blocks, such that there were two fearful-prime blocks, two happy-prime blocks, and two neutral-prime blocks. A different group of 16 surprise faces were used for each type of block (with the same 16 surprise faces repeated in the second block of each type). Assignment of the three groups of 16 surprise faces to the three affective prime categories was alternated, such that across participants each surprise face occurred roughly equally with each category of emotional prime (see Section 3 for description of counterbalancing in subgroups).

Each block consisted of 64 trials. Each of the 16 surprise faces was used on four trials, each time primed by a different face. We used 8 different affective prime faces in each block to minimize the possibility of identity-specific habituation. We used a blocked design with one category of emotion in each block in order to minimize the likelihood that the influence of a prime on a given trial would be counteracted by the influence of an affectively different prime from a neighboring trial.

Each trial began with the central presentation of a fixation cross for 500 ms followed by an affective prime for 30 ms, immediately backward-masked by a surprise face for 300 ms (Fig. 1). The inter-trial-interval (the time between the response and the onset of the fixation cross in the next trial) was varied between 1600 and 2400 ms. We used an oscilloscope to verify that primes were presented for 30 ms and that the software log of prime durations was accurate. We expected these timing and masking parameters to be suitable for producing subliminal affective priming based on prior results with similar methods (Li et al., 2008; Szczepanowski & Pessoa, 2007), even though the 30-ms stimulus-onset asynchrony (SOA) might lead to conscious perception of primes in some participants.

Participants were instructed to judge the valence of each surprise face upon its offset using a 6-point bipolar scale ranging from 1 to 6, corresponding to “most negative”, “mildly negative”, “a little negative”, “a little positive”, “mildly positive”, and “most positive.” Participants responded using one hand on a keypad with buttons on two rows. Button assignment (positive above negative vs. positive below negative) was alternated across participants. There was no time limit, but participants were encouraged to respond quickly, using their “gut feeling” if necessary. Participants were given 1–2 min between blocks to relax. Following completion of the priming phase, participants were asked to return for further testing the next day, but were not informed that memory would be tested.

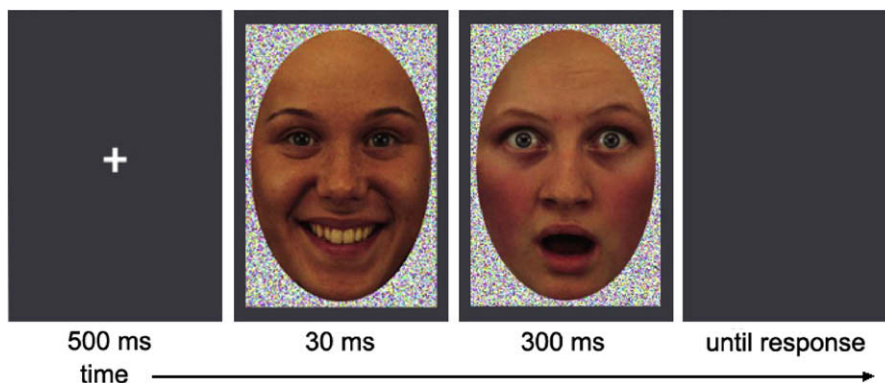


Fig. 1. Subliminal priming procedure. A central fixation cross was shown, followed by a subliminal prime (a fearful, happy, or neutral face), backward-masked by a neutral-valence surprise face of the same gender, followed by a blank screen, at which time participants rated the valence of the surprise face.

2.4. Memory test (Day 2)

The second session occurred 21–27 h after Day 1 (mean = 23.9 h). The session began with a memory test, which included a random sequence of the 48 surprise faces from the prior session along with 22 new surprise faces. On each trial, a fixation cross was shown for 500 ms followed by a surprise face for 800 ms. The inter-trial interval was varied between 1600 and 2400 ms. Participants were told that half of the test faces were new, so as to encourage a criterion that was not overly lenient. Participants made recognition confidence judgments on a keypad using a 4-point bipolar scale ranging from 1 to 4, corresponding to “very confident new”, “mildly confident new”, “mildly confident old”, and “very confident old.” There was no time limit, but participants were encouraged to respond quickly.

2.5. Awareness check

After the memory test, we assessed participants' abilities to process 30-ms prime faces. We began with a subjective test of prime awareness, which required participants to report on their mental states and can be thought of as assessing the degree to which a person ‘knows’ what they perceived (e.g., Seth, Dienes, Cleeremans, Overgaard, & Pessoa, 2008). We also included an objective test using the same prime presentation parameters as on Day 1. This test required participants to discriminate facial affect in a forced-choice format. Together, these two tests allowed a careful and conservative assessment of whether prime presentations were subliminal.

We assessed subjective awareness of prime faces with several questions that concerned the priming phase. The 1-day delay may have influenced the nature of the answers provided, but these questions nonetheless provided indications that some participants were aware of primes on Day 1. Participants were instructed to think back to Day 1 when answering the following questions, which were posed in the following order: (1) Did you see anything besides the surprise faces? (2) Did you see anything right before the surprise faces? (3) There was actually a flicker before each surprise face; what did you see? (4) Did you see a face? (5) What expression did you see? Verbal report of awareness of a face and/or expression was taken as one indication that prime presentations were not strictly-subliminal.

Next, participants were debriefed about the use of subliminal primes. Then, we administered an objective test concerning the extent to which emotional expressions could be perceived under conditions comparable to the original stimulus presentation. Although accurate discrimination ability does not imply subjective awareness of facial affect, we reasoned that subjective awareness of facial affect would be less likely in participants who failed to accurately discriminate the expressions than in those who succeeded in accurately discriminating the expressions. In other words, participants who failed to discriminate the expressions in this objective test were unlikely to have consciously perceived the emotional expressions in the priming phase. The presentation parameters and facial stimuli for this emotion-expression-discrimination test were the same as those in the priming phase, except as follows. First, fearful, happy, and neutral primes were all used in a single randomly ordered sequence. Second, six fearful, six happy, and six neutral faces were used as primes, and 36 surprise faces were used as masks (18 from Day 1 and 18 previously used only in the memory test). Each surprise face was presented three times, each time with the same category of prime, yielding 108 trials. Participants indicated whether the prime was happy, fearful, or neutral using three buttons on a keypad. Due to an error in stimulus timing, some of the trials from eight participants could not be used, but enough trials were available (50% on average) so that data from all participants could be included in the analyses. Of course, for any of the 43 participants the number of trials may have been suboptimal for assessing discrimination abilities. Nonetheless, the combination of verbal report on subjective perception of primes along with objective measurement of prime discriminability was sufficient for identifying a subset of participants most likely to have been aware of prime presentations during the priming phase.

3. Results

3.1. Strictly-Subliminal prime presentations

Given the possibility that some participants were aware of prime faces during the priming phase, we took several steps to determine the relevance of this for both short- and long-lasting effects of affective priming. In particular, we attempted to identify a subset of participants most likely to have processed prime faces in a subliminal manner. Although there are many methods to use in such circumstances (Seth et al., 2008), there is reason to be skeptical of using subjective reports alone or of relying only on objective tests of prime processing. Therefore, we elected to adopt a conservative approach analogous to that used by Szczepanowski and Pessoa (2007), in which we selected a subgroup of participants based on both types of criteria together. We reasoned that strictly-subliminal presentation is most likely when (1) participants' attempts to discriminate among emotional expressions of primes were not accurate, and (2) their subjective reports gave no indication of conscious perception of primes.

Performance data on emotional-expression discrimination were subjected to χ^2 analyses. Above chance-levels of expression discrimination were indicated by significant χ^2 ($p < .05$) for 23 participants. Awareness of prime faces was evident in the subjective reports obtained from 24 participants. A total of 28 of the 43 participants demonstrated either

above-chance discrimination abilities or provided subjective reports of prime awareness (18 participants satisfied both criteria). These participants thus formed the Not-Strictly-Subliminal (NSS) group. The remaining 15 participants comprised the Strictly-Subliminal (SS) group. Of course, it remains possible that prime awareness was missed by the subjective reports (e.g., because of forgetting), or that prime awareness occurred despite chance-level discrimination abilities (e.g., because different strategies were used in this test versus in the priming phase, or because an inaccurate estimate of true discrimination abilities was obtained due to unexplained variability in responses and/or an insufficient number of trials). Nonetheless, these procedures were advantageous because conscious perception of primes was more likely, overall, for the NSS group than for the SS group.

3.2. Priming results

Surprise faces were rated as more positive when primed by happy faces than when primed by fearful faces, but only in the SS group (Fig. 2). To assess priming, we compared mean surprise-face ratings across pairs of conditions in separate contrasts within each group as planned comparisons based on our prior study (Li et al., 2008). Happy face primes led to more positive ratings than fearful face primes in the SS group [$t(14) = 2.58, p < .05$], but not in the NSS group [$t(27) = 0.65, n.s.$]. No other differences between pairs of different prime categories were significant (t -values < 1.24). There were no main effects of group [SS vs. NSS, $F(1, 41) = 0.30, n.s.$], or prime expression [$F(2, 82) = 2.62, p = .07$], nor was there an interaction between group and prime expression [$F(2, 82) = 1.01, n.s.$]. There were no differences in mean surprise-face ratings between the SS and NSS groups with fearful primes [$t(41) = 1.08, n.s.$], happy primes [$t(41) = 0.03, n.s.$], or neutral primes [$t(41) = 0.50, n.s.$].

Affective priming in the SS group was particularly strong early in the priming phase. The magnitude of affective priming, defined as the mean rating difference between surprise faces primed by happy faces and those primed by fearful faces, was high in the first three blocks [$M = 0.24, SD = 0.31, t(14) = 2.99, p < .01$], whereas affective priming in the second three blocks was non significant [$M = 0.11, SD = 0.32, t(14) = 1.31, n.s.$]. This may reflect habituation of priming or a change in response strategy regarding the affective evaluation of the surprise faces.

Further analyses were run to address the concern that the post-hoc sorting of participants into SS and NSS groups might have skewed results by disrupting assignment of stimulus sets to participants (i.e., the counterbalanced pairings of the three groups of surprise faces with each category of emotional prime). Results provided strong evidence for dismissing this concern. First, SS participants were distributed across all three stimulus-set assignments (7, 5, and 3 participants per stimulus set). Second, the magnitude of affective priming (mean ratings of happy-primed faces minus fear-primed faces) did not differ reliably across the three stimulus sets [$F(2, 40) = 2.20, p = .13$]. Moreover, the stimulus set that produced the largest magnitude of affective priming in the SS group had only three participants. Incomplete counterbalancing can thus be ruled out as a potential explanation for priming for the SS group.

Magnitude of affective priming was not associated with the degree of objective discrimination ability for participants within either the SS group [$r = -0.40, p = .13$] or the NSS group [$r = -0.11, n.s.$]. Thus, the ability to discriminate facial affect when intentionally attempting to do so after being informed about the presence of primes (Day 2) was not associated with increased priming magnitude in the absence of any instructions to attend specifically to prime faces (Day 1). The non significant correlation in the SS group is in the opposite direction to the correlation that would be expected if priming were merely a weak reflection of participants' abilities to extract affective information from emotional expressions that can be used both for affective discrimination and awareness of facial affect. Although these correlational results are only null findings, they are consistent with the inference supported above that priming effects in the SS group arose due to subliminal processing.

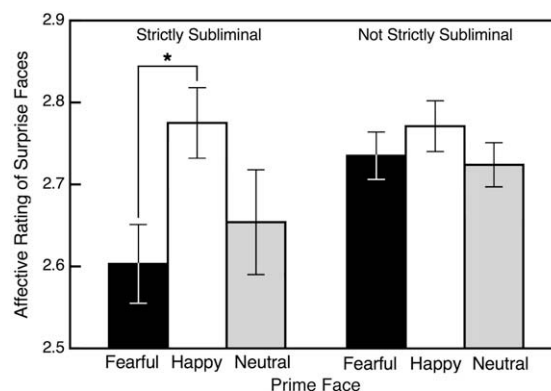


Fig. 2. Mean ratings of surprise faces (1 = most negative, 6 = most positive) for the Strictly-Subliminal group and the Not-Strictly-Subliminal group as a function of prime expression. Strictly-Subliminal participants rated surprise faces primed by happy faces as significantly more positive than surprise faces primed by fearful faces. Indicates $p < .05$. Error bars indicate ± 1 SEM with baseline individual variability removed.

3.3. Memory results

In the SS group, surprise faces primed by happy faces were remembered better than surprise faces primed by fearful faces (Fig. 3). In an initial analysis of recognition results, we computed recognition hit rates irrespective of confidence level and separately as a function of the expression of the prime from Day 1. Mean hit rate was significantly higher for happy-primed surprise faces than for fearful-primed surprise faces [$t(14) = 2.95, p < .05$], and for neutral-primed surprise faces [$t(14) = 2.28, p < .05$], but did not differ between fearful-primed and neutral-primed surprise faces [$t(14) = 1.28, n.s.$]. In the NSS group, hit rate differences between pairs of priming conditions were all non significant (t -values < 1.43). Hit rates averaged across conditions were well above the false alarm rates for trials with new faces for both the SS group [$t(14) = 4.34, p < .01$] and the NSS group [$t(27) = 10.40, p < .01$]. Furthermore, the finding that memory results varied with prime status (fearful versus happy) in the SS group but not in the NSS group was confirmed by a significant interaction between prime status and group [$F(1, 41) = 4.52, p < 0.05$]. There were no differences in recognition hit rates between the SS and NSS groups with fearful primes [$t(41) = 0.34, n.s.$], happy primes [$t(41) = 1.79, n.s.$], or neutral primes [$t(41) = 0.78, n.s.$].

We observed the same pattern of results when recognition hits were counted just for faces endorsed as old with high confidence, or when all four levels of recognition confidence were taken into account (Fig. 4). To differentially weight the memory experiences expressed by confidence ratings in each condition, we calculated memory scores using mean numerical ratings—4 = “very confident old,” 3 = “mildly confident old,” 2 = “mildly confident new,” and 1 = “very confident new.” A higher memory score thus reflects stronger memory. Mean memory scores in the SS group were 2.64, 2.87, and 2.70 for fearful, happy, and neutral conditions, respectively. Pairwise analyses showed higher scores for the happy condition compared to the fearful condition [$t(14) = 2.96, p < .05$], and compared to the neutral condition [$t(14) = 2.36, p < .05$], with no differences between fearful and neutral conditions [$t(14) = 0.79, n.s.$]. Mean memory scores in the NSS group were 2.71, 2.65, and 2.73 for fearful, happy, and neutral conditions, respectively, with no significant differences between scores (t -values < 1.09). There were no differences in memory scores between the SS and NSS groups with fearful primes [$t(41) = 0.62, n.s.$], happy primes [$t(41) = 0.09, n.s.$], or neutral primes [$t(41) = 0.78, n.s.$].

We also found that affective evaluation per se influenced subsequent recognition memory. We calculated mean affective ratings for each surprise face across trials for each participant. We then segregated these ratings for faces rated more negatively and those rated more positively, collapsing across data from all three prime conditions, with a median split made separately for each participant. Surprise faces rated more negatively were remembered better than surprise faces rated more positively. This result was obtained using either the four levels of memory confidence [$t(42) = 3.12, p < .01$] or hit rates alone [$t(42) = 3.25, p < .01$]. When analyzed by group, the recognition advantage for negatively rated faces was apparent in the NSS group [$t(14) = 4.23, p < .01$], but not in the SS group [$t(27) = 0.11, n.s.$], and was significantly larger for the NSS group than the SS group [$t(41) = 2.56, p < .05$]; these results were computed using four levels of memory confidence, but the same pattern was also clear when measured with hit rates (likewise for subsequent analyses). These recognition differences between the SS and NSS groups were not due to differences in the variability (SD) of affective evaluations between the groups [$t(41) = 0.24, n.s.$].

To determine if these effects varied with prime condition, a further analysis was conducted using median splits of affective ratings of surprise faces made separately for each prime condition from each participant (Fig. 5). In the SS group, there was a marginally significant tendency for surprise faces rated more negatively to be remembered better than surprise faces rated more positively for the fearful prime condition [$t(14) = 2.07, p = .05$], but not for the happy prime condition [$t(14) = 0.60, n.s.$] or neutral prime condition [$t(14) = 0.56, n.s.$], when the four levels of recognition confidence were taken

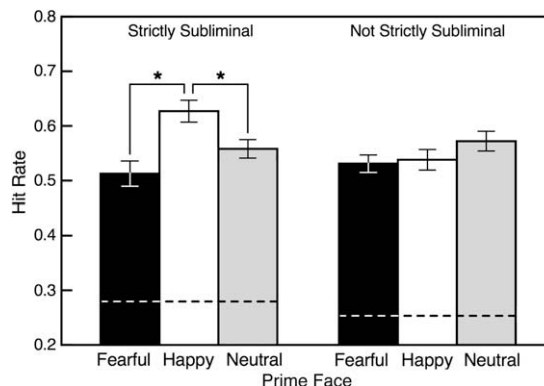


Fig. 3. Mean hit rates for “old” surprise faces for the Strictly-Subliminal group and the Not-Strictly-Subliminal group as a function of prime expression from the priming phase on Day 1. Ratings of “mildly confident old” and “very confident old” were classified as hits. Dashed lines indicate false alarm rates (new faces endorsed as “mildly confident old” or “very confident old”). Strictly-Subliminal participants displayed significantly better memory for surprise faces primed by happy faces than surprise faces primed by fearful or neutral faces. We observed the same pattern when hits included only “very confident old” responses to old faces (see Fig. 4). Indicates $p < .05$. Error bars indicate ± 1 SEM with baseline individual variability removed.

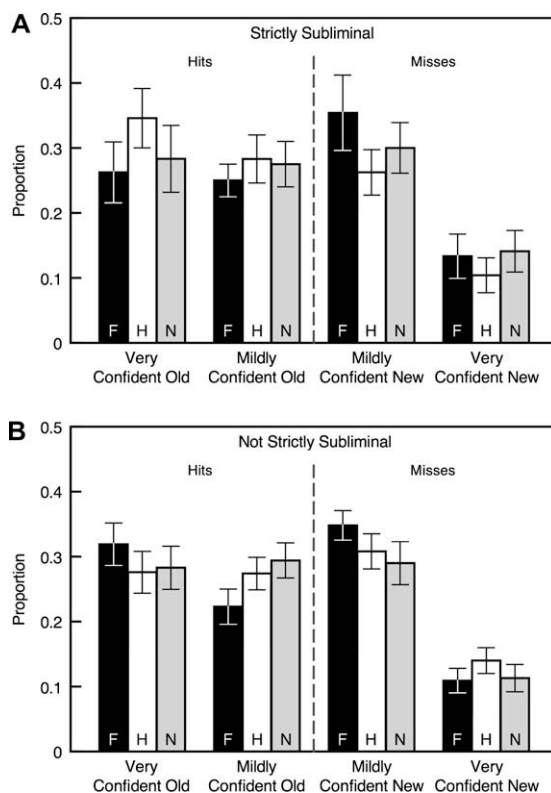


Fig. 4. Proportion of responses for the four levels of memory confidence for “old” surprise faces as a function of prime expression (F = fearful, H = happy, and N = neutral) from the priming phase on Day 1, shown separately for the Strictly-Subliminal group (A) and the Not-Strictly-Subliminal group (B). Ratings of “mildly confident old” and “very confident old” were classified as hits, and ratings of “mildly confident new” and “very confident new” were classified as misses. These findings confirm the pattern of results shown in Fig. 3. Error bars indicate ± 1 SEM with baseline individual variability removed.

into account. In the NSS group, surprise faces rated more negatively were remembered better than surprise faces rated more positively in all three prime conditions [fearful; $t(27) = 2.92, p < .01$, happy; $t(27) = 4.78, p < .01$, neutral; $t(27) = 2.69, p < .05$]. There were no differences in the variability of affective evaluations (*SD*) between prime conditions in the SS group [$F(2, 28) = 0.88, n.s.$] and the NSS group [$F(2, 54) = 0.18, n.s.$].

This same question was also approached with a regression analysis, in which we computed the slope for the linear correlation between mean affective rating and memory score for each participant (outliers outside the 95% confidence ellipse were eliminated before computing the correlation for each participant). Collapsing across data from all three priming conditions and both groups, the mean slope was negative and significantly different from zero [$M = -0.22, SD = 0.30, t(42) = 4.88, p < .01$], demonstrating better memory for more negatively rated surprise faces. In separate analyses, mean slopes were significantly negative for both the SS group [$M = -0.19, SD = 0.33, t(14) = 2.16, p < .05$] and the NSS group [$M = -0.24, SD = 0.28, t(14) = 4.52, p < .01$]. With SS participants, mean slopes were significantly negative in the fearful prime condition [$M = -0.32, SD = 0.10, t(14) = 3.25, p < .01$], but not in the happy or neutral prime conditions (t -values < 0.15). With NSS participants, mean slopes were significantly negative in the fearful [$M = -0.23, SD = 0.52, t(27) = 2.30, p < .05$], happy [$M = -0.25, SD = 0.34, t(27) = 3.97, p < .01$], and neutral [$M = -0.19, SD = 0.42, t(27) = 2.44, p < .05$] conditions. Together, these analyses converge to show that negative affective evaluation was associated with better recognition memory, but preferentially for participants most likely aware of prime faces. Importantly, these results also show that the recognition advantage for surprise faces primed by happy faces in the SS group occurred independently of affective evaluation per se.

4. Discussion

Subliminal priming in this experiment had consequences for both immediate affective evaluation of surprise faces and later memory for the same surprise faces. Surprise faces can readily be interpreted as positive or negative in valence, and we found that biases were systematically induced by primes. Surprise faces were rated as more positive when primed by a happy expression than when primed by a fearful expression.

Recognition of surprise faces 24 h later also depended on prime category. We tested memory using the same surprise faces intermixed with new surprise faces, and we presented these faces without the 30-ms prime faces that had been viewed

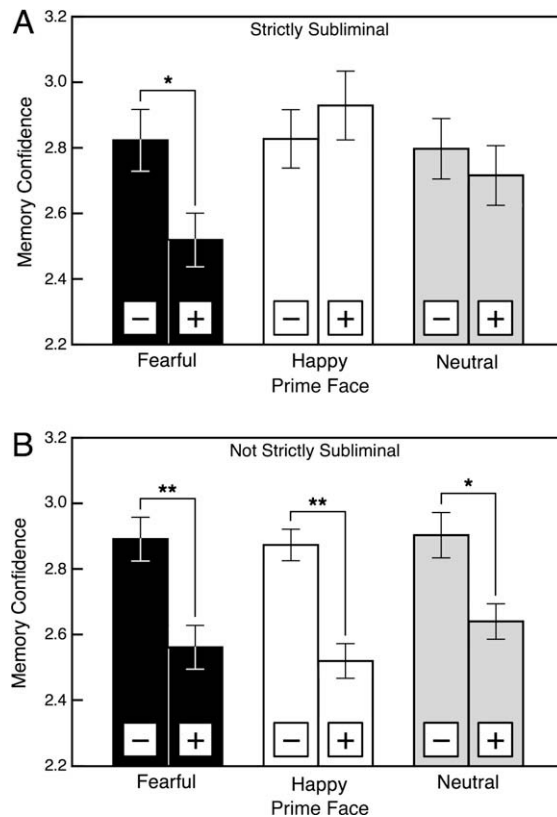


Fig. 5. Mean memory confidence scores (1 = very confident new, 2 = mildly confident new, 3 = mildly confident old, 4 = very confident old) for old surprise faces for the Strictly-Subliminal group (A) and the Not-Strictly-Subliminal group (B) as a function of prime expression and affective evaluation from the priming phase on Day 1. Trials were segregated into most negative (-) and most positive (+) affective evaluations for each participant based on a median split (trials with an affective evaluation equal to the median were excluded). *Indicates $p \leq .05$, ** indicates $p < .01$. Error bars indicate ± 1 SEM with baseline individual variability removed.

earlier. The three groups of surprise faces primed by different expressions did not carry systematically different affect in their physical features per se, and yet, traces of the events of the priming phase influenced memory in a specific way. Happy priming yielded superior recognition compared to both fearful priming and neutral priming.

Both of the two key effects in this experiment— affective priming on Day 1 and differential recognition performance as a function of prime category on Day 2— were observed after we categorized participants into two groups according to their awareness of priming. We used both subjective criteria (verbal reports of no prime awareness) and objective criteria (chance-level discrimination of prime expressions). Members of the Not-Strictly-Subliminal (NSS) group, failing to satisfy at least one criterion, were more likely to have been conscious of primes; members of the Strictly-Subliminal (SS) group, satisfying both criteria, were more likely to have processed primes only subliminally. The SS group was composed of 15 of the 43 participants tested, and it was only the SS group that demonstrated both key effects.

Our findings of subliminal affective priming are consistent with findings from other paradigms (e.g., Murphy & Zajonc, 1993; Stapel et al., 2002). In particular, our findings replicate and extend the findings of Li and colleagues (2008), though several design features differed between these two studies. Only the present study used faces cropped to an oval shape, and only the present study included a neutral condition. Various timing parameters also differed between studies, and only in the present study were participants identified who were most likely to have been aware of prime faces. In both studies, surprise faces subliminally primed by happy faces were perceived as more positive than surprise faces subliminally primed by fearful faces. Li and colleagues (2008) also demonstrated that priming was associated with differences in early visual processing indexed by brain potentials at about 150 ms after prime onset, and that these effects were larger in individuals with trait anxiety. The present experiment yielded the same type of perceptual effect among a group of participants strictly categorized as most likely to have been unaware of the primes, consistent with evidence that affective priming is most potent when it is subliminal (Higgins, 1996; Murphy & Zajonc, 1993; Stapel et al., 2002). Furthermore, the current experiment adds to the literature in this area by demonstrating that unconscious emotional processing can have much longer-lasting effects than previously assumed.

Yet, a logical possibility is that the memory effects observed in the SS group on Day 2 could have been caused entirely by behavioral responses to those faces on Day 1, in which case the memory effects should not be considered a direct result of

the different priming conditions per se. This concern, however, can be dismissed on the basis of our analysis of memory as a function of Day-1 ratings (Fig. 5).¹ This analysis showed that, in the SS group, fear-primed surprise faces with more negative ratings yielded improved recognition compared to fear-primed surprise faces with more positive ratings, but that recognition of happy-primed or of neutral-primed surprise faces did not vary between those with more positive versus more negative ratings. Therefore, the relative recognition advantage from subliminal priming when expressions were happy can be attributed to the unconscious processing of the happy primes, and not to the subsequent affective evaluation responses made for each surprise face.

Prior results are consistent with our finding of superior memory for surprise faces that had been primed the day before by happy faces. Memory for identities of faces was better for those displaying happy expressions at study and, 5 min later, at test than for those displaying sad expressions at study and test (Ridout et al., 2003). Likewise, memory for identities of neutral test faces was found to be better when those same faces displayed a happy rather than an angry expression during the study phase (D'Argembeau & Van der Linden, 2007; D'Argembeau et al., 2003). In another memory paradigm with emotional expressions at study and neutral expressions at test, participants recalled the emotion previously expressed best for the faces that had happy expressions at study (Shimamura et al., 2006). Our design differs in important ways from some of these prior designs, in that the same surprise expressions were evaluated at study and at test, the test phase occurred after a relatively long, 24-h delay, and the affective information at study was subliminal, at least for some participants. Nonetheless, the results converge in showing a memory advantage for faces when shown at learning with subliminal happy rather than neutral or fearful expressions. Our results differ from previous findings of better recognition memory among young adults for images of scenes depicting negative compared to positive affect (Charles, Mather, & Carstensen, 2003). It may be the case that emotional scenes and expressions differentially affect recognition memory.

The inclusion of neutral faces as subliminal primes provided a benchmark against which to compare memory effects for faces primed by fearful and happy faces. Given that memory was best for happy-primed faces, and that there was no difference in memory between fearful-primed faces and neutral-primed faces, we infer that processing of happy expressions mediated the difference in memory across priming conditions. This difference could have arisen if happy faces were more extreme in valence than fearful faces, but this possibility is unlikely given that the norming procedure showed no such difference in rated intensity. Therefore, we suggest that the observed differences in memory were due to subliminal priming that led to differential processing at encoding and/or subsequent rehearsal as a function of facial expression. Furthermore, strictly subliminal processing of happy faces rather than simple attribution of positive affect to the surprise faces appears to be the driving force behind this memory effect. More generally, these results are consistent with the idea that certain perceptual and behavioral changes can be induced only when affective stimuli are unconsciously processed. Exactly why these effects may not occur when stimuli are consciously processed is unclear, but differential results as a function of conscious versus unconscious stimulus processing adds weight to the argument that these results are due to subliminal presentation (Hannula, Simons, & Cohen, 2005).

What neural mechanisms might support the processing of positive affect from happy faces in the absence of awareness of those faces? Li and colleagues (2008) conducted an electrophysiological analysis for surprise faces subliminally primed by happy faces or by fearful faces, and found a corresponding difference in frontocentral potentials at 300–400 ms. The authors speculated that subliminal happy faces may function to orient attention toward the subsequently presented surprise faces. In line with this reasoning, we speculate that happy primes may have led to better encoding and subsequent memory by preferentially engaging an attention focus on the global configuration of facial features, consistent with findings that happy mood can increase the use of global features to classify visual figures (Bridge et al., accepted for publication; Frederickson, 2004; Gasper & Clore, 2002).

A single investigation cannot address the great variety of influences that facial expressions of various emotions have on behavior and cognition. However, the findings clearly underscore the power of affective information that escapes conscious perception and yet can still influence a person's attitudes and behavior, not just at the time sensory information is first processed but the next day as well.

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¹ The analysis of memory as a function of affective rating in the NSS group showed a consistent advantage for faces rated more negatively over those rated more positively. This effect did not require that priming be subliminal, and it probably reflects a mechanism distinct from that producing the memory advantage for happy-primed faces in the SS group.

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