Cogn Affect Behav Neurosci (2013) 13:284–296
DOI 10.3758/s13415-012-0137-3

Priming effects on the N400 in the affective priming paradigm with facial expressions of emotion

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Abstract We studied the effect of facial expression primes on the evaluation of target words through a variant of the affective priming paradigm. In order to make the affective valence of the faces irrelevant to the task, the participants were assigned a double prime–target task in which they were unpredictably asked either to identify the gender of the face or to evaluate whether the word was pleasant or unpleasant. Behavioral and electrophysiological (event-related potential, or ERP) indices of affective priming were analyzed. Temporal and spatial versions of principal components analyses were used to detect and quantify those ERP components associated with affective priming. Although no significant behavioral priming was observed, electrophysiological indices showed a reverse priming effect, in the sense that the amplitude of the N400 was higher in response to congruent than to incongruent negative words. Moreover, a late positive potential (LPP), peaking around 700 ms, was sensitive to affective valence but not to prime–target congruency. This pattern of results is consistent with previous accounts of ERP effects in the affective priming paradigm that have linked the LPP with evaluative priming and the N400 with semantic priming. Our proposed explanation of the N400 priming effects obtained in the present study is based on two assumptions: a double check of affective stimuli in terms of valence and specific emotion content, and the differential specificities of facial expressions of positive and negative emotions.

Keywords Affective priming · N400 · Facial expressions of emotion

Most current models of affect and emotion assume that affective processing proceeds, at least in part, automatically and without the need of conscious deliberation (e.g., Bargh, 1999; Duckworth, Bargh, Garcia, & Chaiken, 2002; Ellsworth & Scherer, 2009; Fazio, 2001; Öhman, Hamm, & Hugdahl, 2000). According to this view, the initial classification of stimulus objects by valence occurs prior to deliberate cognitive analysis, takes place at early stages of information processing, and develops in parallel with perceptual processing (e.g., Barrett & Bar, 2009).

A well-known tool for measuring the effects of automatic evaluation is the affective priming procedure, which involves the sequential presentation of two valenced stimuli (see Fazio, 2001, and Klauer & Musch, 2003, for reviews). On congruent trials, the first and second stimuli (the prime and the target, respectively) are of the same valence, while on incongruent trials, one of these stimuli is positive and the other negative. The participant's task is usually to evaluate the target as good or bad, pleasant or unpleasant (e.g., De Houwer, Hermans, Rothermund, & Wentura, 2002; Fazio, Sanbonmatsu, Powell, & Karders, 1986), although naming and lexical decision tasks have also been employed in studies with verbal targets (e.g., Klauer & Musch, 2001; Wentura, 2000). Priming is observed when performance, measured in terms of accuracy or reaction time (RT), is better on congruent than on incongruent trials. This result has usually been interpreted in terms of spreading-activation mechanisms (e.g., Fazio, 2001), showing facilitated processing of affectively congruent targets and/or impaired processing of incongruent ones. According to this explanation,

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implicit evaluation of the prime stimulus produces a transitory increase in the activation level of representations of stimuli or objects of similar valence, thus leading to facilitated processing of affectively congruent targets. A critical parameter for obtaining this effect is the duration of the prime–target interval or stimulus onset asynchrony (SOA). Affective priming has usually been obtained with short SOA durations, up to around 300 ms (e.g., Fazio et al., 1986; Hermans, Spruyt, & Eelen, 2003). This finding suggests that the effect is mediated by automatic, noncontrolled evaluative mechanisms and that the spreading of valence activation is a fast and short-lived process.

An alternative explanation of the affective priming effect has been proposed in terms of facilitation/competition at the response level (De Houwer et al., 2002; Wentura, 1999). This account assumes that, in the absence of other explicit response assignments, affective primes automatically activate the specific response corresponding to their valence. Response facilitation, or "response priming," would then occur for targets with the same valence as the prime. A finding consistent with this account is that the affective congruency effect is eliminated when the participant is assigned a nonevaluative task (e.g., Klauer & Musch, 2001; Spruyt, Hermans, Pandelaere, De Houwer, & Eelen, 2004). According to this argument, the interpretation of the affective congruency effect is problematic because in most affective priming studies, the influence of prime–target congruency is confounded with that of the congruency between the evaluative response to the target and the response tendency activated by the prime.

Several recent studies have used the event-related potential (ERP) technique to study the electrophysiological correlates of affective processing in the affective priming paradigm. Due to its high temporal resolution, the ERP technique is especially suited to studying brain correlates and the precise timing of fast-acting and short-lived processes, such as those supposed to underlie affective priming effects. Studies on affective priming using the ERP technique have focused especially on the N400 and the late positive potential (LPP) components. The N400 (Kutas & Hillyard, 1980) is a negative deflection observed around 400 ms after target onset with a centro-parietal maximal amplitude and that is sensitive to semantic relatedness and congruency. Typically, enhanced N400 amplitudes are observed in response to semantically incongruent targets (see Kutas & Federmeier, 2011, for a recent review). Enhanced N400 amplitudes have also been reported in several studies with the affective priming paradigm in response to affectively incongruent targets (e.g., Eder, Leuthold, Rothermund, & Schweinberger, 2011; Morris, Squires, Taber, & Lodge, 2003; Steinbeis & Koelsch, 2009; Zhang, Lia, Gold, & Jiang, 2010), although negative results have also been reported (Herring, Taylor, White, & Crites, 2011; Kissler & Koessler, 2011). A critical parameter seems to be the duration of the prime–target interval or SOA. Differences in SOA duration can determine whether an N400 congruency effect is obtained at all (Zhang, Lawson, Guo, & Jiang, 2006; Zhang et al., 2010), can influence the distribution of the N400 effect across the scalp (Zhang et al., 2010), or can even lead to a reversed priming effect, with an enhanced N400 in response to congruent targets. For example, using a procedure in which target emotional faces were preceded by nonsense utterances pronounced with different emotional intonations, Paulmann and Pell (2010) found the expected N400 effect in response to affectively incongruent targets using a 400-ms SOA. However, a reversed N400 effect—that is, a more negative-going deflection in response to congruent targets—was observed with a 200-ms SOA.

Modulations of the LPP that appear in a time window between 400 and 700 ms, usually with a centro-parietal distribution and sensitive to the affective or motivational value of the stimuli, have also been found in some affective priming studies. Enhanced amplitudes of these components have been reported in response to targets that are incongruent in terms of valence (Herring et al., 2011; Werheid, Alpay, Jentzsch, & Sommer, 2005; Zhang et al., 2010) or arousal (Hinojosa, Carretié, Méndez-Bértolo, Míguez & Pozo, 2009). It is interesting to note that sensitivity of the LPP to affective congruency has been observed even in the absence of N400 effects. Herring et al., for example, found this discrepancy and considered it as being suggestive that differential mechanisms are involved in affective and semantic priming. These authors pointed out that the LPP is sensitive to evaluative congruency in the affective priming paradigm and that N400 effects reflect the effects of semantic rather than of evaluative congruency.

Facial expressions of emotion constitute a particularly relevant class of stimuli for use in affective priming studies, due to their social significance and affective power. There is, in fact, behavioral evidence that affective congruency effects on word evaluation can be obtained using positive or negative emotional expressions as primes (Carroll & Young, 2005; Raccuglia & Phaf, 1997; Sternberg, Wiking, & Dahl, 1998) and that this effect shows the expected sensitivity to SOA duration (Aguado, García-Gutierrez, Castañeda, & Saugar, 2007; Fazio et al., 1986; Hermans et al., 2003). Congruency effects using facial expressions as primes have also been obtained in two ERP studies using the affective priming paradigm. In Werheid et al.'s (2005) study, both the primes and the targets were faces showing an emotional expression (happy or angry). Congruent and incongruent trials were defined according to whether or not the two faces showed the same expression, and the participant's task was to identify the expression of the target face. Although behavioral priming was obtained only for positive targets, early (100–200 ms) and late (500–600 ms) ERP effects were observed for both types of targets. The design employed in this study, however, was aimed at evaluating repetition priming, and thus confounded affective congruency with expression congruency. In fact, the authors proposed an interpretation of the observed late ERP effects not in terms of affective congruency, but as reflecting facilitation of emotion recognition due to repetition in the expression-congruent pairs.

In the second study, Li, Zinbarg, Boehm, and Paller (2008) used a subliminal priming paradigm in which participants had to evaluate surprise faces that were preceded by briefly presented happy or fearful faces. Ratings of the target faces were biased in the direction of the preceding prime, and brain potentials also showed different modulations following each prime type (increased P100 amplitudes in trials with fear primes, and increased amplitudes of the P300 component in trials preceded by happy primes). Although these results might reflect priming effects, the authors themselves proposed an alternative interpretation in terms of perceptual integration of the prime and target faces. This explanation is plausible given the temporal parameters used, with a short prime duration and no blank interval between the prime and the target. Under these conditions, for example, a surprise face preceded by a happy prime might have received more positive ratings not because of the influence of the affective valence of the prime, but because what the participant saw was in fact a mixed happy/surprise face. In conclusion, the results of Li et al. (2008) and of Werheid et al. (2005) show that emotional faces presented as primes do influence the processing of target stimuli, as measured by the ERP technique. However, given the design of the trials and the use of faces as both the primes and targets in these studies, it is likely that the results obtained reflect perceptual interactions between the stimuli rather than affective congruency effects.

In the present study, we measured electroencephalography (EEG) activity in a sequential, cross-domain affective priming procedure, with faces as primes and words as targets. This procedure reduced the probabilities of perceptual fusion between the stimuli and of confounding affective congruency with expression repetition. Moreover, we used a dual prime–target task procedure aimed at reducing the probabilities that the participants would engage in explicit evaluation of the faces and that evaluative responses to the target would be primed by response tendencies activated by those faces. To this end, the participants were unpredictably asked in different trials to evaluate the target word (prime–target trials) or to identify the gender of the prime face (prime-only trials). With this manipulation, we tried to ensure that the participant would focus her or his attention on the gender of the face instead of on its affective meaning. At the same time, this procedure guaranteed that different response tendencies would be activated by the prime and the target. Priming obtained under these experimental conditions would be strongly suggestive of an affective congruency effect. This effect might then be attributed to automatic, nonstrategic activation of the valence of the emotion prime, and not to deliberate affective processing or response priming.

In behavioral terms, affective priming should manifest as lower accuracy or slower RTs on affectively incongruent trials. In electrophysiological terms, we expected to find priming effects on brain potentials that have previously been found to be sensitive to semantic and affective congruency in affective priming studies. On the basis of the evidence discussed above, we focused our interest on the N400 and LPP components.

Method

Participants

The participants were 24 psychology students (20 females, four males; ages 17–28 years, mean = 21) who took part in the experiments for course credit. All of them had normal or corrected-to-normal vision and were right-handed.

Apparatus and stimuli

Presentation of the stimuli and registration of responses was controlled through the E-Prime software, version 1.1. The program was run on a computer with 64 MB RAM, and the stimuli were presented on a VGA 17-in. monitor (refresh rate 60 Hz). The participants were seated at a distance of 50 cm from the screen, and responses were registered through a computer keyboard. Sessions were carried out individually in a soundproof, dimly lit room.

The prime stimuli were 32 pictures of male and female models showing a happy or an angry expression, taken from the Karolinska Directed Emotional Faces (KDEF) collection (Lundqvist, Flykt, & Öhman, 1998). There were 16 models (eight male, eight female), each showing both expressions. The happy and angry faces differed in both valence and arousal: $t(30) = 20.06$ and 9.62, respectively, both ps $< .001$. In order to avoid possible influences of hairstyling, the images were cut to conceal most of the hair. The images were also equated in contrast energy (root-mean square contrast = 0.2). Stimuli were presented centered on the screen against a gray background.

The target stimuli were 48 Spanish nouns with positive or negative valence (24 positive, 24 negative), selected according to their valence, concreteness, syllable number, arousal, and frequency ratings obtained in a pilot study (see the Appendix). The mean pleasantness ratings for the selected positive and negative words was 7.90 and 2.14, respectively, $t(46) = 44.09$, $p = .000$. The positive and negative words were equated in terms of frequency of use, concreteness, number of syllables, and arousal (Alameda & Cuetos, 1995). The mean frequencies were 96.79 for positive and 87.29 for negative words, $t(46) = 0.38$, $p > .05$; the mean concreteness scores, 5.75 for positive and 5.76 for negative words, $t(46) = 0.29$, $p > .05$; the mean syllable numbers, 3.21 for positive and 3.08 for negative words, $t(46) = 0.49$, $p > .05$; and finally, the arousal scores were 7.55 for positive and 7.48 for negative words, $t(46) = 0.52$, $p > .05$. A different set of words was used during the practice phase. All words were presented at the center of the screen, written in black letters (Courier New 26-point font) on a gray background.

Procedure

The instructions, presented self-paced on the computer screen, described the task to be performed. After the instructions, the practice phase began. This phase was included with the aim of familiarizing the participants with the keys that they would use in the experimental task. The participants repeated the practice trials until they reached an accuracy criterion of 80 %. The faces and words presented in the practice block were different from those used in the experimental blocks.

Two types of trials were presented, prime–target and prime-only trials, which were distributed randomly (see Fig. 1 for examples). On prime–target trials, a priming procedure with faces as primes and words as targets was employed, with a 300-ms SOA. The main within-subjects factor was the Affective Congruency between the prime and the target. On valence-congruent trials, angry-face primes were followed by a negative word and happy-face primes were followed by a positive word. On incongruent trials, the primes and targets were of opposed valences. Throughout the experimental session, presentation of the face primes was randomized, with the restriction that the same model could not appear in two consecutive trials. Each trial started with the presentation of a fixation point for 1,000 ms, followed by a face acting as a prime for 250 ms. Next, a fixation point with a duration of 50 ms appeared, and finally the target word appeared and was terminated by the participant's response. On these trials, the participant's task was to categorize each word as pleasant or unpleasant. Responses were entered via the computer keyboard, and key assignments were counterbalanced. On prime-only trials, the face prime was followed by a question mark, indicating that the participant should report the gender of the face just seen. The keys used to enter these responses were different from those used for the evaluation task. Trials were separated by a variable intertrial interval, during which only a gray background was presented.

The experimental session was composed of 192 trials (96 prime–target and 96 prime-only), divided in two blocks of 96 trials and separated by a rest period. On each block, the same numbers of prime–target and prime-only trials appeared randomly. Half of the prime–target trials had positive and the other half negative targets. In addition, half of the positive target trials had a negative prime (incongruent condition) and the other half were preceded by positive primes (congruent condition). The same distribution was applied to the trials with a negative target. As a result, 48 congruent (24 with each type of target) and 48 incongruent (24 with each type of target) trials were presented. The gender of the primes was also balanced, so half apiece of the negative and positive primes in each condition were female faces, and half were male faces. Given that 48 word stimuli but only 32 face stimuli were used and that the same faces appeared on prime-only and prime–target trials, words

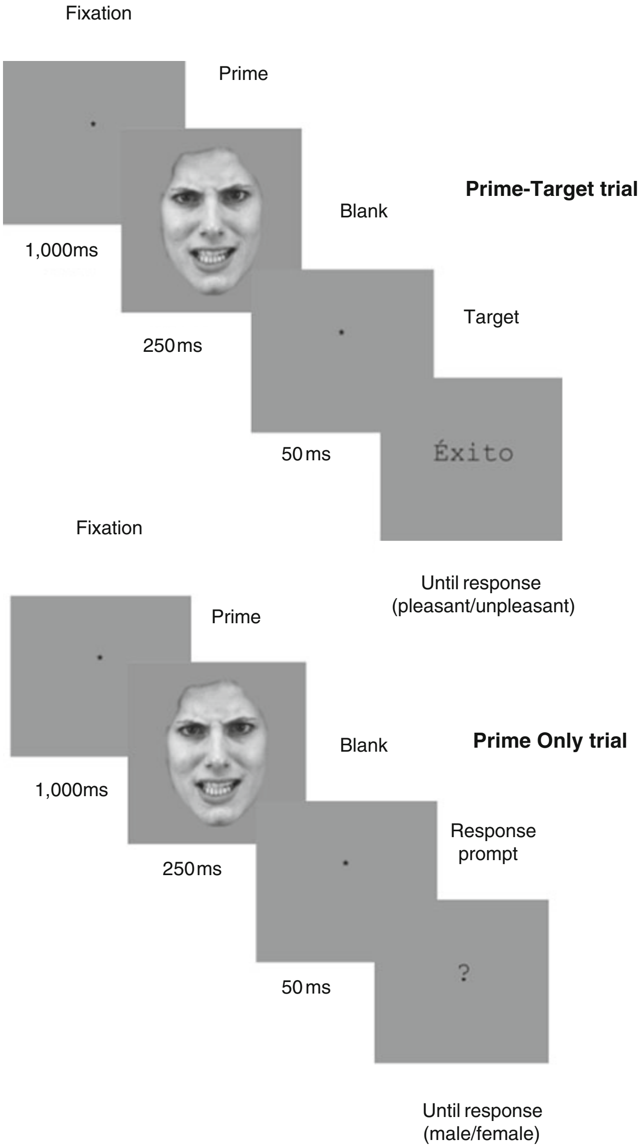

Fig. 1 Example event sequences on prime–target and prime-only trials

and pictures were repeated different numbers of times. More specifically, while each word was seen twice by the participants, each picture was repeated six times in total, three on prime-only and three more on prime–target trials.

EEG procedure and data analysis EEG activity was recorded using an electrode cap (Compumedics Neuroscan`s Quick-Cap) with Ag–AgCl disk electrodes. A total of 62 scalp locations homogeneously distributed over the scalp were used. All of the scalp electrodes were referenced to the linked mastoids. Bipolar horizontal and vertical electrooculography was recorded for artifact rejection purposes. Electrode impedances were kept below 5 KΩ. The signals were recorded continuously with a bandpass from 0.1 to 40 Hz (3-dB points for −6 dB octave roll-off) and a digitization sampling rate of 250 Hz.

Epochs were created, ranging from −250 to 800 ms after target onset. These epochs were baseline corrected and low-pass filtered (20 Hz/24 dB). Muscle artifacts, drifts, and amplifier blockings were removed by visual inspection before offline correction of eye movement artifacts (using the method described by Semlitsch, Anderer, Schuster, & Preelich, 1986). Individual ERPs were calculated for each experimental condition before grand averages were computed.

The components that explained the most ERP variance were detected and quantified through covariance-matrix-based temporal principal components analysis (tPCA). This method has been repeatedly recommended, since the exclusive use of traditional visual inspection of grand averages and voltage computation may lead to several types of misinterpretation (Chapman & McCrary, 1995; Coles, Gratton, Kramer, & Miller, 1986; Dien, Beal, & Berg, 2005; Foti, Hajcak, & Dien, 2009). The main advantage of tPCA over traditional procedures based on visual inspection of recordings and on temporal windows of interest is that it presents each ERP component separately and with its clean shape, extracting and quantifying it free of the influences of adjacent or subjacent components. Indeed, the waveform recorded at a specific electrode over a period of several hundred milliseconds represents a complex superposition of different overlapping electrical potentials. Such recordings can stymie visual inspection. In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component and low between those belonging to different components. The solution is therefore a set of independent factors made up of highly covarying time points, which ideally correspond to ERP components. A temporal factor (TF) score, the tPCA-derived parameter in which the extracted temporal factors may be quantified, is linearly related to amplitude. In the present study, the number of components to select was based on the scree test (Cliff, 1987). Extracted components were submitted to promax rotation, since this rotation has been found to give the best overall results for tPCA (Dien, 2010; Dien et al., 2005). Repeated measures analyses of variance (ANOVAs) were carried out on the TF scores. Three within-subjects factors were included in the ANOVA: Congruency (two levels: congruent and incongruent), Target Valence (two levels: negative and positive), and Electrode (62 levels). The Greenhouse–Geisser epsilon correction was applied to adjust the degrees of freedom of the F ratios where necessary.

Signal overlapping may also occur in the space domain: At any given time point, several neural processes (and, hence, several electrical signals) may occur, so the recording at any scalp location at that moment is the electrical balance of these different neural processes. While tPCA “separates” ERP components across time, spatial PCA (sPCA) separates ERP components across space, each spatial factor ideally reflecting one of the concurrent neural processes underlying each temporal factor. Additionally, sPCA provides a reliable division of the scalp into different recording regions, a strategy that is advisable prior to statistical contrasts, since ERP components frequently show different behavior in some scalp areas than in others (e.g., they present different polarity or react differently to experimental manipulations). Basically, each region or spatial factor is composed of the scalp points where recordings tend to covary. As a result, the shape of the sPCA-configured regions is functionally based and scarcely resembles the shape of the geometrically configured regions defined by traditional procedures such as the creation of regions of interest. Moreover, each spatial factor can be quantified through the spatial factor score, a single parameter that reflects the amplitude of the whole spatial factor. Therefore, sPCAs were carried out for those TFs that were sensitive to our experimental manipulations. Again, the number of extracted factors was based on the scree test, and their spatial factor scores were submitted to promax rotation. Repeated measures ANOVAs were carried out on the spatial factor scores. Two within-subjects factors were included: Congruency (two levels: congruent and incongruent) and Target Valence (two levels: negative and positive). Greenhouse–Geisser epsilon correction was applied to adjust the degrees of freedom of the F ratios, and pairwise comparisons with the Bonferroni correction ($p < .05$) were carried out whenever appropriate.

Results

Behavioral results

Performance in the gender and evaluation tasks was measured in terms of accuracy and RT. Only correct responses were considered in calculating the RT measure, and in order to eliminate extreme values, responses outside the 200- to 2,000-ms range were deleted. Mean accuracy in the gender task (prime-only trials) was .89 ($SEM = .01$), and the mean RT was 750 ms ($SEM = 34.3$). A significant effect of emotional expression was obtained [$t(23) = 2.51$, $p = .019$], with gender being more accurately identified in happy than in angry faces ($M = .90$, $SEM = .009$, and $M = .87$, $SEM = .010$, respectively). A significant effect of facial expression was also found on the RT measure [$t(23) = 3.83$, $p = .001$], with longer correct RTs to happy than to angry faces ($M = 839$, $SEM = 26.8$, and $M = 812$, $SEM = 25.9$, respectively). Mean accuracy in the evaluation task (prime–target trials) was .92 ($SEM = .007$), with a mean RT of 895 ms ($SEM = 23.5$). A repeated measures 2 × 2 ANOVA with Congruency and Target Valence as the factors was performed on evaluation responses to the target. No significant effects were obtained on accuracy (Fs < 1). For the RT measure, none of the effects reached statistical significance, although both congruency and the Congruency × Valence interaction reached marginal significance [$F(1, 23) = 3.68$, $p = .067$, $^2 = .138$, and $F(1, 23) = 3.22$, $p = .086$, $^2 = .123$, respectively]. This interaction was due to a trend toward shorter RTs in the congruent condition in the case of positive targets (see Table 1).

Electrophysiological data

A selection of the grand averages is represented in Fig. 2. These grand averages correspond to those scalp areas where experimental effects (described later) were most evident. As a consequence of the application of the tPCA, seven components were extracted from the ERPs. The factor loadings are represented in Fig. 3. Repeated measures ANOVAs were carried out on the TF scores for the factors Congruency, Target Valence, and Electrode, with the purpose of knowing which of these seven components were sensitive to our experimental manipulations. Hereafter, to make the results easier to understand, the ERP components associated with Temporal Factor 2 and Temporal Factor 1 will be labeled N400 and LPP, respectively, due to their latencies and polarities. The interaction between congruency and target valence was significant for the N400 component [$F(61, 1403) = 6.64$, $p < .05$]. A main effect of valence [$F(1, 23) = 8.01$, $p < .05$] and the interaction between congruency, valence, and electrode [$F(61, 1647) = 3.67$, $p < .05$] were found to be significant in the LPC. Therefore, our data show that primes modulated the amplitude of several target-related components: the N400 (which roughly corresponds to previous N400 effects), which has been related to difficulty in semantic integration (e.g., Kutas & Federmeier, 2000), and the LPP, which have been thought to index the allocation of attentional resources during the processing of emotional content (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak & Nieuwenhuis, 2006).

Subsequent sPCAs were applied to the TF scores with the purpose of specifically locating the scalp regions that were associated with the effects found in the tPCA and further confirming that the components were sensitive to our experimental manipulations. As is shown in Table 2, the sPCAs extracted two spatial factors for the N400 and three spatial factors for the LPP. Repeated measures ANOVAs on the N400 and LPP spatial factor scores (directly related to amplitudes, as previously indicated) were carried out for the Congruency and Target Valence factors. A Congruency × Target Valence interaction was found at parietal-occipital and fronto-central regions for the N400. Post-hoc comparisons showed that negative congruent targets elicited larger amplitudes than did positive congruent stimuli in both regions. Additionally, negative congruent targets were associated with enhanced N400 amplitudes, as compared to negative incongruent targets, at fronto-central electrodes (see Table 2). For the LPP, positive targets elicited enhanced amplitudes relative to negative targets at parietal-occipital, fronto-central, and left temporal regions. An interaction between congruency and target valence was also observed at parietal-occipital regions. The results of the post-hoc analyses revealed that positive incongruent targets elicited enhanced amplitudes as compared to negative incongruent stimuli (see Table 2). The topographical maps corresponding to the scalp distribution of the sPCA effects are shown in Fig. 4.

Table 1 Behavioral priming: Mean reaction times (RTs) and accuracy (Acc.) in prime–target trials as a function of prime–target affective congruency (*SEM*s in parentheses)

Target Valence		Prime–Target Congruency		Incongruent-Congruent difference
		Congruent	Incongruent	
Positive	RT (ms)	875 (24.)	904 (23.9)	29
	Acc.	.95 (.014)	.96 (.015)	.01
Negative	RT (ms)	901 (22.3)	902 (22.8)	1
	Acc.	.96 (.010)	.96 (.009)	.00

Discussion

The objective of the present study was to investigate the neural correlates of affective priming produced by facial expressions of emotion and measured via their influence on evaluations of positive and negative target words. While this sequential face–word procedure minimized possible perceptual interactions between the prime and

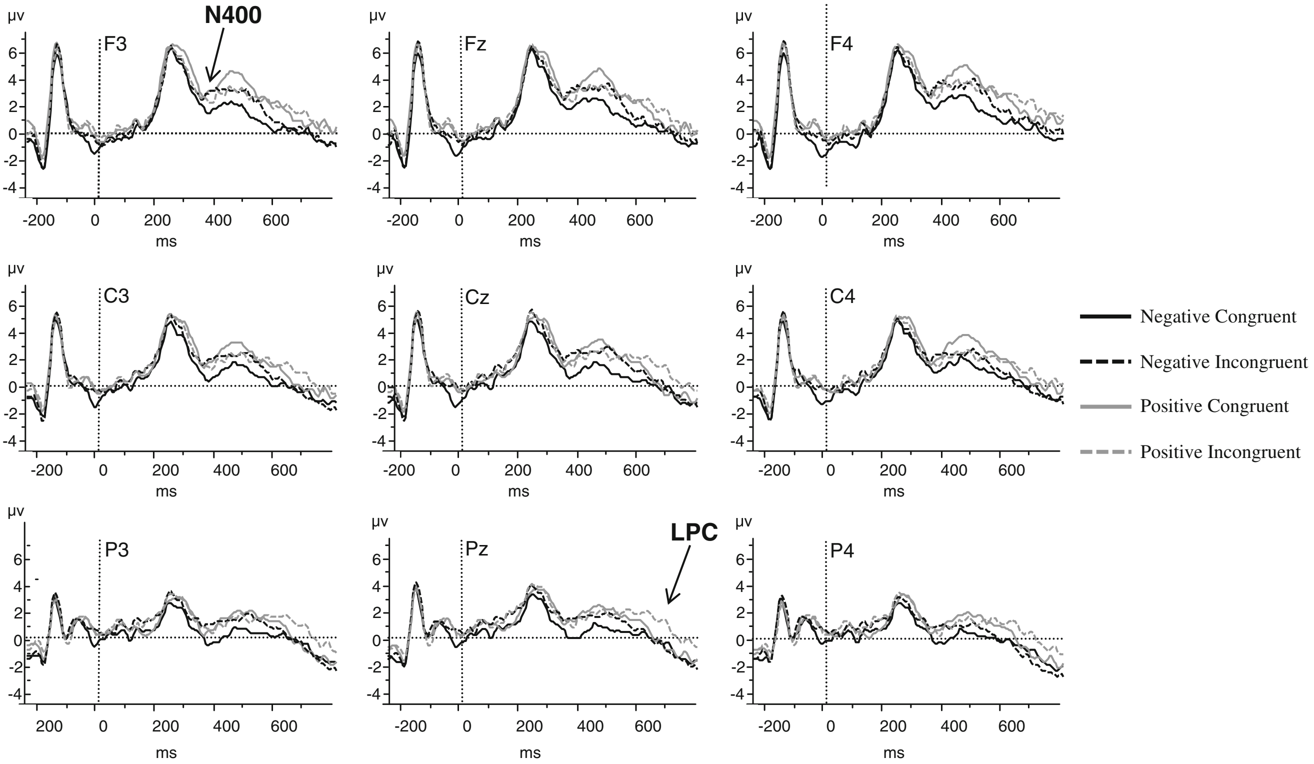

Fig. 2 Grand-average target-locked event-related potential (ERP) waveforms at selected frontal, central, and parietal electrodes as a function of target valence and prime–target affective congruency

the target, the assignment of a dual prime–target task reduced the probability that participants would engage in deliberate evaluation of the face primes and that the primes would activate evaluative responses that might interact with the response to the target. At the behavioral level, affective congruency between the primes and targets had only a marginally significant effect, and this only in the case of positive targets. Analysis of the electrophysiological results revealed significant effects of valence and congruency that indicate that priming effects were manifest at the level of brain responses, and thus that facial expression primes had a significant influence on processing of the target words. We will first discuss the lack of significant priming effects at the behavioral level, and then concentrate on interpretation of the ERP results.

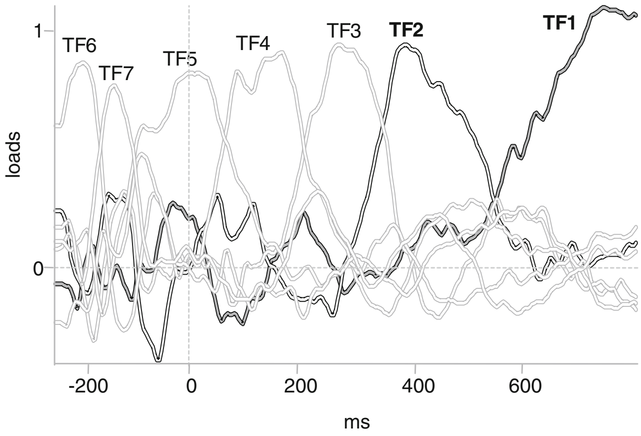

Fig. 3 The tPCA factor loadings after the promax rotation. Temporal Factors 1 and 2 correspond to the LPP and N400 components, respectively

A weak and nonsignificant priming effect was observed in the present study, and this only for positive targets. This is in contradiction with the abundant previous literature on affective priming (see Fazio, 2001, and Klauer & Musch, 2003, for reviews) and with our own previous results using the same double-task procedure employed in this study (Aguado et al., 2007). However, it should be pointed out that priming in evaluative tasks is not a general finding. For example, Klauer and Musch (2001) didn’t find any evidence of affective priming in a series of carefully controlled experiments using a naming task with word targets. In a series of studies comparing semantic and affective priming, Storbeck and Robinson (2004) didn’t find evidence of affective priming using both lexical decision and evaluative tasks either, although semantic priming was indeed present. Moreover, affective priming has been obtained in some studies only with positive, not

Table 2 Results of the statistical analyses on N400 and P700 spatial factors

	Spatial Factor	Congruency	Target Valence	Congruency × Target Valence
TF 2 (N400)	Parietooccipital	$F(1, 23) = 0.69^{\text{n.s.}}$	$F(1, 23) = 3.16^{\text{n.s.}}$	$F(1, 23) = 4.90^{*}$ NegCon > PosCon
	Frontocentral	$F(1, 23) = 0.62^{\text{n.s.}}$	$F(1, 23) = 2.89^{\text{n.s.}}$	$F(1, 23) = 7.25^{*}$ NegCon > PosCon NegCon > NegInc
TF 1 (LPP)	Parietooccipital	$F(1, 23) = 1.02^{\text{n.s.}}$	$F(1, 23) = 6.84^{*}$ *Negative < Positive*	$F(1, 23) = 4.43^{*}$ *NegInc < PosInc*
	Frontocentral	$F(1, 23) = 0.32^{\text{n.s.}}$	$F(1, 23) = 5.59^{*}$ *Negative < Positive*	$F(1, 23) = 0.53^{\text{n.s.}}$
	Left temporal	$F(1, 23) = 0.69^{\text{n.s.}}$	$F(1, 23) = 8.60^{**}$ *Negative < Positive*	$F(1, 23) = 0.03^{\text{n.s.}}$

$^{*}p < .05$. $^{**}p < .01$. n.s., nonsignificant. TF, temporal factor; NegCon, negative congruent trials; PosCon, positive congruent trials; NegInc, negative incongruent trials; PosInc, positive incongruent trials

with negative targets (e.g., Steinbeis & Koelsch, 2009; Werheid et al., 2005). Finally, affective priming has been shown to depend on stimulus variables such as word frequency, leading even to reverse priming effects when high-frequency words are used as the targets (Chan, Ybarra, & Schwartz, 2006). As to the

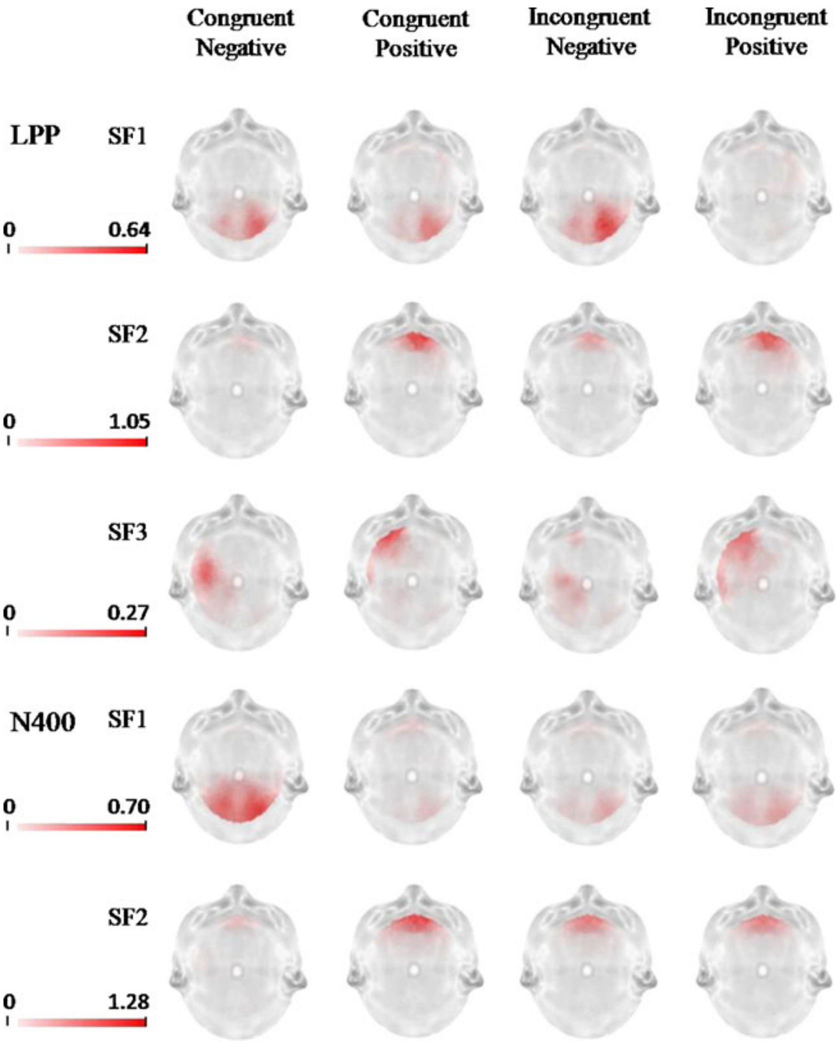

Fig. 4 Scalp maps representing the topographical distribution and values of each spatial factor across conditions. The scale has been adjusted to the highest score (absolute value) observed at each spatial factor across every condition

relationship between the behavioral and ERP results, consistency between these measures is not always observed, and a few studies have reported priming effects at the electrophysiological level in the absence of significant behavioral priming (e.g., Hinojosa et al. 2009; Kissler & Koessler, 2011). One possible explanation of the weak behavioral effects obtained in the present study is related to the demands imposed by the double-task procedure, which involved switching unpredictably between the gender and evaluation tasks. It might be that while the double task assignment was effective in directing the participants' attention away from the affective meaning of the prime faces, it also impaired the sensitivity of the task to detect subtle priming effects. The longer RT registered for target responses, as compared to that of prime responses (895 vs. 750 ms, respectively) suggests that the evaluation task might have required considerable processing resources, modulating or reducing the influence of the prime face on processing of the target word.

Turning now to the electrophysiological results, significant effects of target valence were found on the LPP component, with enhanced amplitudes in the presence of positive target words in parieto-occipital, fronto-central, and left temporal scalp locations. However, no effects of congruency were found on this component. A more complex pattern of results was found in the case of the N400. Increased negativities of this component were observed on congruent trials with negative targets—that is, in response to negative words preceded by angry faces—in parieto-occipital and fronto-central locations.[1] N400 amplitudes were enhanced on these trials as compared to positive congruent trials and, more unexpectedly, to negative incongruent trials. This last result is opposite to the usual finding of an enhanced N400 on incongruent trials that is reported in most semantic processing studies (see Kutas & Federmeier, 2011) and that has also been shown with the affective priming paradigm (Eder et al., 2011; Morris et al., 2003; Schirmer, Kotz, & Friederci, 2005; Steinbeis & Koelsch, 2009; Zhang et al., 2010). In what follows, we will first discuss briefly the results corresponding to the LPP component, and then we will concentrate on the N400, where complex congruency effects were found.

Consistent with the previous results, we found a modulation of the LPP by the valence of the target words. The finding of valence effects on LPPs is not rare (e.g., Conroy & Polich, 2007; Delplanque, Silvert, Hot, & Sequeira, 2005; Hajcak & Olvet, 2008) and has been related to the relevance or motivational significance of the stimulus (Hajcak & Olvet, 2008; Ito, Larsen, Smith, & Cacioppo, 1998). Also as in previous reports (Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Winkler, & Junghofer, 2009), we observed an augmentation of the amplitude of the LPP in response to positive targets. On the other hand, the lack of sensitivity of the LPP to affective congruency in our results contrasts with previous reports showing enhanced amplitudes of this component in response to targets that are incongruent in terms of valence or arousal (Herring et al., 2011; Hinojosa et al. 2009; Werheid et al., 2005; Zhang et al., 2010). If, as Herring et al. suggested, evaluative congruency modulates the LPP in the affective priming paradigm, the absence of this modulation in our study would be perfectly consistent with the absence of significant priming at the behavioral level.

As we discussed in the introductory section, enhanced N400 effects on incongruent trials have been found in several studies using the affective priming paradigm (Eder et al., 2011; Morris et al., 2003; Steinbeis & Koelsch, 2009; Zhang et al., 2010). However, we also mentioned some studies reporting insensitivity of the N400 to affective congruency (Herring et al., 2011; Kissler & Koessler, 2011), or even reversed N400 effects (Hinojosa et al., 2009; Paulmann & Pell, 2010). A satisfactory account of the N400 effects found in our study should address the fact that these effects show sensitivity to congruency relations that go beyond general affective valence. A tentative explanation of the present results is based on the contextual integration view of the N400. According to this account, the N400 indexes the process by which a target stimulus is integrated into the preceding context to form a unified representation (e.g., van Berkum, Hagoort, & Brown, 1999). What we propose is that in the affective priming paradigm, this integration process involves two levels of affective evaluation, one of which refers to valence and the other to specific emotion content, and that this has different consequences for positive and negative emotional stimuli. These evaluative dimensions are similar to those of the hierarchical model of affect developed by Watson and Tellegen (1985), in which the higher hierarchical level corresponds to affective valence and the lower level to discrete emotions with specific content (see Smith & Scott, 1997, for a similar effort to integrate categorical and dimensional

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[1] Most of the early studies had found that the N400 has a centro-parietal distribution. However, N400 effects with frontal distributions have been reported under some circumstances (e.g., Ganis & Kutas, 2003; Herbert, Junghofer, & Kissler, 2008). Some authors have assumed that frontal N400 components are associated with familiarity effects in recognition memory (Nyhus & Curran, 2009). However, it has been recently established that there are no functional differences between the central and centro-parietal N400s (Voss & Federmeier, 2011).

approaches in the specific case of facial expressions of emotion). The consequences of this double evaluation of valence and emotion content would be different for positive and negative affective stimuli, due to the different specificities of positive and negative affect and of their associated facial expressions. More specifically, a smiling face is the common expressive hallmark of different positive emotions, and may thus be easily integrated with a broad range of positively valenced words presented as targets in a priming paradigm (see Federmeier, Kirson, Moreno, & Kutas, 2001, for a relevant N400 study showing a facilitating effect of positive moods on processing of target words). In contrast, the integration of a negative target word with a preceding angry face would be a relatively more demanding task, due to the need to discriminate between negative targets that are congruent with the specific emotion content activated by the negative expression and those that are related to other negative emotions. This increased difficulty might explain the enhanced N400 effects observed in negative congruent as compared to positive congruent trials. A similar rationale might be used to explain the inverse N400 effect obtained with negative targets—that is, higher amplitudes on congruent than on incongruent trials. Integrating a negative word with the preceding angry face would require additional processing, because besides checking the affective congruency between the word and the face, congruent trials would require an additional evaluation of the congruency between the specific emotion contents of these two stimuli.

The results of our study have implications for the controversy over the relative roles of spreading activation and response competition in affective priming. Evidence consistent with the response competition account has been obtained in some ERP studies (Bartholow, Riordan, Saults, & Lust, 2009; Eder et al., 2011; Goerlich et al., 2012). Of special relevance here is the finding by Goerlich et al. that N400 effects on incongruent trials were shown when participants were asked to categorize the targets affectively (Exp. 1), but not when they were asked to categorize the targets on nonaffective dimensions (Exp. 2). The task conditions of Goerlich et al.'s Experiment 2 are similar to ours, in the sense that in both cases an effort was made to avoid response competition. The difference was that in our case, we gave the participants explicit instructions to categorize the prime and target stimuli on different dimensions: gender in the case of the face primes, and pleasantness in the case of the target words. Thus, our results are consistent with those of Goerlich et al. in the sense that, in either case, the typical N400 effect was absent under conditions that tended toward minimizing response competition. On the other hand, the fact that N400 amplitudes reflected the interactive effects of congruency and valence in our study, but not in that of Goerlich et al.'s, might be attributed to the different prime types used in each case (happy/sad musical excerpts and happy/angry emotional faces, respectively). Given the longstanding and varied experience that most people have with facial expressions of emotion, facial expressions might activate a more specific set of emotion associations than do musical excerpts, leading to complex priming effects such as those found in our study.

One limitation of our results is that they were obtained with a sample composed mainly of females. This might have some importance, as some studies have found gender differences in affective priming, with stronger behavioral priming in female than in male participants (Hermans, Baeyens, & Eelen, 1998; Schirmer et al., 2005). Moreover, an ERP study (Schirmer, Kotz, & Friederici, 2002) found that modulation of the N400 in an affective priming paradigm appeared with shorter SOA durations in women than in men, suggesting earlier decoding of affective meaning in women. These results suggest a higher sensitivity of female participants to affective congruency. Thus, caution should be taken when generalizing our conclusions to the male population.

To sum up, the results of our study have shown that the N400 and the LPP, two ERP components that index different stages of information processing, are differentially sensitive to affective valence and prime–target congruency in the affective priming paradigm. As we discussed on the introduction and the Discussion section, considerable evidence relates these components with incongruence detection and affective processing. The new evidence from our study reveals a complex pattern of valence and congruency effects on the N400 component. This evidence suggests that congruency effects in the affective priming paradigm are probably more complex than is predicted by more traditional accounts in terms of valence-processing and spreading-activation mechanisms. Our results suggest, instead, that a complete account of priming effects with affective stimuli must also take into account the activation of emotion-specific content by emotion primes and the ways that this content interacts with the specific affective meaning of the target stimulus.

Author note This work was supported by Grant No. Psi2010-18682 from the Spanish Ministerio de Ciencia e Innovación. The participation of T.D.-R. was supported by FPU Grant No. AP2010-1312 from the Spanish Ministry of Education.

Appendix 1

Table 3 Affective and psycholinguistic indexes for the target words

Word		Valence	Arousal	Concreteness	Frequency	Syllables
Positive Words						
Atracción	attraction	7.73	7.73	3.27	42	3
Aventura	adventure	7.80	7.47	5.87	111	4
Celebración	celebration	8.07	7.07	6.27	19	4
Cita	date	7.20	7.47	6.20	77	2
Deseo	desire	7.93	7.20	4.80	239	3
Enamorado	lover	8.53	7.07	5.87	65	5
Entusiasmo	enthusiasm	7.53	7.33	4.87	121	4
Euforia	euphoria	7.47	8.40	4.27	21	3
Éxito	success	8.33	7.53	4.13	187	3
Extraordinario	extraordinary	8.13	7.27	3.60	41	5
Fiesta	party	8.33	8.20	6.47	140	2
Ganador	winner	7.73	7.40	6.53	6	3
Lotería	lottery	7.00	7.07	7.73	18	4
Niños	children	7.73	7.33	8.47	497	2
Orgasmo	orgasm	8.67	8.53	5.67	25	3
Pasión	passion	8.00	8.13	5.53	132	2
Piropo	compliment	7.53	7.27	6.73	1	3
Premio	prize	7.93	7.00	7.13	86	2
Seducción	seduction	7.60	7.80	4.67	29	3
Sexo	sex	8.20	7.20	7.73	203	2
Sobresaliente	outstanding	8.27	7.87	6.73	5	5
Sorpresa	surprise	7.67	8.13	5.07	137	3
Superación	self-improvement	8.27	7.47	4.20	20	4
Victoria	victory	7.87	7.20	6.20	101	3
Negative Words						
Abandono	abandonment	1.93	7.20	6.00	65	4
Amenaza	threat	1.80	8.07	5.40	94	4
Ataque	attack	2.40	7.93	4.60	76	3
Bochorno	embarrassment	2.13	7.27	5.87	11	3
Conflicto	conflict	2.47	7.73	6.13	91	3
Crisis	crisis	2.13	7.67	5.33	168	2
Desorden	untidiness	2.93	7.00	6.33	48	3
Desprecio	disdain	1.60	7.07	4.87	63	3
Dificultad	difficulty	2.87	7.20	5.07	94	4
Dolor	pain	1.27	8.00	5.47	234	2
Fracaso	failure	2.00	7.47	6.07	83	3
Gritos	shouts	2.53	7.67	7.07	108	2
Hambre	hunger	2.53	7.07	7.00	129	2
Humillación	humiliation	1.33	7.80	7.47	23	4
Infección	infection	1.80	7.33	6.93	13	3
Inútil	useless	1.93	7.00	5.13	118	3
Malo	bad	2.47	7.27	4.47	153	2
Monstruo	monster	2.73	7.20	4.60	56	2
Navaja	knife	2.27	7.07	8.33	50	3
Operación	surgery	2.80	7.33	6.73	110	4
Peligro	danger	1.80	8.20	5.20	136	3
Ridículo	ridiculous	2.13	7.87	4.73	82	4
Separación	separation	2.33	7.20	5.93	45	4
Sufrimiento	suffering	1.20	8.00	3.53	45	4

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