

## Using ERPs to investigate valence processing in the affect misattribution procedure

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### Abstract

The construct validity of the affect misattribution procedure (AMP) has been challenged by theories proposing that the task does not actually measure affect misattribution. The current study tested the validity of the AMP as a measure of affect misattribution by examining three components of the ERP known to be associated with the allocation of motivated attention. Results revealed that ERP amplitudes varied in response to affectively ambiguous targets as a function of the valence of preceding primes. Furthermore, differences in ERP responses to the targets were largely similar to differences in ERPs elicited by the primes. The existence of valence differentiation in both the prime-locked and the target-locked ERPs, along with the similarity in this differentiation, provides evidence that the affective content of the primes is psychologically registered, and that this content influences the processing of the subsequent, evaluatively ambiguous targets, both of which are required if the priming effects found in the AMP are the result of affect misattribution. However, the behavioral priming effect was uncorrelated with ERP amplitudes, leaving some question as to the locus of this effect in the information-processing system. Findings are discussed in light of the strengths and weaknesses of using ERPs to understand the priming effects in the AMP.

**Descriptors:** Affect misattribution procedure, ERP, EPN, P2, LPP, Affective priming

The affect misattribution procedure (AMP; Payne, Cheng, Govorun, & Steward, 2005), often used to study implicit attitudes, is a sequential priming task in which primes (typically pleasant and unpleasant images) are shown briefly prior to the presentation of unfamiliar, evaluatively neutral targets (Chinese ideographs), which participants must categorize as more or less pleasant than the average Chinese ideograph. Although participants are told to ignore the primes and focus on the targets when making their evaluations, target ratings tend to be biased by the pleasantness of the primes (see Payne et al., 2005). Unlike other affective priming paradigms (e.g., Fazio, Sanbonmatsu, Powell, & Kardes, 1986) and other implicit attitude measures, such as the Implicit Association Task (Greenwald, McGhee, & Schwartz, 1998), priming effects in the AMP are difficult to attribute to response interference (see Bartholow, Riordan, Saults, & Lust, 2009) or task switching (Hilgard, Bartholow, Dickter, & Blanton, 2015; Klauer & Mierke, 2005), making effects more readily interpretable in terms of unintentional displacement of automatic affective reactions triggered by the primes onto unrelated targets (Payne et al., 2005). The AMP has shown high reliability and specificity (see Cameron, Brown-Iannuzzi, & Payne, 2012) as well as relatively large effect sizes

comparable to those found with traditional self-report measures (Gawronski & De Houwer, 2014).

Much progress has been made in understanding the mechanisms underlying the AMP (e.g., Bar-Anan & Nosek, 2012; Cameron et al., 2012; Gawronski & Ye, 2014a, 2014b; Hashimoto, Minami, & Nakauchi, 2012; Oikawa, Aarts, & Oikawa, 2011; Payne et al., 2013; Scherer & Lambert, 2009). The aim of the current study was to contribute further to this understanding by addressing two debates surrounding the AMP. First, while the AMP typically involves primes related to pleasant and unpleasant feelings and response options related to pleasantness, it also has been adapted to paradigms involving nonevaluative, semantic prime stimuli. For instance, Imhoff, Schmidt, Bernhardt, Dierksmeier, and Banse (2011) presented participants with pictures of people belonging to five categories of sexual maturation, and then had them guess whether the target Chinese ideographs had a sexual or nonsexual meaning. Results revealed that frequency of attributing a sexual meaning to the ideographs increased along with the sexual maturity of the individuals in the prime pictures, suggesting that priming effects in the AMP may be driven by activation of semantic concepts rather than affective feelings (Blaison, Imhoff, Huhnel, Hess, & Banse, 2012). According to this account, even though pictures of puppies may evoke positive affect, they also may activate evaluative concepts such as good or pleasant, which are subsequently misattributed to the targets. To clarify this issue, Gawronski and Ye (2014a) used a mere exposure manipulation to create positive feelings toward unfamiliar prime stimuli (nonsense words) by presenting them as part of an unrelated language learning task

Preparation of this article was supported in part by grant R01 AA020970 from the National Institute on Alcohol Abuse and Alcoholism.

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completed prior to the AMP. These authors found that, in comparison to a set of nonsense words that had not been presented previously, these previously presented nonsense words led to more favorable evaluations of the Chinese ideographs during the AMP, supporting an affect-driven misattribution interpretation of the AMP.

The validity of the AMP also has been challenged on the grounds that the priming effect results from participants intentionally rating the primes instead of the targets. Bar-Anan and Nosek (2012) had participants retrospectively report their beliefs about whether their ratings were influenced by the primes and whether they intentionally rated the primes instead of the targets. They found that the AMP's psychometric properties were good only for participants who reported being aware of the priming effect and who intentionally rated the primes at least some of the time. In response, Payne et al. (2013) suggested that, rather than relying on accurate introspective knowledge about the cause of their behavior, participants in the Bar-Anan and Nosek (2012) study were relying on post hoc confabulations to explain their behavior. Across three studies, Payne and colleagues found evidence that retrospective reports are not faithful indicators of the causal processes at work in the AMP, since participants rely on whatever explanations are readily available to make sense of past behavior. This explanation is buttressed by the finding that giving participants an additional response option to "pass" when they felt that they were being influenced by the prime on a particular trial did not reduce the priming effect. Furthermore, Gawronski & Ye (2014b) used a mere exposure manipulation to demonstrate that, when participants do not have knowledge of the affect-eliciting properties of the primes, and therefore do not have a plausible explanation of their behavior in terms of affect-based ratings of the primes, retrospective reports of intentionality are not associated with priming effects.

The current study sought to provide further evidence that affective-based misattribution does occur in affect-related AMP paradigms. In doing so, this evidence would both decrease the plausibility of semantic-based misattribution explanations in these contexts and challenge strong forms of the intentional prime rating theory. The study examines whether ERP components known to be sensitive to the valence of eliciting stimuli vary in response to the Chinese ideographs, as a function of the valence of the preceding primes.

Previous studies have revealed several ERP components that are modulated by the affective valence or arousal properties of visual stimuli. The early posterior negativity (EPN) is observed as a negative voltage deflection over temporo-occipital scalp sites, generally emerging 200–300 ms following the onset of emotional pictures, which reliably differentiates valenced from neutral visual stimuli (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). This differential processing of emotional and neutral stimuli has been attributed to differences in emotional arousal, with EPN covarying with the arousal level of emotional pictures (Junghöfer, Bradley, Elbert, & Lang, 2001; Schupp, Junghöfer, Weike, & Hamm, 2003).

The P2 is a positive-going deflection prominent over parieto-occipital sites, generally emerging 180–300 ms poststimulus, which has been associated with attentional processing of perceptual cues and is known to increase along with the motivational significance of eliciting stimuli (Begleiter & Platz, 1969; Ito & Urland, 2003; Kanske & Kotz, 2007; Schapkin, Gusev, & Kuhl, 2000). These early emotion-related effects often have been interpreted as indicating rapid deployment of attention to motivationally relevant stimuli (Herbert, Junghofer, & Kissler, 2008), which facilitates processing

of an attended emotional category through the modulation of other processing stages (Kanske, Plitschka, & Kotz, 2011).

Finally, the late positive potential (LPP) is a relatively large positive-going deflection in the stimulus-locked waveform elicited by emotional stimuli that is maximal over parietal scalp locations. The LPP consists of a P3-like peak, generally occurring 300–500 ms following stimulus onset, followed by a sustained positivity that can last several seconds (see Gable, Adams, & Proudfit, 2015). Prevailing theory holds that LPP amplitude reflects the motivational significance of the eliciting stimulus (Codispoti, Ferrari, & Bradley, 2006; Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Gable & Harmon-Jones, 2010; Hajcak & Olvet, 2008; Weinberg & Hajcak, 2010). Evidence in support of this interpretation has come from studies showing that LPP amplitude is sensitive to both the inherent, bottom-up relevance of visual stimuli (e.g., the arousal and valence properties of emotional pictures; Delplanque et al., 2006; Hajcak, Dunning, & Foti, 2009; Schupp et al., 2000; Weinberg & Hajcak, 2010) and to various top-down features that influence the goal or task relevance of the stimuli (see Hilgard, Weinberg, Proudfit, & Bartholow, 2014; Weinberg, Hilgard, Bartholow, & Hajcak, 2012; also see Squires, Squires, & Hillyard, 1975). Numerous studies have confirmed that valenced (positive or negative) images elicit larger LPP amplitudes than evaluatively neutral images (e.g., Briggs & Martin, 2008, 2009; Delplanque, Silvert, Hot, & Sequeira, 2005; Schupp et al., 2000, 2003).

To date, ERPs have been used in only one study investigating the AMP (Hashimoto et al., 2012), with the primary goal of revealing whether AMP effects are due to earlier attention allocation (indexed by the P2) or later emotion evaluation (indexed by the LPP). Results revealed that the amplitude of the P2 elicited by the primes was larger in participants with small behavioral priming effects. The authors suggest that affect misattribution is less likely to take place when participants direct more attention to the primes. A related idea was suggested by Oikawa et al. (2011), who demonstrated that having participants explicitly rate the primes before explicitly rating the targets eliminated the AMP effect. However, it is not clear whether the attentional processing reflected in the P2 indexes top-down, intentional focus on the primes or a largely bottom-up, automatic response that could occur even if participants were "doing nothing" with the primes as they were instructed. As noted by Hashimoto et al., evidence indicates that the P2 is strongly sensitive to emotional valence regardless of whether evaluations are implicit or explicit, and suggests that the P2 may primarily index automatic increases in selective attention (Huang & Luo, 2006). Hashimoto and colleagues also found that targets following negative primes elicited larger LPP than targets following positive primes, but only among participants with large priming effects. The implications of this effect were not discussed.

Unfortunately, the Hashimoto et al. (2012) study was limited in some important ways. First, their sample included only 20 participants who were then split into two groups of 10 based on the size of their behavioral priming effects. Analyses then involved tests at nine different scalp regions, which resulted in considerable instability in the Valence  $\times$  Group effects at each of these regions. A second issue concerns interpretation of their ERP data. The analytic approach taken by Hashimoto et al., in which ERPs elicited by the targets were baseline-corrected using an interval preceding the primes, makes it difficult to isolate psychological responses to the targets. In particular, visual inspection of their Figure 4 suggests that apparent differences in target-related ERP amplitudes reflect a carryover from the LPP elicited by the primes (i.e., voltage

differences preceding target onset were carried through to the target-locked response).

The appropriate baseline in serial presentation paradigms remains an unresolved issue (Flaisch, Junghöfer, Bradley, Schupp, & Lang, 2008; Urbach & Kutas, 2006). However, we believe that baseline correcting just prior to each imperative stimulus (i.e., separately for primes and targets) is more appropriate for understanding the AMP, in that this approach permits inferences regarding target processing that are not confounded with prime-elicited responses. Specifically, if target-locked ERPs are baseline corrected using a target-preceding interval, any differentiation in target-related responses can be attributed to psychological effects of the primes on target processing that are distinct from carryover in physiological responses elicited by the primes. This inference cannot be made using a baseline that precedes prime onset. While the AMP is thought to measure affective content that is psychologically carried over from the primes to the targets, it is not clear that a corresponding analogy should be applied to ERP responses. Indeed, as reviewed by Urbach and Kutas (2006), selecting the time immediately prior to a given event as the baseline is critical in order to separate out the causal consequences of that event from other, previously occurring factors. Applied in the current context, this means that determining effects of manipulated conditions on target-locked ERPs in the AMP critically depends upon the use of a baseline that occurs just prior to the target.

### The Present Study

The present study used ERP methods to clarify the extent to which misattribution of affect from primes to subsequent targets occurs in the AMP. The sensitivity of the EPN, P2, and LPP to the motivational salience of visual stimuli can be leveraged to index the extent to which primes and targets activate underlying motivational intensity or affect, which ostensibly are responsible for AMP priming effects. While the deliberate prime rating theory of AMP effects reviewed previously is consistent with prime-elicited affect, it is difficult to see how the account could be consistent with the presence of target-elicited affect as a function of the valence of a previously presented prime. If participants simply treat the target Chinese ideographs as a signal to report evaluations of the prime images, there is no reason to expect ERP responses to the targets to vary according to the affective valence of the primes because that affective categorization would already have happened (i.e., in response to the primes). Instead, if the valence of the primes implicitly influences the evaluative categorization of the targets, then the ERPs to the targets themselves should differentiate the valence of the primes.

Further, it is integral to the notion of affect misattribution that affect should be transferred from the primes to the targets. Thus, the affect misattribution theory of AMP effects predicts not only that targets are processed differently as a function of prime valence (Hashimoto et al., 2012) but that this differential processing should mirror the processing of the primes themselves. In other words, patterns of valence effects in the prime-locked ERP should be similar to patterns in the target-locked ERPs. The present study tests these hypotheses by testing whether amplitudes of the EPN, P2, and LPP vary as a function of valence similarly for primes and targets.

Additionally, we investigated whether valence effects reflected in the ERPs were associated with the strength of the AMP effect reflected in the behavioral data. An association between valence effects in the ERPs and the behavioral priming effect would provide evidence that the psychological processes indexed by the

ERPs are contributing to the AMP behavioral effects. If ERPs elicited by targets differ as a function of prime valence, an association between ERPs and behavioral responses would provide evidence that the differential motivational significance of the targets is contributing to behavioral evaluations.

## Method

### Participants

Sixty-nine undergraduates (37 women) enrolled in introductory psychology participated in the study in exchange for partial course credit. Criteria for eligibility required that participants have no history of brain injury or serious head trauma, not be bald or wear a hairstyle that might interfere with attachment of scalp electrodes (e.g., cornrows, weaves, dreadlocks, etc.), and not be able to read Chinese ideographs. Five participants were excluded from analyses based on poor EEG recording quality or excessive movement artifacts, leaving the final sample for those analyses at 64.

### Materials and Tasks

**AMP.** Each trial consisted of a 250-ms blank screen, followed by a prime image displayed at the center of the screen for 500 ms. Next, a blank screen was presented for 500 ms followed by the target ideograph for 750 ms.<sup>1</sup> The target was then replaced by a blank screen during which participants responded to the preceding ideograph; no response deadline was imposed. All stimuli were presented on a white background. Participants were instructed to “do nothing” with the prime picture and to indicate whether the Chinese character was “relatively pleasant or unpleasant” by pressing one of two keyboard keys (*z* and */*). Response mapping was counterbalanced across participants. Instructions also told participants to “make your judgments FAST, based on your gut reaction.” The task took roughly 14 min to complete.<sup>2</sup>

The primes consisted of 12 pictures (all approximately 300 × 230 pixels) selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). On the basis of the normative data reported by Lang and colleagues, using valence and arousal scales anchored at 1 (*very negative* and *very calm*, respectively) and 9 (*very positive* and *very arousing*, respectively), four of the pictures (puppies, kittens, a rabbit, and a seal) were considered positive ( $M_{\text{valence}} = 7.95$ ;  $M_{\text{arousal}} = 5.94$ ), four were negative (a snarling dog, cockroach, angry bear, and spider;  $M_{\text{valence}} = 3.76$ ;  $M_{\text{arousal}} = 5.94$ ), and four were neutral (rolling pin, towel, basket, and stool), with valence ratings near the scale midpoint ( $M_{\text{valence}} = 4.85$ ;  $M_{\text{arousal}} = 2.34$ ).<sup>3</sup> These specific images were chosen to ensure consistency with previous AMP studies (see Scherer & Lambert, 2009, 2012). The AMP consisted of 324 trials (27 presentations of each of the 12 primes). The targets consisted of 80 Chinese ideographs, which were randomly presented without replacement for each cycle of 80 trials (Payne et al., 2005; downloaded from <http://bkpayne.web.unc.edu/research-materials/>).

1. These durations are much longer than the 75-ms prime and 125-ms blank screen that are typical of the AMP (see Payne et al., 2005). This change was necessary to permit separation of the EEG responses elicited by primes versus targets.

2. The AMP was preceded by a different task that is not reported in the present paper. The hypotheses guiding this excluded task are separate from the theoretical concerns addressed here.

3. The IAPS picture numbers for the images used in this study were as follows: positive images = 1440, 1463, 1610, 1710; negative images = 1220, 1270, 1300, 1321; neutral images = 7002, 7025, 7175, 7010.

**Electrophysiological Recording.** The EEG was recorded from 28 silver/silver chloride (Ag/AgCl) electrodes placed according to the expanded 10/20 electrode placement system using an electrode cap (Electro-Cap International, Eaton, OH). The online recording was referenced to the right mastoid, with an average mastoid reference derived offline. Recordings were amplified with a Neuroscan Synamps amplifier (Compumedics, Charlotte, NC) and filtered online at .01 to 30 Hz with a sampling rate of 1000 Hz. Eye movements were recorded with bipolar electrodes placed about 2 cm lateral to each outer canthus (saccades) and additional electrodes placed about 1 cm above and below the left eye (blinks). Blinks were removed from the EEG using a regression-based procedure (Semlitsch, Anderer, Schuster, & Presslich, 1986). Both prime-locked and target-locked epochs of  $-100$  to  $1,000$  ms poststimulus were defined for each trial. Epochs containing voltage deflections of  $\pm 75$  microvolts ( $\mu\text{V}$ ) or linear drifts of more than  $50 \mu\text{V}$  were eliminated. Trials were then averaged according to electrode and stimulus conditions separately for prime-locked and target-locked epochs. The average number of trials included in each average per participant was 249 and 251 for primes and targets, respectively. On average, the number of trials as a function of valence (positive, negative, neutral) was equal across subjects.

### Analytic Approach

**Behavioral responses.** Given the inherent nonindependence in AMP responses (owing to systematic interindividual and interstimulus variability), logistic hierarchical linear modeling (HLM) was used to account for these stable patterns of variability while taking advantage of the large number of responses acquired for each participant (Baayen, Davidson, & Bates, 2008). The model contained random effects of subject (64 total), prime (IAPS pictures: 12 total), and target (ideographs: 80 total) with intercepts allowed to vary for each effect. The primary independent variable of interest—valence (positive, neutral, negative)—was included as a fixed effect. We expected to replicate the typical AMP effect, in which the targets are more often rated as pleasant following positive primes compared to negative primes, with targets following neutral primes eliciting intermediate ratings (see Payne et al., 2005).

**ERP amplitudes.** Like the behavioral data, all ERP data were analyzed using HLM, which conveys a number of advantages over traditional repeated measures analysis of variance (ANOVA) for analyzing psychophysiological data (Kristjansson, Kircher, & Webb, 2007; Page-Gould, in press). Visual inspection of the stimulus-locked waveforms indicated a negative-going deflection prominent at temporo-occipital electrodes, consistent with the EPN identified in previous research using emotional images (Schupp et al., 2006; Schupp, Schmälzle, & Flaisch, 2014). The EPN was slightly earlier than is typical, emerging around 135 ms, and was measured as the average amplitude 135–180 ms poststimulus at temporo-occipital electrodes P7, P8, O1, and O2. Following the EPN, a posterior, positive-going deflection was observed, consistent with the P2 identified in previous studies (e.g., Freunberger, Klimesch, Doppelmayr, & Höller, 2007; Kanske et al., 2011). Here, the P2 emerged somewhat later than the typical 200–300 ms range, and was measured as the average amplitude 210–350 ms poststimulus at electrodes P7, P3, PZ, P4, P8, O1, and O2.

Finally, numerous studies of emotional picture processing have identified the LPP as a sustained positivity emerging relatively late (after 400 ms) in the stimulus-locked waveform at parietal electrodes (e.g., Ferrari, Codispoti, Cardinale, & Bradley, 2008;

Weinberg, Ferri, & Hajcak, 2013). Visual inspection of the waveforms indicated a deflection occurring around 650 ms following prime onset (see Figure 1), which likely reflects a combination of prime offset and target anticipation effects. Thus, to ensure consistency in the time windows of the LPP across the prime-locked and target-locked waveforms, the LPP was quantified here as the average amplitude 400–600 ms poststimulus at temporoparietal-occipital sites P7, P3, PZ, P4, P8, O1, and O2. This is somewhat more posterior than is typical (see Weinberg et al., 2013), but consistent with Hashimoto et al. (2012) who also found greater indication of the LPP at posterior sites than at central-parietal sites. Prime- and target-locked ERP waveforms depicting the EPN, P2, and LPP as a function of prime valence are given in Figure 1 and 2.

## Results

### Behavioral Data

Analyses revealed a main effect of prime valence,  $F(2,20581) = 33.84$ ,  $p < .0001$ ,  $R^2 < .01$ .<sup>4</sup> As expected, simple effects  $t$  tests indicated that targets were most likely to be rated as pleasant following positive primes ( $M = 0.53$ ,  $SD = 0.40$ ) and least likely to be rated pleasant following negative primes ( $M = 0.44$ ,  $SD = 0.50$ ), with neutral-primed target ratings falling in between ( $M = 0.49$ ,  $SD = 0.50$ ), all  $p$ s  $< .001$ .

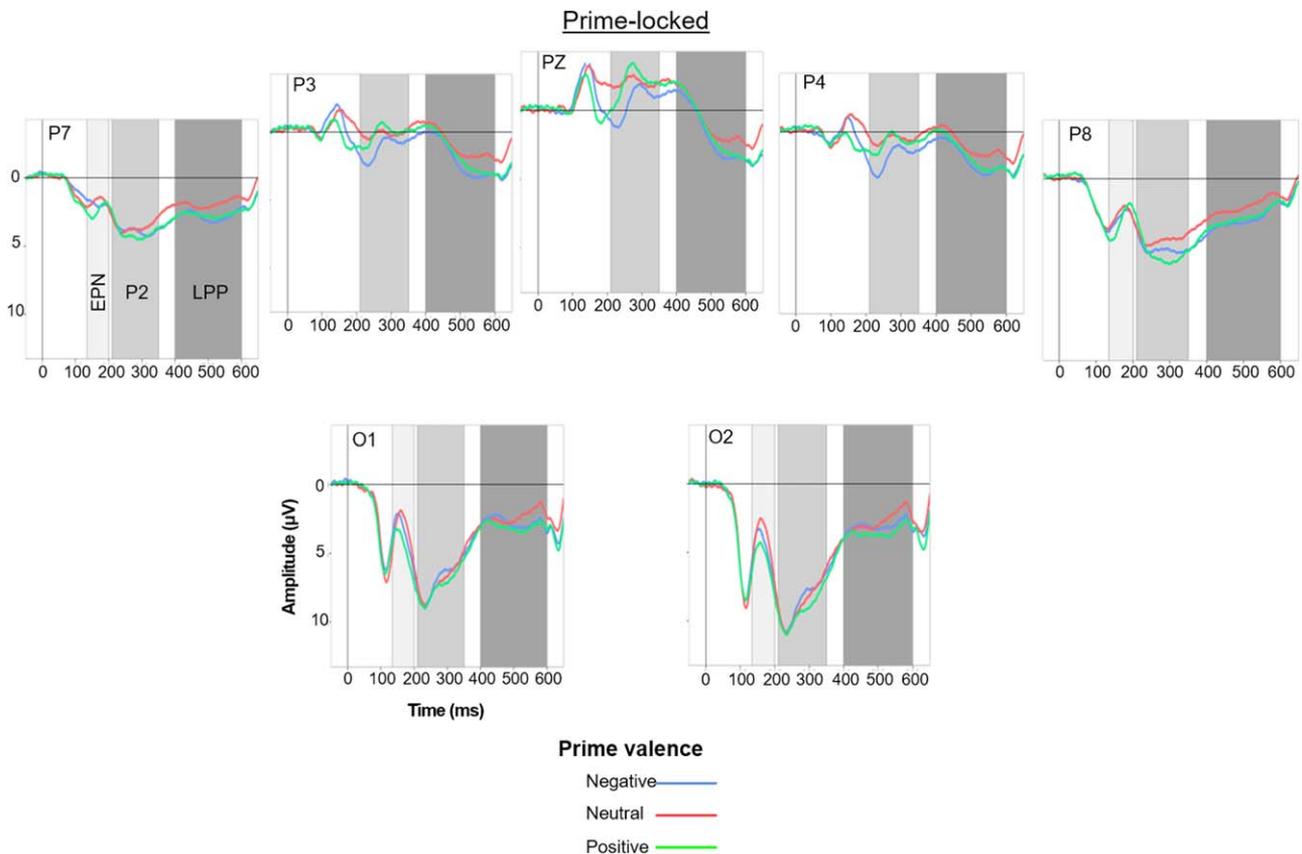
### ERP Data

Prime valence effects (negative, neutral, positive) were examined separately for each component of interest (EPN, P2, LPP) in both the prime-locked and target-locked waveforms, resulting in six HLMs, each modeling random effects of subject and electrode, with electrode nested within subject and intercepts allowed to vary for each effect. Mean ERP amplitudes as a function of component, stimulus type, and prime valence are given in Table 1. The reader should keep in mind that valence in the context of the target-locked amplitudes is determined by the primes that preceded the target ideographs, not the ideographs themselves.

**EPN amplitude.** Analysis of the prime-locked EPN amplitudes indicated a significant main effect of valence,  $F(2,582) = 10.41$ ,  $p < .001$ ,  $R^2 = .02$ . Simple effects tests revealed that the EPN elicited by neutral primes was the largest (most negative) and differed significantly from the EPNs elicited by both positive primes,  $t(582) = 4.52$ ,  $p < .001$ ,  $R^2 = .03$ , and negative primes,  $t(582) = 2.78$ ,  $p = .006$ ,  $R^2 = .01$ . Positive and negative prime EPNs did not differ from each other,  $t(582) = -1.56$ ,  $p = .119$ ,  $R^2 < .01$ .

Analysis of the target-locked EPN amplitudes indicated a marginally significant main effect of valence,  $F(2,582) = 2.78$ ,  $p = .063$ ,  $R^2 < .01$ , reflecting a pattern similar to that seen in the prime-locked EPN. Simple effects tests revealed that the EPN elicited by targets following neutral primes was the largest and differed from the EPN elicited by targets following negative primes,  $t(582) = 2.33$ ,  $p = .020$ ,  $R^2 < .01$ ; the EPN elicited by targets following neutral and positive primes did not differ, however,

4. Denominator degrees of freedom in HLM reflect the nesting of trials (324 per subject) within subjects ( $N = 69$ ), resulting in a much larger denominator than with ANOVA.  $R^2$  is calculated based on the method introduced by Edwards, Muller, Wolfinger, Qaqish, and Schabenberger (2008).



**Figure 1.** ERP waveforms time-locked to the onset of the primes as a function of prime valence. The shaded areas in each figure indicate the time windows during which the EPN, P2, and LPP amplitudes were quantified for analyses. Time zero on the  $x$  axis indicates prime onset; prime offset occurred after 500 ms.

$t(582) = 1.44, p = .150, R^2 < .01$ .<sup>5</sup> As with the prime-locked EPN, positive prime trials and negative prime trials did not differ from each other,  $t(582) = 0.96, p = .149, R^2 < .01$ .

**P2 amplitude.** The model testing prime-locked P2 amplitudes showed a significant main effect of valence,  $F(2,1020) = 7.92, p < .001, R^2 < .01$ . Simple effects tests revealed that the P2 elicited by negative primes was the largest (most positive) and differed from those elicited by both positive primes,  $t(1020) = 2.30, p = .023, R^2 < .01$ , and neutral primes,  $t(1020) = 3.98, p < .001, R^2 = .02$ . Furthermore, the P2 elicited by positive primes was marginally larger than the P2 elicited by neutral primes,  $t(1020) = -1.78, p = .075, R^2 < .01$ .

Analysis of the target-locked P2 amplitudes also showed a significant main effect of valence,  $F(2,1020) = 8.03, p < .001, R^2 = .01$ . As with the primes, simple effects tests revealed that the P2 elicited by targets following negative primes was the largest and differed from the P2 elicited by targets following positive primes,  $t(1020) = 4.01, p < .001, R^2 = .02$ , and targets following neutral primes,  $t(1020) = 2.09, p = .038, R^2 < .01$ . Unlike with the prime-

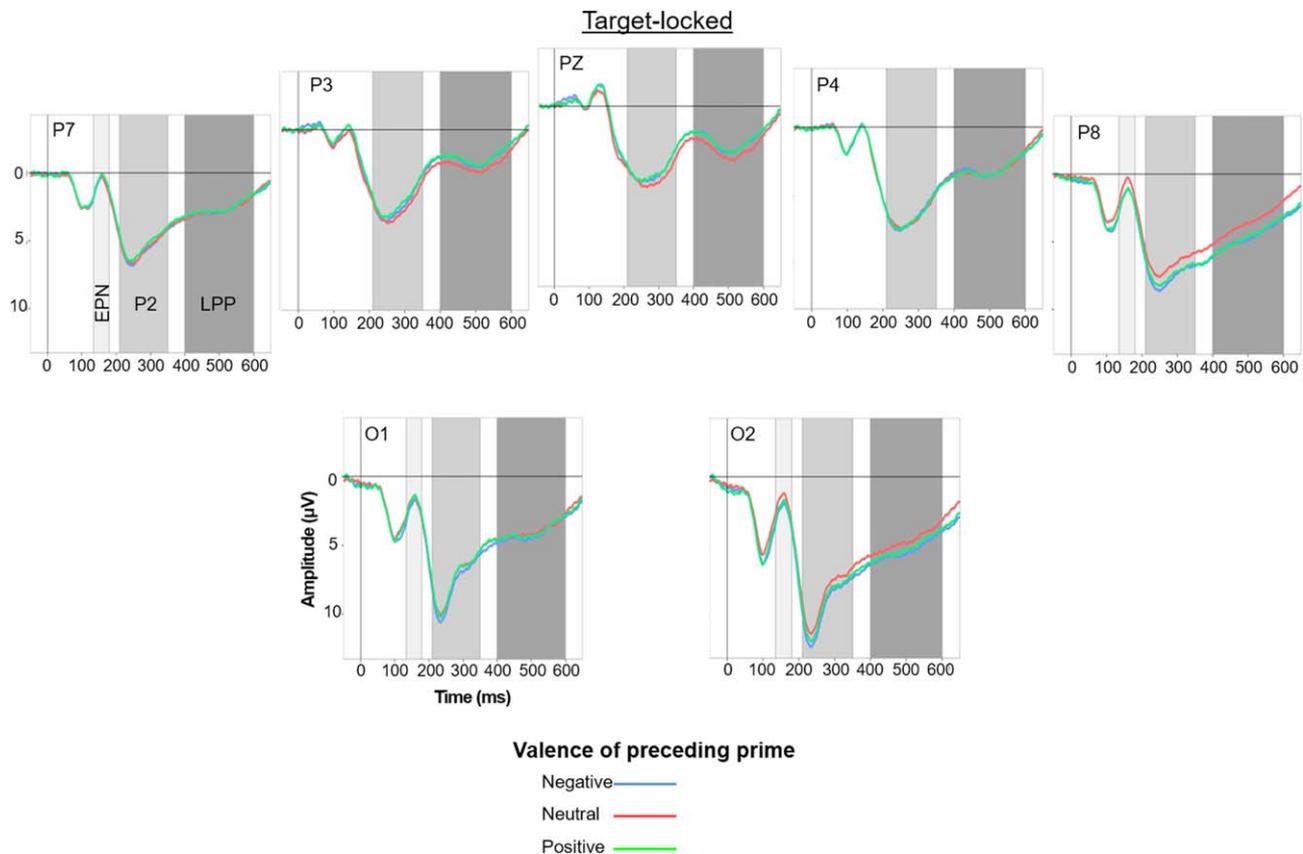
locked P2, the P2 elicited by targets that followed positive primes was smaller than that elicited by targets that followed neutral primes,  $t(1020) = 1.96, p = .050, R^2 < .01$ .

**LPP amplitude.** The model examining prime-locked LPP amplitudes indicated a significant main effect of valence,  $F(2,1020) = 24.47, p < .001, R^2 = .02$ . Simple effects tests revealed that the LPP elicited by neutral primes was smaller (less positive) than the LPP elicited by both negative primes,  $t(1020) = 6.30, p < .001, R^2 = .04$ , and positive primes,  $t(1020) = -5.74, p < .001, R^2 = .03$ , which did not differ from one another,  $t(1020) = 0.81, p = .421, R^2 < .01$ .

Analysis of the target-locked LPP amplitudes indicated a significant main effect of valence,  $F(2,1020) = 5.33, p < .001, R^2 = .01$ . Like the prime-locked data, simple effects tests revealed that the LPP elicited on neutral trials was smaller than the LPP elicited on positive trials at a marginally significant level,  $t(1020) = 1.71, p = .086, R^2 < .01$ . However, unlike the prime-locked waveforms, neutral trials were not smaller than negative trials,  $t(1020) = 1.58, p = .114, R^2 < .01$ , and negative trials were greater than positive trials,  $t(1020) = 3.26, p = .001, R^2 = .01$ .

Although not predicted, visual inspection of the target-locked waveforms (Figure 2) suggests a right-lateralized valence effect in the LPP. Previous research has shown that evaluative categorization (i.e., requiring participants to indicate the pleasantness of a target) produces a more pronounced valence effect in the LPP at right hemisphere relative to left hemisphere parietal locations (e.g., Cacioppo, Crites, & Gardner, 1996), an effect typically not

5. Note that these analyses are based on estimated marginal means, which are adjusted for all terms in the model. While these estimated means were largely similar to the unadjusted means across all analyses, for this test the values for positive and negative primes were inconsistent, with negative trials showing a smaller value than positive trials for the adjusted means but a larger value than positive trials for the unadjusted means. For the adjusted means,  $M = 1.64$  for neutral trials,  $M = 1.83$  for positive trials, and  $M = 1.96$  for negative trials.



**Figure 2.** ERP waveforms time-locked to the onset of the targets as a function of the valence of preceding primes. The shaded areas in each figure indicate the time windows during which the EPN, P2, and LPP amplitudes were quantified for analyses. Time zero on the x axis indicates target onset; target offset occurred at 750 ms.

observed for nonevaluative categorization (see Crites & Cacioppo, 1996). This suggests the possibility that valence effects in the target-locked LPP more closely mirrored valence effects evident in the prime-locked LPP at right hemisphere than at left hemisphere locations. To test this possibility, we ran additional models testing for a Valence  $\times$  Hemisphere interaction using data from lateral parietal sites (P7 on the left, P8 on the right).

The model testing the prime-locked LPP showed only a main effect of valence,  $F(2,351) = 6.72, p = .001, R^2 = .02$ , but no main effect of hemisphere,  $F(1,351) = 0.01, p = .942, R^2 < .01$ , and no Hemisphere  $\times$  Valence interaction,  $F(2,351) = 0.02, p = .976, R^2 < .01$ . As with the analysis including all electrodes, the LPP

**Table 1.** Mean ERP Amplitudes as a Function of Stimulus Type and Prime Valence

Component	Stimulus	Prime valence		
		Negative	Positive	Neutral
EPN	Prime	3.48 (4.56)	3.85 (4.80)	2.94 (4.35)
	Target	1.96 (4.26)	2.09 (4.31)	1.78 (4.24)
P2	Prime	3.88 (5.13)	3.31 (6.60)	3.01 (6.01)
	Target	6.71 (4.29)	5.77 (4.63)	6.21 (4.27)
LPP	Prime	2.75 (2.71)	2.70 (3.06)	2.00 (3.06)
	Target	3.30 (3.92)	2.52 (3.88)	2.90 (3.62)

*Note.* Values in parentheses are standard deviations. Statistical tests reported in the results used estimated marginal means rather than the raw means listed in this table. Any tests where the estimated marginal means differed markedly from the raw means listed here are referenced with a footnote in the manuscript.

elicited by neutral primes was smaller (less positive) than the LPP elicited by both negative primes,  $t(351) = 3.48, p < .001, R^2 = .03$ , and positive primes,  $t(351) = -2.71, p = .007, R^2 = .02$ . The model testing the target-locked LPP showed significant main effects of valence,  $F(2,351) = 3.43, p = .034, R^2 = .01$ , and hemisphere,  $F(1,351) = 61.58, p < .001, R^2 = .15$ , which were qualified by a Hemisphere  $\times$  Valence interaction,  $F(2,351) = 4.27, p = .015, R^2 = .01$ . Follow-up simple effects tests showed no effect of prime valence at the left hemisphere location,  $F(2,144) = 1.34, p = .264, R^2 = .01$ , but a significant valence effect at the right hemisphere location,  $F(2,144) = 6.45, p = .002, R^2 = .04$ . Like the prime-elicited LPP waveforms, follow-up contrasts revealed that the LPP elicited by targets that followed neutral primes were smaller than the LPP elicited by targets that followed both negative primes,  $t(144) = -1.98, p = .049, R^2 < .03$ , and positive primes,  $t(144) = 3.58, p < .001, R^2 = .08$ . Positive trials and negative trials did not differ at a typical statistically significant level,  $t(144) = 1.71, p = .090, R^2 = .02$ .

**ERPs as a function of behavioral priming effects.** To assess whether valence effects in the ERPs were associated with the AMP effect (i.e., behavioral priming), we next investigated the relationship between various indices of the behavioral effect on the prime- and target-locked ERPs. First, we examined whether the strength of the correlations between prime- and target-locked ERP responses depended on whether a trial was consistent with the misattribution effect. To do so, we split trials into two groups. Trials in which a positive prime was followed by a pleasant response to the

**Table 2.** Correlations Between Prime-Locked and Target-Locked ERPs and Tests of Whether They Differ for Valence-Congruent and Valence-Incongruent Responses

		Target-locked				
		EPN	P2	LPP		
Prime-locked						
EPN		.52**	.34**	.43**		
P2		.09**	.61**	.13**		
LPP		.40**	.11**	.34**		
Component	Trial type	<i>b</i>	<i>SE</i>	<i>F</i>	<i>p</i>	
EPN	Congruent	.35	.03	0.04	.841	
	Incongruent	.36	.03			
P2	Congruent	.45	.02	0.62	.433	
	Incongruent	.44	.02			
LPP	Congruent	.15	.03	2.09	.148	
	Incongruent	.19	.02			

Note. *F* and *p* values given in the bottom portion of the table are for difference of slope tests; denominator degrees of freedom for these tests ranged from 861 (EPN) to 1509 (P2 and LPP). Difference of slope tests involved a mixed-model that modeled random effects of subject and electrode.

\*\* $p < .01$ .

subsequent target and trials where a negative prime was followed by an unpleasant response to the target were labeled congruent, whereas positive primes followed by an unpleasant response and negative primes followed by a pleasant response were labeled incongruent. Prime/target correlations for each component (e.g., prime P2/target P2 correlation) were compared as a function of the two-level congruency variable. Results are described in Table 2. While prime and target responses were correlated for each of the three ERPs, these correlations did not differ as a function of whether trials were consistent with a priming effect. To follow through with the exploratory analyses of hemispheric differences in the LPP, we also tested whether the correlation difference between congruent and incongruent trials differed as a function of hemisphere. Results did not indicate a significant prime LPP  $\times$  Congruency  $\times$  Hemisphere interaction,  $F(1,489) = 0.04$ ,  $p = .838$ ,  $R^2 = .01$ .<sup>6</sup>

## Discussion

The current research sought to examine the legitimacy of the claim that priming effects measured by the AMP operate through a process of affect misattribution. This account has been challenged by theories that attribute priming effects to participants who violate task instructions by explicitly rating the primes (Bar-Anan & Nosek, 2012). We investigated these contrasting views by analyzing three ERP components sensitive to affect and the motivational salience of visual stimuli. We reasoned that similarity in prime valence effects between the prime-locked and target-locked ERPs would provide evidence of affective transfer from the valenced primes to the otherwise affectively neutral targets (i.e., affect misattribution). If, instead, participants merely treat the Chinese ideographs as imperative stimuli signaling the moment to indicate their judgments of the prime images, then the valence of the primes

should not influence the affective/motivational processing of the targets (Hashimoto et al., 2012).

Results revealed that both the prime-locked and the target-locked EPN, P2, and LPP amplitudes differed as a function of prime valence. For the targets, the EPN was the largest (most negative) on neutral trials, whereas the P2 and LPP were the largest on negative trials. Additionally, for the P2 and LPP, neutral trials elicited larger amplitudes than positive trials. These findings are consistent with the notion that the inherent motivational relevance of the primes has an influence on the processing of the otherwise inherently neutral targets.

An affect misattribution account also assumes that it is by virtue of the affective, evaluative content of the prime stimuli that the targets assume some of the properties of the valenced prime images. Thus, not only are the targets expected to be imbued with varying degrees of motivational relevance, this motivational relevance should be similar to that of the previous prime. The results were mixed with respect to this issue, showing some similarities and some divergences between the prime-locked and target-locked ERPs (see Table 1). For the EPN, the relationship between the positive, negative, and neutral primes was maintained for the targets, though with some variation in the magnitude of valence differences. For the P2, negative trials elicited the largest amplitudes for both primes and targets; however, whereas positive primes elicited larger amplitudes than neutral primes (as expected), this relationship reversed for the targets (i.e., neutral-primed targets elicited larger amplitude than positive-primed targets). The LPP showed the least similarity across primes and targets overall, except that neutral trials elicited smaller amplitudes than positive trials for both stimuli.

However, exploratory analyses of hemispheric lateralization effects in the LPP revealed greater similarity between prime-locked and target-locked responses over right hemisphere compared to left hemisphere electrodes. Consistent with previous research comparing evaluative and nonevaluative categorizations (Cacioppo et al., 1996; Crites & Cacioppo, 1996), valence effects in the target-locked responses were more evident over the right hemisphere than the left hemisphere (which was not the case for prime-locked responses), and valence effects between prime-locked and target-locked LPPs were more similar at right hemisphere locations. This lateralization of valence effects in the LPP provides additional evidence for the affective priming explanation of the AMP (also see Hashimoto et al., 2012), both because the association between prime-locked and target-locked LPP responses is larger over the right hemisphere, as would be expected if stimulus valence effects are thought to be more evident at those locations (Cacioppo et al., 1996), and because lateralization in the target-locked but not the prime-locked LPP supports the idea that participants were evaluatively categorizing the targets, as they were instructed to do, but were not overtly categorizing the primes.

Beyond consideration of the lateralization of valence effects in the target-elicited LPP, these data are notable simply for indicating that an inherently nonsalient stimulus like the Chinese ideographs used here can produce patterns of LPP responses akin to what numerous studies have reported for inherently emotional images. Specifically, at least over right hemisphere locations, the target-locked LPP was larger to targets preceded by negative and positive primes than targets preceded by neutral primes, consistent with dozens of reports indicating larger LPPs to valenced than to neutral visual cues (e.g., Codispoti et al., 2006; Delplanque et al., 2006; Gable & Harmon-Jones, 2010; Hajcak & Olvet, 2008; Weinberg & Hajcak, 2010). These findings suggest that the targets acquired some of the motivational properties of the primes. The fact that

6. We also examined the prime ERPs and target ERPs separately as a function of congruency (not their correlations). None of these tests revealed a difference as a function of congruency. In addition, we also computed two forms of a continuous measure of behavioral priming effects, and correlated these values separately with the prime ERPs and target ERPs. Results, again, did not indicate a relationship between the behavioral and ERP data.

amplitude values of each component were larger in response to the targets than to the primes also supports the idea that participants treated the targets as task relevant, while the inherently emotional prime stimuli were viewed as less so.

Nevertheless, the utility of the ERP data for understanding the behavioral AMP effect in this study is limited by the fact that there was no evidence of any association between ERPs and behavior. That is, although prime-locked and target-locked ERPs correlated with one another in a manner consistent with affect misattribution, there was no evidence that valence effects in the ERPs corresponded to priming effects in behavioral classification of targets. Moreover, the magnitude of prime-locked and target-locked ERP correlations did not vary as a function of whether trials were consistent with a priming effect, as might be expected if the behavioral priming effect is a direct reflection of the processes represented by these neurophysiological responses. Thus, more research will be needed to understand the neural locus of AMP priming effects as manifest in behavioral responses to targets.

With respect to understanding the mechanism(s) driving AMP priming effects, it need not be the case that only one of the proposed explanations is correct. As in most AMP studies, here we interrogated the data primarily at the level of valence condition averages. It is possible, however, that at the level of individuals trials (within or between subjects) different processes are operating to differing degrees. The intentional prime-rating account put forward by Bar-Anon and Nosek (2012) posits only that a subset of individuals in a given study violate task instructions and explicitly rate the primes. This does not preclude the possibility that other individuals truly experience affect misattribution. Applied to the current data, this possibility suggests that the ERP averages we examined reflect combinations of trials (within individuals) and strategies (across individuals) arising from different causal mechanisms. Indeed, it seems likely that a small subset of individuals in the current sample overtly rated the primes rather than the targets. Inspection of the behavioral data showed five participants who experienced extremely large priming effects, responding in a valence-congruent manner on over 90% of the trials. If extreme values like these reflect intentional rating of the primes, then a subsequent reduction in affect misattribution to the targets would be expected, which could account for the lack of correspondence between the behavioral and ERP data.

Some additional consideration of the EPN data from this study is warranted, given that EPN amplitudes were larger on neutral-primed trials than on either positive- or negative-primed trials. This finding is inconsistent with most previous EPN studies, which typically report the opposite (i.e., larger EPN to valenced than to neutral stimuli; see Junghöfer et al., 2001; Schupp, Junghöfer, Weike, & Hamm, 2004; Schupp et al., 2006). Further, other previous studies have found either no effects of affective context on the EPN (Schupp, Schmäzle, Fleisch, Weike, & Hamm, 2013), or found that presentation of emotional pictures leads to reduced EPN (and LPP) amplitudes to subsequently shown pictures regardless of their valence (Fleisch, Stockburger, & Schupp, 2008). These findings

have been attributed to sustained attentional interference across successive picture presentations. Here, affective modulation of the primes led to similar affective modulation in the target-locked EPN, indicating some facilitation in processing rather than an interference effect. It seems likely that differences in participants' goals and structural features of the tasks could account for these discrepant sets of findings, but additional research would be needed to better understand these differences.

In addition, the negativity referred to as the EPN here emerged earlier (~135 ms) than what is generally reported (~200 ms; see Schupp et al., 2006, 2007), which, together with the unusual valence effect found here, could raise some doubt as to whether this negativity is indeed the EPN. However, a closer examination of the extant literature suggests considerable heterogeneity in the EPN. For example, one previous study shows an early negativity (prior to the EPN) that appears to be larger for neutral than for emotional pictures, consistent with the present data (Schupp et al., 2007). Additionally, the time window that was quantified as the EPN in the previously mentioned study looks much more like a large positivity in response to neutral images that was absent for valenced images. At least one other EPN study also appears to have captured what looks like a positivity during the EPN window (Schupp et al., 2013), while another quantified the EPN over both a negativity and a positivity (Junghofer et al., 2001). Finally, another study quantified amplitudes over three different windows (P1: 88–152, N1: 160–224, and N2: 232–292 ms), referring to all of them as “EPN analyses.” Thus, it seems that the timing and morphology of early negative-going deflections elicited by emotional versus neutral images varies considerably across paradigms, suggesting the need for more refinement in what is considered an EPN.

In sum, the current study provides some neurophysiological support for the validity of the AMP as a measure of affect misattribution. Contrary to what would be expected if participants intentionally rate the primes and effectively ignore or discount the targets, three ERP components known to be associated with the motivated guidance of attention varied in response to targets as a function of prime valence. Furthermore, ERP differences found in response to the targets shared similarities with the ERPs elicited by the primes, although some differences between primes and targets also were evident. The presence of valence differentiation in both the prime-locked and the target-locked ERPs, along with the similarity in this differentiation, lends neurobiological support for the claim that the affective content of the primes is psychologically registered, and that this content influences the processing of the subsequent, evaluatively ambiguous targets, both of which are required if the priming effects found in the AMP are the result of affect misattribution. Nevertheless, this evidence should be interpreted with caution since the behavioral priming effect was not associated with the prime-locked or target-locked ERPs, or the prime-target ERP correlations. The presence of such associations would provide a stronger reason to believe that the valence differentiation found in the target-locked ERPs is driving the behavioral priming effect.

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(RECEIVED November 16, 2015; ACCEPTED September 13, 2016)