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Running Head: AFFECTIVE PRIMING AND RESPONSE CONFLICT

Psychophysiological Evidence of Response Conflict and Strategic Control of Responses in

Affective Priming

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## Abstract

This experiment investigated the role of conflict in the response and evaluative categorization systems in the affective congruency effect using event-related brain potentials (ERPs).

Participants completed a primed evaluative decision task in which the proportion of congruent to incongruent trials was manipulated. The size of the affective congruency effect increased along with the proportion of congruent trials. ERP data identified the locus of this effect in the response system: the lateralized readiness potential (LRP) showed that preferential response activation occurred in motor cortex following prime onset, and the fronto-central N2 (conflict monitoring) component indicated that conflict occurred when the response activated by the prime differed from the target response, irrespective of the affective congruency of the prime and target. The extent of this conflict covaried with strategic processing of primes, as participants directed less attention to primes that were likely to elicit conflict. These data support a response conflict account of affective congruency effects in the evaluative decision task and indicate that strategic control of attention is important in determining the extent to which conflict occurs.

Key words: affective priming, affective congruency, response conflict, categorization, event-related potentials, ERPs, lateralized readiness potential

When attitudes or their associated evaluations are activated they have a pervasive effect on decisions and social judgments (see Fazio, 2001). Experimentally, this phenomenon has been demonstrated with various affective priming tasks, in which a valenced prime stimulus precedes a target stimulus that must be classified as either positive or negative (i.e., evaluative decision tasks). As first demonstrated by Fazio, Sanbonmatsu, Powell, and Kardes (1986), targets are categorized more quickly when the prime and target are affectively congruent than when they are affectively incongruent (for a review see Klauer & Musch, 2003). Moreover, at least under some conditions, affective congruency effects occur in ostensibly nonevaluative tasks, such as lexical decision tasks (e.g., Hermans, Smeesters, De Houwer, & Eelen, 2002; Wentura, 1998) and word pronunciation tasks (Bargh, Chaiken, Raymond, & Hymes, 1996; Hermans, De Houwer, & Eelen, 1994).

Early explanations of the affective congruency effect (e.g., Fazio et al., 1986; see also De Houwer & Hermans, 1994; Hermans et al., 1994) focused on spreading activation processes similar to those occurring in semantic priming (e.g., Neely, 1977). Recently, many researchers have instead conceptualized the effect in terms of conflict, although the potential source(s) of this conflict are debated. Klauer and Musch (2003) argued that conflict-like effects in affective priming can stem from synergy and conflict in both response tendencies and in the evaluative categorization process (see also Klauer, Musch, & Eder, 2005). Both are plausible mechanisms, given theory and research indicating that cues that provide information relevant to an upcoming stimulus can act on both stimulus evaluation and response activation (e.g., Gehring, Gratton, Coles, & Donchin, 1992; Meyer, Yantis, Osman, & Smith, 1985; Requin, 1985).

In general, the response conflict model proposes that both primes and targets activate response tendencies (see Wentura & Rothermund, 2003). On congruent trials primes and targets

activate the same response tendency, whereas on incongruent trials primes and targets activate opposing response tendencies. Thus, target responses on congruent trials are facilitated, relative to incongruent trials, because the correct target response is partially pre-activated by the prime. In contrast, on incongruent trials the response activated by the prime conflicts with the correct target response, thus slowing its execution. Evidence from several studies supports this model (e.g., De Houwer, Hermans, Rothermund, & Wentura, 2002; Gawronski, Deutsch, & Seidel, 2005; Klauer & Musch, 2002; Klinger, Burton, & Pitts, 2000; Wentura, 1999).

However, other work suggests that the evaluative categorization process might be responsible for the effect. For example, Abrams, Klinger and Greenwald (2002) found that the affective congruency effect occurred in a subliminal priming paradigm regardless of whether target words were assigned to the same or to the opposite response key during the testing and practice phases. More recently, Klauer et al. (2005) attempted to separate so-called “central” priming (i.e., facilitation and inhibition of target responses during categorization) from response-related priming using a double-dissociation task. Their data revealed priming in both central and response-related processes, though response-related priming effects were much larger than central priming effects.

On the whole, then, the extant literature provides mixed support for a locus of conflict-related affective priming effects in evaluative categorization (e.g., Abrams et al., 2002; Klauer et al., 2005) and response-related processes (e.g., DeHouwer et al., 2002; Wentura, 1999; see also Spruyt, Hermans, De Houwer, Vandromme, & Eelen, 2007). Given that both hypothesized mechanisms ultimately have neural sources, augmenting traditional behavioral measures with a brain-based measure could help to disentangle their relative contributions to affective congruency effects. Neural measures have been incorporated in two recent studies of affective

priming (Li, Zinbarg, Boehm, & Paller, 2008; Zhang, Lawson, Guo, & Jiang, 2006), but these studies were not focused on investigating the influence of the categorization or response systems. Separating categorization and response processes with behavioral data alone is difficult because behavioral responses represent the cumulative output of both of these systems (and others). This issue can be problematic even in tasks designed to separate responses emanating from different stages of processing, as such tasks tend to assume a serial, discrete-stage model of the information processing system that often is not supported (see Coles, Smid, Scheffers, & Otten, 1995).

#### *Neural Measures of the Categorization and Response Systems*

Fortunately, relative involvement of the categorization and response systems can be distinguished by measuring specific components of the event-related brain potential (ERP). The ERP represents a direct and temporally precise measure of the electrical activity of the brain associated with information processing (see Fabiani, Gratton, & Federmeier, 2007). A number of ERP components (positive and negative deflections in the ERP waveform) have been associated with particular information-processing operations. In general, variation in the amplitude of a given component reflects variation in the level of engagement of the information-processing operation(s) it is thought to represent, while variation in component latency reflects the timing with which those operations are carried out (see Rugg & Coles, 1995).

Three ERP components are of primary interest in this research (see Table 1). First, the latency of the P3 (or P300) component is thought to reflect the speed or ease with which evaluative categorization occurs. Considerable research shows that the latency at which the P3 peaks increases as stimulus evaluation becomes more difficult (e.g., Kutas, McCarthy, & Donchin, 1977; McCarthy & Donchin, 1981; see also Coles et al., 1995). Thus, on the basis of

the central priming view (see Klauer et al., 2005), if the evaluative category of the target differs from that of the prime, categorization of the target would be expected to be more difficult, thus leading to slower P3 latency than if the target and prime share an evaluative category.<sup>1</sup>

Two ERP components are useful for determining the extent to which conflict in response processes occurs in affective priming. First, the lateralized readiness potential (LRP) indexes neural activity in pre-motor and motor areas of cortex (see Brunia, 1988; Requin, 1985) associated with preparing and generating behavioral responses (see Coles, 1989; Coles et al., 1995). Specifically, as a participant prepares to make a particular behavioral response, a negativity develops in the ERP that is maximal at central scalp locations contralateral to the responding hand (reflecting the contralateral organization of motor cortex). For example, as a participant prepares to make a left-hand response, the “readiness potential” (see Kornhuber & Deecke, 1965) will be largest over the right side of the scalp, its amplitude directly reflecting how strongly the response is activated (see Coles, 1989). (Additional details about calculation of the LRP are given in the Method section and in footnote 5.) Unlike behavioral measures that provide a discreet index of response output, the LRP provides a dynamic measure of response activation over time. Thus, in tasks in which a target stimulus is preceded by a warning cue or prime, the LRP can be used to determine whether and to what extent a response is activated by the prime prior to the onset of the target (see Gratton et al., 1990). Moreover, in tasks involving 2 response options mapped to opposite hands, the polarity of the LRP reveals which response (e.g., correct or incorrect) is activated by the warning or prime stimulus. In this way, the LRP can be used to determine whether a response activated by a given prime will conflict with the response required by a given target.

An additional component, the N2 (or N200), consistently has been linked to the hypothesized conflict-monitoring function of the anterior cingulate cortex (see Botvinick, Braver, Barch, Carter, & Cohen, 2001; van Veen & Carter, 2002a). The N2 tends to be larger on trials involving conflict between competing response representations, such as incongruent color-word trials in the Stroop task (e.g., Liotti, Woldorff, Perez, & Mayberg, 2000). Moreover, previous work indicates that the N2 is enhanced on trials involving competing response activations but not on trials involving conflict in stimulus categorization (van Veen & Carter, 2002b; van Veen, Cohen, Botvinick, Stenger, and Carter, 2001; but see Wendt, Heldmann, Münte, & Kluwe, 2007), that N2 amplitude covaries with the degree of incorrect response activation measured via muscle movement (Kopp, Rist, & Mattler, 1996), and that the N2 emanates from the anterior cingulate cortex (Liotti et al., 2000), a region thought to be specifically sensitive to response-related conflict as opposed to conflict in other processes (e.g., Lui, Banich, Jacobsen, & Tanabe, 2006; Milham & Banich, 2005; Milham et al., 2001). The N2 also often is larger on trials requiring a low-frequency response (e.g., Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003), presumably because activating the correct response on such trials conflicts with the (prepotent) response activated by more frequently-occurring trials (see Jones, Cho, Nystrom, Cohen, & Braver, 2002).

The combination of LRP and N2 measures used here therefore provides a particularly sensitive assessment of the extent to which response conflict occurs in affective priming. Any preferential response activation following prime onset (and prior to target onset) will be evident in the amplitude and polarity of the LRP. To the extent that such response activation conflicts with the response required by a target, the N2 should be enhanced following target onset. Additionally, the relative independence of the P3 and LRP components can help to further

disentangle conflict occurring in response-related and evaluative categorization processes. The P3 is believed to be independent of response-related processes, sensitive primarily to stimulus categorization (e.g., Crites, Cacioppo, Gardner, & Berntson, 1995; Magliero, Bashore, Coles, & Donchin, 1984; McCarthy & Donchin, 1981). In contrast, the LRP represents a relatively pure measure of response activation irrespective of stimulus evaluation parameters (see Coles et al., 1995). These distinctions are supported by a number of studies demonstrating that the P3 and LRP are differentially sensitive to categorization and response-related processes, respectively (e.g., Gratton, Coles, & Donchin, 1992; Smid, Lamain, Hogeboom, Mulder, & Mulder, 1991; Smulders, Kok, Kenemans, & Bashore, 1995).

#### *Probability and Information-Processing Strategies*

Cognitive scientists have long been interested in how probability information is used to modulate behavior (e.g., Hick, 1952; Hyman, 1953; see also Requin, Brener, & Ring, 1991). Typically, target response time decreases as the likelihood of a particular target increases, presumably because the probability information allows response preparation to occur prior to the onset of the target stimulus (see Gehring et al., 1992). To date, effects of probability information on the affective congruency effect have been tested in two published studies (Klauer, Rossnagel, & Musch, 1997; Spruyt et al., 2007), both of which showed that the effect increased along with the proportion of congruent trials.

Existing models attribute such moderator effects to strategic allocation of attention between relevant (i.e., target identification) and irrelevant (i.e., prime identification) aspects of stimulus processing. For example, in explaining their results, Klauer et al. (1997) adapted Logan and Zbrodoff's (1979) idea that participants strategically attend to cues in proportion to their validity in predicting the target. In essence, these authors posited that participants process prime

information more deeply when the proportion of congruent trials is either above or below chance level (cf., Spruyt et al, 2007). Gratton et al. (1992) proposed a somewhat different model of strategic attention control to explain probability effects in conflict-related tasks, theorizing that participants strategically control their attention away from information that is likely to elicit conflict. According to this view, in the context of an evaluative decision task participants should limit their processing of prime information when the probability of incongruent trials is high (i.e., when the prime is likely to be associated with a different response than the target). In the current experiment, ERP measures of prime processing were used to test these models.

ERPs also are useful here in determining the extent to which probability information influences target processing. Specifically, the amplitude of the P3 component is highly sensitive to probability, increasing to a given stimulus as the subjective probability of its occurrence decreases (e.g., Duncan-Johnson & Donchin, 1977; Squires et al., 1976). This property of the P3 provides a means of testing whether target processing is based primarily on incongruence between the evaluative category of the target relative to the prime, as suggested by some theorists (e.g., Klauer et al., 2005), or instead is determined primarily by whether the category of a given prime accurately predicts the category of a given target, regardless of whether prime and target are from the same affective category.

### *The Current Research*

The current research had two main goals: (1) to test the role of conflict in response versus evaluative categorization processes in affective priming, and (2) to test differing models of the use of probability information in the strategic control of responses. Participants completed an evaluative decision task in which the proportion of congruent trials was manipulated across trial blocks. The affective congruency effect was predicted to increase along with the proportion of

congruent trials (Klauer et al., 1997; Spruyt et al., 2007). This hypothesis was based on the notion that participants will strategically control their attention away from prime information that is likely to elicit conflict (Gratton et al., 1992). The tenets of the response conflict hypothesis would be supported by response activation following prime onset reflected in the LRP that depends upon the relative probability of congruent and incongruent targets, and, in a related manner, by enhancement of the N2 component to targets requiring a response opposite the one activated by the prime. In contrast, if congruent trials are facilitated relative to incongruent trials because the prime pre-activates the evaluative category needed to correctly identify the target (e.g., Abrams et al., 2002; Klauer et al., 2005), P3 latency should be slower on incongruent relative to congruent trials. Moreover, if the affective congruency effect stems from automatic activation of evaluative categories, the probability manipulation should not moderate this effect (see Klauer et al., 1997; Spruyt et al., 2007).

## Method

### *Participants*

Forty undergraduate students (20 women) at a large, Midwestern university completed the experiment for partial course credit. All were native English speakers, had normal or corrected-to-normal vision and reported no major medical or psychiatric conditions or history of head injury. To avoid differences in electrophysiological responses resulting from differences in brain laterality, participants were all right-handed (Oldfield, 1971).

### *Materials*

All primes and targets were positive and negative English words chosen from the Affective Norms for English Words stimulus set (ANEW; Bradley & Lang, 1999). As detailed by Bradley and Lang, undergraduate respondents in their study used a self-assessment manikin to

rate the valence of each word by selecting one of 9 figures ranging from smiling and happy to frowning and unhappy, and used a separate set of 9 figures, ranging from wide-eyed and excited to sleepy and relaxed, to rate the arousal of each word. These ratings were then converted to numerical 9-point scales (for valence, 1 = *very negative* to 9 = *very positive*; for arousal, 1 = *very calm* to 9 = *very aroused*). In the current study, the primes were 10 positive (valence  $M = 8.0$ ; arousal  $M = 6.5$ ) and 10 negative (valence  $M = 1.9$ ; arousal  $M = 6.5$ ) verbs, and the targets were 10 positive (valence  $M = 7.6$ ; arousal  $M = 5.7$ ) and 10 negative (valence  $M = 2.8$ ; arousal  $M = 5.6$ ) nouns. Based on data reported by Kučera and Francis (1967), the mean usage frequency of the primes and targets, respectively, was 38.1 (median = 10.0) and 61.5 (median = 6.0) occurrences per million words.<sup>2</sup> Selection of primes and targets was based on length (all 4-6 letters long), distinction in valence and similarity in arousal. Table 2 presents the prime and target words used here, along with their arousal and valence ratings and ANEW word numbers.

The evaluative decision task used here consisted of two kinds of trials, which we refer to as “target” trials and “prime-only” trials. On target trials (70% of all trials), a prime word was presented for 200ms, followed by a 50ms blank screen prior to the onset of the target word (i.e., SOA = 250 ms). Participants’ task was to categorize each target as positive or negative by pressing one of two buttons with their left or right index fingers (counterbalanced across participants). Target words remained onscreen until a response was made, or for 3 sec, after which the next trial began following an inter-trial interval of 1000, 1250 or 1500 ms (varying randomly). Prime-only trials (30% of all trials) consisted only of a prime word presented for 200 ms. Participants were instructed to do nothing on prime-only trials and to simply wait for the next trial to begin. These trials were included because ERP activity elicited by primes overlaps with activity elicited by targets on target trials. In order to properly characterize target-related

ERPs, it is necessary to record activity associated with primes alone, which later can be subtracted from the ERPs elicited on target trials. The resulting difference waveforms represent processing of targets corrected for overlapping prime processing effects. Additionally, prime-only trials permit examination of prime processing that is not confounded by overlapping target-related ERP activity.<sup>3</sup>

The task was divided into 6 blocks of 80 trials each (56 target trials, 24 prime-only trials). The probability of positive and negative targets (and, thus, left-hand vs. right-hand responses) was kept at 50% in each block. However, the probability of congruent trials was manipulated across blocks to produce 20%, 50%, and 80% probability levels (2 blocks of each; the order of which varied randomly across participants). Participants were not informed of the varying probability levels occurring across blocks.

#### *Electrophysiological Recording*

The electroencephalogram (EEG) was recorded from 28 tin electrodes fixed in a stretch-lycra cap and placed in standard locations (American Encephalographic Society, 1994). All scalp electrodes were referenced online to the right mastoid; an average mastoid reference was calculated offline. All signals were amplified with Neuroscan Synamps amplifiers (Compumedics, Charlotte, NC) and filtered on-line at .10 to 40 Hz at a sampling rate of 1000 Hz. Impedance was kept below 5K $\Omega$ . Ocular artifacts (i.e., blinks) were corrected from the EEG signal off-line using a regression-based procedure (Semlitsch, Anderer, Schuster, & Presslich, 1986). Trials containing voltage deflections of +/- 75 microvolts ( $\mu$ V) were discarded before the averaging of waveforms. After artifact elimination, EEG data were averaged off-line according to electrode and stimulus conditions and low-pass filtered at 18 Hz. Only correct response trials were used in creating average waveforms. The number of trials on which target averages were

based varied from 20 (congruent trials in the 20% congruent condition) to 84 (congruent trials in the 80% congruent condition) across participants and conditions.

#### *ERP Component Measurement*

For each participant, the averaged waveforms elicited on prime-only trials were subtracted from the averaged waveforms elicited on target trials, resulting in corrected target ERPs that were not confounded by prime-related activity. These corrected ERP waveforms were used to derive the target-related N2 and P3 components. Visual inspection of the single-participant averaged waveforms showed that, similar to previous research on conflict effects (e.g., Nieuwenhuis et al., 2003), the N2 occurred approximately 250-500 ms post-stimulus for all participants ( $M = 398$  ms), and was largest at frontal and fronto-central locations (particularly at the midline, FCz electrode). The N2 therefore was quantified as the largest negative-going peak 250-500 ms post-stimulus at FCz. The P3 occurred approximately 500-800 ms post-stimulus for all participants ( $M = 599$  ms) and was largest and peaked most quickly at the midline parietal scalp location (Pz).<sup>4</sup> The P3 was quantified as the largest positive-going peak within that epoch at the Pz electrode.

The LRP typically is largest in electrodes placed over the motor cortex (i.e., just lateral to midline over central scalp locations; C3 on the left; C4 on the right), which was the case here. The LRP is calculated by first subtracting the potential recorded at the scalp site ipsilateral to (on the same side as) the movement (e.g., C3 for left-hand responses) from that contralateral to (on the opposite side from) the movement (e.g., C4 for left-hand responses), and then averaging these difference potentials for left- and right-hand movements. When these procedures are performed with respect to the correct response hand in each condition, negative deflections in the waveform reflect preferential activation of the correct response, whereas positive deflections

indicate preferential activation of the incorrect response (see Coles, 1989).<sup>5</sup> Of primary interest here was the portion of the LRP developing shortly after prime onset, which shows the extent to which primes elicited preferential response activation (see Coles, 1989; Gehring et al., 1992; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988; Gratton et al., 1992). Here, initial activation of responses was measured as the mean amplitude of the LRP during the 250ms between prime onset and target onset on trials where the correct behavioral response ultimately was emitted.

## Results

### *Behavioral Data*

*Reaction times (RTs).* Behavioral data from 2 participants (1 man, 1 woman) were discarded (one due to equipment failure; the other misunderstood instructions), leaving a sample of 38 participants. Latencies on incorrect categorization trials ( $M = 3.0\%$ ) were excluded from the analysis of the RT data. Prior to analysis, RT data were adjusted to reduce positive skew (Fazio, 1990). For each participant, latencies exceeding 2 *SD* above their mean were replaced with latencies exactly 2 *SD* above that mean (see Klauer et al., 1997). Remaining extreme outliers (< 1% of values) were modified to the value of the next-most-extreme, non-outlying data point in the distribution (i.e., Winsorizing; see Wilcox, 2003), which maintained the ordinal position of extreme values while reducing their influence on conditional means.

The transformed RT data were subjected to a 2 (Sex of participants) x 2 (Congruence; congruent, incongruent) x 2 (Target valence; positive, negative) x 3 (Congruence probability; 20%, 50%, 80%) mixed factorial ANOVA with repeated measures on all but the first factor. This analysis showed a significant main effect of Congruence,  $F(1, 36) = 19.5, p < .001$ , which was qualified by the predicted Congruence x Probability interaction,  $F(2, 72) = 5.34, p < .01$  (see Figure 1a). Simple effect tests showed that incongruent trials elicited slower responses than

congruent trials in the 80% congruent condition ( $M_s = 731$  &  $679$  ms, respectively),  $t(37) = 4.35$ ,  $p < .001$ ,  $d = .70$ , and in the 50% congruent condition ( $M_s = 714$  &  $691$  ms, respectively),  $t(37) = 2.51$ ,  $p < .05$ ,  $d = .42$ . However, RTs to congruent and incongruent trials did not differ significantly in the 20% congruent condition ( $M_s = 717$  &  $714$  ms, respectively),  $t(37) = -0.26$ ,  $p = .80$ ,  $d = -.04$ . Close inspection of the congruency effect across probability levels revealed that, similar to Gratton et al.'s (1992) results, this effect was driven by a significant linear decrease in RT on congruent trials with increasing congruence probability,  $F(1, 36) = 4.56$ ,  $p < .05$ ; the linear increase for incongruent trials was not significant,  $F(1, 36) = 0.80$ ,  $p = .38$ .

*Error rates.* The proportion of errors in each condition was analyzed using a similar 2 (Sex) x 2 (Congruence) x 2 (Target valence) x 3 (Congruence probability) mixed factorial ANOVA.<sup>6</sup> This analysis showed a significant main effect of Congruence,  $F(1, 36) = 6.14$ ,  $p < .05$ , qualified by a Congruence x Probability interaction,  $F(2, 72) = 4.99$ ,  $p < .01$  (see Figure 1b). Simple effect tests showed that participants made more errors on incongruent compared to congruent trials in the 80% congruent condition ( $M_s = 4.8\%$  &  $1.9\%$ , respectively),  $t(37) = 2.87$ ,  $p < .01$ ,  $d = .47$ , and in the 50% congruent condition ( $M_s = 3.7\%$  &  $2.1\%$ , respectively),  $t(37) = 2.02$ ,  $p < .05$ ,  $d = .33$ . However, in the 20% congruent condition error rates on congruent and incongruent trials did not differ significantly ( $M_s = 2.4\%$  &  $2.8\%$ , respectively),  $t(37) = 0.83$ ,  $p = .41$ ,  $d = .13$ . Linear contrast analyses showed that errors on incongruent trials decreased along with decreasing congruence probability,  $F(1, 36) = 10.60$ ,  $p < .01$ ; the modest linear increase in errors on congruent trials across probability levels was not significant ( $F < 1$ ). The only other significant effect in this analysis was a Congruence x Valence interaction,  $F(1, 36) = 11.09$ ,  $p < .01$ ; post-hoc comparison of the means showed that the congruence effect was larger for positive

targets ( $d = .40$ ) than for negative targets ( $d = .14$ ). This interaction is irrelevant to the present hypotheses so will not be discussed.

### *ERPs*

ERP data from 5 additional participants were discarded; 2 due to recording difficulties and 3 to a high proportion of movement artifacts. Thus, ERP analyses were based on data from 33 participants (15 men, 18 women).

*Response activation at prime onset: LRP amplitude.* The response conflict hypothesis predicts that the prime-congruent response is preferentially activated prior to target onset, which should facilitate responses on congruent trials and impede responses on incongruent trials. But, if participants strategically adjust their processing on the basis of probability information (e.g., Gratton et al., 1992; Logan & Zbrodoff, 1979), the response activated by a prime will not necessarily depend on the valence of the prime (and, thus, its evaluative congruence with a given target) but on whether that prime is likely to predict a congruent or incongruent target. Figure 2 shows LRP waveforms as a function of trial type and congruence probability. Consistent with the strategic control hypothesis, primes elicited preferential activation of the congruent response on congruent trials in the 80% and 50% congruent conditions, but elicited preferential activation of the incongruent response in the 20% congruent condition. A 2 (Sex) x 2 (Congruence) x 3 (Congruence probability) mixed ANOVA of the mean LRP amplitudes confirmed that the Congruence x Probability interaction was significant,  $F(2, 62) = 3.35, p < .05$ . This interaction was probed by testing linear contrasts of the probability effect separately for congruent and incongruent trials (see Table 3). The linear contrast was significant for incongruent trials, indicating that as the probability of congruent trials decreased, preferential activation of the

incongruent response increased. The converse pattern was evident for congruent trials, though this linear contrast was not significant.

*Response conflict monitoring: N2 amplitude.* To the extent that the differential response activation patterns seen in the LRP produced differences in conflict, the amplitude of the N2 should be larger on incongruent than congruent trials in the 80% and 50% congruent conditions and larger on congruent than incongruent trials in the 20% congruent condition. To test this idea, N2 amplitudes were subjected to a 2 (Sex) x 2 (Congruence) x 2 (Target valence) x 3 (Congruence probability) mixed factorial ANOVA with repeated measures on all but the first factor. The main effect of Congruence was marginally significant,  $F(1, 31) = 3.96, p = .055$ , indicating that, overall, the N2 was larger on incongruent than on congruent trials. This effect was qualified by the predicted Congruence x Probability interaction,  $F(2, 62) = 13.32, p < .001$  (see Figure 3 and Table 3). This interaction was investigated using simple effect tests of the congruency effect within each probability condition. In the 80% congruent condition, incongruent targets elicited a larger N2 than did congruent targets,  $t(32) = 3.52, p < .01, d = .63$ . A similar pattern emerged in the 50% congruent condition, though the effect was smaller,  $t(32) = 2.53, p < .05, d = .45$ . In the 20% congruent condition, however, congruent trials elicited larger N2 than did incongruent trials,  $t(32) = -4.27, p < .01, d = -.75$ . We also computed linear contrasts of the probability effect separately for congruent and incongruent trials (see Table 3). Whereas the N2 elicited by incongruent trials decreased significantly along with congruence probability, the N2 elicited by congruent trials was unaffected by congruence probability. The analysis also showed a significant main effect of Probability,  $F(2, 62) = 3.87, p < .05$ ; the size of the N2 generally increased (became more negative) as a linear function of congruence probability ( $M_s = -7.81, -8.25, \& -9.54 \mu V$ , respectively). No other effects were significant in this analysis.<sup>7</sup>

*Evaluative categorization of targets: P3latency.* To test whether evaluative categorization of targets was delayed on incongruent compared to congruent targets (consistent with conflict occurring at the evaluative categorization stage), the P3 latency data were subjected to a 2 (Sex) x 2 (Congruence) x 3 (Congruence probability) x 2 (Target valence) mixed factorial ANOVA. Neither the main effect of Congruence nor the Congruence x Probability interaction was significant ( $F_s < 1$ ). There was a significant main effect of Sex,  $F(1, 31) = 4.16, p < .05$ , which was qualified by a Congruence x Sex interaction,  $F(1, 31) = 8.35, p < .01$ . Among women, P3 latency was somewhat faster to congruent than incongruent targets ( $M_s = 560$  &  $582$  ms, respectively), whereas men showed the reverse pattern ( $M_s = 645$  &  $626$  ms, respectively). However, post-hoc Tukey HSD tests showed that neither of these comparisons was significant ( $p_s > .11$ ). The analysis also showed a Valence x Sex interaction,  $F(1, 31) = 7.26, p < .01$ , suggesting that whereas the P3 peaked somewhat more quickly to positive than negative targets among women, men showed the reverse pattern. However, post-hoc Tukey HSD tests indicated that these comparisons were not significant ( $p_s > .15$ ). No other effects were significant.<sup>8</sup>

*P3 amplitude.* We also tested whether evaluative categorization of targets was more pronounced on incongruent compared to congruent trials by subjecting peak P3 amplitudes to a 2 (Sex) x 2 (Congruence) x 3 (Congruence probability) x 2 (Target valence) mixed factorial ANOVA. The main effect of Congruence was not significant ( $F < 1$ ). However, a significant Congruence x Probability interaction was observed,  $F(2, 62) = 15.11, p < .001$  (see Table 3). Simple effect tests showed that incongruent trials elicited larger P3 amplitude than congruent trials in the 80% congruent blocks,  $t(32) = 4.31, p < .001, d = .75$ . In contrast, congruent trials elicited larger P3 amplitude than incongruent trials in the 20% congruent blocks,  $t(32) = -2.62, p < .01, d = -.46$ . P3 amplitudes elicited by congruent and incongruent trials did not differ

significantly in the 50% congruent blocks,  $t(32) = -0.78, p > .40, d = -.14$ . Linear contrasts showed that, as congruence probability decreased, P3 amplitude for congruent targets increased (though not significantly) and P3 amplitude for incongruent targets decreased. No other effects were significant in this analysis.

*Associating ERP and behavioral congruence effects.* To the extent that neural measures of response activation and conflict are associated with differences in behavioral affective congruency effects, variability in the LRP and/or N2 measures should be related to variability in behavioral responses. We used two approaches to test this idea. First, we calculated simple, bivariate correlations among the LRP, N2 and RT measures using difference scores. For example, to capture the difference in response activation on incongruent versus congruent trials in the 80% and 20% congruent conditions, an LRP difference score was calculated by subtracting the “congruency effect” (LRP voltage on incongruent minus congruent trials) in the 80% congruent condition from the congruency effect in the 20% congruent condition. Similar difference score variables were created for the N2 and RT data. Correlations among these scores indicated that larger (more positive) LRP scores were associated with larger (more negative) N2 scores,  $r = -.48, p < .005$ , and that larger N2 scores were associated with larger (more positive) RT scores,  $r = -.57, p < .01$ . However, the bivariate association between the LRP and RT scores was not significant ( $r = .07, p > .20$ ), and thus a typical meditational analysis was not warranted.

The second approach we took to testing whether the LRP and/or N2 data covaried with the behavioral affective congruency effect was to include the ERP data as covariates in separate repeated ANCOVAs testing the effects of congruency and probability on RTs. The logic of these analyses is that, if the patterns seen in the RT (Figure 1) depend on variation in the ERP measures of response activation and conflict, including these measures as covariates should

reduce the magnitude of the original effects (i.e., Congruence x Probability interaction) and should produce higher-order interactions involving the covariates. In the ANCOVA including the LRP covariate, the Congruence x Probability interaction was not significant,  $F(2, 60) = 2.04, p > .10$ , but a significant 3-way interaction emerged involving Congruence, Probability and the LRP covariate,  $F(2, 60) = 4.16, p < .05$ . The form of this interaction was probed by testing the Congruence x Probability interaction separately for participants with relatively large versus relatively small LRP difference scores (median split). Among participants with large differences in their LRPs between the 80% and 20% conditions the Congruence x Probability interaction was significant,  $F(2, 30) = 6.73, p < .01$ . Inspection of the means showed that, in the 80% congruent condition the congruency effect was large and positive ( $M = 79.1$  ms), whereas in the 50% congruent condition the congruency effect was small ( $M = 5.2$  ms) and in the 20% congruent condition it was reversed ( $M = -48.4$  ms). This pattern mirrors the LRP amplitudes in these conditions (see Figure 2), indicating that large differences in activation of neural response channels across conditions produces corresponding differences in response output. In contrast, among participants with relatively small differences in their LRPs between the 80% and 20% congruent conditions the Congruence x Probability interaction was not significant,  $F(2, 28) = 1.08, p = .35$ . For these participants, the behavioral congruency effects were smaller overall and were less affected by the probability manipulation ( $M$ s = 29, 31, & 20 ms in the 80%, 50%, & 20% congruent conditions, respectively). The ANCOVA including the N2 covariate produced an analogous set of findings, where those whose N2 amplitudes indicated a larger difference in conflict across conditions showed more robust behavioral effects compared to those with smaller N2 differences.

*Attention to and evaluation of primes.* To test whether processing of primes was determined by the likelihood of conflict (i.e., processing increasing along with congruence probability), we examined the ERP waveforms elicited by primes as a function of congruence probability. These waveforms are presented in Figure 4. Two components are of interest here, as they relate to the extent to which participants attended to and evaluated the primes. First, the amplitude of the P1 component (the first positive deflection, peaking at around 206 ms post-stimulus) has been linked to the amount of selective attention allocated to a stimulus (reviewed in Anllo-Vento, Schoenfeld, & Hillyard, 2004). Second, the amplitude of the P3 component (peaking here around 659 ms) elicited by warning stimuli in sequential priming tasks has been used in previous work to indicate the degree to which participants extract information from the primes, in order to prepare target responses (e.g., Gratton et al., 1990).

As shown in Figure 4, the amplitudes of both of these components covaried with congruence probability. These differences were confirmed with separate 3 (Probability) x 2 (Valence) x 5 (Electrode) ANOVAs. The ANOVA on the P1 amplitudes showed a significant main effect of Probability,  $F(2, 62) = 6.89, p < .01$ . A follow-up contrast showed that the linear trend in the mean amplitudes across probability conditions ( $M_s = 4.5, 5.2, \& 6.1 \mu V$ , in 20%, 50%, & 80% congruent conditions, respectively) was significant,  $F(1, 31) = 9.47, p < .01$ . An Electrode x Probability interaction,  $F(8, 248) = 3.47, p < .01$ , indicated that although the linear trend pattern was evident at all midline locations, the differences in the P1 were largest at the Fz (frontal midline) electrode. The ANOVA on the P3 amplitudes showed only a significant main effect of Probability,  $F(2, 62) = 4.71, p < .05$ . A follow-up contrast analysis showed a significant linear trend,  $F(1, 31) = 7.05, p = .01$ , with mean P3 amplitude increasing along with congruence probability ( $M_s = 6.4, 6.7, \& 7.7 \mu V$ , in 20%, 50%, & 80% congruent conditions, respectively).

## Discussion

Two main goals were advanced for this research. The first was to investigate the psychological locus of affective congruency effects, previously hypothesized to be in response activation, evaluative categorization or both (see Klauer & Musch, 2003; Klauer et al., 2005), using a combined behavioral and electrophysiological approach. The evidence from this experiment points clearly to an important role for the response system in producing affective congruency effects in the evaluative decision task. The behavioral data replicated previous findings (Klauer et al., 1997; Spruyt et al., 2007) indicating that the affective congruency effect increases along with the proportion of congruent trials. In a general sense, this pattern is difficult to reconcile with the view that the affective congruency effect stems from automatic activation of evaluative categories, in that such effects presumably would occur regardless of contextual factors like probability (cf., Spruyt et al., 2007) or processing strategies more generally (see Klauer & Teige-Mocigemba, 2007; Teige-Mocigemba & Klauer, 2008).

But, the pattern of behavioral and psychophysiological responses is entirely consistent with the view that the affective congruency effect results from conflict in response-related processes. The LRP waveforms (Figure 2) indicate that responses were activated following prime onset, before targets even appeared. This finding generally corroborates existing models of response conflict in affective priming (e.g., De Houwer et al., 2002; Klauer & Teige-Mocigemba, 2007; Wentura, 1999; Wentura & Rothermund, 2003), and extends existing models by showing that response activation at prime onset is driven not simply by the evaluative category of the prime, but is determined according to which target response is likely to be required, given the relative probability of congruent targets (see also Kopp et al., 1996, Kopp, Mattler, Goertz, & Rist, 1996). In other words, whether the response activated by the prime will

conflict with the response required by the target is not simply a function of the evaluative match between the prime and target. Similarly, the amplitude of the N2 component, thought to index the magnitude of response conflict detected by the ACC (e.g., van Veen & Carter, 2002a), also varied as a function of whether the response required by the target was predictable from the prime, not simply whether there was an evaluative match between prime and target. These findings are conceptually similar to other recent work showing that fronto-central negativities in the response-locked ERP can be increased when the response called for by a currently activated response strategy opposes the one required by a given target, even when the target itself does not engender conflict (Bartholow et al., 2005). In sum, the LRP and N2 data from this study provide the first direct evidence that response conflict in the evaluative decision task arises from primes pre-activating responses, and that conflict can occur even when the prime and target share an evaluative category. Importantly, although RT and LRP amplitude were not correlated in a simple bivariate sense, the ANCOVA including LRP difference scores as a covariate showed that the magnitude and pattern of behavioral affective congruency effects depended on the extent to which primes differentially activated congruent versus incongruent responses across probability conditions, as reflected in the LRP.

The P3 latency data were inconsistent with the hypothesis that conflict occurs at the level of evaluative categorization. According to the conflict-at-categorization view, categorization of the target should be quicker on congruent (relative to incongruent) trials because the evaluative category of the target has been pre-activated by the prime (see Klauer et al., 2005). Quicker, less effortful categorization of congruent relative to incongruent targets would be indicated by faster P3 latency on congruent trials (see Kutas et al., 1977); this did not occur here. The P3 amplitude data provide another index of target categorization. Amplitude of the P3 is known to be highly

sensitive both to variations in evaluative categorization (e.g., Cacioppo, Crites, Berntson, & Coles, 1993) and to probability information (e.g., Friedman et al., 2001; Squires et al., 1976). Here, the P3 was larger to low-probability targets, regardless of whether or not they shared the evaluative category of the prime. These data are consistent with previous research showing that the P3 is larger when target stimuli disconfirm the prediction of warning (prime) stimuli, regardless of whether the targets are prime-congruent (see Gehring et al., 1992), but are inconsistent with the view that incongruity between the evaluative categories of the prime and target contributes to affective priming effects.

It might seem counter-intuitive that an ERP component linked to response conflict monitoring (N2) temporally precedes the component most closely associated with evaluative categorization (P3), given that evaluative processes often are assumed to precede response-related processes. For example, Spruyt et al. (2007) claimed, “response selection can take place only *after* the identity of the instigating stimuli has been processed to some extent” (p. 101; emphasis in original). Our argument is not inconsistent with this idea. Although the process of stimulus evaluation begins from the moment a stimulus appears, it is important to note that P3 latency reflects the time when stimulus evaluation has been *completed*, not when it begins (see Coles et al., 1995). Considerable research indicates that response processes often are instigated prior to the completion of stimulus evaluation in speeded RT tasks (e.g., Miller & Hackley, 1992; Smid, Mulder, & Mulder, 1990). This sequence can readily produce conflict as participants can begin to activate responses before they have fully identified (i.e., evaluated) the target, often based on simple response strategies. For example, if participants are expecting congruent trials, they could begin to activate the ‘positive’ target response following a positive prime before the target even appears. Such a strategy also can produce errors derived from

guessing (Gratton et al., 1988). This idea also is consistent with prior speculation concerning the effects of probability on strategic response activation in affective priming (Klauer et al., 1997), in which it was assumed that responses can be generated based on a simple, binary expectation concerning the valence of the target rather than on its identity. Particularly in the present case, where response activation clearly occurred prior to target onset (see Figure 2), it is indeed plausible to assume that response conflict temporally preceded the completion of evaluative categorization (see also Yeung, Botvinick, & Cohen, 2004).

The second major goal of this study was to better understand how participants use probability information to control their responses in affective priming tasks. Several aspects of the data point to the conclusion that participants used probability information to strategically manage the influence of conflict on their performance. First, participants appeared to limit their processing of primes as a function of the probability of conflict. The amplitude of the P1 and P3 components elicited by the primes decreased linearly along with the probability of congruent trials (see Figure 4). In other words, during trial blocks when the response associated with the prime was likely to conflict with the response required by the target, participants processed the primes less deeply. Second, probability information had asymmetrical effects on response activation and conflict for incongruent versus congruent trials. As indicated in Table 3, decreasing the probability of congruent trials had a larger effect on response activation for incongruent than for congruent trials. This pattern also was reflected in the N2 component, indicating that probability-based differences in strategic control of response activation had a parallel effect on the experience of response conflict, leading to changes on incongruent trials but not on congruent trials (see Table 3).

Other researchers have argued that the magnitude of the affective congruency effect is determined by the amount of attention paid to the primes (see Gawronski et al., 2005; Musch & Klauer, 2001). The current data are largely consistent with this view. Previously, Gratton et al. (1992) reported that the P3 elicited by warning cues in a nonevaluative target identification task was smaller when the warning predicted an incongruent versus a congruent trial. Other previous research (e.g., Sirevaag, Kramer, Coles, & Donchin, 1989) indicates that P3 amplitude is determined not only by the information conveyed by a stimulus but also by the extent to which that information is used in task performance. We have argued that probability information primarily affects the strategic control of response activation in the service of conflict regulation. To the extent that response activation following primes is influenced by the extent of prime processing, it should be the case that differential activation of congruent versus incongruent responses was larger in the 80% congruent condition (where primes were processed most) than in the 20% congruent condition (where primes were processed least). Consistent with this idea, examination of the effect sizes confirms that the difference in LRP amplitude for congruent versus incongruent trials was nearly twice as large in the 80% congruent blocks ( $d = .61$ ) than in the 20% congruent blocks ( $d = .31$ ).

The amplitude of the P3 elicited by targets also appears related to strategic use of probability information. The P3 was enhanced to targets that could not easily be predicted, regardless of whether they shared the evaluative category of the prime. This pattern suggests that the P3 could signal recognition of whether or not the currently activated response strategy is appropriate (see Donchin, 1981). For instance, the LRP data showed that, following prime onset participants strategically activate the congruent response when congruent targets are highly likely. This strategy fails, however, when the target is actually incongruent, leading to a larger P3

than when the target is congruent and response activation was appropriate. A similar pattern occurs when the incongruent response is activated by the prime but the target is congruent. These data are consistent with findings from other prior work attempting to localize the effects of probability information in the stimulus categorization and response systems. Gehring et al. (1992) used a task in which a warning stimulus indicated (with varying probability) whether an upcoming target would require a left-hand or right-hand response. As in the current study, the P3 component was sensitive to whether the target was accurately predicted by the warning stimulus. It is also important to note that, although both the P3 and N2 components are sensitive to stimulus infrequency (e.g., Friedman et al., 2001; Nieuwenhuis et al., 2003), the current data cannot easily be explained simply on the basis of frequency. For instance, despite the fact that congruent trials were just as infrequent in the 20% congruent condition as incongruent trials were in the 80% congruent condition, the N2 was larger in the latter case ( $M = -10.61 \mu\text{V}$ ) than in the former ( $M = -8.83 \mu\text{V}$ ),  $p = .03$  (Tukey's HSD), and the overall amplitude of the N2 was smaller in the 20% congruent condition compared to the 80% congruent condition.

Taken together, these data support the idea that evaluative information was extracted from primes strategically, but not simply according to whether primes could be used to predict the target category (see Klauer et al., 1997; Logan & Zbrodoff, 1979). Rather, participants appeared to limit processing of primes that were likely to elicit conflict, supporting the strategic control model proposed by Gratton et al. (1992). The current data also extend recent work by Klauer and Teige-Mocigemba (2007; see also Teige-Mocigemba & Klauer, 2008), who reported that explicitly instructing participants to use the prime to prepare for an opposite-valence target, or paying participants for fast and accurate responses on incongruent trials, results in elimination of affective congruency effects. Our data show that participants can use probability information

to develop such a strategy on their own (i.e., without being told), and provides evidence of the neurocognitive mechanisms through which this strategy affects behavior.

It is important to acknowledge that the current findings are relevant primarily for understanding affective priming in evaluative categorization tasks. It seems likely that response-related conflict plays a much smaller role – and categorization processes a larger role – in affective congruency effects demonstrated with other tasks. For example, Spruyt et al. (2007) presented data consistent with the idea that affective congruency effects obtained in an evaluative categorization task are driven by response-related processes, but that affective priming in a naming task is not. This conclusion was based largely on the fact that the affective congruency effect was moderated by congruency proportion in the evaluative categorization task (as was the case here) but not in the naming task.

In conclusion, the current data support the idea that the affective congruency effect is associated with response conflict (see also De Houwer et al., 2002; Gawronski et al., 2005; Klauer et al., 1997; Klauer & Musch, 2002; Klinger et al., 2000; Wentura, 1999), and provide the first direct evidence that this conflict arises from responses being differentially activated following prime onset. Moreover, the current data provide a link between affective priming research and the extensive literature on the use of probability information in speeded choice response tasks (see Duncan-Johnson & Donchin, 1982; Gehring et al., 1992; Gratton et al., 1992; Requin et al., 1991). Social psychological research has long been influenced by the methods and theory of cognitive science (see Markus & Zajonc, 1985). Indeed, the affective priming paradigm itself, and the initial explanation of the affective congruency effect (spreading of activation), represent an extension of semantic priming techniques first developed by cognitive psychologists. Just as cognitive scientists have used physiological data to constrain cognitive

theories (see Mangun & Hillyard, 1995), social psychologists can likewise constrain theories concerning the cognitive mechanisms responsible for social behavior by studying the physiological manifestations of the involvement of those mechanisms. The current work illustrates the utility of continuing to build methodological and theoretical bridges between social psychology and cognitive neuroscience, as narrowing the gap between these areas of inquiry clearly benefits both (see Cacioppo, Berntson, Sheridan, & McClintock, 2000).

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## Footnotes

1. It is important to note that the concept of “evaluative categorization” in the P3 literature does not necessarily carry an affective connotation, but simply refers to the process of extracting information from a stimulus in order to categorize it in some manner. Moreover, as indicated in Table 1 the P3 is not uniquely associated with evaluative categorization, in that this component is sensitive to a number of other, related processes such as context updating (i.e., updating the contents of working memory; Donchin & Coles, 1988), novelty detection (see Friedman, Cycowicz, & Gaeta, 2001), and subjective probability of the occurrence of task-relevant stimuli (Johnson & Donchin, 1978; Squires, Wickens, Squires, & Donchin, 1976). Still, studies in which stimuli are equally novel, familiar, relevant and subjectively likely but differ in their evaluative connotations have shown that the amplitude and latency of the P3 differ as a function of evaluative categories (e.g., Ito et al., 1998; Schupp et al., 2000). Thus, the P3 remains a useful online index of the extent to which evaluative categorization processes differ on congruent versus incongruent trials in this research.
2. Usage frequency data for two of the words, “cuddle” and “hooker,” were not available because they were not included in the Kučera and Francis (1967) analysis. The frequency for “father” (383 per million words) represented an extreme outlier among positive targets. When this figure is excluded, the mean usage frequency for positive targets drops to 43.6 occurrences per million words.
3. Research indicates that this relatively large percentage of “null” target trials (30%) is sufficient to properly characterize the overlapping signal elicited by the primes and thus permit its removal from the target ERP (see Woldorff, 1993), and that this percentage coupled with the use of temporally jittered stimulus presentation (e.g., manipulating inter-trial intervals)

significantly reduces the so-called Omitted Stimulus Response that can accompany an expected but absent stimulus event (see Busse & Woldorff, 2003).

4. Some might question why the P3 peaked later in this study than in many studies, or indeed whether the late positivity measured here is a P3 at all. P3 latency is very sensitive to the difficulty of stimulus categorization (see Magliero et al., 1984; McCarthy & Donchin, 1981). It is not uncommon for P3 latency to be in the 500-800ms range with complex socially- or motivationally-relevant stimuli such as the valenced words used here (see Fabiani et al., 2007), and research indicates that such “late” P3s represent the same evaluative categorization process as P3s occurring earlier in tasks with simpler stimuli (see Crites et al., 1995).

5. The formula for deriving the LRP is as follows (see Coles et al., 1995):

$$\text{LRP} = [\text{Mean}(C4' - C3')_{\text{left-hand response}} + \text{Mean}(C3' - C4')_{\text{right-hand response}}] / 2$$

6. Given that error rate data often suffer from violations of nonindependence, we also analyzed the arcsine of the square root of the percent of errors using the same ANOVA design. This analysis produced the same pattern of findings as reported in the text. Thus, for simplicity, we opted to present the analysis of the untransformed data.

7. Though our main analysis focused on data from the FCz electrode, an ancillary analysis using data from all electrodes also produced a significant Congruence x Probability interaction,  $F(2, 62) = 18.24, p < .001$ , indicating that this effect was widespread across the scalp.

8. Similar findings emerged when analyses included data from a larger array of electrodes. The main difference in the findings when all midline electrodes were included is that the effect sizes associated with the difference in amplitude between congruent and incongruent targets in the 20% and 80% congruent conditions were more similar ( $ds = -.33$  &  $.33$ , respectively).

Table 1.

*ERP Components of Interest in this Research and the Information-Processing Operations they Represent.*

Components	Information-processing operations	Hypothesized neural sources	Relevant citations	Predictions
P3 (or P300)	Evaluative categorization	Widely distributed	Ito et al., 1998	Slower latency and larger amplitude when evaluative category of the target differs from that of the prime;*
	Novelty detection		Friedman et al., 2001	
	Context updating		Donchin & Coles, 1988	
	Subjective probability		Squires et al., 1976	Larger amplitude for low-probability targets/categories
	Decision-making		Nieuwenhuis et al., 2005	
N2 (or N200)	Conflict detection	Medial frontal cortex (anterior cingulate)	Van Veen & Carter, 2002	Larger amplitude when the response activated by the prime differs from the target response, regardless of affective matching
	Stimulus infrequency		Nieuwenhuis et al., 2003	
LRP	Preparation for a given overt response	Pre-motor area; motor cortex	Coles, 1989; Coles et al., 1995	Responses activated by primes depend on probability of given targets, regardless of affective matching with primes

*Note.* The particular information-processing operation represented by a given component depends upon several factors, including the task or paradigm in which it is elicited. LRP = lateralized readiness potential.

\*The first prediction listed for the P3 applies to the hypothesis that conflict and facilitation occur during evaluative categorization; other predictions apply to the response conflict hypothesis.

Table 2.  
*Prime and Target Words, their ANEW Word Numbers, and Mean Valence and Arousal ratings.*

	Primes				Targets			
	Word	Valence	Arousal	Word #	Word	Valence	Arousal	Word #
Positive	Cheer	8.1	6.1	69	Baby	8.2	5.5	31
	Joke	8.1	6.7	826	Bride	7.3	5.6	670
	Kiss	8.3	7.3	248	Champ	7.2	6.0	682
	Love	8.7	6.4	263	Child	7.1	5.5	70
	Thrill	8.1	8.0	438	Savior	7.7	5.8	373
	Caress	7.8	5.1	64	Father	7.1	5.9	161
	Cuddle	7.7	4.4	94	Friend	7.7	5.7	174
	Desire	7.7	7.4	508	Spouse	7.6	5.2	407
	Party	7.9	6.7	305	King	7.3	5.5	247
	Flirt	7.5	6.9	352	Mother	8.4	6.1	286
Negative	Abuse	1.8	6.8	1	Whore	2.3	5.9	492
	Betray	1.7	7.2	37	Beggar	3.2	4.9	36
	Drown	1.9	6.6	591	Snob	3.4	5.6	403
	Hurt	1.9	5.9	222	Hooker	3.3	4.9	793
	Poison	2.0	6.0	319	Thief	2.1	6.9	435
	Rape	1.3	6.8	344	Vandal	2.7	6.4	471
	Vomit	2.0	5.8	481	Loser	2.2	5.0	851
	Hate	2.1	6.9	201	Robber	2.6	5.6	964
	Detest	2.2	6.1	114	Pest	3.1	5.6	313
	Crash	2.3	7.0	89	Menace	2.9	5.5	275

*Note.* ANEW = Affective Norms for English Words (Bradley & Lang, 1999). Word # refers to the word number used to identify each word in the ANEW data set.

Table 3.

*Mean LRP, N2 and P3 Component Amplitudes (in microvolts) for Congruent and Incongruent Trials as a Function of Congruence Probability.*

ERP Components	Congruence Probability			Linear contrast
	80%	50%	20%	
LRP				
Congruent trials	-0.37	-0.09	0.17	$F = 2.50, p = .12$
Incongruent trials	0.32	0.20	-0.40	$F = 5.19, p < .05$
N2				
Congruent trials	-8.34	-7.79	-8.83	$F = 0.26, p = .61$
Incongruent trials	-10.61	-8.71	-6.79	$F = 14.38, p < .001$
P3				
Congruent trials	8.25	8.56	9.32	$F = 2.43, p = .13$
Incongruent trials	10.56	8.32	8.17	$F = 12.94, p = .001$

*Note.* Degrees of freedom for all linear contrast  $F$ -tests were 1 (numerator) and 31 (denominator). ERP = event-related potential; LRP = lateralized readiness potential. The linear contrast tests the difference between the means in the 80% and 20% congruence probability conditions within each trial type. In each case, tests of non-linearity (e.g., quadratic contrasts) were nonsignificant.

## Figure Captions

*Figure 1.* Mean target response times (panel A) and error rates (panel B) as a function of trial type and the probability of congruent trials. Vertical bars denote  $\pm 1$  SE.

*Figure 2.* The lateralized readiness potential (LRP) measured at central electrodes (C3 and C4) on congruent and incongruent trials across congruence probability levels. Of primary interest here was the amplitude of the LRP between prime onset and target onset, which indicates relative response activation elicited by the primes. The formula used to derive the LRP is applied with reference to the correct response hand in each condition, such that negative (upward) deflections reflect preferential activation of the correct response, whereas positive (downward) deflections indicate preferential activation of the incorrect response.

*Figure 3.* ERP waveforms measured at FCz depicting the N2 component (prominent negativity peaking approximately 400 ms post-stimulus) as a function of target congruence and the probability of congruent trials. The vertical arrow on the timeline indicates target onset.

*Figure 4.* ERP waveforms (at the Fz electrode) elicited by primes in the 20%, 50%, and 80% congruent conditions. The P1 component peaks at 206 ms, and the P3 component peaks at 650 ms. The vertical arrow on the timeline indicates prime onset.

Fig.1

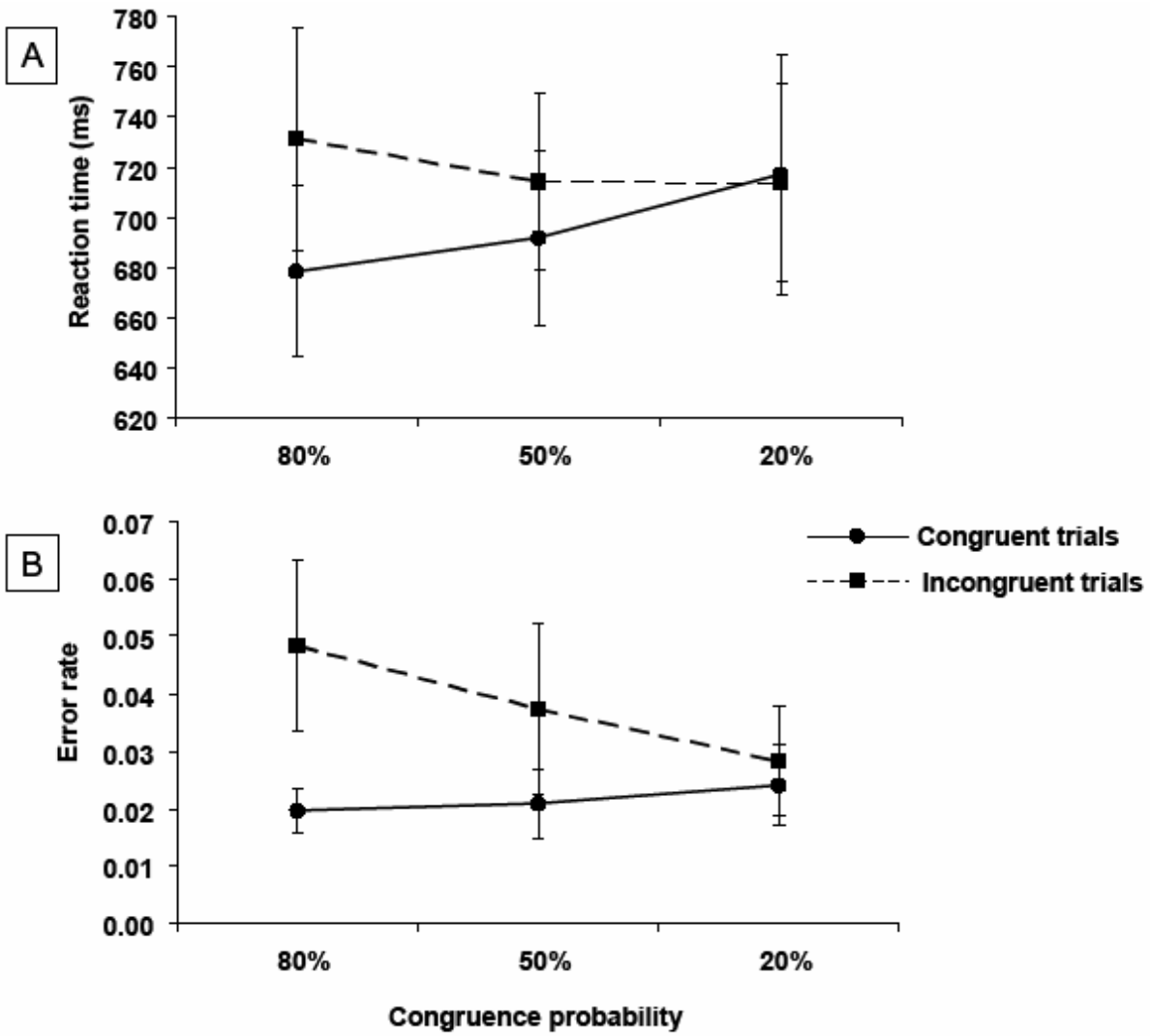


Fig.2

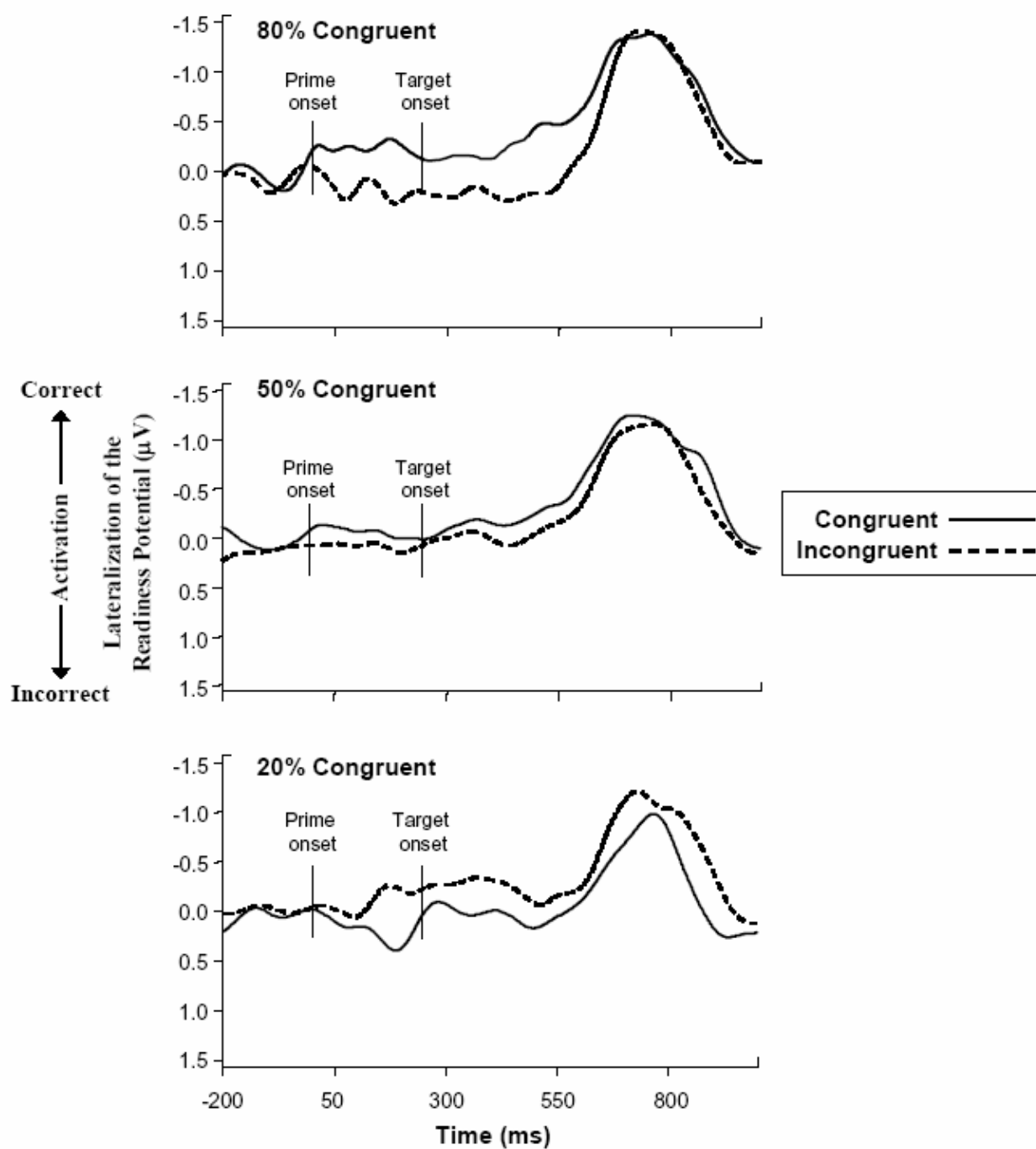


Fig.3

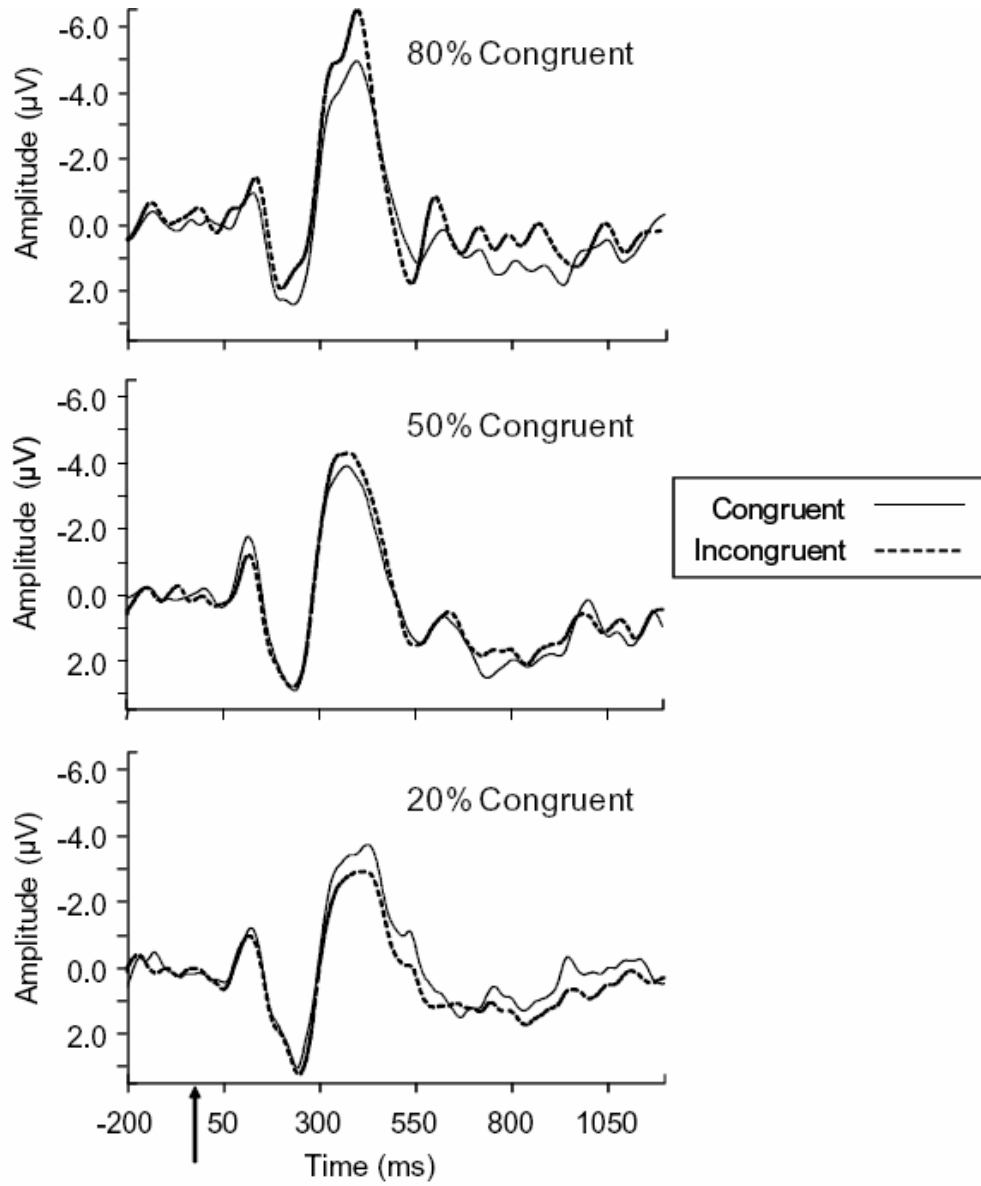


Fig.4

