Friendly drug-dealers and terrifying puppies: Affective primacy can attenuate the N400 effect in emotional discourse contexts

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Abstract Words that are semantically congruous with their preceding discourse context are easier to process than words that are semantically incongruous with their context. This facilitation of semantic processing is reflected by an attenuation of the N400 event-related potential (ERP). We asked whether this was true of emotional words in emotional contexts where discourse congruity was conferred through emotional valence. ERPs were measured as 24 participants read two-sentence scenarios with critical words that varied by emotion (pleasant, unpleasant, or neutral) and congruity (congruous or incongruous). Semantic predictability, constraint, and plausibility were comparable across the neutral and emotional scenarios. As expected, the N400 was smaller to neutral words that were semantically congruous (vs. incongruous) with their neutral discourse context. No such N400 congruity effect was observed on emotional words following emotional discourse contexts. Rather, the amplitude of the N400 was small to *all* emotional words (pleasant and unpleasant), regardless of whether their emotional valence was congruous with the valence of their emotional discourse context. However, consistent with previous studies, the emotional words produced a larger late positivity than did the neutral words. These data suggest that comprehenders bypassed deep semantic processing of valence-incongruous emotional words within the N400 time window, moving rapidly on to evaluate the words' motivational significance.

Keywords Discourse · Emotion · ERP · N400 · Late positivity · Language

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Conveying emotional meaning relies on a complex, multi-modal system of communication. Prosody, facial expression, gesture, and posture can all encode information of emotional relevance (de Gelder, Vroomen, & Pourtois, 2004; Schacht & Sommer, 2009). Even a single written emotional word has the power to arouse, hurt, or heal. How can emotional information be accessed so quickly and induce such powerful responses? One long-standing idea is that, because of its value in promoting survival, the brain prioritizes our access to emotional information over other aspects of meaning (LeDoux, 1996; Zajonc, 1980, 2000). In the present study, we used event-related potentials (ERPs)—a direct measure of online neural processing—to ask whether this is true of emotional words in emotional written discourse contexts within the first few hundred milliseconds of their onset.

A written word is simply a string of letters. For it to have meaning, it must activate stored information, along multiple different dimensions, within long-term memory. An emotional word will not only activate knowledge along semantic dimensions; it will also activate information along emotional dimensions. For example, the word *snake* may activate knowledge about its semantic category (e.g., animal, reptile) and its semantic properties (e.g.,

scaly, long, slithers), as well as information about its emotional salience (highly salient and arousing) and its affective valence (negative).[1] In his seminal 1957 book, Osgood argued that the emotional attributes of words and concepts are quite different from other semantic attributes. He described "evaluation" (i.e., emotion) as a "highly generalizable attribute . . . [that] is most often the dominant attribute of judgment" (Osgood, Suci, & Tannenbaum, 1957, pp. 187–188). More generally, the idea that emotional processing dominates over other types of cognitive processing has been articulated in the affective primacy hypothesis, which argues that because of its privileged status in promoting survival, our access and evaluation of affective information is, in some cases, prioritized over our access and evaluation of nonaffective information, avoiding extensive perceptual and semantic processing and quickly triggering adaptive affective responses (Storbeck & Clore, 2007; Zajonc, 1980).

However, as was discussed by Lai, Hagoort, and Casasanto (2012), the *context* in which an emotional stimulus appears can influence whether or not it is actually beneficial to bypass other types of semantic processing. For example, if we hear the word *snake* in the middle of a dangerous jungle, it would be adaptive to quickly prioritize its affective evaluation, without deeply processing its other semantic features, so that we can respond appropriately. However, if we hear an arousing word like *snake* in more neutral contexts like work or school, it may be beneficial to deeply process its semantic features (perhaps even more so than for neutral items) to ensure that its meaning is interpreted and encoded accurately.

A large ERP literature has suggested that context can influence our retrieval of the meaning of incoming stimuli extremely quickly—within (and sometimes before) 300 ms of their onset, as reflected by modulation of the N400 ERP component (Kutas & Federmeier, 2011). If the semantic information activated by an incoming word is supported by its context, the N400 for that word is attenuated: It is easier to retrieve the word's semantic features. However, if the context fails to activate any of the semantic features associated with an incoming word, more semantic features of that word must be retrieved from semantic memory, leading to a larger

N400.[2] This is also true at the level of discourse. For example, in the two-sentence scenario, "Colin saw a small object on the ground. He realized it was a button . . . ," the semantic features of *button* are consistent with semantic information activated by the context, and the N400 is smaller than if the incoming word were *giraffe*, which is inconsistent with the semantic features activated by the discourse context (Kuperberg, Paczynski, & Ditman, 2011b; Van Berkum, Hagoort, & Brown, 1999).

When we comprehend *emotional* words in context, however, we can activate *both* semantic and emotional representations (Lai et al., 2012). This raises the question of what takes priority in influencing N400 modulation to an incoming emotional word: matches between the context and the incoming word along emotional dimensions, or between the context and the incoming word along other semantic dimensions?

Some evidence that we prioritize along emotional dimensions has come from a previous study from our lab (Holt, Lynn, & Kuperberg, 2009), in which we compared ERPs to emotional and neutral words following neutral, nonconstraining discourse contexts—for instance, "Colin decided to walk to the market. On the way, he saw a snake/diamond/button on the ground." We showed that the N400 was larger to the emotional words (both pleasant and unpleasant) than to the neutral words, despite all three types of sentences being fully matched on semantic predictability (which was low) and plausibility. We suggested that the enhanced N400 on the emotional words was driven by the mismatch between the neutral context and the emotional information activated by the word, although it was unclear whether this mismatch was at the level of emotional salience or specific emotional valence. This finding is interesting because it suggests that even during natural reading comprehension of plausible sentences, emotional words can be processed quite differently from nonemotional words. In this case, in a *neutral* discourse context, the unexpected emotional features of the incoming word led to a *deeper* semantic analysis, reflected by the larger N400 (see Van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009, for a similar interpretation). As we noted

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[1] Here, we adopt a two-dimensional model of affective meaning: emotional valence and emotional salience (Bradley & Lang, 2007). Valence ranges from unpleasant (motivating aversion) to pleasant (motivating approach) and can be conceptualized as the direction of emotion response and evaluation. Emotional salience ranges from calming to acutely arousing and can be conceptualized as the magnitude of emotion response and evaluation. Though categorical approaches to emotion are not discussed here, they are still broadly consistent with our subsequent arguments.

[2] An ongoing debate has focused on whether a context activates relevant semantic information before the onset of the incoming word (semantic preactivation or lexico-semantic prediction), thereby facilitating lexical access (Federmeier & Kutas 1999; Lau, Phillips, & Poeppel, 2008), or whether relevant stored semantic information only becomes active while (Marslen-Wilson, Brown, & Tyler, 1988) or after (Chwilla, Hagoort, & Brown, 1998) the form of an incoming word is decoded (this has sometimes been termed *semantic matching* or *integration*, but note that this particular use of the term *integration* is different from its use to refer to the mechanisms by which the meaning of an incoming word is combinatorially integrated into its sentence context; e.g., Lau et al., 2008). In this article, we do not assume a discrete stage of lexical access (see Kutas & Federmeier, 2011, for a discussion), but simply refer to the N400 as reflecting the degree of match or mismatch between the features of an incoming word and features activated by its context, along a particular semantic or emotional dimension.

above, this makes adaptive sense: Processing the salient emotional words more deeply in neutral or ambiguous contexts would ensure interpretational accuracy and deep encoding.

In the present study, we asked how emotional words are processed in *emotional* discourse contexts. As discussed above, encountering an emotional stimulus in an emotional context is quite different from encountering an emotional stimulus in a neutral context. As the affective primacy hypothesis argues, in some contexts (e.g., highly salient ones, like a scary jungle), it may be more adaptive to bypass deep semantic processing of incoming emotional stimuli (like *snake*), at least during the initial stages of their evaluation. This would predict that any match between an incoming word and its context along emotional dimensions—particularly emotional salience, which is closely linked to the arousal response—may actually override any mismatches in discourse congruity, and that the N400 evoked by emotional words in incongruous emotional contexts might be smaller than the N400 to neutral words in incongruous neutral contexts.

Some evidence for this idea has come from three previous studies that all introduced emotional words (pleasant and unpleasant) in emotional discourse contexts (Bartholow, Fabiani, Gratton, & Bettencourt, 2001; León, Díaz, de Vega, & Hernández, 2010; Moreno & Vázquez, 2011). These words were either congruous or incongruous with the contexts. In all studies, discourse congruity was conferred through emotional valence. Incongruous emotional words were of opposite valence to their context, and congruous emotional words were of the same valence (e.g., from Moreno & Vázquez, 2011, "Those little thoughtful details revealed how much [he] loved/envied me."). The first study (Bartholow et al., 2001) failed to show a larger N400 to the valence-incongruous than to the valence-congruous emotional words, instead finding effects predominantly on later positivities. The authors interpreted this as suggesting that the semantic processes indexed by the N400 were not relevant to the context demands (of social expectancy and person perception). The two other studies (León et al., 2010; Moreno & Vázquez, 2011), however, did show some effect of valence congruity on the N400 produced by the emotional words, and their authors concluded that participants made concrete inferences and expectations about the emotions of the described characters. Note, however, that in both of these studies, the effect of valence incongruity on the emotional words was smaller than the effect of semantic congruity seen on neutral words (see Fig. 1 in both studies). In addition, in all three studies, the amplitude of the N400 evoked by the valence-incongruous emotional words was smaller than the N400 produced by the semantically incongruous neutral words.

Together, these three studies raise the intriguing possibility that matches between an incoming emotional word and an emotional discourse context on emotional *salience* may, to various degrees, override discourse incongruities, even if these discourse incongruities are conferred through emotional valence. In all three studies, the N400 produced by the emotional words was not as sensitive to discourse incongruity (conferred through valence) as the N400 produced by neutral words (on which discourse congruity was conferred through other semantic features).

Before coming to this conclusion, however, we note several important caveats in the interpretation of these previous studies. First, in none of the studies was the manipulation of valence congruity on the emotional words directly comparable with the manipulation of semantic congruity on the neutral words. In all cases, the valence incongruities on the emotional words resulted in real-world implausibilities (e.g., from Moreno & Vázquez, 2011, "Those little thoughtful details revealed how much [he] envied me," and from León et al., 2010, following a context describing a flood that strikes Carlos's hometown, "Carlos was feeling more and more flattered."). In contrast, the incongruities on the neutral words were frank semantic anomalies that arose at the level of the sentence or a single clause (e.g., from León et al., "Carlos shaved with the wastebasket."). León et al. even demonstrated that these neutral incongruous words evoked a large N400 effect (vs. neutral congruous words) when presented without the discourse context, while the valence words showed no such effect. As such, any differences between the effects of valence congruity and semantic congruity on N400 modulation could potentially be explained by differences between discourse-level congruity and gross semantic violations. In order to directly contrast the effects of valence congruity on emotional words with the effects of semantic congruity on neutral words, valence-incongruous emotional words should be at least as implausible, unrelated, and unexpected in relation to their broader discourse context as semantically incongruous neutral words: The relationships between the critical word and the discourse should be comparable for all congruous and all incongruous conditions.

Second, in all three studies, the neutral words always followed an emotional context rather than a neutral context. This makes it difficult to directly compare the N400 effects of discourse congruity on the neutral words with those from most previous studies, which have typically introduced a neutral word after a neutral discourse context (e.g., Kuperberg et al., 2011b; Van Berkum et al., 1999).

A third difficulty in interpreting these previous studies is that they each reported somewhat different findings on another waveform that followed the N400—the late positivity. The late positivities are a family of ERP components observed from roughly 400 to 1,000 ms. They are highly sensitive to the salience of a wide variety of emotional stimuli, including emotional words presented both in isolation from any context (Citron, 2012; Kissler, Assadollahi, & Herbert, 2006) and in discourse contexts (Fields & Kuperberg, 2012; Holt et al., 2009). They are thought to reflect a reallocation of attentional resources and a continued assessment of the motivational significance of the eliciting stimulus (Hajcak, Weinberg, MacNamara,

& Foti, 2012). In some cases, the late positivity is also larger to unpleasant than to pleasant emotional stimuli, even when arousal is matched—evidence of a so-called *negativity bias* (Fields & Kuperberg, 2012; Holt et al., 2009; Ito, Larsen, Smith, & Cacioppo, 1998; but for positivy bias see Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Winkler, & Junghofer, 2009).

In the study by Bartholow et al. (2001), the emotional words evoked a larger late positivity than did the neutral words. This, however, was not true of the studies by León et al. (2010) or Moreno and Vázquez (2011), in which no late positivity effect was seen to the emotional (vs. neutral) words. As was noted by Fischler and Bradley (2006), the amplitude of the late positivity evoked by emotional words is partially determined by how much the comprehender attends to its emotional features. In discourse, this will likely vary depending on the precise linguistic context, and indeed, understanding when a late positivity is and is not evoked on emotional words during language comprehension will be an important goal for future research. For the purposes of interpreting any reduced N400 modulation on emotional words, however, it is important to be sure that these words were perceived as being salient, arousing, or motivationally significant enough to trigger the reallocation of attentional resources, as reflected by the late positivity. We will return to this idea in the Discussion section.

The present study

In the present study, we directly contrasted the effects of valence congruity of emotional words with the effects of semantic congruity of neutral words on the N400 during discourse comprehension. To do this, we implemented a full crossing of emotion and congruity in short, two-sentence scenarios: Pleasant, unpleasant, or neutral critical words appeared in both congruous and incongruous contexts, which were confirmed using plausibility and cloze probability ratings. In each scenario, the first sentence established a pleasant, unpleasant, or neutral situation (e.g., "Colin saw a *stunning/horrifying/small* object on the ground."). The second sentence differed at a single critical word—to which ERPs were time-locked—that was either congruous or incongruous with the preceding sentence (e.g., emotional, "Colin saw a *horrifying/stunning* object on the ground. He realized it was a <u>snake/diamond</u> right away." vs. neutral, "Colin saw a *small* object on the ground. He realized it was a <u>button/giraffe</u> right away."); see Table 1 for further examples. Note that, as in the three previous studies of emotional words in emotional discourse contexts (Bartholow et al., 2001; León et al., 2010; Moreno & Vázquez, 2011), the discourse incongruity between the emotional context and the incoming emotional word was conferred by emotional valence. Importantly, however, unlike these previous studies, the congruity manipulations in the present study were

Table 1 Examples of stimuli

Emotional	Neutral
Lucy was a(n) *awful/great* engineer. Her creations were big <u>failures/successes</u> every time	Lucy was a *female* engineer. Her creations were big <u>bridges/murals</u> every time
Randy sat *angrily/politely* during the town meeting. People figured he was a(n) <u>irritable/delightful</u> person.	Randy sat *quietly* during the town meeting. People figured he was a <u>reserved/vocal</u> person.
The *spiteful/approachable* girls were meeting their new classmate. They said <u>hurtful/courteous</u> things to her.	The *college* girls were meeting their new classmate. They said <u>introductory/classified</u> things to her.
People noticed that the *suspicious/dedicated* analyst was staying late. They thought he was a(n) <u>spy/asset</u> then.	People noticed that the *new* analyst was staying late. They thought he was a <u>bachelor/bartender</u> then.
Julie explored the *rotting/enchanting* garden. The strong smell of <u>decay/roses</u> surrounded her.	Julie explored the *vegetable* garden. The strong smell of <u>tomatoes/glue</u> surrounded her.
David received an *unfortunate/fortunate* email. It had a large <u>virus/discount</u> attached to it.	David received a *company* email. It had a large <u>file/battery</u> attached to it.
The professor filled his final exam with *impossible/easy* questions. All of his students <u>flunked/aced</u> the test.	The professor filled his final exam with *typical* questions. All of his students <u>completed/faxed</u> the test.
The model posed for the *sleazy/acclaimed* photographer. He kept taking <u>lewd/glamorous</u> photos of her.	The model posed for the *fashion* photographer. He kept taking <u>color/yearbook</u> photos of her.

The first sentence of each scenario contained a word (in italics above) that established the context as emotional (pleasant or unpleasant) or neutral. The second sentence of each scenario contained a critical word that was either congruous or incongruous with the preceding context (underlined above). ERPs were time-locked to the critical word in Sentence 2

comparable for both neutral and emotional scenarios. For each condition of each scenario, both of the individual sentences were interpretable and well-formed, with the incongruity occurring across sentence boundaries. Discourse congruity was operationalized by the same measures in the neutral and the emotional scenarios: The valence-incongruous words were just as unpredictable as the incongruous neutral critical words, while the valence-congruous words were just as predictable as the congruous neutral words, as measured by cloze probability (Taylor, 1953). The neutral and emotional discourse stems were also matched on their contextual semantic constraint, which could also influence the magnitudes of the ERPs evoked by unexpected words (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007). Finally, discourse plausibility was also assessed across conditions by means of rating studies. During the experiment, participants were asked simply to read for comprehension and to answer inferential comprehension questions distributed randomly throughout the stimulus set.

To confirm the emotion categories of "pleasant," "unpleasant," and "neutral," we collected valence and arousal ratings for all of the critical words. On the basis of many previous studies at the level of words (Fischler & Bradley, 2006; Kissler et al., 2006), and some studies at the level of whole discourse (Bartholow et al., 2001; Chung et al., 1996; Fields & Kuperberg, 2012; Holt et al., 2009), we predicted that the more-arousing emotional words would evoke a larger late positivity than would the less-arousing neutral words. We also considered the possibility that we would also see a negativity bias for the emotional words, with a larger late positivity to unpleasant than to pleasant words, even when these words were matched on arousal (Fields & Kuperberg, 2012; Holt et al., 2009; Ito et al., 1998).

Our main focus, however, was on the N400 component. On the basis of previous studies of the N400 to neutral words in neutral discourse contexts, we expected that the congruous neutral critical words (e.g., *button*) would yield a smaller N400 than would semantically incongruous neutral words (e.g., *giraffe*; Hagoort, Hald, Bastiaansen, & Petersson, 2004; Kutas & Hillyard, 1984; Van Berkum et al., 1999). The key question was how the N400 would be modulated on the emotional words. We considered two possibilities.

The first was that discourse congruity conferred via emotional valence would be treated in exactly the same way as discourse congruity conferred by any other semantic feature. This would predict a smaller N400 to pleasant emotional words following congruous (vs. incongruous) discourse contexts, and, similarly, a smaller N400 to unpleasant emotional words following congruous (vs. incongruous) discourse contexts. It would also predict that the magnitudes of these N400 effects would be the same as on neutral congruous (vs. incongruous) words.

The second possibility was that the match between the context and the incoming word on emotional *salience* would override any discourse congruity conferred by valence. This would predict a reduced N400 discourse congruity effect for emotional as compared to neutral words, with a smaller N400 to the valence-incongruous emotional words following an emotional discourse context than to semantically incongruous neutral words following a neutral discourse context. This would imply that, even during written discourse comprehension, prioritized access to the emotional salience of incoming emotional words following an emotional context can lead to their reduced semantic processing at the earliest stages of extracting their meaning.

Method

Construction of stimuli

A stimulus set of 228 scenarios was constructed with six conditions (Emotion[3] × Congruity permutations) per scenario; that is, altogether there were 1,368 (228 × 6) sentence pairs. The sentence pairs varied across the emotion dimension (pleasant, unpleasant, or neutral) in the first sentence, which set up the context (e.g., "Colin saw a *horrifying/stunning/small* object on the ground."). The second sentence varied at a critical word that was either congruous or incongruous with this context.

When the first sentence contained an emotional word, the critical word in the second sentence was also emotional and was either congruous or incongruous with the context set up by the first sentence. The congruous emotional critical words in the second sentence shared the same valence as the emotional words in the first sentence (e.g., a pleasant sentence pair, "Colin saw a *stunning* object on the ground. He realized it was a <u>diamond</u> right away."; and an unpleasant sentence pair, "Colin saw a *horrifying* object on the ground. He realized it was a <u>snake</u> right away."). In contrast, incongruous emotional critical words in the second sentence were of the opposite valence from the context set up by the first sentence (e.g., "Colin saw a *stunning* object on the ground. He realized it was a <u>snake</u> right away."; or "Colin saw a *horrifying* object on the ground. He realized it was a <u>diamond</u> right away."). Note that the names of the conditions refer to the valence of the critical words; for example, "unpleasant incongruous" refers to unpleasant critical words that are incongruous with their pleasant context. When the first sentence was neutral, the critical word in the second sentence was also neutral in valence, and again was either congruous or incongruous with the context (e.g., congruous, "Colin saw a *small* object on the ground. He

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[3] We use the term *Emotion* rather than *Valence* for this factor because the conditions differed on both valence and arousal (see below), and thus any main effect on this factor could not be attributed to valence alone.

Table 2 Stimulus ratings and characteristics

	Pleasant congruous	Pleasant incongruous	Unpleasant congruous	Unpleasant incongruous	Neutral congruous	Neutral incongruous
Cloze	6.8 % (13 %)	0	8.0 % (15 %)	0	6.1 % (11 %)	0
Constraint	23 % (14 %)	23 % (14 %)	23 % (14 %)	23 % (14 %)	22 % (12 %)	22 % (12 %)
Plausibility	6.01 (0.45)	2.70 (0.68)	5.89 (0.53)	2.72 (0.71)	5.56 (0.65)	3.00 (0.88)
Semantic similarity	0.061 (0.098)	0.054 (0.098)	0.038 (0.085)	0.032 (0.081)	0.064 (0.106)	0.024 (0.067)
Valence	5.50 (0.63)		2.19 (0.55)		4.33 (0.45)	4.12 (0.51)
Arousal	4.38 (0.83)		4.204 (0.790)		3.305 (0.562)	3.307 (0.557)
Concreteness	3.75 (1.09)		3.89 (0.99)		4.21 (1.06)	4.56 (1.14)
Word length	7.60 (2.11)		7.05 (2.19)		7.21 (2.24)	7.20 (2.20)
Frequency	7.76 (1.73)		7.76 (1.65)		8.43 (1.79)	7.48 (1.78)

Means are shown, with standard deviations in parentheses. Cloze and constraint are reported as percentages. Plausibility ratings (with 1 as *least plausible* and 7 as *most plausible*) and semantic similarity values were calculated for each of the six scenarios types. Each pleasant and unpleasant word appeared in a congruous and an incongruous scenario, leaving four critical word types. Valence, arousal, and concreteness ratings were obtained for each of these four critical word types using 7-point scales, where 1 was *most unpleasant*, *least arousing*, or *least concrete*, while 7 was *most pleasant*, *most arousing*, or *most concrete*, respectively. Word lengths and frequencies were obtained from the HAL database; missing values were omitted from the analysis. The valence labels refer to the critical words, not the contexts (i.e., "pleasant incongruous" refers to pleasant words that were incongruous with their unpleasant context)

realized it was a button right away."; and incongruous, "Colin saw a *small* object on the ground. He realized it was a giraffe right away.");[4] see Table 1 for additional examples. Thus, in all scenarios, the second sentences were coherent in isolation, but implausible in the full discourse context—any incongruity arose because the meaning of the critical word was inconsistent with the meaning of the first sentence. In 73 of the scenarios, the critical word was an adjective; in 77 scenarios, it was a noun; and in 78 scenarios, it was a verb. The parts of speech of the critical words were matched across all six conditions in each scenario. Critical words never appeared in the sentence-final position.

Norming studies and stimulus characteristics

A series of norming studies were carried out with participants who did not take part in the ERP

experiment. We first aimed to match the cloze probabilities of the critical words across the conditions, as well as the semantic constraints of their contexts. In this cloze-matched stimulus set, we then gathered plausibility ratings for each scenario. In addition, we verified the experimenters' intuitions that the neutral critical words used in both the congruous and incongruous sentences indeed differed significantly in both valence and arousal from the emotional critical words. Finally, we collected normative ratings of the concreteness of the critical words and retrieved their natural-log frequencies from the English Lexicon Project (Balota et al., 2007).

In all of the norming studies, the participants were recruited through online postings to take a short survey (hosted by SurveyMonkey.com) and were compensated for their time if they properly completed the norming studies, regardless of eligibility. Informed consent was obtained for all of the participants, who also completed a guided practice prior to each survey. The stimulus characteristics of the scenarios and the critical words in the final set of stimuli are reported in Table 2.

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[4] Every incongruous neutral critical word had a conceivable context in which it would have been congruous. These other contexts were not included, as this would have resulted in two equivalent neutral-word conditions rather than a single congruous and incongruous condition for each level of valence.

Cloze probability and constraint of scenarios

Three "scenario stems" were created for each scenario, one stem for each level of emotion in Sentence 1. Each stem consisted of the first sentence and the second sentence up until, but excluding, the critical word. The last few words of each scenario were replaced with an ellipsis (e.g., "Julie explored the rotting garden. The strong smell of . . ."). These scenario stems were distributed among six randomized lists, such that each list contained one scenario stem from half of the scenarios. Participants were asked to read each scenario stem and then, in a free-response box, to type the single word that most likely followed in the sentence. A total of 160 participants submitted responses, and five were excluded due to incomplete or insufficient answers, leaving 155 eligible participants with a mean age of 23.3 years. The cloze probabilities of the critical words in each of the congruous conditions were calculated as the proportions of participants who responded with that word. Constraint was calculated as the proportion of the single most common response out of the total number of responses for each scenario stem, regardless of whether or not it matched the critical word. Critical words were changed on the basis of participants' responses, and the final stimulus set showed no differences in the cloze probabilities between the three types of congruous critical words in an omnibus analysis of variance (ANOVA) [$F(2, 227) = 1.28$, $p = .278$; see Table 2]. The incongruous critical words all, by definition, had cloze probabilities of zero. Constraint also did not differ between the pleasant, unpleasant, and neutral scenario stems [$F(2, 227) = 0.55$, $p = .5778$; see Table 2].

Plausibility ratings of scenarios

In the final cloze-matched stimulus set, we also gathered plausibility ratings for each scenario at the point of the critical word. For each permutation of each scenario, we included all of the first sentence and the second sentence up to and including the critical word. The last few words of each scenario were replaced with an ellipsis, to indicate that the scenario continued after this word (e.g., "Julie explored the rotting garden. The strong smell of decay . . ."). These scenario stems were distributed among six randomized lists, such that each list contained one permutation of each scenario. For each list, 35–40 participants were asked to "give each scenario a rating of how much it makes sense" on a scale from 1 to 7, where 1 described a sentence that *doesn't make sense at all* and 7 described a sentence that *makes complete sense*. Participants' responses were excluded if they reported early language exposure other than English (before the age of 5), current or past psychiatric illness, neurological illness or damage including stroke and concussion, or current treatment with psychoactive medication. In

total, 240 participants completed the task, 87 of whom did not meet the inclusion criteria, leaving 153 eligible participants with a mean age of 22.3 years. These plausibility ratings were evaluated in an Emotion (pleasant, unpleasant, or neutral) × Congruity (congruous or incongruous) ANOVA. As expected, the congruous scenarios were rated as being significantly more plausible than the incongruous scenarios [main effect of congruity: $F(1, 1362) > 7,000$, $p < .001$]. Though we found no main effect of emotion [$F(2, 1362) = 1.50$, $p > .20$], there was an interaction between emotion and congruity [$F(2, 1362) = 41.4$, $p < .001$]. Follow-up tests revealed a significant effect of congruity in the pleasant, unpleasant, and neutral scenarios, where the incongruous scenarios were rated as being more implausible than the congruous scenarios. However, the differences in plausibility between the congruous and incongruous critical words were smaller than those between the neutral words [mean difference = 2.44; $F(1, 454) > 7,500$, $p < .001$] and either the pleasant [mean difference = 3.31; $F(1, 454) > 14,500$, $p < .001$] or the unpleasant [mean difference 3.17; $F(1, 454) > 12,000$, $p < .001$] words.

Valence and arousal ratings of the critical words

To verify the experimenters' intuitions regarding which critical words were "neutral" or "emotional," we collected valence and arousal ratings of the individual critical words. Some ratings had been gathered for other studies in the lab (Fields & Kuperberg, 2012; Holt et al., 2009), but the majority of the valence and arousal ratings were collected specifically for this study. The critical words of Sentence 2 that had not been rated in previous studies were divided randomly into four lists, each of which was to be rated on valence and arousal. Another 364 participants, recruited online, were asked to rate one list of words on valence, followed by a different list of words on arousal. A scale of 1 to 7 was used for both arousal and valence, where 1 was *least arousing* or *most negative*, and 7 was *most arousing* or *most positive*, with an overt option to skip unfamiliar words. As expected, omnibus ANOVAs produced main effects of critical-word group (pleasant, unpleasant, neutral congruous, and neutral incongruous) for both the valence [$F(3, 227) = 1,458.9$, $p < .0001$] and arousal [$F(3, 227) = 155.8$, $p < .0001$] ratings. A follow-up Tukey honestly significant difference (HSD) test on valence showed that the pleasant and unpleasant words both differed from the neutral words, and from each other, but that the two types of neutral words (those taken from the congruous and incongruous conditions) were rated equally. A Tukey HSD test on arousal showed that the pleasant and unpleasant words, which did not differ from one another ($p > .9$), had higher arousal ratings than did both neutral conditions ($p < .0001$), which also did not differ from one another ($p > .9$).

Concreteness, frequency, and word length of critical words

We next collected normative ratings of concreteness of the critical words in Sentence 2 (pleasant, unpleasant, neutral congruous, and neutral incongruous) and retrieved their natural-log frequencies from the English Lexicon Project (Balota et al., 2007).

To assess the concreteness ratings of the critical words, participants were asked to rate one list of words on concreteness on a scale from 1 to 7. A total of 123 participants completed the task, but seven did not meet the inclusion criteria, leaving 116 participants with a mean age of 24. 2 years. An ANOVA revealed a significant difference between the groups of words on concreteness [$F(3, 227) = 24.93$, $p < .0001$]. A follow-up Tukey HSD test indicated that, while the pleasant and unpleasant words were matched on concreteness, the neutral critical words were rated as being more concrete than the pleasant and unpleasant critical words, and the neutral words from the incongruous sentences were given higher concreteness ratings than were the neutral words from the congruous sentences (see Table 2).

We also observed some differences across the four groups of critical words in lexical frequency, defined as the natural log of the HAL frequency per million words [$F(3, 227) = 11.78$, $p < .0001$]. Tukey HSD follow-up tests showed that the neutral critical words used in the congruous sentences were higher in frequency than each of the three other word types, which did not differ significantly from one another. This arose because the neutral words produced in the cloze probability study tended to be of higher frequency than the pleasant and unpleasant words.

In addition, we found differences across the four conditions in word length [$F(3, 227) = 2.64$, $p = .0485$], primarily because the pleasant words were slightly longer than the unpleasant words (7.6 vs. 7.05 letters). Neither the pleasant nor the unpleasant words, however, differed significantly in word length from either of the neutral groups, as is shown in Table 2.

Latent semantic analysis

Finally, we carried out a latent semantic analysis (LSA) assessing the pairwise semantic similarity values (SSVs) between the critical words and their preceding scenario texts (calculated using a topic space based on general reading up to the first year of college, obtained from CU Boulder at lsa. colorado.edu: Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). The available values were entered into an ANOVA, with Emotion and Congruity as factors. Overall, incongruous words tended to have lower SSV values than did congruous words (Table 2), but the congruity effects differed significantly across the different levels of emotion

[$F(2, 1318) = 4.97$, $p = .007$]. Follow-ups revealed that the congruity effect was larger for neutral (mean difference, 0. 04) than for pleasant (mean difference, 0.007) or unpleasant (mean difference, 0.006) words; see Table 2.

Lists and subsets

From the final set of stimuli, six randomized, counterbalanced lists were generated, such that all participants would see each critical word and each scenario only once. Each list contained 38 scenarios for each of the six conditions. Within each list, the order of sentence presentations was randomized.

As noted above, some differences across the six experimental conditions—in concreteness, frequency, word length, and SSVs—could not be matched due to the constraints imposed by the cloze probability norms. In order to determine whether these differences confounded our main findings, we created subsets of scenarios in which the critical words were fully matched across experimental conditions on each of these variables. The first subset was created using 192 of the 228 original scenarios, which matched the four types of critical words (pleasant, unpleasant, neutral congruous, and neutral incongruous) on frequency and length. The second subset was created using 209 of the scenarios, which matched the four types of critical words on concreteness. The third subset was created using 198 of the scenarios such that the effects of congruity on SSV values were matched across the three levels of emotion. Although previous literature had indicated that each of these subsets could address confounds within particular time windows, we conservatively repeated every significant statistical test in all three subsets in each time window.

Participants

A group of 27 Tufts undergraduate students initially participated in the ERP study. The data for three of the original participants were subsequently excluded due to excessive artifacts, leaving 24 participants whose data were included in the final analyses (six male, 18 female; mean age 19. 8 years, *SD* 1.13). All participants were right-handed, native English speakers (having learned no other language before the age of 5) between the ages of 18 and 25, with no history of psychiatric or neurological disorders. All participants had normal or corrected-to-normal vision and no history of head trauma. They were compensated for their time and provided informed consent in accordance with the procedures of the Institutional Review Board of Tufts University.

Experimental procedure

Participants sat in a quiet, dimly lit room. Each of the six lists was viewed by four nonexcluded participants. Before

each trial, participants were presented with the word "READY" and pressed a button to initiate the trial. Trials began with a 500-ms fixation cross followed by the two sentences, presented one word at a time, with a duration of 400 ms per word and an interstimulus interval of 100 ms between words. The last word of each sentence was presented with a period and remained onscreen for 750 ms. Words were presented in white text on a black background at the center of a monitor 24 in. from the participant's chair. Participants were directed to pay attention to the best of their ability and to read and comprehend each scenario. At random intervals, they were asked to answer a comprehension question after a scenario that required some inductive reasoning about that scenario to answer (e.g., after the scenario "Ed sent Mandy a creepy e-mail this morning. She shuddered after reading it," we asked, "Did Ed have Internet access?"). These questions were presented as a whole on the screen, and a "yes" or "no" answer was required in order to continue. The questions never addressed the emotional valence of the scenario, and the same question was presented for all permutations of that scenario (which, as noted above, appeared counterbalanced across different lists). Trials were grouped into six blocks of equal length, with participants being offered a break between blocks.

EEG recording A set of 29 tin electrodes were held in place on the scalp by an elastic cap (Electro-Cap International, Inc., Eaton, OH). Electrodes were also placed below the left eye and at the outer canthus of the right eye to monitor vertical and horizontal eye movements (electrodes LE and HE in Fig. 1) and on the left and right mastoids (A1 and A2 in Fig. 1). The electroencephalography (EEG) signal was referenced to the left mastoid for both data collection and analysis. Impedance was kept below 5 kΩ for all scalp electrodes, below 2.5 kΩ for each mastoid electrode, and below 10 kΩ for the two eye channels. The EEG signal was amplified by an Isolated Bioelectric Amplifier System, Model HandW-32/BA (SA Instrumentation, San Diego, CA) with a bandpass of 0.01 to 40 Hz, and was continuously sampled at 200 Hz by an analog-to-digital converter. The stimuli and behavioral responses were simultaneously monitored by a digitizing computer. Trials were rejected if they contained a blink, large head movements, a "blocked" electrode, or missing data.

Statistical analysis

After artifact rejection, the EEG responses were time-locked to the critical words in the second sentence and were averaged across all 38 trials in each of the six conditions, using a −100- to 0-ms prestimulus baseline. We focused on examining modulation of activity within the N400 and late positivity time windows. The N400 time window was set to
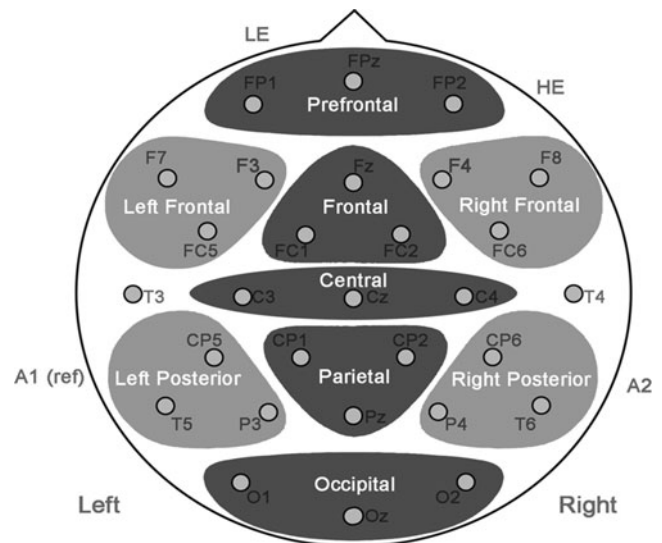

Fig. 1 Electrode montage. Mid regions are dark gray, and peripheral regions are light gray

300–500 ms, on the basis of numerous previous studies of the N400 component, and the late positivity time window was set at 500–700 ms, on the basis of our previous study using emotional sentences (Holt et al., 2009).

In order to examine how the modulation of the waveforms varied across the scalp, the scalp was subdivided into regions along its anterior–posterior distribution, at both mid and peripheral sites (each region contained three electrode sites; see Fig. 1). Two omnibus repeated measures ANOVAs, one covering mid regions (dark gray in Fig. 1) and another covering peripheral regions (light gray in Fig. 1), were conducted for each time window.

In the mid-regions omnibus ANOVA, the within-subjects variables were emotion (three levels: pleasant, neutral, and unpleasant), congruity (two levels: congruous and incongruous), and region (five levels: prefrontal, frontal, central, parietal, and occipital). Interactions with region were followed up by examining Emotion × Congruity effects in each three-electrode region individually. Interactions between emotion and congruity were followed up by examining the effects of congruity at each level of emotion and/or examining effects of emotion at each level of congruity. Significant effects of emotion in each region were further followed up by testing pairwise effects using the Fisher LSD method (unpleasant vs. neutral, pleasant vs. neutral, and unpleasant vs. pleasant) when protected by the omnibus.

In the peripheral-regions omnibus ANOVA, the within-subjects variables were emotion (three levels: pleasant, neutral, and unpleasant), congruity (two levels: congruous and incongruous), region (two levels: frontal and parietal), and hemisphere (two levels: left and right). Interactions between emotion and congruity were followed up as described

Fig. 2 Effect of congruity at each level of emotion. Critical words in neutral scenarios showed a large N400 congruity effect, with congruous words eliciting a smaller negativity than did incongruous words. In contrast, pleasant and unpleasant critical words did not show any N400 congruity effects: Both congruous and incongruous words elicited equally small negativities
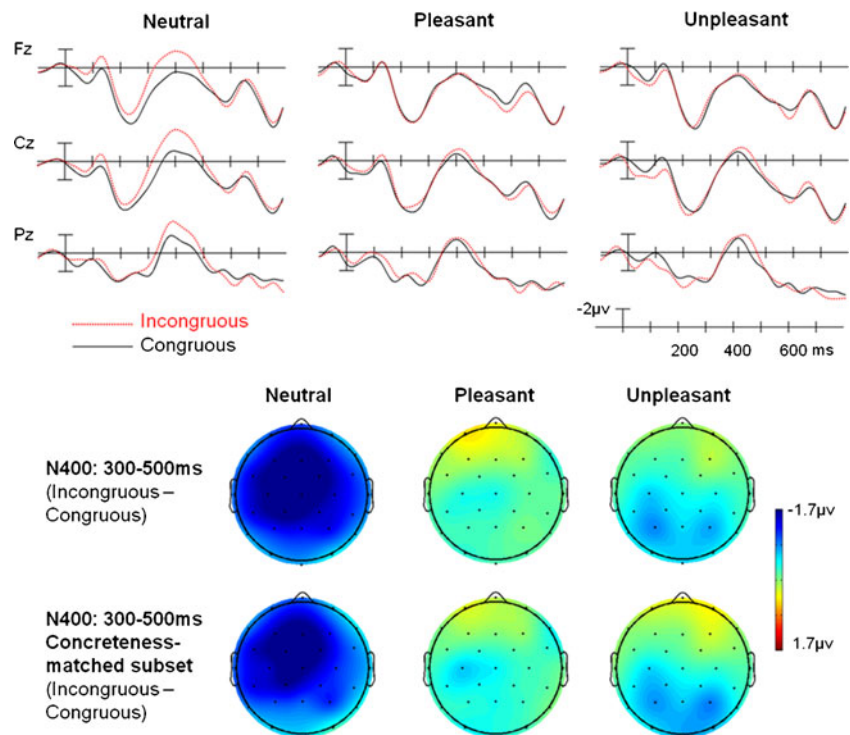
above. Interactions involving region (and not hemisphere) were followed up by examining effects in pairs of regions (collapsed across the left and right hemispheres), while interactions involving both region and hemisphere were followed up by examining effects in the left and right frontal and posterior peripheral regions separately.

All significant effects with two or more degrees of freedom were corrected using the Geisser–Greenhouse method (Geisser & Greenhouse, 1958), with alpha set at .05 for all tests. All significant tests were repeated using the matched subsets of stimuli to see whether they remained significant.

Results

The grand-average ERP waveforms elicited by each of the six types of critical words are shown in Fig. 2, which shows ERPs to congruous and incongruous words plotted separately for each level of emotion (with 24 participants and 38 trials per condition before artifact rejection).

N400: 300–500 ms

The negative-going N400 component was evident over most of the scalp. Omnibus ANOVAs at both the mid and peripheral regions showed significant main effects of emotion [mid regions, $F(2, 46) = 18.58$, $p < .001$; peripheral regions, $F(2, 46) = 15.44$, $p < .001$] and congruity [mid regions, $F(1, 23) = 12.90$,

$p = .002$; peripheral regions, $F(1, 23) = 13.74$, $p = .001$]. However, these main effects were accompanied by significant Emotion × Congruity interactions in both the mid-region ANOVA [$F(2, 46) = 5.35$, $p = .01$] and the peripheral-region ANOVA [$F(2, 46) = 4.42$, $p = .02$].[5]

Follow-up of the Emotion × Congruity interaction at each level of emotion revealed a robust N400 congruity effect on the neutral words [mid-region ANOVA, $F(1, 23) = 13.28$, $p = .001$; peripheral-region ANOVA, $F(1, 23) = 12.73$, $p = .002$], which was widespread but larger in frontal than in posterior mid regions [Congruity × Region interaction, $F(4, 92) = 7.53$, $p = .001$], with incongruous neutral words evoking a larger negativity than did congruous neutral words. In contrast, as is shown in Fig. 2, neither pleasant nor unpleasant words evoked a significant N400 effect: We found no main effects or interactions involving congruity in either the mid- or peripheral-region ANOVAs (all Fs < 2, all ps > .15).

Next, in order to determine whether the reduced N400 congruity effect on the emotional relative to the neutral

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[5] At some electrode sites, there appeared to be some early modulation of activity before the N400 time window (see Fig. 2). We do not report analyses of these early components, as we did not have clear a priori hypotheses for how they would be modulated in this paradigm. However, in order to ensure that modulation in the N400 time window was not driven by differences in early components, we repeated this omnibus analysis using a longer baseline of −100 to +100 ms. The Emotion × Congruity interaction remained significant [mid regions, $F(2, 46) = 5.08$, $p = .014$; peripheral regions, $F(2, 46) = 3.90$, $p = .033$].
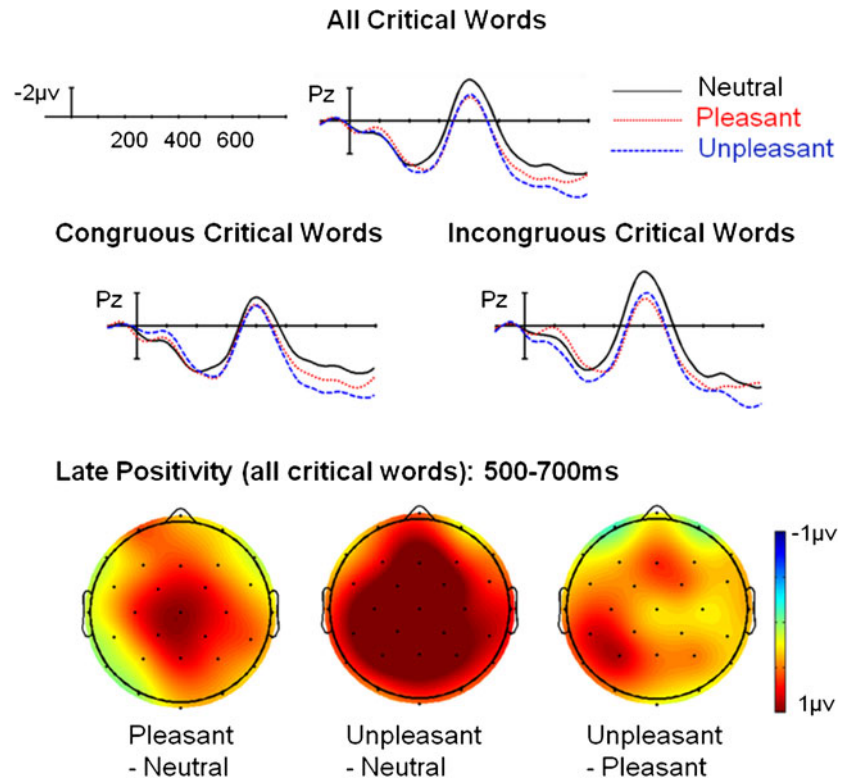
words was driven by a reduced N400 to incongruous emotional versus neutral words, or rather by an increased N400 to congruous emotional versus neutral words, we examined the effect of emotion at each level of congruity. This showed clear effects of emotion on the incongruous words [mid-region ANOVA, $F(2, 46) = 19.42$, $p < .001$; peripheral-region ANOVA, $F(2, 46) = 16.73$, $p < .001$] due to a smaller negativity to incongruous pleasant and unpleasant words than to incongruous neutral words (all $ps < .001$). In contrast, no effect of emotion was apparent on congruous critical words [mid-region ANOVA, $F(2, 46) = 1.74$, $p = .18$; peripheral-region ANOVA, $F(2, 46) = 1.42$, $p = .25$].

These main effects and interactions, including the follow-ups, remained significant in the subset in which word length and HAL frequency were matched, and in the subset with LSA values controlled. However, in the subset with concreteness matched, the Emotion × Congruity effect on the N400 additionally interacted with region in the mid-region omnibus ANOVA [$F(8, 184) = 2.68$, $p = .04$] and was not significant in the peripheral-region ANOVA [$F(2, 46) = 2.40$, $p = .10$]. In the follow-ups for this concreteness-matched subset, neutral words still elicited a substantial congruity effect [$F(1, 23) = 7.68$, $p = .01$], but the effect was smaller over prefrontal and frontal mid regions. A small N400 congruity effect also emerged on the unpleasant words in a single occipital region [$F(1, 23) = 9.2$, $p = .01$], but congruity remained nonsignificant for pleasant words [mid regions, $F(1, 23) = 0.58$, $p = .45$; peripheral regions, $F(1, 23) = 0.56$, $p = .46$]. Emotion effects within each level

of congruity remained unchanged from the full set of stimuli.

Late positivity: 500–700 ms

Immediately following the N400 component, a robust positivity was observed, peaking at around 600 ms (shown in Fig. 3). In this late positive time window, we observed a significant main effect of emotion in both the mid- and peripheral-region omnibus ANOVAs [mid regions, $F(2, 46) = 13.98$, $p < .001$; peripheral regions, $F(2, 46) = 11.66$, $p < .001$]. This emotion effect varied across the scalp, as indicated by an Emotion × Region interaction in the mid-region ANOVA [$F(8, 184) = 2.82$, $p = .041$] and an Emotion × Region × Hemisphere effect in the peripheral-region ANOVA [$F(2, 46) = 4.182$, $p = .022$]. Follow-up ANOVAs showed effects of emotion in every region (all Fs > 2.92, all $ps < .05$). Pair-wise follow-ups in frontal, central, and parietal regions showed that unpleasant words elicited the largest positivity, pleasant words a slightly smaller positivity, and neutral words the smallest positivity (all $ps < .05$); see Fig. 3. Over the occipital region, only the difference between unpleasant and neutral words reached significance ($p < .01$). Over all peripheral regions, unpleasant words elicited larger positivities than did neutral words ($ps < .025$), but unpleasant words elicited a larger positivity than did pleasant words only in the left posterior periphery ($p = .003$). We found no main effects of congruity and no interactions involving

congruity and emotion (all Fs < 1.14, ps > .25). This pattern of effects on the late positivity remained significant across all three subsets.

Effects at sentence-final position

The sentence-final word was the same in all six conditions, and was assessed using the same tests described above. During the N400 time window, no effects or interactions approached significance in either the mid- or the peripheral-region omnibus ANOVA (all Fs < 2.5, all ps > .1). During the late positivity time window, a main effect of emotion reached significance in both the mid-region (F = 4.49, p = .028) and peripheral-region (F = 3.90, p = .042) omnibus ANOVAs, because sentence-final words that followed unpleasant critical words elicited a larger positivity than did sentence-final words that followed neutral or pleasant critical words. Other than a Congruity × Hemisphere interaction over the peripheral electrodes (F = 8.39, p = .01), no other effects or interactions approached significance for the late positivity (all Fs < 2.5, all ps > .10).

Discussion

Since the seminal studies of Kutas and Hillyard (1980, 1984), researchers have known that the N400 to an incoming word is modulated by its congruity with its preceding context (Kutas & Federmeier, 2011). The primary aim of this study was to determine whether this is also true for congruous versus incongruous emotional words following emotional discourse contexts. To this end, we fully crossed emotion (pleasant, unpleasant, and neutral) and congruity (congruous and incongruous) within short, two-sentence discourse scenarios, and measured ERPs on the critical words in the second sentence.

Our findings were striking: We found quite different patterns of activity on the emotional and neutral critical words. As expected, we saw a robust discourse congruity effect on the N400 to neutral words following neutral discourse contexts (Kuperberg et al., 2011b; Van Berkum et al., 1999; Van Berkum, Zwitserlood, Hagoort, & Brown, 2003). However, the effect of discourse congruity was markedly reduced on emotional words following emotional discourse contexts. Rather, the amplitude of the N400 was small to *all* emotional words, regardless of whether or not their emotional valence was or was not congruous with the valence of their emotional discourse context. This was the case when the context was positively valenced and the emotional critical word was negatively valenced, and when the context was negatively valenced and the emotional critical word was positively valenced.

In addition to these findings on the N400, we also observed a larger late positivity for emotional than for neutral

words. This effect was not modulated by discourse congruity and is consistent with many previous studies of emotional words in isolation (Citron, 2012; Kissler et al., 2006) and in discourse contexts (Bartholow et al., 2001; Chung et al., 1996; Fields & Kuperberg, 2012; Holt et al., 2009). In the present study, this provides evidence that, as participants read these discourse scenarios, they perceived the incoming emotional words as salient, arousing, and motivationally significant enough to trigger a reallocation of attentional resources for continued analysis (Hajcak et al., 2012). The late positivity was also sensitive to valence: Consistent with our previous studies (Fields & Kuperberg, 2012; Holt et al., 2009), it was larger to unpleasant than to pleasant words, even when they were matched for arousal (a negativity bias; see Ito et al., 1998).

We interpret the attenuation of the N400 to the emotional words—both congruous and incongruous—as reflecting prioritized access to their emotional salience at the earliest stages of extracting their meaning. We will argue that, consistent with the general framework of affective primacy, this led comprehenders to bypass deep semantic processing of the valence-incongruous emotional words within the N400 time window, allowing the comprehenders to move straight on to further analysis of the words' motivational significance, reflected by the late positivity. Importantly, however, we will argue that a prioritization of emotional salience does not always lead to a superficial semantic analysis in the N400 time window. Rather, we suggest that the nature of the context has a critical influence on how the N400 is modulated to incoming emotional words. Before exploring these ideas more fully, we will first consider potential confounds and alternative explanations for the reduced N400 congruity effect on the emotional words.

Potential confounds and alternative explanations

It is well established that the N400 is modulated by lexical predictability, which is usually operationalized using cloze measures (Federmeier et al., 2007; Kutas & Hillyard, 1984; Taylor, 1953). In this study, we were careful to control cloze probabilities across the neutral and emotional scenarios: Cloze values (and congruous-vs.-incongruous cloze differences) were matched between the pleasant, unpleasant, and neutral words. Despite this matching, the N400 congruity effect was robust on the neutral words and minimal on the emotional words. Differences in N400 modulation between the emotional and neutral words cannot therefore be explained by differences in lexical predictability. Note, however, that the contexts we used were of relatively low lexical constraint (in general, no single critical word was highly expected), so plausibility ratings may be a better reflection than cloze probabilities of how well the properties of incoming words matched their contexts. Therefore, to address the possibility that the N400

was larger to the semantically incongruous neutral words because they were more implausible than the valence-incongruous emotional words, we collected plausibility ratings for all 1,368 scenario permutations of the stimuli, up to and including the critical word. We found that, despite their larger N400, the semantically incongruous neutral words were actually rated as being *less* implausible than the valence-incongruous emotional words (see Table 2). We therefore concluded that, as a whole, discourse-level factors like semantic predictability, constraint, and plausibility were unlikely to have contributed to the observed pattern of N400 effects.

The N400 can be sensitive to matches between a context and an incoming word along multiple semantic dimensions, including associative, categorical, featural, and schema-based relationships, and these relationships do not always pattern with real-world plausibility (e.g., Camblin, Gordon, & Swaab, 2007; Ditman, Holcomb, & Kuperberg, 2007; Federmeier & Kutas, 1999; Paczynski & Kuperberg, 2012). To assess their influence in this study, we extracted SSVs between each of our critical words and its context in each scenario, using LSA (Landauer & Dumais, 1997; Landauer et al., 1998; available at http://lsa.colorado.edu). LSA captures knowledge about multiple types of semantic relationships between words and concepts, but it is relatively insensitive to word order, syntax, or propositional meaning. As is shown in Table 2, the valence-incongruous emotional words and their emotional contexts were slightly more semantically related (higher SSVs) than the semantically incongruous neutral words and their neutral contexts. However, when we repeated all ERP analyses on a subset of our materials that fully matched the difference in SSVs between congruous and incongruous critical words at each level of emotion, we saw no changes in the pattern of N400 amplitudes across conditions. Of course, *emotional salience* can itself be considered a broad semantic feature, and the reduced N400 to all emotional words following an emotional context can be conceptualized as reflecting a semantic match at this broad level of representation. We will return to this idea in the next section.

The third potential confound that we considered was concreteness. We know from previous studies that the N400 is smaller to abstract than to concrete words, both in and outside sentence contexts, particularly at anterior electrode sites (Holcomb, Kounios, Anderson, & West, 1999; Huang, Lee, & Federmeier, 2010; Kounios & Holcomb, 1994; Lee & Federmeier, 2008). In the present study, the emotional words were generally more abstract than the neutral words. Our selection of critical words was tightly constrained by our cloze probability norming, and emotional words are, as a whole, more abstract than neutral words (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011). To exclude the possibility that the N400 to the incongruous emotional words was attenuated

because they were more abstract than the incongruous neutral words, we repeated all ERP analyses on a subset of the stimuli that fully matched the critical words for concreteness. We found exactly the same pattern of findings: a clear N400 congruity effect for the neutral words, but not for the emotional words (save for a small effect in a single region on the unpleasant words); see the concreteness-matched subset at the bottom of Fig. 2. Similarly, in subsets matched for frequency and word length, all significant N400 effects elicited using the full stimulus set were replicated.

A fourth possibility that we considered was that the emotional discourse contexts led to a general disengagement of semantic processing on all upcoming words, regardless of whether or not they were emotional. We think that this is unlikely, because a robust N400 congruity effect has been described in three different studies that had introduced neutral words in emotional written sentence and discourse contexts (León et al., 2010; Moreno & Vázquez, 2011; Jiménez-Ortega et al., 2012). However, to address this possibility in our own data, we carried out analyses on the neutral words that immediately preceded the critical words in both the neutral and emotional scenarios. We found no difference in the amplitudes of the N400 to neutral words that followed emotional discourse contexts and to those that followed emotional discourse contexts (data not shown).

Finally, an important factor to consider in interpreting the reduced N400 to the emotional words is the role of component overlap from the subsequent late positivity. As noted above, the late positivity was larger to the emotional than to the neutral words, and it appeared to start within the N400 time window, at around 400 ms. Component overlap, however, cannot explain the full pattern of findings: If the positivity evoked by the emotional words was simply "pulling down" the N400 on these words, one would also have expected the N400 to *congruous* emotional words to be pulled down and to be smaller than the N400 to congruous neutral words. However, we only saw a reduced N400 to the *incongruous* emotional words. In addition, whereas the late positivity was larger to the unpleasant than to the pleasant words (a negativity bias), we found no effect of valence in the N400 time window.

Prioritization of emotional salience can lead to reduced semantic analysis on the N400

Having excluded these confounds, we concluded that our results support the second hypothesis that we outlined at the end of the introduction: that, in these emotional discourse contexts, the match between the context and the incoming word on emotional salience initially (within the N400 time window) overrode any discourse incongruity between the context and the incoming word that was conferred by

emotional valence. In this sense, one might conceptualize emotional salience as a broad feature of stimuli that, in this study, dominated over effects of discourse congruity within the N400 time window. To spell this out more specifically, the neutral contexts (e.g., "Colin saw a small object on the ground. He realized it was a . . .") activated a particular set of semantic features (e.g., something small). Incongruous neutral critical words (e.g., *giraffe*) mismatched these features and were therefore subject to deeper semantic processing within the N400 time window. The emotional contexts (e.g., "Colin saw a horrifying object on the ground. He realized it was a . . .") also activated some set of semantic features, including valence, but were additionally identified as emotionally salient. We argue that this led the brain to prioritize access to the incoming emotional word's salience (see also Hinojosa, Carretié, Méndez-Bértolo, Míguez, & Pozo, 2009), bypassing retrieval of its semantic and valence features within the N400 time window, and immediately triggering an additional evaluative process, including valence evaluation, that was reflected by the robust late positivity effect (Hajcak et al., 2012). This interpretation is broadly consistent with the affective primacy hypothesis, which argues that in some contexts, prioritizing access to emotional information can lead to a relatively superficial semantic analysis, but can quickly trigger an affective response (Lai et al., 2012; LeDoux, 1996).

This interpretation illustrates two important and related points about the functional significance of the N400 component. First, although an attenuation of the N400 can sometimes reflect full "access" to the semantic features of an incoming word (such as in a lexically constraining context), at other times a reduced N400 simply tells us that the semantic features of an incoming word match features that are highly active and prioritized over other features by the context. In other words, the context establishes what features of the incoming words are most relevant to activate, and in emotional contexts, salient features dominate over other semantic features, attenuating N400 congruity effects. Second, although the N400 *can* pattern with discourse coherence, in many situations it does not pattern with coherence, plausibility, or truth value, when it simply reflects the first stage of extracting the meaning of incoming words. Other examples of an absent N400 effect to words that are clearly implausible in relation to their discourse context include so-called *temporary semantic illusions* (e.g., Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Nieuwland, & Van Berkum, 2005; Sanford, Leuthold, Bohan, & Sanford, 2011; see Kuperberg, 2007, for a review). Of course, this raises the question of what drives peoples' assessments of implausibility in these situations (in exit interviews, participants commonly identified the valence-incongruous scenarios as being unexpected and, as noted above, the incongruous emotional scenarios were rated as being even more implausible than the incongruous neutral scenarios). In

"semantic illusion" sentences, effects of plausibility are often seen in the late positivity time window (on the "semantic P600"; Kuperberg, 2007) or on the sentence-final word (e.g., Paczynski & Kuperberg, 2012). In this study, however, we observed no effects of discourse coherence on either the late positivity or the sentence-final words of the emotional sentences. On the other hand, an effect of valence itself did manifest in the late positivity (as a negativity bias), which is consistent with the view that participants deferred their processing of some semantic features until this time window.

The influence of context on the processing of emotional words in discourse

Importantly, we are not claiming that the semantic analysis of emotional words in discourse contexts is always superficial within the N400 time window, or that prioritizing our access to the salient features of incoming emotional words always leads to "affective primacy," which bypasses deep semantic analysis. Indeed, as we discussed in the introduction, we have previously shown that in *neutral* discourse contexts, emotional words produced a *larger* N400, indicating deeper semantic processing, than did neutral words in the same neutral discourse contexts (Holt et al., 2009). Thus, the effect of prioritizing access to emotionally salient features on semantic processing within the N400 time window appears to depend on the context itself (Lai et al., 2012). In a neutral context, prioritized access to the emotional features of incoming emotional words may lead to a deeper semantic analysis (a larger N400 in Holt et al., 2009), whereas in emotionally salient contexts, it will lead to a shallower semantic analysis (a smaller N400, in this study). As we discussed in the introduction, this makes adaptive sense: In an emotional context, bypassing deep semantic analysis of an incoming emotional stimulus may help ensure survival (LeDoux, 1996), but in a neutral context, retrieving the semantic features of an unexpected emotional word ensures that it will be accurately identified and deeply encoded for later recognition (Kensinger & Corkin, 2003; see Mather & Sutherland, 2011, for a discussion).

We also do not wish to imply that the N400 is always insensitive to incongruities of emotional valence, or that we always prioritize access to emotional salience over valence. In this study, we did not see an effect of valence congruity on the N400, which is consistent with some previous studies that also have not found effects of valence congruity on the N400s evoked by emotional nouns preceded by other emotional nouns (Herring, Taylor, White, & Crites, 2011; but see Zhang, Li, Gold, & Jiang, 2010), by emotional pictures (Kissler & Koessler, 2011), and by emotional adjectives (e. g., *dead puppy* vs. *dead tyrant*; Fischler & Bradley, 2006). It is also consistent with previous studies that showed no N400 modulation to the vocal prosody of words that had the same

or the opposite valence, relative to the vocal prosody of the preceding context (Kotz & Paulmann, 2007; Paulmann & Kotz, 2008).

Other studies, however, have reported effects of valence congruity in the N400 time window. For example, a smaller N400 is seen to single words whose emotional valence matches (vs. mismatches) the emotional prosody with which they are spoken (Schirmer & Kotz, 2003) or the prosody of the preceding sentence context (Schirmer, Kotz, & Friederici, 2002, 2005). Likewise, a smaller N400 is also seen to written words whose emotional valence matches (vs. mismatches) the comprehender's mood (Chung et al., 1996), and to words that are consistent (vs. inconsistent) with the comprehender's underlying belief systems (Van Berkum et al., 2009).

We propose that the critical factor that determines whether or not the N400 to an incoming emotional word will be sensitive to the valence congruity of its context is the degree to which that context constrains for positive or negative features (see Storbeck & Clore, 2007, for a discussion of relevant behavioral findings). In all of the studies that did report a congruity effect on the N400, the context (i.e., the prosody, mood, or belief) constrained strongly for emotional valence, and it was often present at the same time as the target emotional words. In contrast, those studies that have failed to present N400 valence congruity effects have usually used nonconstraining contexts. In the present study, for example, valence was established in a previous sentence, and the discourse context did not constrain strongly for a particular emotional word (as reflected by our cloze ratings).

We further propose that, during the comprehension of emotional discourse, a trade-off takes place between prioritizing access to the salience and the valence properties of incoming emotional words within the N400 time window. As was discussed in the introduction, access to the salience features of an incoming stimulus is known to trigger a reallocation of attention and further evaluation of the stimulus's arousal or motivation significance, as reflected by a late positivity effect (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak et al., 2012). This hypothesis therefore predicts that in cases in which emotional valence is prioritized over emotional salience, effects of valence incongruity will be seen on the N400, but the late positivity will be relatively small and late. However, in cases in which initial access to emotional salience is prioritized over emotional valence, the N400 will be insensitive to valence congruity, and the late positivity will be robust and early.

In fact, some evidence for this hypothesis comes from comparing the results of this study with those of the three other studies that have also manipulated the valence congruity of emotional words in emotional contexts, discussed in the introduction (Bartholow et al., 2001; León et al.,

2010; Moreno & Vázquez, 2011). Recall that, as in the present study, Bartholow et al. reported a major reduction in N400 amplitudes to valence-incongruous emotional words, as well as a robust late positivity to emotional versus neutral words, which was sensitive to emotional valence (see also Fischler & Bradley, 2006). In contrast, the two other studies (León et al., 2010; Moreno & Vázquez, 2011) did reveal some effect of emotional valence on the N400 (though diminished), but they reported no late positivity effect to emotional (vs. neutral) words. We suggest that the contexts used by the latter two studies may have been more valence-constraining. For example, León et al. used long, embellished scenario contexts, which are more likely to have constrained for valence features than are the shorter scenarios used here and by Bartholow et al., or the single adjectives used by Fischler and Bradley (e.g., the word *dead* does not bias toward either *dead puppy* or *dead tyrant*).

Open questions

In this study, we asked how a written discourse context influences the processing of *emotional* words, and we discussed our findings in relation to those of other studies examining the effects of context on emotional words. Another important way to examine the relationships between emotion and language would be to study the influences of emotional contexts on the comprehension of *neutral* target words. As we already noted, when discussing potential alternative interpretations of our data, a robust N400 congruity effect *has been* seen to neutral words following emotional written sentence and discourse contexts (Jiménez-Ortega et al., 2012; León et al., 2010; Moreno & Vázquez, 2011). However, two previous studies have reported slightly different effects of *mood* on the N400s evoked by neutral words in neutral discourse contexts: The N400 is attenuated to incongruous (vs. high-cloze) words after the induction of a positive versus neutral (Federmeier, Kirson, Moreno, & Kutas, 2001) or a negative versus positive (Chwilla, Virgillito, & Vissers, 2011) mood. Given the ideas discussed in this article about potential trade-offs between valence and arousal in influencing semantic processing (see also Mather & Sutherland, 2011), it will be important for future studies to determine whether the effects of mood, and other forms of emotional context, on semantic processing are driven primarily by arousal, valence, or both.

It will also be important for future studies to determine how individual and group differences in emotional processing can influence language comprehension. Interesting ERP evidence has now emerged for differences between men and women in their sensitivities to emotional prosody (Schirmer et al., 2002, 2005; Schirmer et al., 2006) and social pragmatic expectations (van den Brink et al., 2012) during

language comprehension.[6] The N400 evoked by emotional words can also be influenced by personality traits such as trait anxiety (e.g., Holt et al., 2009) and individual belief systems (Van Berkum et al., 2009). Finally, all of these findings have important implications for language comprehension in patients with neuropsychiatric disorders that are characterized by misattributions of emotional valence (e.g., mood disorders, see Beck, Rush, Shaw, & Emery, 1979) or emotional salience (e.g., schizophrenia; see Holt et al., 2011; Kapur, 2003; Kuperberg, Kreher, Swain, Goff, & Holt, 2011a).

Finally, it will be important to combine EEG with techniques that are more sensitive to spatial information, such as magnetoencephalography or magnetic resonance imaging, to determine where and when the language and emotional networks interact during real-time comprehension. The present findings imply close interactions between the brain regions that are sensitive to emotional salience (such as the amygdala) and the underlying neural sources of the N400. While these N400 sources remain controversial, there is some evidence that they include the anterior lateral temporal cortex (Halgren et al., 2002; Lau et al., 2011; McCarthy, Nobre, Bentin, & Spencer, 1995; Nobre & McCarthy, 1995), which has close connections not only to multiple regions across the association cortex that store semantic information (Patterson, Nestor, & Rogers, 2007; Lambon Ralph & Patterson, 2008), but also to the medial temporal cortex, including the amygdala (Vuilleumier & Pourtois, 2007). If we are correct in our hypothesis that, following an emotional discourse context, accessing an emotional word's salience is prioritized over accessing other semantic information, we would predict an inverse relationship between activity in the amygdala and activity in the lateral anterior temporal cortex to emotional (vs. neutral) words between 300 and 500 ms after the words' onset.

Conclusions

In sum, we have presented evidence that short written emotional discourse contexts can lead to reduced semantic processing of subsequent emotional words in the N400 time window, regardless of the words' valence, their valence congruity, their expectedness, or their plausibility. These findings suggest that, in emotional discourse contexts, the brain prioritizes access to the emotional salience of incoming words over their valence and other semantic features

within at least 300 ms after their onset, and that it treats valence congruity on emotional words and semantic congruity on neutral words quite differently during online discourse comprehension.

References

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., et al. (2007). The English Lexicon Project. *Behavior Research Methods, 39,* 445–459. doi:10.3758/BF03193014

Bartholow, B. D., Fabiani, M., Gratton, G., & Bettencourt, B. A. (2001). A psychophysiological examination of cognitive processing of and affective responses to social expectancy violations. *Psychological Science, 12,* 197–204.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive therapy of depression*. New York, NY: Guilford Press.

Bradley, M. M., & Lang, P. J. (2007). Emotion and motivation. In J. T. Cacioppo, L. G. Tassinary, & G. G. Bernston (Eds.), *Handbook of psychophysiology* (3rd ed., pp. 581–607). Cambridge, UK: Cambridge University Press.

Camblin, C. C., Gordon, P. C., & Swaab, T. Y. (2007). The interplay of discourse congruence and lexical association during sentence processing: Evidence from ERPs and eye tracking. *Journal of Memory and Language, 56,* 103–128. doi:10.1016/j.jml.2006.07.005

Chung, G., Tucker, D. M., West, P., Potts, G. F., Liotti, M., Luu, P., et al. (1996). Emotional expectancy: Brain electrical activity associated with an emotional bias in interpreting life events. *Psychophysiology, 33,* 218–233. doi:10.1111/j.1469-8986.1996.tb00419.x

Chwilla, D. J., Hagoort, P., & Brown, C. M. (1998). The mechanism underlying backward priming in a lexical decision task: Spreading activation versus semantic matching. *Quarterly Journal of Experimental Psychology, 51A,* 531–560. doi:10.1080/027249898391521

Chwilla, D. J., Virgillito, D., & Vissers, C. T. (2011). The relationship of language and emotion: N400 support for an embodied view of language comprehension. *Journal of Cognitive Neuroscience, 23,* 2400–2014. doi:10.1162/jocn.2010.21578

Citron, F. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language, 122,* 211–226. doi:10.1016/j.bandl.2011.12.007

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52,* 95–111. doi:10.1016/S0301-0511(99)00044-7

de Gelder, B., Vroomen, J., & Pourtois, G. (2004). Multisensory perception of affect, its time course and its neural basis. In G. A. Calvert, C. Spence, & B. E. Stein (Eds.), *The handbook of multisensory processes* (pp. 581–596). Cambridge, MA: MIT Press.

Ditman, T., Holcomb, P. J., & Kuperberg, G. R. (2007). The contributions of lexico-semantic and discourse information to the resolution of ambiguous categorical anaphors. *Language & Cognitive Processes, 22,* 793–827. doi:10.1080/01690960601057126

Federmeier, K. D., Kirson, D. A., Moreno, E. M., & Kutas, M. (2001). Effects of transient, mild mood states on semantic memory

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[6] In the present study, most of the participants (18 of 24) were women. In order to overtly confirm that our inferences held for young women, we repeated all analyses using a post-hoc sample of the 18 female participants. The pattern of effects was nearly identical, and despite the lower power, the effects were generally more robust than in the full data set. It may therefore be that the effects of emotional discourse on the processing of emotional words are weaker in men, and it will be important to test this hypothesis in future studies.

organization and use: An event-related potential investigation in humans. *Neuroscience Letters, 305,* 149–152. doi:10.1016/S0304-3940(01)01843-2

Federmeier, K. D., & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language, 41,* 469–495. doi:10.1006/jmla.1999.2660

Federmeier, K. D., Wlotko, E. W., De Ochoa-Dewald, E., & Kutas, M. (2007). Multiple effects of sentential constraint on word processing. *Brain Research, 1146,* 75–84. doi:10.1016/j.brainres.2006.06.101

Fields, E. C., & Kuperberg, G. R. (2012). It's all about you: An ERP study of emotion and self-relevance in discourse. *NeuroImage.* doi:10.1016/j.neuroimage.2012.05.003

Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: Words, phrases, and task effects. *Progress in Brain Research, 156,* 185–203. doi:10.1016/S0079-6123(06)56009-1

Geisser, S., & Greenhouse, S. W. (1958). An extension of Box's results on the use of the *F* distribution in multivariate analysis. *Annals of Mathematical Statistics, 29,* 885–891.

Hagoort, P., Hald, L. A., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science, 304,* 438–441. doi:10.1126/science.1095455

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2012). ERPs and the study of emotion. In S. J. Luck & E. S. Kappenman (Eds.), *Oxford handbook of ERP components* (pp. 441–474). New York, NY: Oxford University Press.

Halgren, E., Dhond, R. P., Christensen, N., Van Petten, C., Marinkovic, K., Lewine, J. D., & Dale, A. M. (2002). N400-like magnetoencephalography responses modulated by semantic context, word frequency, and lexical class in sentences. *NeuroImage, 17,* 1101–1116.

Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology, 45,* 487–498. doi:10.1111/j.1469-8986.2007.00638.x

Herring, D. R., Taylor, J. H., White, K. R., & Crites, S. L. (2011). Electrophysiological responses to evaluative priming: The LPP is sensitive to incongruity. *Emotion, 11,* 794–806. doi:10.1037/a0022804

Hinojosa, J. A., Carretié, L., Méndez-Bértolo, C., Míguez, A., & Pozo, M. A. (2009). Arousal contributions to affective priming: Electrophysiological correlates. *Emotion, 9,* 164–171. doi:10.1037/a0014680

Holcomb, P. J., Kounios, J., Anderson, J. E., & West, W. C. (1999). Dual-coding, context-availability, and concreteness effects in sentence comprehension: An electrophysiological investigation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 721–742. doi:10.1037/0278-7393.25.3.721

Holt, D. J., Lakshmanan, B., Freudenreich, O., Goff, D. C., Rauch, S. L., & Kuperberg, G. R. (2011). Dysfunction of a cortical midline network during emotional appraisals in schizophrenia. *Schizophrenia Bulletin, 37,* 164–176. doi:10.1093/schbul/sbp067

Holt, D. J., Lynn, S. K., & Kuperberg, G. R. (2009). Neurophysiological correlates of comprehending emotional meaning in context. *Journal of Cognitive Neuroscience, 21,* 2245–2262. doi:10.1162/jocn.2008.21151

Huang, H. W., Lee, C. L., & Federmeier, K. D. (2010). Imagine that! ERPs provide evidence for distinct hemispheric contributions to the processing of concrete and abstract concepts. *NeuroImage, 49,* 1116–1123. doi:10.1016/j.neuroimage.2009.07.031

Ito, T. A., Larsen, J. T., Smith, N. K., & Cacioppo, J. T. (1998). Negative information weighs more heavily on the brain: The negativity bias in evaluative categorizations. *Journal of Personality and Social Psychology, 75,* 887–900. doi:10.1037/0022-3514.75.4.887

Jiménez-Ortega, L., Martín-Loeches, M., Casado, P., Sel, A., Fondevila, S., Herreros de Tejada, P., et al. (2012). How the emotional content of discourse affects language comprehension. *PLoS One, 7,* e33718. doi:10.1371/journal.pone.0033718

Kapur, S. (2003). Psychosis as a state of aberrant salience: A framework linking biology, phenomenology, and pharmacology in schizophrenia. *The American Journal of Psychiatry, 160,* 13–23.

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition, 31,* 1169–1180. doi:10.3758/BF03195800

Kissler, J., Assadollahi, R., & Herbert, C. (2006). Emotional and semantic networks in visual word processing: Insights from ERP studies. *Progress in Brain Research, 156,* 147–183. doi:10.1016/S0079-6123(06)56008-X

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing: An ERP study. *Biological Psychology, 80,* 75–83. doi:10.1016/j.biopsycho.2008.03.004

Kissler, J., & Koessler, S. (2011). Emotionally positive stimuli facilitate lexical decisions: An ERP study. *Biological Psychology, 86,* 254–264. doi:10.1016/j.biopsycho.2010.12.006

Kotz, S. A., & Paulmann, S. (2007). When emotional prosody and semantics dance cheek to cheek: ERP evidence. *Brain Research, 1151,* 107–118. doi:10.1016/j.brainres.2007.03.015

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 804–823. doi:10.1037/0278-7393.20.4.804

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology. General, 140,* 14–34. doi:10.1037/a0021446

Kuperberg, G. R. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research, 1146,* 23–49. doi:10.1016/j.brainres.2006.12.063

Kuperberg, G., Kreher, D., Swain, A., Goff, D., & Holt, D. (2011a). Selective emotional processing deficits to social vignettes in schizophrenia: An ERP study. *Schizophrenia Bulletin, 37,* 148–163. doi:10.1093/schbul/sbp018

Kuperberg, G. R., Paczynski, M., & Ditman, T. (2011b). Establishing causal coherence across sentences: An ERP study. *Journal of Cognitive Neuroscience, 23,* 1230–1246. doi:10.1162/jocn.2010.21452

Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 17,* 117–129.

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62,* 621–647. doi:10.1146/annurev.psych.093008.131123

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207,* 203–205. doi:10.1126/science.7350657

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307,* 161–163. doi:10.1038/307161a0

Lai, V. T., Hagoort, P., & Casasanto, D. (2012). Affective primacy vs. cognitive primacy: Dissolving the debate. *Frontiers in Psychology, 3,* 243. doi:10.3389/fpsyg.2012.00243

Lambon Ralph, M. A., & Patterson, K. (2008). Generalization and differentiation in semantic memory: Insights from semantic dementia. *Annals of the New York Academy of Sciences, 1124,* 61–76. doi:10.1196/annals.1440.006

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction,

and representation of knowledge. *Psychological Review, 104,* 211–240. doi:10.1037/0033-295X.104.2.211

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes, 25,* 259–284. doi:10.1080/01638539809545028

Lau, E. F., Burns, S., Gramfort, A., Delaney-Busch, N., Fields, E. C., Fanucci, K., . . . Kuperberg, G. R. (2011, September). *Using multimodal imaging to distinguish active prediction from passive priming.* Poster presented at the 51st Annual Meeting of the Society for Psychophysiological Research and Annual Neurobiology of Language Conference, Boston, MA.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (De)constructing the N400. *Nature Reviews Neuroscience, 9,* 920–933. doi:10.1038/nrn2532

LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life.* New York, NY: Simon & Schuster.

Lee, C. L., & Federmeier, K. D. (2008). To watch, to see, and to differ: An event-related potential study of concreteness effects as a function of word class and lexical ambiguity. *Brain and Language, 104,* 145–158. doi:10.1016/j.bandl.2007.06.002

León, I., Díaz, J. M., de Vega, M., & Hernández, J. A. (2010). Discourse-based emotional consistency modulates early and middle components of event-related potentials. *Emotion, 10,* 863–873. doi:10.1037/a0019983

Marslen-Wilson, W., Brown, C. M., & Tyler, L. K. (1988). Lexical representations in spoken language comprehension. *Language & Cognitive Processes, 3,* 1–16. doi:10.1080/01690968808402079

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6,* 114–133. doi:10.1177/1745691611400234

McCarthy, G., Nobre, A. C., Bentin, S., & Spencer, D. D. (1995). Language-related field potentials in the anterior-medial temporal lobe: I. Intracranial distribution and neural generators. *Journal of Neuroscience, 15,* 1080–1089.

Moreno, E. M., & Vázquez, C. (2011). Will the glass be half full or half empty? Brain potentials and emotional expectations. *Biological Psychology, 88,* 131–140. doi:10.1016/j.biopsycho.2011.07.003

Nieuwland, M. S., & Van Berkum, J. J. A. (2005). Testing the limits of the semantic illusion phenomenon: ERPs reveal temporary semantic change deafness in discourse comprehension. *Cognitive Brain Research, 24,* 691–701. doi:10.1016/j.cogbrainres.2005.04.003

Nobre, A. C., & McCarthy, G. (1995). Language-related field potentials in the anterior–medial temporal lobe: II. Effects of word type and semantic priming. *Journal of Neuroscience, 15,* 1090–1098.

Osgood, C. E., Suci, G. J., & Tannenbaum, P. (1957). *The measurement of meaning* (9th ed.). Urbana, IL: University of Illinois Press.

Paczynski, M., & Kuperberg, G. R. (2012). Multiple influences of semantic memory on sentence processing: Distinct effects of semantic relatedness on violations of real-world event/state knowledge and animacy selection restrictions. *Journal of Memory and Language, 67,* 426–448. doi:10.1016/j.jml.2012.07.003

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience, 8,* 976–987. doi:10.1038/nrn2277

Paulmann, S., & Kotz, S. A. (2008). An ERP investigation on the temporal dynamics of emotional prosody and emotional

semantics in pseudo- and lexical-sentence context. *Brain and Language, 105,* 59–69. doi:10.1016/j.bandl.2007.11.005

Sanford, A. J., Leuthold, H., Bohan, J., & Sanford, A. J. (2011). Anomalies at the borderline of awareness: An ERP study. *Journal of Cognitive Neuroscience, 23,* 514–523. doi:10.1162/jocn.2009.21370

Schacht, A., & Sommer, W. (2009). Emotions in word and face processing: Early and late cortical responses. *Brain and Cognition, 69,* 538–550. doi:10.1016/j.bandc.2008.11.005

Schirmer, A., & Kotz, S. A. (2003). ERP evidence for a sex-specific Stroop effect in emotional speech. *Journal of Cognitive Neuroscience, 15,* 1135–1148. doi:10.1162/089892903322598102

Schirmer, A., Kotz, S. A., & Friederici, A. D. (2002). Sex differentiates the role of emotional prosody during word processing. *Cognitive Brain Research, 14,* 228–233. doi:10.1016/S0926-6410(02)00108-8

Schirmer, A., Kotz, S. A., & Friederici, A. D. (2005). On the role of attention for the processing of emotions in speech: Sex differences revisited. *Cognitive Brain Research, 24,* 442–452. doi:10.1016/j.cogbrainres.2005.02.022

Schirmer, A., Lui, M., Maess, B., Escoffier, N., Chan, M., & Penney, T. B. (2006). Task and sex modulate the brain response to emotional incongruity in Asian listeners. *Emotion, 6,* 406–417. doi:10.1037/1528-3542.6.3.406

Storbeck, J., & Clore, G. L. (2007). On the interdependence of cognition and emotion. *Cognition & Emotion, 21,* 1212–1237. doi:10.1080/02699930701438020

Taylor, W. L. (1953). Cloze procedure: A new tool for measuring readability. *Journalism Quarterly, 30,* 415–433.

Van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic integration in sentences and discourse: Evidence from the N400. *Journal of Cognitive Neuroscience, 11,* 657–671. doi:10.1162/089892999563724

Van Berkum, J. J. A., Holleman, B., Nieuwland, M., Otten, M., & Murre, J. (2009). Right or wrong? The brain's fast response to morally objectionable statements. *Psychological Science, 20,* 1092–1099. doi:10.1111/j.1467-9280.2009.02411.x

Van Berkum, J. J. A., Zwitserlood, P., Hagoort, P., & Brown, C. M. (2003). When and how do listeners relate a sentence to the wider discourse? Evidence from the N400 effect. *Cognitive Brain Research, 17,* 701–718. doi:10.1016/S0926-6410(03)00196-4

van den Brink, D., Van Berkum, J. J., Bastiaansen, M. C., Tesink, C. M., Kos, M., Buitelaar, J. K., et al. (2012). Empathy matters: ERP evidence for inter-individual differences in social language processing. *Social Cognitive and Affective Neuroscience, 7,* 173–183. doi:10.1093/scan/nsq094

Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: Evidence from functional neuroimaging. *Neuropsychologia, 45,* 174–194. doi:10.1016/j.neuropsychologia.2006.06.003

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35,* 151–175. doi:10.1037/0003-066X.35.2.151

Zajonc, R. B. (2000). Feeling and thinking: Closing the debate over the independence of affect. In J. P. Forgas (Ed.), *Feeling and thinking: The role of affect in social cognition* (pp. 31–58). Cambridge, UK: Cambridge University Press.

Zhang, Q., Li, X., Gold, B. T., & Jiang, Y. (2010). Neural correlates of cross-domain affective priming. *Brain Research, 1329,* 142–151. doi:10.1016/j.brainres.2010.03.021