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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 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 their motivational significance.

Keywords

emotion; salience; valence; N400; late positivity; ERP; language; discourse

Introduction

Conveying emotional meaning relies on a complex, multimodal 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 longstanding idea is that, because of its value in promoting survival, the brain prioritizes our access to emotional information over other aspects of meaning (Zajonc, 1980 & 2000; LeDoux, 1996). 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.

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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, p. 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 non-affective information, avoiding extensive perceptual and semantic processing and quickly triggering adaptive affective responses (Zajonc, 1980; Storbeck & Clore, 2007).

However, as 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 neutral items) to ensure that its meaning is interpreted and encoded accurately.

A large ERP literature suggests that context can influence our retrieval of the meaning of incoming stimuli extremely quickly – within (and sometimes before) 300ms of their onset, as reflected by modulation of the N400 ERP component (Kutas & Federmeier, 2011). If semantic information activated by an incoming word is supported by its context, the N400 to that word is attenuated: it is easier to retrieve its semantic features. However, if the context fails to activate any of the semantic features associated with an incoming word, then 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 was *giraffe*, which is inconsistent with the semantic features activated by the discourse context (Van Berkum, Hagoort, & Brown, 1999; Kuperberg, Paczynski, & Ditman, 2011).

[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 (motivation 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 subsequent arguments.

[2]There has been debate about whether a context activates relevant semantic information before the onset of the incoming word (semantic pre-activation 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 paper, we do not assume a discrete stage of lexical access (see Kutas & Federmeier 2011 for discussion), and 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.

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 comes from a previous study from our lab (Holt, Lynn, & Kuperberg, 2009), in which we compared ERPs to emotional and neutral words following neutral, non-constraining discourse contexts, e.g. 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 non-emotional 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 et al., 2009 for a similar interpretation). As noted above, this makes adaptive sense: processing the salient emotional words more deeply in neutral or ambiguous contexts ensures 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 comes from three previous studies that all introduced emotional words (pleasant and unpleasant) in emotional discourse contexts (Bartholow, Fabiani, Gratton, & Bettencourt, 2001; Leon, Diaz, de Vega, & Hernandez, 2010; Moreno & Vazquez, 2011). These words were either congruous or incongruous with these 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 & Vazquez, Those little thoughtful details revealed how much [he] loved/envied me). The first study (Bartholow et al., 2001) failed to see a larger N400 to the valence incongruous than 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 (Leon et al., 2010; Moreno & Vazquez, 2011), however, did find some effect of valence congruity on the N400 produced by the emotional words, and concluded that participants made concrete inferences and expectations about the emotions of the described characters. Of note, however, in both these studies, the effect of valence incongruity on the emotional words was smaller than the effect of semantic congruity seen on neutral words (see Figure 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 (where 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 these 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 & Vazquez, Those little thoughtful details revealed how much [he] envied me, and from Leon et al., 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 Leon et al., *Carlos shaved with the wastebasket*). Leon and colleagues 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 relationship between the critical word to the discourse should be comparable for all congruous and for 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 most previous studies, which typically introduce a neutral word after a neutral discourse context (e.g. Van Berkum et al., 1999; Kuperberg et al., 2010).

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 400-1000ms. They are highly sensitive to the salience of a wide variety of emotional stimuli, including emotional words presented in isolation of any context (Citron, 2012; Kissler, Assadollahi, & Herbert, 2006) as well as in discourse contexts (Holt et al., 2009; Fields & Kuperberg, 2012). 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 positivity 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 the neutral words. This, however, was not true of the studies by Leon et al. (2010) or Moreno & Vazquez (2011), where no late positivity effect was seen to the emotional (versus neutral) words. As noted by Fischler & 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 isn't 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 salient, arousing, or motivationally significant enough to trigger the reallocation of attentional resources, reflected by the late positivity. We will return to this idea in the Discussion.

The Present Study

In the present study we directly contrasted the effects of valence congruity on emotional words with the effects of semantic congruity on 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, 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 **snake/diamond** right away; e.g. neutral: Colin saw a **small** object on the ground. He realized it was a **button/giraffe** 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; Leon et al., 2010; Moreno & Vazquez, 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 manipulation in the present study was comparable for both neutral and emotional scenarios. For each condition of each scenario, both 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 neutral incongruous critical words, while the valence congruous words were just as predictable as the neutral congruous words, as measured with cloze probability (Taylor, 1953). Neutral and emotional discourse stems were also matched on their contextual semantic constraint, which can also influence the magnitude of ERPs evoked by unexpected words (Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007). Finally, discourse plausibility was also assessed across conditions through 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 of all critical words. Based on 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; Holt et al., 2009; Fields & Kuperberg, 2012; Chung et al., 1996), we predicted that the more arousing emotional words would evoke a larger late positivity than the less arousing neutral words. We also considered the possibility that we would also see a negativity bias on the emotional words, with a larger late positivity to unpleasant words than to pleasant words, even when these words were matched on arousal (Holt et al., 2009; Ito et al., 1998; Fields & Kuperberg, 2012).

Our main focus, however, was on the N400 component. Based on 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 semantically incongruous neutral words (e.g. *giraffe;* Kutas & Hillyard, 1984; Hagoort, Hald, Bastiaansen, & Petersson, 2004; 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 through 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 (versus incongruous) discourse contexts, and, similarly, a smaller N400 to unpleasant emotional words following congruous (versus incongruous) discourse contexts. It would also predict that the magnitude of this N400 effect would be the same as on neutral congruous (versus 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 to emotional than 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.

Methods

Construction of Stimuli

A stimulus set of 228 scenarios was constructed. There were six conditions (Emotion[3] × Congruity permutations) per scenario, i.e. altogether there were 1368 (228*6) sentence-pairs. 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. 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 **diamond** right away; an unpleasant sentence-pair: Colin saw a **horrifying** object on the ground. He realized it was a **snake** right away.). In contrast, incongruous emotional critical words in the second sentence were of opposite valence to the context set up by the first sentence (e.g. Colin saw a **stunning** object on the ground. He realized it was a **snake** right away; or Colin saw a **horrifying** object on the ground. He realized it was a **diamond** 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 realized it was a **button** right away.;

[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.

e.g. 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. Part of speech of each of the critical words was 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 in 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 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 concreteness of the critical words, and retrieved their natural-log frequencies from the English Lexicon Project (Balota, Yap, Cortese, Hutchison, Kessler, Loftis… & Treiman, 2007).

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

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 constituted 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. 160 participants submitted responses, and 5 were excluded due to incomplete or insufficient answers, leaving 155 eligible participants with a mean age of 23.3. The cloze probability of the critical words in each of the congruous conditions was calculated as the proportion 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 based on participants' responses, and the final stimulus set showed no difference in the cloze probability between the three types of congruous critical words in an omnibus ANOVA ($F(2, 227) = 1.28$, $p = 0.278$), see Table 2. Incongruous critical words all, by definition, had cloze probabilities of zero. Constraint also did not differ between pleasant, unpleasant, and neutral scenario stems ($F(2, 227) = 0.55$, $p = 0.5778$), see Table 2.

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

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 until 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. 35-40 participants were asked to read each list and "give each scenario a rating of how much it makes sense" on a scale from 1 to 7, where 1 "describes a sentence that doesn't make sense at all" and 7 "describes 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. 240 participants in total completed the task, and 87 did not meet inclusion criteria, leaving 153 eligible participants with a mean age of 22.3. These plausibility ratings were evaluated in an Emotion (pleasant, unpleasant, neutral) × Congruity (congruous, incongruous) ANOVA. As expected, the congruous scenarios were rated as significantly more plausible than the incongruous scenarios (main effect of Congruity: $F(1, 1362) > 7000$, $p < 0.001$). Though there was no main effect of Emotion ($F(2, 1362) = 1.50$, $p > 0.20$), there was an interaction between Emotion and Congruity ($F(2, 1362) = 41.4$, $p < 0.001$). Follow-up tests revealed a significant effect of Congruity in the pleasant, unpleasant, and neutral scenarios, where the incongruous scenarios were rated as more implausible than the congruous scenarios. However, the differences in plausibility between congruous and incongruous critical words were smaller to the neutral words (mean difference = 2.44, $F(1, 454) > 7500$, $p < 0.001$), than to either the pleasant (mean difference = 3.31, $F(1, 454) > 14500$, $p < 0.001$) or the unpleasant (mean difference 3.17, $F(1, 454) > 12000$, $p < 0.001$) 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 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. 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. 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" and "most positive", with an overt option to skip unfamiliar words. As expected, omnibus ANOVAs produced a main effect of critical word group (pleasant, unpleasant, neutral congruous and neutral incongruous) for both valence ($F(3, 227) = 1458.9$, $p < 0.0001$) and arousal ($F(3, 227) = 155.8$, $p < 0.0001$) ratings. A follow-up Tukey HSD test on valence showed that pleasant and unpleasant words both differed from the neutral words, and from each other, but 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 ($p > 0.9$), had higher arousal ratings than both neutral conditions ($p < 0.0001$), which also did not differ from one another ($p > 0.9$).

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 concreteness ratings of the critical words, participants were asked to rate one list of words on concreteness on a scale from 1 to 7. 123 participants completed task, but 7 did not meet inclusion criteria, leaving 116 participants with a mean age of 24.2. An ANOVA revealed a significant difference between the groups of words on Concreteness ($F(3, 227) = 24.93$, $p < 0.0001$). A follow-up Tukey HSD test indicated that, while the concreteness of the pleasant and unpleasant words were matched, neutral critical words were rated as more concrete than pleasant and unpleasant critical words, and neutral words from the incongruous sentences were given higher concreteness ratings than neutral words from the congruous sentences, see Table 2.

There were also some differences across the four groups of critical words in lexical frequency, defined as the natural log of HAL frequency per million words ($F(3, 227) = 11.78$, $p < 0.0001$). Tukey HSD follow-ups 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, there were differences across the four conditions in word length ($F(3, 227) = 2.64$, $p = 0.0485$), primarily because pleasant words were slightly longer than unpleasant words (7.6 vs. 7.05 letters). Neither pleasant nor unpleasant words, however, differed significantly in word length from either of the neutral groups, as shown in Table 2.

Latent Semantic Analysis—Finally, we carried out a Latent Semantic Analysis (LSA), assessing pairwise Semantic Similarity Values (SSV) values between the critical words and their preceding scenario texts (calculated using a “General reading up to first year of college” topic space, obtained from CU Boulder at lsa.colorado.edu: Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). Available values were entered into an ANOVA, with Emotion and Congruity as factors. Overall, incongruous words tended to have lower SSV values than congruous words (Table 2), but the Congruity effect differed significantly across the different levels of Emotion ($F(2, 1318) = 4.97$, $p = 0.007$). 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 thirty-eight scenarios for each of the six conditions. Within each list, the order of sentence presentations was randomized.

As noted above, there were some differences across the six experimental conditions in concreteness, frequency, word length, and SSV values that 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 scenarios, which matched the four types of critical words on concreteness. The third subset was created using 198 scenarios such that the effect of Congruity on SSV values was matched across the three levels of Emotion. Though previous literature indicates that each of these subsets may address confounds within particular time windows, we conservatively repeated every significant statistical test in all three subsets in each time window.

Participants

Twenty-seven Tufts undergraduate students initially participated in the ERP study. The data for three of the original participants were subsequently excluded due to excessive artifact, leaving 24 participants whose data were included in the final analyses (6 male; mean age 19.8, 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 non-excluded participants. Before each trial, participants were presented with the word, "READY", and pressed a button to initiate the trial. Trials began with a 500ms fixation cross followed by the two sentences, presented one word at a time, with a duration of 400ms per word and an interstimulus interval of 100ms between words. The last word of each sentence was presented with a period, and remained onscreen for 750ms. Words were presented in white text on black background at the center of a monitor, 24 inches 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 the 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 required a "yes" or "no" answer 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. Participants were offered a longer break between each block.

EEG Recording—Twenty-nine 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 (LE and HE in figure 1), and on the left and right mastoids (A1 and A2 in figure 1). The 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 Co., San Diego, CA) with a bandpass of 0.01 to 40 Hz and was continuously sampled at 200 Hz by an analogue-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 movement, "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 −100-0ms pre-stimulus baseline. We focused on examining modulation of activity within the N400 and late positivity time windows. The N400 time window was set to 300-500ms based on numerous previous studies of the N400 component, and the late positivity time window was set at 500-700ms, based on 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 Figure 1). Two omnibus repeated-measures ANOVAs, one covering mid-regions (dark gray in Figure 1) and another covering peripheral regions (light gray in Figure 1), were conducted for each time window.

In the mid-regions omnibus ANOVA, the within regions omnibus ANOVA, the within-subject variables were Emotion (3 levels: pleasant, neutral, unpleasant), Congruity (2 levels: congruous, incongruous), and Region (5 levels: prefrontal, frontal, central, parietal, 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 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 (3 levels: pleasant, neutral, unpleasant), Congruity (2 levels: congruous, incongruous), Region (2 levels: frontal, parietal) and Hemisphere (2 levels: left, right). Interactions between Emotion and Congruity were followed up as described above. Interactions involving Region (and not Hemisphere) were followed up by examining effects in pairs of Regions (collapsed across left and right hemispheres), while interactions involving both Region and Hemisphere were followed up by examining effects in 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). Alpha was set at 0.05 for all tests. All significant tests were repeated using the matched subsets of stimuli to see if they remained significant.

Results

Grand-average ERP waveforms elicited by each of the six types of critical words are shown in Figure 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: 300-500ms

The negative-going N400 component was evident over most of the scalp. Omnibus ANOVAs at both the mid-regions and peripheral regions showed significant main effects of Emotion (mid-regions: $F(2, 46) = 18.58$, $p < 0.001$; peripheral regions: $F(2, 46) = 15.44$, $p < 0.001$) and Congruity (mid-regions: $F(1, 23) = 12.90$, $p = 0.002$; peripheral regions: $F(1, 23) = 13.74$, $p = 0.001$). However, these main effects were accompanied by significant Emotion × Congruity interactions in both the mid-regions ANOVA ($F(2, 46) = 5.35$, $p = 0.01$) and the peripheral regions ANOVA ($F(2, 46) = 4.42$, $p = 0.02$) [5].

[5]At some electrode sites, there appeared to be some early modulation of activity before the N400 time window, see Figure 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 −100ms to +100ms. The Emotion × Congruity interaction remained significant (midd significant (mid-regions: $F(2, 46) = 5.08$, $p = 0.014$; peripheral regions: $F(2, 46) = 3.90$, $p = 0.033$).

Follow-up of the Emotion × Congruity interaction at each level of Emotion revealed a robust N400 Congruity effect on the neutral words (mid N400 Congruity effect on the neutral words (mid-regions ANOVA: $F(1, 23) = 13.28$, $p = 0.001$; peripheral regions ANOVA: $F(1, 23) = 12.73$, $p = 0.002$), which was widespread but larger in frontal than posterior mid-regions (Congruity × Region interaction, $F(4, 92) = 7.53$, $p = 0.001$), with incongruous neutral words evoking a larger negativity than congruous neutral words. In contrast, as shown in Figure 2, neither pleasant words nor unpleasant words evoked a significant N400 effect: there were no main effects or interactions involving Congruity in either mid-regions or peripheral regions ANOVAs (all $Fs < 2$, all $ps > 0.15$).

Next, in order to determine whether the reduced N400 congruity effect on the emotional relative to the neutral words was driven by a reduced N400 to incongruous emotional versus neutral words, or 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-regions ANOVA: $F(2, 46) = 19.42$, $p < 0.001$; peripheral regions ANOVA: $F(2, 46) = 16.73$, $p < 0.001$) due to a smaller negativity to incongruous pleasant and unpleasant words than to incongruous neutral words (all $ps < 0.001$). In contrast, there was no effect of Emotion on congruous critical words (mid-regions ANOVA: $F(2, 46) = 1.74$, $p = 0.18$; peripheral regions ANOVA: $F(2, 46) = 1.42$, $p = 0.25$).

These main effects and interactions, including follow-ups, remained significant in the subset matching for word length and HAL frequency, and in the subset controlling LSA values. However, in the subset matching for concreteness, the Emotion × Congruity effect on the N400 additionally interacted with Region in the mid-regions omnibus ANOVA ($F(8, 184) = 2.68$, $p = 0.04$) and was not significant in the peripheral regions ANOVA ($F(2, 46) = 2.40$, $p = 0.10$). In the follow-ups for this concreteness-matched subset, neutral words still elicited a substantial congruity effect ($F(1, 23) = 7.68$, $p = 0.01$), but the effect was smaller over prefrontal and frontal mid-regions. There was also a small N400 congruity effect on the unpleasant words in a single occipital region ($F(1, 23) = 9.2$, $p = 0.01$), but congruity remained non-significant for pleasant words (mid-regions: $F(1, 23) = 0.58$, $p = 0.45$; peripheral regions: $F(1,23) = 0.56$, $p = 0.46$). Emotion effects within each level of Congruity remained unchanged from the full set of stimuli.

Late positivity: 500-700ms

Immediately following the N400 component, a robust positivity was observed, peaking at around 600ms (shown in Figure 3). In this late positive time window, there was a significant main effect of Emotion in both mid-regions and peripheral regions omnibus ANOVAs (mid-regions: $F(2, 46) = 13.98$, $p < 0.001$; peripheral regions: $F(2, 46) = 11.66$, $p < 0.001$). This Emotion effect varied across the scalp, as indicated by an Emotion × Region interaction in the mid-regions ANOVA ($F(8, 184) = 2.82$, $p = 0.041$) and an Emotion × Region × Hemisphere effect in the peripheral regions ANOVA ($F(2, 46) = 4.182$, $p = .022$). Follow-up ANOVAs showed effects of Emotion in every region (all $Fs > 2.92$, all $ps < 0.05$). 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 $ps < 0.05$), see Figure 3. Over the occipital region, only the difference between unpleasant and neutral words reached significance ($p < 0.01$). Over all peripheral regions, unpleasant words elicited larger positivities than neutral words ($ps < 0.025$), but unpleasant words elicited a larger positivity than pleasant words only in the left posterior periphery ($p = 0.003$). There were no main effects of Congruity and no interactions involving Congruity and Emotion (all $Fs < 1.14$, $ps > 0.25$). 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 tests described above. During the N400 time-window, no effects or interactions approached significance in either the mid-regions or peripheral regions omnibus ANOVA (all Fs < 2.5, all ps > 0.1). During the late positivity time window, a main effect of Emotion reached significance in both the mid late positivity time window, a main effect of Emotion reached significance in both the mid-regions ($F = 4.49$, $p = 0.028$) and peripheral regions ($F = 3.90$, $p = 0.042$) omnibus ANOVA, because sentence-final words that followed unpleasant critical words elicited a larger positivity than sentence-final words that followed neutral or pleasant critical words. Other than a Congruity × Hemisphere interaction over the peripheral electrodes ($F = 8.39$, $p = 0.01$), no other effects or interactions approached significance for the late positivity (all Fs < 2.5, all ps > 0.10).

Discussion

Since the seminal studies by Kutas & Hillyard (1980, 1984), we 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 was also true of congruous versus incongruous emotional words following emotional discourse contexts. To this end, we fully crossed Emotion (pleasant, unpleasant, and neutral) and Congruity (congruous, incongruous) within short, two-sentence discourse scenarios, and measured ERPs on 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., 2010; 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 congruous or not 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 on emotional than neutral words. This effect was not modulated by discourse congruity, and is consistent with many previous studies of emotional words in isolation (Citron, 2012; Herbert et al., 2008; 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, it 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 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 a deep semantic processing of the valence incongruous emotional words within the N400 time window, allowing them to move straight on to further analysis of their 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 will 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 (Taylor, 1953; Kutas and Hillyard, 1984; Federmeier et al., 2007). In this study, we were careful to control cloze probabilities across the neutral and emotional scenarios: cloze values (and congruous versus incongruous cloze differences) were matched between 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. Of note, however, 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 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 1368 scenario permutations of the stimuli, up until and including the critical word. We found that, despite their larger N400, the semantically incongruous neutral words were actually rated as *less* implausible than the valence incongruous emotional words (see Table 2). We therefore conclude 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 Semantic Similarity Values (SSVs) between each of our critical words and its context in each scenario, using Latent Semantic Analysis (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 is relatively insensitive to word order, syntax or propositional meaning. As 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 amplitude 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 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 (Huang, Lee, & Federmeier, 2010; Holcomb, Kounios, Anderson, & West, 1999; 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 was attenuated to the incongruous emotional words because they were more abstract than the incongruous neutral words, we repeated all ERP analyses in a subset of stimuli that fully matched the critical words for concreteness. We found exactly the same pattern of findings: a clear N400 congruity effect on the neutral words, but not on the emotional words (save for a small effect in a single region on the unpleasant words), see "concreteness-matched subset" in Figure 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 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 introduced neutral words in emotional written sentence and discourse contexts (Leon et al., 2010; Moreno & Vazquez, 2011; Jimenez-Ortega, Martin-Loeches, Casado, Sel, Fondevila, de Tejada, …Sommer, 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 amplitude of the N400 to neutral words that followed emotional discourse contexts and 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 400ms. 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 one also expect 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), there was 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 conclude 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, Carretie, Mendez-Bertolo, Miguez, & Pozo, 2009), bypassing a retrieval of its semantic and valence features within the N400 time window, and immediately triggering an additional evaluative processes, 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, there are many times when it does not pattern with coherence, plausibility, coherence or truth value, and 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 emotional scenarios as incongruous and, as noted above, the incongruous emotional scenarios were rated as 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, there were no effects of discourse coherence on either the late positivity or on 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 discussed in the Introduction, we have previously shown that in *neutral* discourse contexts, emotional words produced a *larger* N400, indicating deeper semantic processing, than 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 emotional features of incoming emotional words may lead to a deeper semantic analysis (a larger N400 in Holt el al., 2009), whereas in emotionally salient contexts, it will lead to a shallower semantic analysis (a smaller N400 in this study). As discussed in the Introduction, this makes adaptive sense: in an emotional context, bypassing a 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 is accurately identified and deeply encoded for later recognition (Kensinger & Corkin, 2003; see Mather & Sutherland, 2011 for 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 did not find effects of valence congruity on the N400

evoked by emotional nouns preceded by other emotional nouns (Herring, Taylor, White, & Crites, 2011, but see Zhang, Li, Gold, & Jiang, 2010), emotional pictures (Kissler & Koessler, 2011) and emotional adjectives (e.g. *dead puppy* versus *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 opposite valence as vocal prosody of the preceding context (Kotz & Paulmann, 2007; Paulmann & Kotz, 2008).

Other studies have, 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 (versus 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). And a smaller N400 is also seen to written words whose emotional valence matches (versus mismatches) the comprehender's mood (Chung et al., 1996), and to words that are consistent (versus inconsistent) with the comprehender's underlying belief systems (Van Berkum, Holleman, Nieuwland, Otten, & Murre, 2009).

We propose that the critical factor that determines whether or not the N400 to an incoming emotional word will be sensitive to 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 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 was often present at the same time as the target emotional words. In contrast, those studies that failed to see N400 valence congruity effects usually used non-constraining 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 would further like to propose that, during the comprehension of emotional discourse, there is a trade-off between prioritizing access to the salience and the valence properties of incoming emotional words within the N400 time window. As discussed in the Introduction, access to the salience features of an incoming stimulus is known to trigger a re-allocation of attention and further evaluation of its 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 where 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 where 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 the three other studies that also manipulated the valence congruity of emotional words in emotional contexts, discussed in the Introduction (Bartholow et al., 2001; Leon et al., 2010; Moreno & Vazquez, 2011). Recall that, like the present study, Bartholow et al. (2001) reported a major reduction in N400 amplitude 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 and Bradley, 2006). In contrast, the two other studies (Leon et al., 2010; Moreno & Vazquez, 2011) did see some effect of emotional valence on the N400 (though diminished), but reported no late positivity effect to emotional (versus neutral) words. We suggest that the contexts used by these two studies may have been more valence constraining. For example, Leon et al. used long, embellished scenario contexts, which are more likely to have constrained for valence features than the shorter scenarios used here and by Bartholow and colleagues, or the single adjectives used by Fischler & Bradley (e.g. "dead" does not bias towards 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 other studies examining the effects of context on emotional words. Another important way to examine the relationships between emotion and language is to study the influences of emotional contexts on the comprehension of *neutral* target words. As already noted when discussing potential alternative interpretations of our data, a robust N400 congruity effect *is* seen to neutral words following emotional written sentence and discourse contexts (Leon et al., 2010; Moreno & Vazquez, 2011; Jimenez-Ortega, Martin-Loeches, Casado, Sel, Fondevila, de Tejada, …Sommer, 2012). However, two previous studies have reported slightly different effects of *mood* on the N400 evoked by neutral words in neutral discourse contexts: the N400 is attenuated to incongruous (versus 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 paper about potential tradeoffs 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. There is now interesting ERP evidence for differences between men and women in their sensitivity to emotional prosody (Schirmer et al., 2002 & 2005; Schirmer, Lui, Maes, Escoffier, Chan, & Penney, 2006) and social pragmatic expectations (van den Brink, Van Berkum, Bastiaansen, Tesink, Kos, Buitelaar, & Hagoort, 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 Kapur 2003; Holt, Lakshmanan, Freudenreich, Goff, Rauch, & Kuperberg, 2011).

Finally, it will be important to combine EEG with techniques that are more sensitive to spatial information, such as MEG or MRI, to determine where and when 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 (McCarthy, Nobre, Bentin, & Spencer, 1995; Nobre & McCarthy, 1995; Halgren, Dhond, Christensen, Van Petten, Marinkovic, Lewine, & Dale, 2002; Lau et al., 2011), 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, then we would predict an inverse relationship between activity in the amgydala

[6]In this study, most of our participants (18 of 24) were women. In order to overtly confirm that our inferences hold 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, effects were generally more robust than in the full data set. It may therefore be that the effects of an emotional discourse on the processing emotional words are weaker in men, and it will be important to test this hypothesis in future studies.

and activity in the lateral anterior temporal cortex to emotional (versus neutral) words between 300-500ms after their onset.

Conclusions

In sum, we present evidence that short written emotional discourse contexts can lead to reduced semantic processing of subsequent emotional words in the N400 time window, regardless of their 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 300ms after their onset, and that it treats valence congruity on emotional words and semantic congruity on neutral words quite differently during online discourse comprehension.

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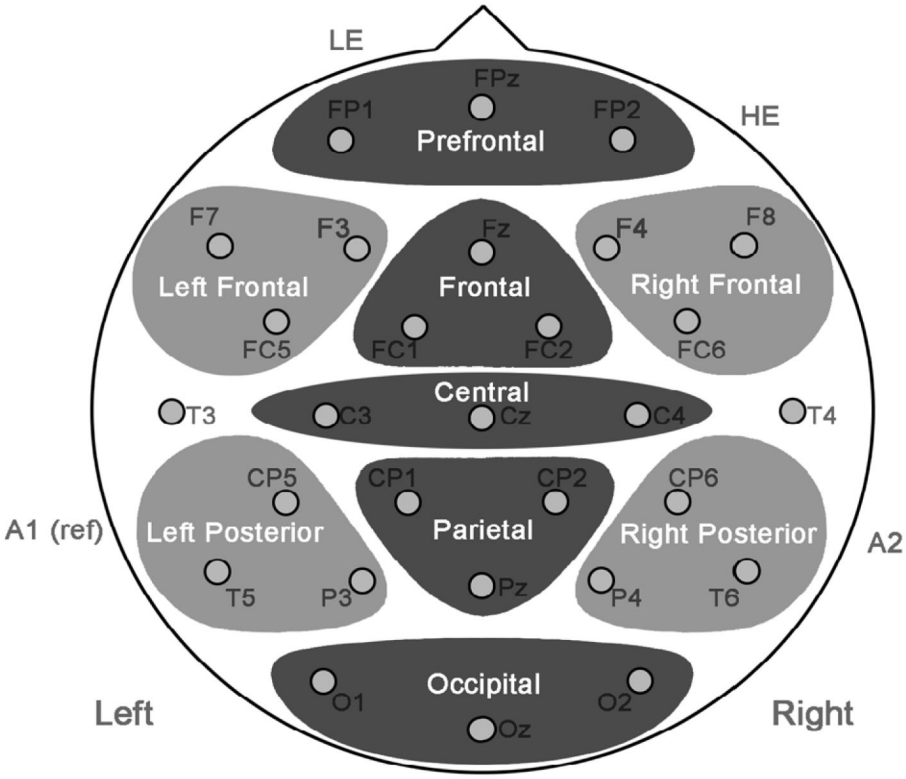

Figure 1.
Electrode Montage. Mid-regions are dark gray, and peripheral regions are light gray.

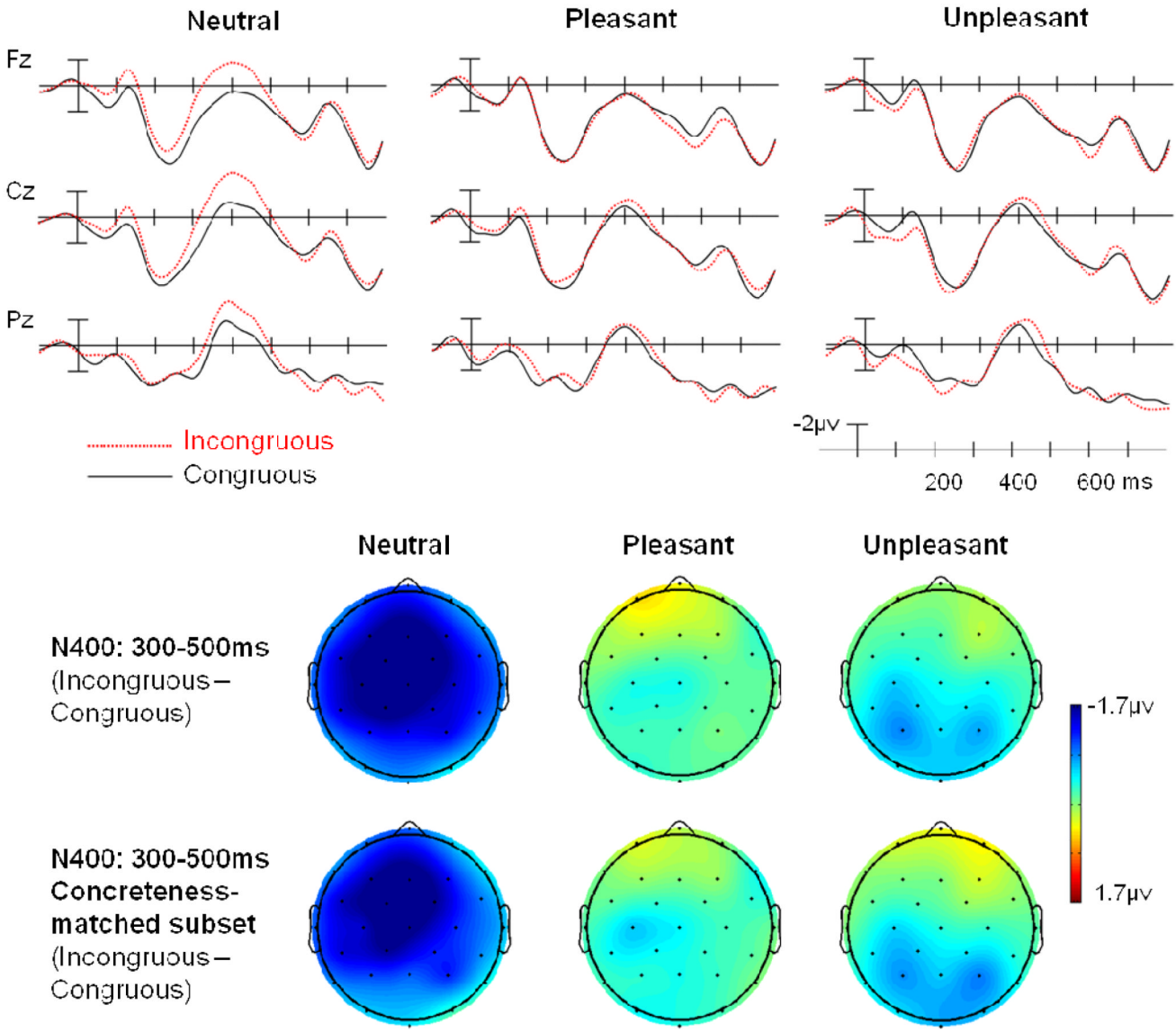

Figure 2.

The 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 incongruous words. In contrast, pleasant and unpleasant critical words did not show any N400 congruity effects. Both congruous and incongruous words elicited an equally small negativity.

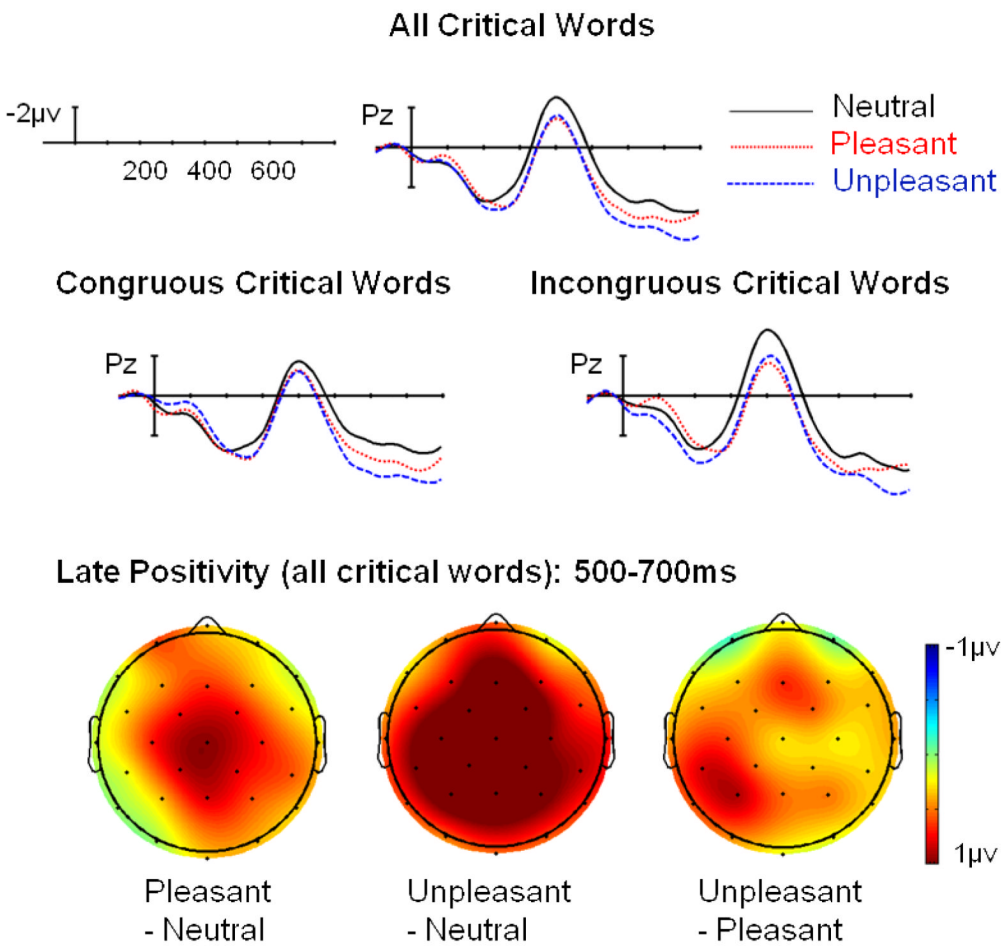

Figure 3.
The effect of Emotion on the late positivity. Over centro centro-parietal electrodes, both pleasant and unpleasant words elicited a larger late positivity than neutral words. This effect was more widespread for unpleasant than pleasant words.

Table 1

Examples of Stimuli

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

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

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Table 2

Stimuli ratings and characteristics

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 (SSVs) 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. 1 was most unpleasant, least arousing, and least concrete, while 7 was most pleasant, most arousing, and 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).

Mean **(SD)**	**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 (109)		3.89 (0.99)		4.21 (106)	4.56 (114)
Word Length	7.60 (2.11)		7.05 (2.19)		7.21 (2.24)	7.20 (2.20)
Frequency	7.76 (173)		7.76 (165)		8.43 (179)	7.48 (178)