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It's All About You: An ERP Study of Emotion and Self-Relevance in Discourse

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Abstract

Accurately communicating self-relevant and emotional information is a vital function of language, but we have little idea about how these factors impact normal discourse comprehension. In an event-related potential (ERP) study, we fully crossed self-relevance and emotion in a discourse context. Two-sentence social vignettes were presented either in the third or the second person (previous work has shown that this influences the perspective from which mental models are built). ERPs were time-locked to a critical word toward the end of the second sentence which was pleasant, neutral, or unpleasant (e.g., *A man knocks on Sandra's/your hotel room door. She/You see(s) that he has a gift/tray/gun in his hand.*). We saw modulation of early components (P1, N1, and P2) by self-relevance, suggesting that a self-relevant context can lead to top-down attentional effects during early stages of visual processing. Unpleasant words evoked a larger late positivity than pleasant words, which evoked a larger positivity than neutral words, indicating that, regardless of self-relevance, emotional words are assessed as motivationally significant, triggering additional or deeper processing at post-lexical stages. Finally, self-relevance and emotion interacted on the late positivity: a larger late positivity was evoked by neutral words in self-relevant, but not in non-self-relevant, contexts. This may reflect prolonged attempts to disambiguate the emotional valence of ambiguous stimuli that are relevant to the self. More broadly, our findings suggest that the assessment of emotion and self-relevance are not independent, but rather that they interactively influence one another during word-by-word language comprehension.

Keywords

Emotion; Event-related Potentials; Language; Late positive potential; Self-relevance; Perspective

Introduction

When we encounter language in our everyday lives, from newspapers, to books, to daily conversations, it is full of emotional and personal significance. Surprisingly however, there has been little psycholinguistic research on how either emotion or self-relevance influences language comprehension, and the few studies examining these factors have mostly considered them separately. The present study aimed to determine the effects of both emotional content and self-relevance on the neurocognitive processes engaged during word-

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by-word discourse comprehension. To do this, we measured event-related potentials (ERPs) as participants read short scenarios carrying pleasant, unpleasant,[1] or neutral information from either a self or other perspective.

We start by reviewing behavioral and ERP research on emotion and self-relevance with a focus on language. We will then consider research that has examined both factors in conjunction before describing the motivation and design of the present study.

Behavioral research

It is well established that emotional stimuli capture and hold attention more than neutral stimuli (Compton, 2003). For example, emotional pictures "pop out" and are more easily recognized in an array (Hansen and Hansen, 1988; Ohman et al., 2001a,b), emotional stimuli are looked at more often and for longer (Calvo and Lang, 2004; Nummenmaa et al., 2006), and the "attentional blink" (the inability to identify a target stimulus that immediately follows another target stimulus in a rapidly presented sequence) is reduced if the second target is emotionally valenced (Anderson, 2005). This effect of emotion on attention has also been described in paradigms using word stimuli (Fox et al., 2001; Stormark et al., 1995). For example, in the emotional Stroop task participants are slower to name the color of emotional than neutral words, suggesting that their meaning captures more attention leading to increased interference with task demands (MacKay et al., 2004; McKenna and Sharma, 1995; Pratto and John, 1991).

Behavioral studies of self-relevance show effects that are similar to those of emotion. For example, in the classic "cocktail party effect" self-relevant information presented in an unattended auditory channel captures attention while other information does not (Moray, 1959). This observation has since been confirmed using a number of different paradigms including dichotic listening tasks (Bargh, 1982) and Stroop tasks where interference during color naming is greater for self-relevant than non-self-relevant words (Bargh and Pratto, 1986; Geller and Shaver, 1976; Williams et al., 1996).

ERP research

One of the drawbacks of traditional behavioral measures is that they require an overt response, so it can be difficult to determine which stage of processing is influenced by a given manipulation: any stage prior to response execution is a possible candidate. ERPs on the other hand allow precise online monitoring of neurocognitive activity and can help answer such questions. ERPs are the electrical potentials (summated post-synaptic potentials) elicited by specific stimuli and recorded on the scalp. The resulting waveform is divided into identifiable components (positive and negative peaks or deflections), which are generally taken to reflect different cognitive processes (for a review of the ERP technique and ERP components, see Luck, 2005).

Emotion—A number of studies have examined emotional processing using ERPs, and many have used linguistic stimuli, usually manipulating the emotional content of single words. While some of these studies have found effects on early components (before around 300 ms), including the P1, N1, P2, and N2, results have been mixed and there is no clear consensus on how emotion impacts perceptual and pre-semantic stages of lexical processing (for a review, see Kissler et al., 2006). On the N400, most studies have either reported null effects (e.g., Fischler and Bradley, 2006) or have noted that modulation of the N400 is difficult to interpret because of overlap from a positivity that often starts within the N400

[1]Throughout this manuscript we will use "pleasant" to refer to positive valence and "unpleasant" to negative valence. This is to avoid confusion when discussing positive and negative voltage in the ERP waveforms.

time window and that, as discussed below, is clearly modulated by emotional variables (Holt et al., 2009, Exp. 1; Kissler et al., 2006).

By far the most consistent finding in the emotion ERP literature is modulation of a late positive component (although the effect is certainly not language specific; similar effects are seen using nonverbal emotional stimuli including pictures and emotional facial expressions: Hajcak et al., 2010; Olofsson et al., 2008). A larger positivity is often seen to emotional (pleasant and unpleasant) words than to neutral words, starting at around 400–500 ms and extending for several hundred milliseconds (Hajcak et al., 2011; Kissler et al., 2006). The direct contrast between pleasant and unpleasant stimuli on the late positivity has yielded more mixed findings. Some studies have reported a larger positivity on unpleasant stimuli, even when matched in arousal to pleasant stimuli (Holt et al., 2009; Huang and Luo, 2006; Ito and Cacioppo, 2000; Ito et al., 1998). This has been interpreted as a neural correlate of the ‘negativity bias’: the “tendency for the negative motivational system to respond more intensely than the positive motivational system to comparable amounts of activation” (Ito et al., 1998, p. 888; see also Baumeister et al., 2001; Rozin and Royzman, 2001; Taylor, 1991). Other studies, however, have found null effects for this contrast (Fischler and Bradley, 2006; Franken et al., 2008), or even larger positivities to pleasant stimuli (Briggs and Martin, 2009; Kissler et al., 2009).

The functional significance of the late positivity to emotional stimuli is not entirely clear. It is often interpreted as reflecting a reallocation of domain-general attentional and processing resources, and as being related to or partly composed of the P3 component, with emotional stimuli acting as “natural targets” because of their inherent salience or motivational significance (Hajcak et al., 2011). The arousal dimension of emotion has sometimes been seen as a fairly direct correlate of such motivational significance and therefore the main determinant of late positive amplitude to emotional stimuli. However, as noted above, the late positivity can sometimes be modulated by valence, even when arousal is matched, and other recent studies have begun to examine how motivational significance varies independently of both valence and arousal (Briggs and Martin, 2009; Franken et al., 2008; Weinberg and Hajcak, 2010). Indeed, it is likely that the late positivity is not a unitary component, but rather that it reflects multiple, temporally overlapping processes that may be differentially modulated by different aspects of emotion (Delplanque et al., 2006; Foti et al., 2009; Hajcak et al., 2011; MacNamara et al., 2009).

Self-relevance—The impact of self-relevance on cognitive processing has also been examined with ERPs. Modulation of components before approximately 200 ms (N1, P1, N170/VPP) have mostly shown null results, while components between 200 and 300 ms (N2/N250, P2) have revealed mixed findings (e.g., Keyes et al., 2010; Sui et al., 2009; Tanaka et al., 2006). Only one study has reported an effect on the N400 (Müller and Kutas, 1996).

Similar to emotional stimuli, the most consistent impact of self-relevance in ERP studies is on the late positivity. Larger positivities have been described to subjects’ own names compared to other names (presented auditorily and visually; e.g., Berlad and Pratt, 1995; Folmer and Yingling, 1997; Perrin et al., 2005; Tacikowski and Nowicka, 2010), to text in subjects’ own handwriting compared to others’ handwriting (Chen et al., 2008), to pictures of subjects’ own faces compared to other faces (e.g., Keyes et al., 2010; Ninomiya et al., 1998; Sui et al., 2009; Tacikowski and Nowicka, 2010), to pictures of subjects’ own versus others’ objects (e.g., bags, shoes, cups; Miyakoshi et al., 2007), and to a mix of self-relevant versus non-self-relevant words (e.g., middle names, high school name, car model, hometown, etc.; Gray et al., 2004). A larger positivity is also seen when participants make judgments about themselves compared to making judgments about others (Nakao et al., 2009; Watson, 2008, Exp. 5; Yu et al., 2010), when they retrieve memories or facts about themselves versus a close other (Magno and Allan, 2007), and when they perform a task versus watching another person perform the same task (Leng and Zhou, 2010; Senkfor et al., 2002). Similar to the late positivity effect evoked by emotional stimuli, this effect has usually been interpreted as reflecting increased attention and cognitive processing allocated to self-relevant stimuli and tasks due to their inherent motivational significance (e.g., Gray et al., 2004).

Interactions between emotion and self-relevance—As is clear from the review above, emotion and self-relevance show similar behavioral effects as well as similar ERP effects on the late positivity. Their interaction, however, has been less studied, with only a few ERP experiments manipulating both emotion and self-relevance in the same paradigm.

In most of the studies examining both of these factors together, emotion has been manipulated through the stimuli while self-relevance has been manipulated through the task carried out by subjects. For example, Li and Han (2010) found that an early portion of the late positivity was enhanced to images of hands in painful situations, but only if participants imagined the hands were their own. Other studies have asked participants to judge whether positive or negative trait adjectives describe themselves or (in some cases) someone else. Shestyuk and Deldin (2010) found a larger late positivity to pleasant than unpleasant adjectives when participants made judgments about themselves, but not about Bill Clinton. Watson et al. (2007) conducted a similar study but only used self judgments (like me/not like me) and averaged ERPs based on participants' responses in order to examine the "self-positivity bias" (broadly, the tendency for positive valence to be associated with the self; Alicke and Govorun, 2005; Armor and Taylor, 2002; Mezulis et al., 2004). They found more positive amplitudes from 450–600 ms to trait adjectives that were consistent with the self-positivity bias (positive adjectives judged "like me" and negative adjectives judged "not like me") than those that were inconsistent with the self-positivity bias.[2]

Work on the self-positivity bias, however, highlights a potential drawback of approaches using judgment tasks to manipulate self-relevance: asking participants to judge the self-relevance of an unpleasant stimulus does not necessarily mean that it will actually be processed as being self-relevant. Participants are free to simply judge unpleasant stimuli as not self-relevant (and likely will: Mezulis et al., 2004). A better approach may be to manipulate both self-relevance and emotion in the stimuli themselves.

To date, only a pair of studies by Herbert et al. (2011a,b) have taken this approach. They asked participants to read pleasant, neutral, and unpleasant nouns preceded by "my" (self-relevant), "his" (other relevant; used only in the Herbert et al., 2011a study), or "the" (control). When the nouns were preceded by "my", they found larger late positivities to emotional than to neutral nouns. No such effects of emotion, however, were seen when the nouns were preceded by "he" or "the". This is surprising given the large number of ERP studies that have found robust effects of emotion on the late positivity without self-relevance manipulations (Hajcak et al., 2011; Kissler et al., 2006). Further complicating the interpretation of these studies, the modulation of the positivity to emotional self-relevant stimuli differed despite nearly identical paradigms: in the Herbert et al. (2011 a) study pleasant nouns in a self-relevant context elicited a larger positivity than unpleasant or neutral nouns, but in the Herbert et al. (2011b) study unpleasant nouns in a self-relevant context elicited a larger positivity than pleasant or neutral nouns.

[2]In the published paper, the text and figures are inconsistent, with the figure showing more positive amplitudes for stimuli inconsistent with the self-positivity bias. However, the authors confirm that the labels for the waveforms were inadvertently switched (B. Dritschel, personal communication, August 30,2010; I. Jentzsch, personal communication, September 2, 2010).

The current study

In sum, most previous ERP studies of emotion and self-relevance have shown effects on the late positivity. In those studies examining the interaction between these two factors, the clearest effects have also been on the late positivity. However, in some studies, participants were free to explicitly judge unpleasant stimuli as being not self-relevant. While this approach may yield interesting information about the self-positivity bias, it remains unclear how the brain reacts to emotional stimuli for which self-relevance is unambiguously established. The only studies that address this question used restricted stimuli (two-word noun phrases) and yielded somewhat contradictory results.

In the current study, we independently manipulated self-relevance and emotion during the processing of two-sentence discourse scenarios. This allowed us to build up a narrative, which better approximates natural reading and comprehension and makes for a stronger, more flexible manipulation. Our design was based on a recent study carried out in our lab (Holt et al., 2009). As in that study, pleasant, neutral, and unpleasant critical words were embedded in a neutral context. In the present study, we manipulated this neutral context such that it was presented either in the third person (other condition) or the second person (self condition), e.g., *A man knocks on Sandra's/your hotel room door. She/You see(s) that he has a <u>gift/tray/gun</u> in his hand*. Previous research has shown that second-person sentences lead to processing from the reader's own perspective, while third person sentences lead to processing from an observer's perspective (Brunyé et al., 2009). In order to ensure deep processing and to further encourage participants to read the second-person scenarios as referring to themselves, the task was to verbally produce a single sentence to continue the story either in the first person (self condition) or in the third person (other condition).

Our first aim was to determine whether there were effects of unambiguously establishing self-relevance in the context, prior to the onset of a critical word. One possibility is that establishing a self-relevant context increases arousal and/or attention, leading to top-down effects that might enhance the early sensory stages of processing incoming words. As noted above, few previous ERP studies have examined the processing of stimuli that have been unambiguously pre-established as self-relevant. However, previous work in several other domains has shown that top-down attention can enhance early sensory processing. For example, in spatial attention paradigms, stimuli in attended locations are associated with enhanced visual processing relative to those in non-attended locations (Hillyard et al., 1998). And in language research, there is evidence that different types of contextual manipulations can, under some circumstances, lead to top-down attentional effects which manifest on early components, including the P1/N1 (e.g., St. George et al., 1994) and the P2 (e.g., Federmeier et al., 2005). Based on these data, we predicted that the prior establishment of a self-relevant context in the present study would lead to top-down attentional effects that would enhance the modulation of early (pre-N400) components such as the P1, N1, and/or P2.

As reviewed above, many previous studies have shown effects of both emotion and self-relevance at a later stage of processing, on the late positivity, and this is thought to reflect increased attentional re-allocation and deeper cognitive processing for both types of stimuli. We hypothesized that similar processes would be engaged during the comprehension of social vignettes and therefore predicted main effects of both Emotion and Self-Relevance on the late positivity, with a larger positivity to critical words in self-relevant than non-self-relevant contexts and to emotional (pleasant and unpleasant) words than to neutral words. We were also interested in whether we would see a neural correlate of the negativity bias, with a larger positivity to unpleasant than pleasant words, even when these were matched on arousal.

Of most interest, however, was whether and how emotion and self-relevance would interact on the late positivity. One possibility was that the effects of self-relevance and the effects of emotion would summate or that one would amplify the other. For example, the late positivity to emotional (versus neutral) words might be larger in self-relevant than in non-self-relevant contexts. This would imply that self-relevance and emotion act relatively independently of one another, either through triggering distinct neural mechanisms operating within the same time window or by independently acting on a common neurocognitive process. On the other hand, a more complex interaction, with qualitatively different effects of one factor for different levels of the other, would imply a more interdependent relationship between the processing of emotion and self-relevance in this time window.

Methods

Stimuli

222 sets of two-sentence scenarios were developed, each with two Self-Relevance conditions (self and other) and three Emotion[3] conditions (pleasant, neutral, and unpleasant). These were crossed in a 2 × 3 factorial design so that there were six versions for each scenario: self-pleasant, self-neutral, self-unpleasant, other-pleasant, other-neutral, and other-unpleasant (see Table 1 for examples). All scenarios were written in the present tense. The first sentence (4–13 words long) always introduced a situation involving one or more people, only one of which was specifically named (the protagonist), and it was always neutral or ambiguous in valence, e.g., *A man knocks on Sandra's hotel room door*. The named protagonist was male half the time and female the other half. To create the self conditions, the named person was changed to "you", e.g., *A man knocks on your hotel room door*. In some scenarios this necessitated changing the conjugation of the verb, but the first sentence was otherwise identical across the self and other conditions. The second sentence (4–17 words) continued the scenario and always contained a pronominal ana-phor that referred back to the protagonist introduced in the first sentence (i.e., the named person in the other condition and "you" in the self condition). This second sentence was the same across all emotion conditions except for one word, the critical word, which was pleasant, neutral or unpleasant, e.g., *She/You see(s) that he has a gift/tray/gun in his hand*. The part of speech of the critical word was the same across the three Emotion conditions for each scenario: 37 of the scenarios had noun critical words, 54 had verb critical words, and 131 had adjective critical words. The second sentence was otherwise emotionally neutral or ambiguous and ended with a content word that did not refer back to any person in the scenario. All scenarios were written so that they would be plausible for most college students, both male and female.

A series of norming studies of the stimuli were carried out in participants who did not take part in the ERP experiment. All participants were recruited through online postings. Inclusion criteria for participants in these ratings studies were the same as for the ERP study (see below). Results of these norming studies, together with other norms, are summarized in Table 2.

Frequency and numbers of letters for critical words—Log-transformed word frequencies from the HAL corpus (Lund and Burgess, 1996) were obtained from the English Lexicon Project database (http://elexicon.wustl.edu; Balota et al., 2007) for all critical words. A between-items ANOVA showed no difference across the three Emotion conditions, $F(2, 651)=.531$, $p=.588$, see Table 2 for means and standard deviations.

[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.

For word length (number of letters), a between-items ANOVA showed a marginally significant effect of Emotion, $F(1, 663)=2.87$, $p=.057$. Fisher LSD tests showed that this was due to unpleasant critical words being slightly (<0.6 letters) shorter than pleasant or neutral critical words, see Table 2 for means and standard deviations. The words were identical across the two Self-Relevance conditions apart from six scenarios in which verb critical words were conjugated differently in the self scenarios and were one letter longer.

Cloze probabilities of critical words and semantic constraint of scenarios—For each scenario, we constructed a stem that included the first sentence and the second sentence up until, but not including, the critical word and ended with an ellipsis to indicate that the scenario continued after the critical word. 116 participants (29 per scenario, mean age = 22.9, 73 females) were asked to give the word that they thought was most likely to come next. Cloze probabilities for each of the six conditions were calculated based on the percentage of respondents who produced a word that matched the critical word exactly, see Table 2. A 3 × 2 mixed model ANOVA with Emotion as a within-items factor and Self-Relevance as a between-items factor revealed no significant main effects of either Emotion, $F(2, 884)=0.24$, $p=.784$, or Self-Relevance, $F(1, 442)=0$ (cloze probabilities were exactly equal), and there was no interaction between Emotion and Self-Relevance, $F(2, 884)=0.53$, $p=.587$.

The frequency of the modal response was calculated as a measure of semantic constraint for each scenario. A paired samples t-test revealed no differences between the self and other contexts in constraint, $t(221)=0.52$, $p=.6$.

Concreteness ratings of critical words—Concreteness ratings were gathered for critical words via online postings from 116 participants (at least 14 for each word, mean age=24.2, 71 females) who did not participate in the ERP study. Next to each world was a scale on which participants completed their ratings (1=least concrete (most abstract) to 7=most concrete). A between-items ANOVA showed a significant effect of Emotion, $F(2, 660)=7.13$, $p=.001$. Fisher LSD tests showed that neutral critical words were rated as slightly, but significantly, more concrete than pleasant or unpleasant critical words, which did not differ from one another, see Table 2 for means and standard deviations.

Valence and arousal ratings of critical words—Valence and arousal ratings of critical words were calculated from an internal database of rating studies run by our lab in which subjects rated either valence or arousal on a 7 point scale (at least 20 raters per word). As expected, a between-items ANOVA showed significant effects of Emotion for both valence, $F(2, 663) = 1999.65$, $p<.001$, and arousal, $F(2, 663)=141.76$, $p<.001$. Fisher LSD tests confirmed that the pleasant words were rated as more positively valenced than the neutral and unpleasant words, and that the neutral words were rated as more positively valenced than the unpleasant words. For arousal, as expected, pleasant and unpleasant critical words were rated as more arousing than neutral critical words. In addition, pleasant critical words were rated as more arousing than unpleasant words.

Valence and arousal ratings of full scenarios—For each scenario, we constructed a stem that included the first sentence and the second sentence up until and including the critical word and ending with an ellipsis to indicate that the scenario continued after the critical word. 270 subjects (at least 20 per scenario; 169 female) who met the same eligibility criteria as those who participated in the ERP study rated each scenario for both valence and arousal in an online study. As expected, a within-items ANOVA on the valence ratings revealed a main effect of Emotion, $F(2, 442)=2612.67$, $p<.001$. Fisher LSD tests showed that pleasant scenarios were rated as more positively valenced than neutral scenarios, which were rated as more positively valenced than unpleasant scenarios. There was no main effect of Self-Relevance, $F(1, 221)=1.75$, $p=.187$, but there was an Emotion by Self-Relevance interaction, $F(2, 442)= 26.50$, $p<.001$. Fisher LSD tests showed that the self-pleasant scenarios were rated as more positively valenced than the other-pleasant scenarios and that self-unpleasant scenarios were rated as more negatively valenced than other-unpleasant scenarios. There was a marginally significant difference on the neutral scenarios with those in the self condition being rated as slightly more positive.

For the arousal ratings, there was a main effect of Emotion, $F(2, 442)=73.37$, $p<.001$. As expected, the pleasant and unpleasant scenarios were rated as more arousing than neutral scenarios. In contrast to the ratings on the single critical words, unpleasant scenarios were rated as more arousing than pleasant scenarios. There was no Emotion by Self-Relevance interaction, $F(2, 442)=0.02$, $p=.980$, but there was a main effect of Self-Relevance, $F(1, 221)=162.71$, $p<.001$, due to scenarios in the self condition being rated as more arousing than those in the other condition.

ERP study

Subjects—Twenty-nine people who responded to an advertisement on a Tufts University online community site (tuftslife.com) originally participated in the ERP study. Three participants were excluded from analysis due to excessive artifact in the EEG, leaving 26 participants in the final analysis (11 males). All participants were right-handed native English speakers (having learned no other language before the age of 5) between the ages of 18 and 29 (M=20.7, SD=2.3), with no history of psychiatric or neurological disorders. Participants were paid for their participation and provided informed consent in accordance with the procedures of the Institutional Review Board of Tufts University.

Stimulus presentation—Scenarios were divided into six lists, which were counterbalanced such that the same critical word did not appear more than once in any list and a given scenario's context did not appear more than once per list. Each of the six lists included 222 sentence pairs (1/2 in each Self-Relevance condition and 1/3 in each of the three Emotion conditions).

Participants were randomly assigned to one of the six lists and sat in a comfortable chair in a dimly-lit room. Stimuli were presented on a computer monitor in white font centered on a black background. The longest critical words were subtended at a visual angle of approximately 5° and the average visual angle was approximately 2°. All trials began with the word “READY”. The participant pressed a button on a gamepad to begin the trial. The first sentence then appeared in full and stayed on the screen until the participant pressed a button to advance. The second sentence began with a fixation cross displayed for 500 ms, followed by an interstimulus interval (ISI) of 100 ms, followed by each word of the sentence presented individually for 400 ms with an ISI of 100 ms. The final word of the scenario appeared on the screen for a longer duration of 750 ms, 400 ms ISI. Scenarios were presented in six blocks of 37 scenarios with a break in between each block.

In order to ensure that each scenario was read deeply, participants were instructed to verbally produce a short, single sentence that followed naturally from the sentences they had just read, i.e., that continued the story. After the final word of each scenario, a question mark appeared on the screen, cuing participants to produce their verbal responses. Participants spoke into a microphone so that the experimenter was able to listen to their responses to ensure that they were in keeping with the content of each scenario. In addition, in 11 scenarios (randomly interspersed among each list), a yes or no comprehension question followed the participant's response, providing another objective measure of attention and comprehension.

ERP recording and analysis—The EEG response was recorded from 29 tin electrodes held in place by an elastic cap (Electro-Cap International, Inc., Eaton, OH; see Fig. 1 for montage). Additional electrodes were placed below the left eye and at the outer canthus of the right eye to monitor vertical and horizontal eye movements. There were also two mastoid electrodes (A1, A2) and the EEG signal was referenced to the left mastoid. The EEG signal was amplified by an Isolated Biometric Amplifier (SA Instrumentation Co., San Diego, California) with a band pass of 0.01–40 Hz and continuously sampled at 200 Hz. The impedance was kept below 2.5 kΩ for mastoid electrodes, 10 kΩ for EOG electrodes, and 5 kΩ for all other electrodes.

Averaged ERPs, time-locked to the critical words, were formed offline from trials free of ocular and muscular artifact and low pass filtered at 15 Hz. Overall, 7.7% of trials were rejected for artifact. A 2 × 3 within-subjects ANOVA showed that the rejection rate did not differ across the Self-Relevance, $F(1, 25)=0.10$, $p=.754$, or Emotion, $F(1, 50)=1.88$, $p=.164$, conditions and that there was no interaction between the two variables, $F(2, 50)=0.09$, $p=.913$. Artifact-free data were quantified by calculating the mean amplitude (relative to a 100 ms prestimulus baseline) in time windows of interest (see Results).

In order to examine how the modulation of the waveforms varied across the scalp, the scalp was subdivided into three-electrode regions along its anterior–posterior distribution, at both middle and peripheral 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) across the scalp, were conducted for each time window.

In the mid-regions omnibus ANOVA, the within-subject variables were Emotion (3 levels: pleasant, neutral, unpleasant), Self-Relevance (2 levels: self, other) and Region (5 levels: prefrontal, frontal, central, parietal, occipital, see Fig. 1). We followed up any interactions with Region by examining effects in each three-electrode region individually. Interactions between Emotion and Self-Relevance were followed up in two ways. First, we examined the effects of Self-Relevance at each level of Emotion. Second, we examined the effects of Emotion at each level of Self-Relevance.

In the peripheral regions omnibus ANOVA, the within-subjects variables were Emotion (3 levels: pleasant, neutral, unpleasant), Self-Relevance (2 levels: self, other), Region (2 levels: frontal, posterior, see Fig. 1) and Hemisphere (2 levels: left, right). Interactions were followed up as described above. In addition, 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 Hemisphere were followed up by examining effects in left and right frontal and peripheral regions separately.

For all analyses, the Greenhouse and Geisser (1959) correction was applied to repeated measures with more than one degree of freedom, and a significance level of alpha=.05 was used for all comparisons.

Results

Examination of the waveform revealed the following components: the P1 (peaking at approximately 80 ms), the N1 (peaking at approximately 130 ms), the P2 (peaking at approximately 250 ms), the N400 (peaking at around 400 ms) and the late positivity (which began around 400 ms and continued through approximately 800 ms). The P1 and N1 were measured as the mean amplitude from 50–100 ms and 100–150 ms respectively. Although effects on the P2 appeared to continue past 300 ms, we wanted to avoid overlap with the N400 as previous work with similar stimuli has shown effects of emotion on this component

(Holt et al., 2009). We therefore measured the P2 as the mean amplitude between 200 and 300 ms, a time window that is consistent with previous work examining the P2 in a discourse context (e.g., Federmeier et al., 2005). The N400 itself was obscured by overlap with the P2 and the late positivity (which began around the peak of the N400) and therefore could not be examined in the present study (analyses within the 300–500 ms time window, as well as a late negativity that followed the late positivity, are available as supplementary material on our website at www.nmr.mgh.harvard. edu/kuperberglab/materials.htm). To avoid overlap with the N400 we measured the late positivity as the mean amplitude between 500 and 800 ms.

Early components: P1 (50–100 ms), N1 (100–150 ms) and P2 (200–300 ms)

As predicted, analyses revealed main effects of Self-Relevance and/or Self-Relevance × Region interactions on the P1, N1, and P2.

On the P1 and N1, there were significant Self-Relevance × Region interactions in the mid-regions ANOVA, and on the P1 there was also a Self-Relevance × Region interaction in the peripheral regions ANOVA. On the P2, there were main effects of Self-Relevance as well as Self-Relevance × Region interactions in both the mid-regions and peripheral regions ANOVAs. Follow-ups in individual regions showed significant effects of Self-Relevance at the prefrontal and occipital regions on the P1 (which presented as a negativity in the occipital region), at the prefrontal region on the N1, and at the prefrontal, frontal, and central regions on the P2. See Table 3 and Fig. 2 for results and statistics.

There was also an Emotion × Self-Relevance × Hemisphere interaction in the peripheral regions ANOVA on the N1, $F(2, 50)=3.39$, $p=.046$, $\eta^2=.119$, but follow-ups at each level of Emotion and Self-Relevance revealed no significant effects, all *F*s <3.72, all *p*s>.07. There were no other significant main effects or interactions involving Emotion on the P1, N1, or P2, all *F*s <2.75, all *p*s>.07.

Late positivity (500–800 ms)

The effects involving Self-Relevance and Emotion separately are summarized in Table 3 and Table 4 respectively. Self-Relevance interacted with Region, with follow-ups at individual regions showing a larger late positivity to critical words in the self condition at prefrontal and frontal regions, see Table 3 and Fig. 2. There were both main effects of Emotion and Emotion × Region interactions. Pleasant and Unpleasant critical words elicited a larger positivity than neutral critical words with a centro-parietal distribution. Unpleasant critical words also elicited a larger positivity than pleasant critical words, but with a frontal distribution, see Table 4, Fig. 3. Because we were interested in examining the difference between pleasant and unpleasant stimuli independent of arousal, we created subsets of our stimuli in which pleasant and unpleasant conditions were matched for arousal based on our single word and scenario ratings respectively. Analyses on waveforms averaged from these subsets showed that the main effect of Emotion remained significant, *F*s>8, *p*s<.001, and pairwise comparisons showed that the pattern of results, including the difference between pleasant and unpleasant, remained the same.

Of most interest was an interaction between Emotion and Self-Relevance which was significant in the mid-regions ANOVA, $F(2,50)=4.02$, $p=.026$, $\eta^2=.138$, and marginally significant in the peripheral regions ANOVA, $F(2, 50)=2.70$, $p=.078$, $\eta^2=.098$. This interaction was resolved in two ways: first, by examining effects of Self-Relevance at each level of Emotion (Table 5, Fig. 4) and second, by examining effects of Emotion at each level of Self-Relevance (Table 6, Fig. 5).

As shown in Table 5 and Fig. 4, there were no effects of Self-Relevance on the waveforms produced by either pleasant or unpleasant critical words. However, there were effects of Self-Relevance on the neutral critical words: neutral words encountered in the self scenarios produced a significantly more positive waveform than those encountered in the other scenarios. This effect was broadly distributed (a main effect of Self-Relevance), but was larger in more fronto-central regions (a Self-Relevance × Region interaction, with follow-ups at each region showing effects at prefrontal, frontal, central and parietal regions, but not at occipital or peripheral posterior regions).

As shown in Table 6 and Fig. 5, both the mid-regions and peripheral regions omnibus ANOVAs showed significant effects of Emotion and/or significant Emotion × Region interactions in both the self and other scenarios. Follow-up analyses at each individual region showed effects of Emotion that reached or approached significance at all regions. Importantly, however, the modulation of the late positivity across the three emotion conditions differed between the self and other scenarios, see Fig. 5. In the other scenarios, the waveforms to the unpleasant critical words diverged from those to both the pleasant and neutral critical words at mid-frontal and peripheral frontal regions. More posteriorly, within parietal and occipital regions, the waveforms to the pleasant critical words also diverged from those to the neutral critical words. In the self scenarios, the neutral critical words evoked a significantly larger positivity than both the pleasant and unpleasant critical words within the most anterior prefrontal region. In the frontal regions, the waveform to the unpleasant words became more positive such that it was the same as that to the neutral words and more positive than that to the pleasant words. More posteriorly, in parietal regions, the positivity to the unpleasant critical words remained larger than to the pleasant words and also became larger than to the neutral words; in the occipital region, the positivity to the pleasant words was just as large as that to the unpleasant critical words and also significantly larger than that to the neutral critical words.

Discussion

In this study, we independently manipulated emotion and self-relevance as participants read two-sentence social vignettes. This enabled us to determine the effects of each of these variables independently, as well as their interactions in a discourse context. We showed a modulation of early components (the P1, N1, and P2) by self-relevance, as well as effects of both emotion and self-relevance in the late positivity time window. In addition, we observed a unique pattern of interaction between self-relevance and emotion on the late positivity with follow-ups revealing effects of self-relevance on neutral but not on emotional (pleasant and unpleasant) critical words. We discuss each of these findings below before considering some open questions and summarizing the implications of our data.

Effects of self-relevance

In the present study, self-relevance was established in the context prior to the time-locked critical word. We were interested in whether this pre-establishment of self-relevance would influence early processing of incoming words. We found that it did: there were effects of self-relevance on the P1, N1, and P2 components.

Although early ERP components are often affected by physical differences in stimuli, our results cannot be attributed to such differences: the critical words were identical across self and other conditions except for six critical verbs which had slightly different conjugations across conditions, and when analyses were run with these six scenarios excluded, the results remained the same. We therefore attribute these early effects to the establishment of self-relevance in the preceding context and suggest that this upstream information influenced the earliest stages of word processing.

Previous work, mostly using spatial attention paradigms, has shown that early components, reflecting activity within sensory cortices, can be influenced by attention. In such work, these effects have been attributed to a top-down attentional amplification of sensory processing (Hillyard et al., 1998). Top-down attentional effects have also been described during language processing. For example, St. George et al. (1994) found that the P1/N1 complex to words in an ambiguous paragraph was enhanced when a title that disambiguated the content of that paragraph was provided. They interpreted this as reflecting enhanced attention to visual processingofincomingwords when top-down cues about the schema were provided. On the P2 component, Federmeier et al. (2005) found a significant effect to words in more constraining than less constraining contexts. This was interpreted as reflecting an attentional enhancement of processing features of the incoming critical word that matched those that were predicted by the constraining context. In the present study, there was no interaction between the context and the characteristics of the stimuli themselves, and because we matched scenarios for constraint and cloze probability, our results cannot be attributed to differences in predictability. Instead, we interpret the enhanced P1, N1, and P2 effects as reflecting a more general influence of self-relevance, possibly through increased arousal (ratings of arousal were generally increased in the self-relevant scenarios), which led to top-down attentional amplification of early stages of visual word processing.

Effects of self-relevance re-emerged in the late positivity time window, where similar effects have been found in numerous previous studies as described in the Introduction. Importantly, however, in this time window they were modulated by emotion, as we discuss below.

Effects of emotion

Replicating many previous studies, including the emotional discourse study from our own lab (Holt et al., 2009), we found a main effect of emotion on the late positivity. As noted in the Introduction, there has been some debate about what factors modulate the late positivity evoked by emotional stimuli and its functional underpinnings. It has often been viewed as reflecting domain-general attentional processes that are influenced by the inherent motivational significance of emotional stimuli (Hajcak et al., 2011). Within this framework, the late positivity has often been seen as being primarily modulated by the arousal level of stimuli (e.g., Cuthbert et al., 2000; Olofsson et al., 2008; Schupp et al., 2000). This idea is consistent with our observation that the late positivity was larger to the more arousing emotional (pleasant and unpleasant) words than to the less arousing neutral words.

However, we also found an effect of valence itself on the late positivity: a larger positivity was evoked to unpleasant than to pleasant critical words. As discussed in the Introduction, it has been argued that there is an inherent attentional bias toward negative stimuli, sometimes termed a “negativity bias” (Baumeister et al., 2001; Holt et al., 2009; Ito et al., 1998; Rozin and Royzman, 2001; Taylor, 1991). The main debate has been whether this effect of valence can be attributed to differences in arousal between pleasant and unpleasant stimuli. In the present study, although we did find that unpleasant scenarios were rated as more arousing in our norming study, analyses conducted on an arousal-matched subset of our stimuli showed the same pattern of results. This provides further evidence that arousal alone cannot account for these effects of valence on the late positivity (see also Holt et al., 2009; Ito et al., 1998). Our findings are therefore more consistent with arguments for a negativity bias that is independent of arousal, and/or for other stimulus factors playing a role in driving this effect (Briggs and Martin, 2009; Franken et al., 2008; Weinberg and Hajcak, 2010).

Consistent with the idea that the negativity bias may be independent of arousal, the scalp distribution of the late positivity effect of valence (unpleasant versus pleasant words) was different from that of the late positivity effect of emotion (unpleasant and pleasant versus neutral words). The former effect of valence was more anteriorly distributed while the latter effect of emotion was more posteriorly distributed. Using similar stimuli, Holt et al. (2009, Exp. 1) found the same basic pattern (see also Delaney-Busch and Kuperberg, 2011). As noted in the Introduction, although often referred to as a single component, the late positivity (or late positive potential) likely constitutes multiple, temporally overlapping components, which may each be influenced by different aspects of emotion (Delplanque et al., 2006; Foti et al., 2009; Hajcak et al., 2011; MacNamara et al., 2009). In the present study, it is therefore possible that the somewhat distinct spatial distributions of emotion and valence effects reflect the contributions of distinct neural mechanisms mediating the processing of arousal and valence operating within the late positive time window. This would be broadly consistent with fMRI and PET studies reporting differential activations for arousal and valence (Anderson et al., 2003; Cunningham et al., 2004; Lewis et al., 2007; Posner et al., 2009), although the poor temporal resolution of these techniques make it difficult to know which of these regions were modulated in the late positivity time window.

Interaction between self-relevance and emotion

Most importantly, we observed interactions between self-relevance and emotion on the late positivity. However, this interaction did not arise from an additive effect of emotion and self-relevance. Instead we found that neutral words evokedalarger late positivity when they were self-relevant than non-self-relevant, but that there was no effect of self-relevance on the emotional words.[4]

This apparently non-additive interaction between emotion and self-relevance suggests an interdependent relationship between these two variables. One possibility is that self-relevance and emotion each triggered a reallocation of attentional resources, reflected by the late positivity, but that such resources were assigned in an all-or-nothing fashion. In other words, additional resources were allocated if the context indicated that the scenario was self-relevant or if a critical word was emotional, but there was no additional effect when these combined: if processing was already enhanced by a self-relevant context, no further resources were allocated to emotional words. This explanation, however, is somewhat unsatisfying because previous work has found additive effects of each of these factors in other paradigms. For example, in an oddball paradigm Berlad and Pratt (1995) reported that both infrequent and self-relevant stimuli led to a larger positivity but infrequent self-relevant stimuli elicited an even larger positivity, and Schupp et al. (2007) found that the effect of emotion on the late positivity was larger for task-relevant stimuli.

A better explanation of the interaction may be related to the valence ambiguity of many of the neutral words. Stimuli rated as neutral (e.g., “surprise”) may be inherently more ambiguous in valence than pleasant and unpleasant stimuli—i.e., they tend to be rated as neutral because they can be *either* pleasant or unpleasant depending on the context. We suggest that when the context established self-relevance participants were more motivated to disambiguate the valence of neutral stimuli, and that this additional processing was reflected by the enhanced late positivity to the self-relevant neutral critical words. Consistent with this interpretation, this effect had a relatively more frontal distribution, similar to the frontal distribution of the late positivity effect to unpleasant versus pleasant critical words, which, as suggested above, may be related to valence processing.

Additional processing to stimuli of uncertain valence has been documented before. It has been argued that when an environment presents stimuli with ambiguous or uncertain

[4]Of course, a lack of power is always one explanation for a null effect. However, in this case, the significant effect on the neutral stimuli, as well as the other highly significant effects in this time window, suggest that the effect of self-relevance on emotional stimuli would have to be small to be undetectable. Regardless, the significant interaction shows that the effect of self-relevance was stronger on the neutral than on the emotional words.

valence, attention and processing resources are orientated towards such stimuli because only then can the motivational relevance of all stimuli be fully assessed (Hirsh and Inzlicht, 2008). Indeed, previous work has shown that stimuli of ambiguous valence can elicit larger ERP effects than negative valence in some circumstances. For example, Hirsh and Inzlicht (2008) showed a larger feed-back related negativity (FRN) to uncertain feedback than to negative feedback (although in this study, this effect only held for people higher in neuroticism; see also Gu et al., 2010). It is worth nothing that this study used only self-relevant stimuli. The present findings suggest that additional processing on ambiguous stimuli may not necessarily occur if they are not self-relevant. In other words, we may be most motivated to disambiguate the valence of ambiguous stimuli when they are relevant to ourselves.

Open questions

Our findings raise several important questions for future studies. First, it remains unclear to what extent the different effects we saw within the late positivity time window reflect the same neurocognitive processes or temporally overlapping components representing distinct neurocognitive processes. Based on their different scalp distributions, we have suggested that the process that distinguished emotional from neutral stimuli (perhaps an effect of arousal) was distinct from that which distinguished both pleasant and unpleasant valence and self and non-self-relevant neutral stimuli (perhaps associated with the processing of valence). The poor spatial resolution of ERPs, however, makes these explanations difficult to disentangle. Future work using techniques with better spatial resolution, suchas MEG or MRI, may help answer these questions.

Another set of open questions relates to how exactly self-relevance and emotion interact on the late positivity under different circumstances. Here we have shown an effect of self-relevance on the late positivity for neutral, but not emotional, stimuli. We suggested that this enhanced prolonged processing reflected continued attempts to disambiguate the valence of these self-relevant ambiguous stimuli. The circumstances under which such processes are engaged, however, might vary depending on the experimental environment. As noted in the Introduction, the few previous studies that have examined interactions between self-relevance and emotion describe effects of self-relevance on the late positivity evoked by emotional stimuli. These studies, however, either did not include neutral stimuli (Shestyuk and Deldin, 2010; Watson et al., 2007) or they included neutral stimuli that were likely less ambiguous than that in our study (Herbert et al., 2011a,b; Li and Han, 2010). One possibility therefore is that processing resources are allocated to assess motivational relevance in a dynamic fashion that depends on a particular experimental environment. This might also depend on the task at hand. In the present study, participants' task was to produce a sentence that continued the discourse scenario. Although this did not explicitly draw attention to emotion, understanding the valence of the scenario was important for developing a coherent continuation, and this may have encouraged attempts to disambiguate the valence of self-relevant neutral stimuli. It will therefore be important for future studies to examine how both experimental environment and task influence the pattern of interaction between self-relevance and emotion. Future research should also explore how these interactions change in neuropsychiatric disorders such as schizophrenia where inappropriate emotional processing of neutral, non-self-relevant ambiguous social vignettes has been associated with misattribution biases and delusions (Holt et al., 2011).

Finally, future studies should explore how the self-positivity bias affects online processing. The self-positivity bias describes the tendency for people to associate positive affect with the self across a variety of domains (Alicke and Govorun, 2005; Armor and Taylor, 2002; Mezulis et al., 2004). One might therefore predict that in self-relevant social vignettes like the ones used here pleasant critical words would be more expected than neutral or unpleasant critical words. Rather than manifesting on the late positivity, this might manifest on the N400, which is the ERP component that most directly reflects how expected a word is in relation to its preceding semantic context (Kutas and Federmeier, 2011). In the present study, we were unable to examine N400 modulation because the late positivity began relatively early, within the N400 time window, and therefore obscured this component. Such component overlap has been reported in previous work and is most likely to occur with more active tasks (for a direct comparison of tasks with similar stimuli, see Holt et al., 2009). In future work, we would therefore like to examine the same stimuli using a more passive comprehension task to test the hypothesis that in a self-relevant context pleasant words are more expected than unpleasant words and evoke a smaller N400.

Conclusions

In sum, we have shown clear effects of both self-relevance and emotion during word-by-word comprehension of written discourse. Effects of self-relevance were seen at the earliest stages of processing incoming words, suggesting that self-relevance can exert a top-down attentional influence on early perceptual processing. We also replicated our previous work by demonstrating a larger late positivity to emotional than to neutral words during discourse comprehension, as well as a larger late positivity to unpleasant than pleasant stimuli which cannot be attributed to differences in their arousal. Finally, we found a unique pattern of interaction between self-relevance and emotion on the late positivity, with a larger positivity to self-relevant than non-self-relevant neutral words. We have suggested that this reflects prolonged attempts to disambiguate the emotional valence of ambiguous stimuli that are relevant to the self.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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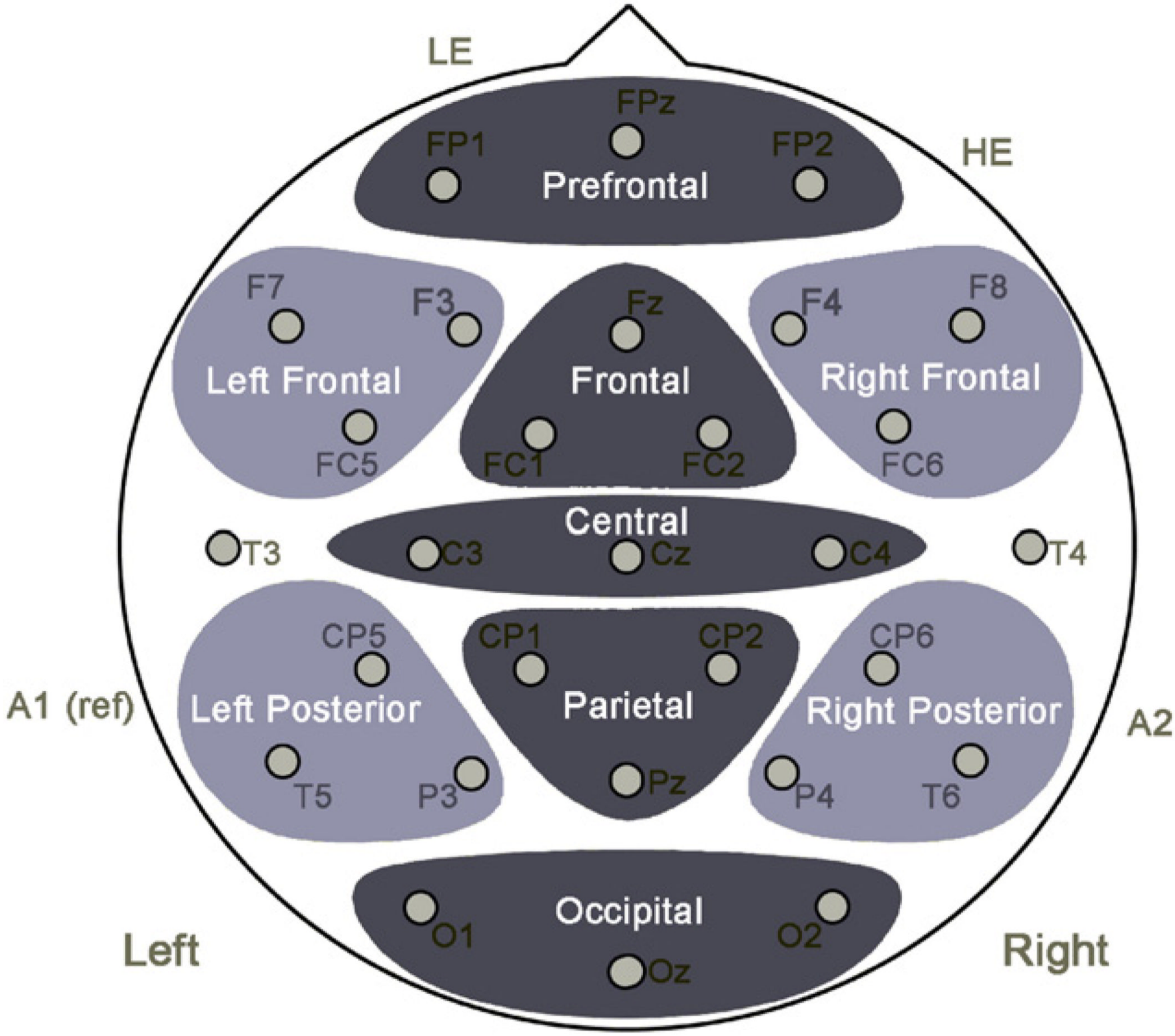

Fig. 1. Electrode montage with regions used for analysis

For the purposes of statistical analyses, the scalp was divided into three-electrode regions. Regions in dark grey were part of the mid-regions omnibus ANOVA and regions in light grey were part of the peripheral regions omnibus ANOVA.

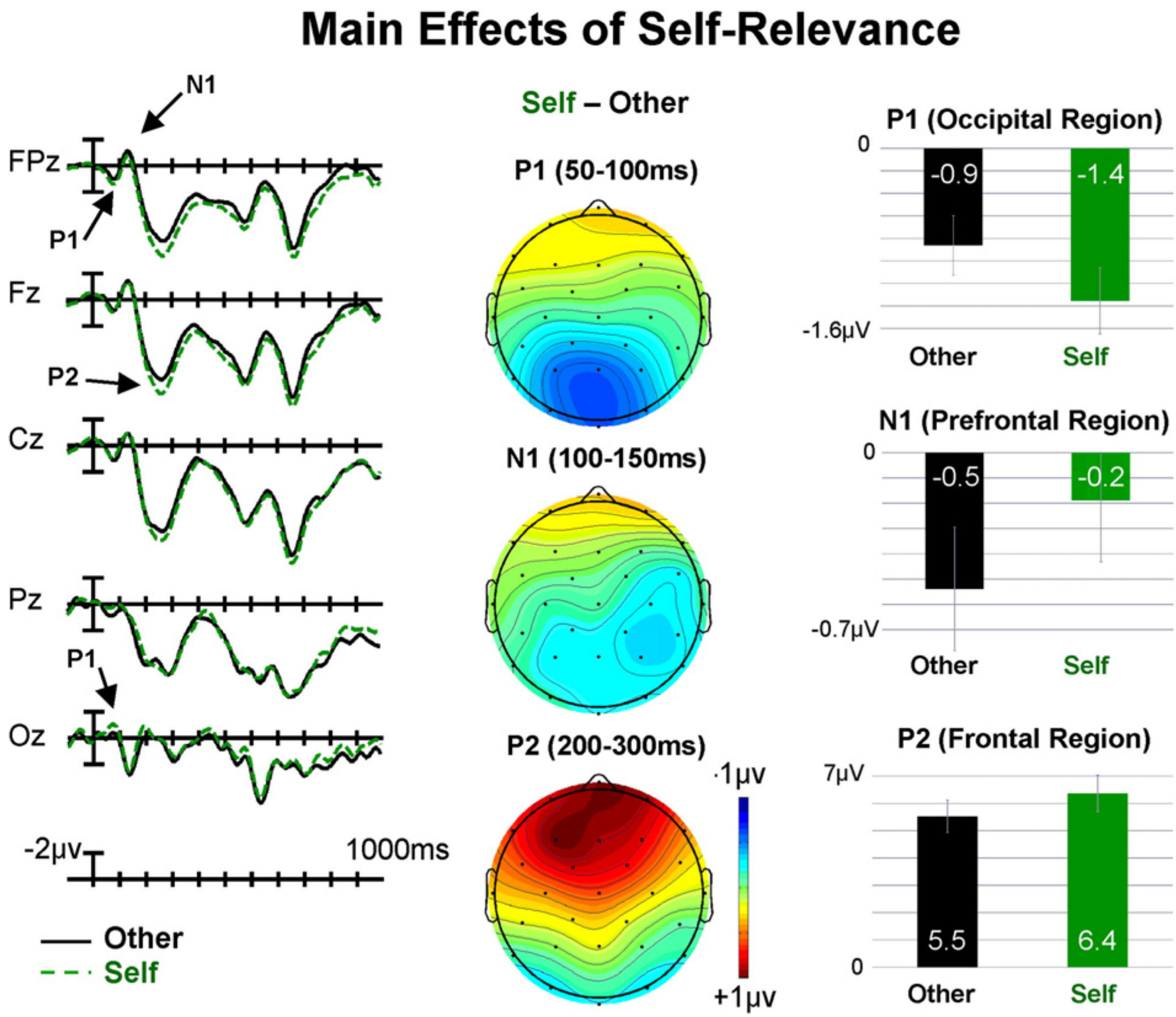

Fig. 2. Main effects of Self-Relevance

Self-Relevance modulated the P1 (50–100 ms), N1 (100–150 ms), and P2 (200–300 ms). Bar graphs show mean voltages for the P1, N1, and P2 in the self and other conditions averaged across electrode sites within the occipital (O1, Oz, O2), prefrontal (FP1, FPz, FP2), and frontal (Fz, FC1, FC2) regions where effects were largest on each of these components respectively. Error bars show the standard error for each mean.

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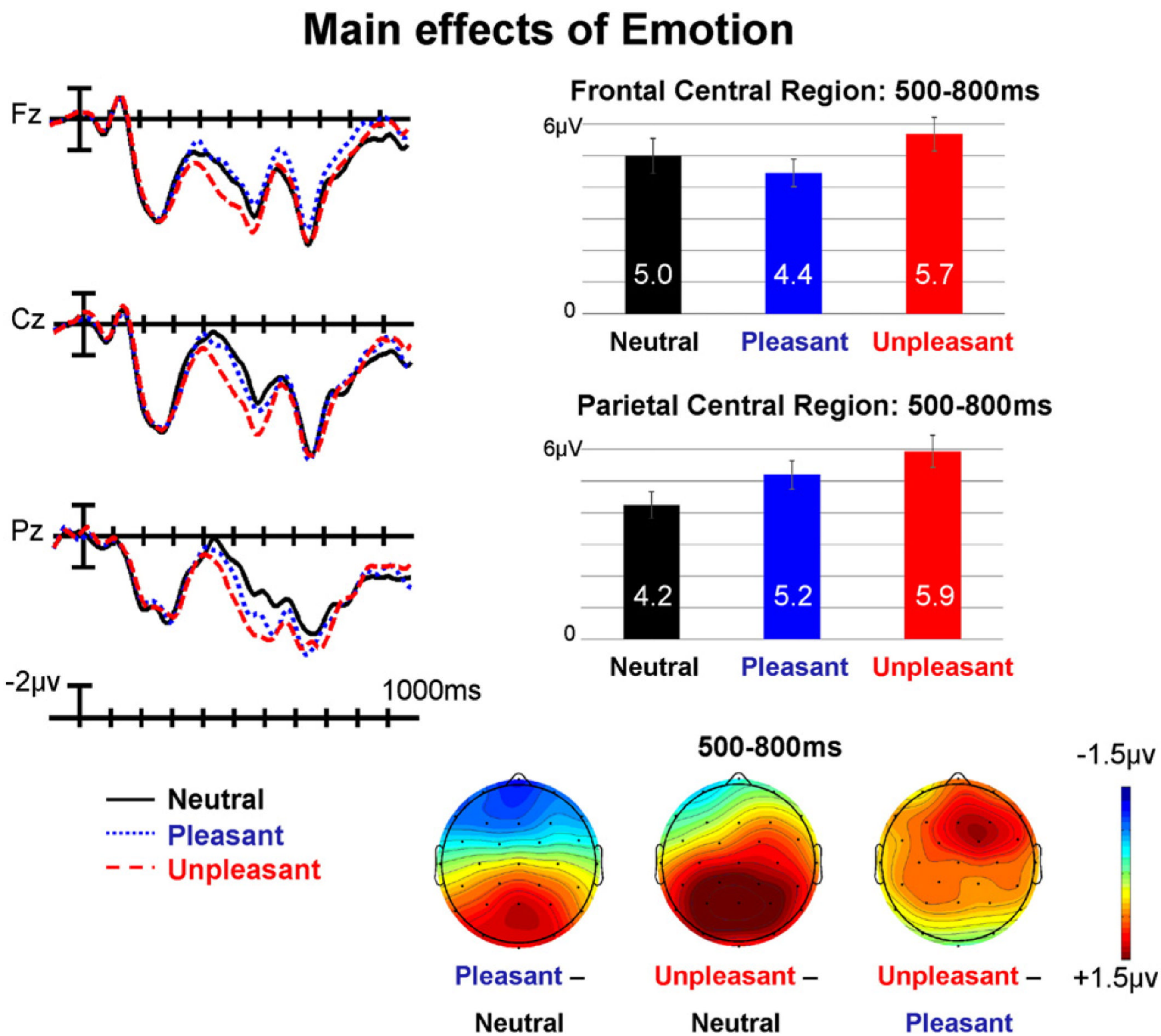

Fig. 3. Main effects of Emotion

Effects of Emotion were seen on the late positivity (500–800 ms). Emotional (pleasant and unpleasant) critical words evoked a larger late positivity at posterior sites than neutral stimuli. Unpleasant critical words evoked a larger late positivity than pleasant critical words, particularly at anterior sites. Bar graphs show mean voltages for the late positivity in the pleasant, neutral, and unpleasant conditions averaged across sites within the frontal (Fz, FC1, FC2) and the parietal (CP1, CP2, Pz) regions. Error bars show the standard error for each mean.

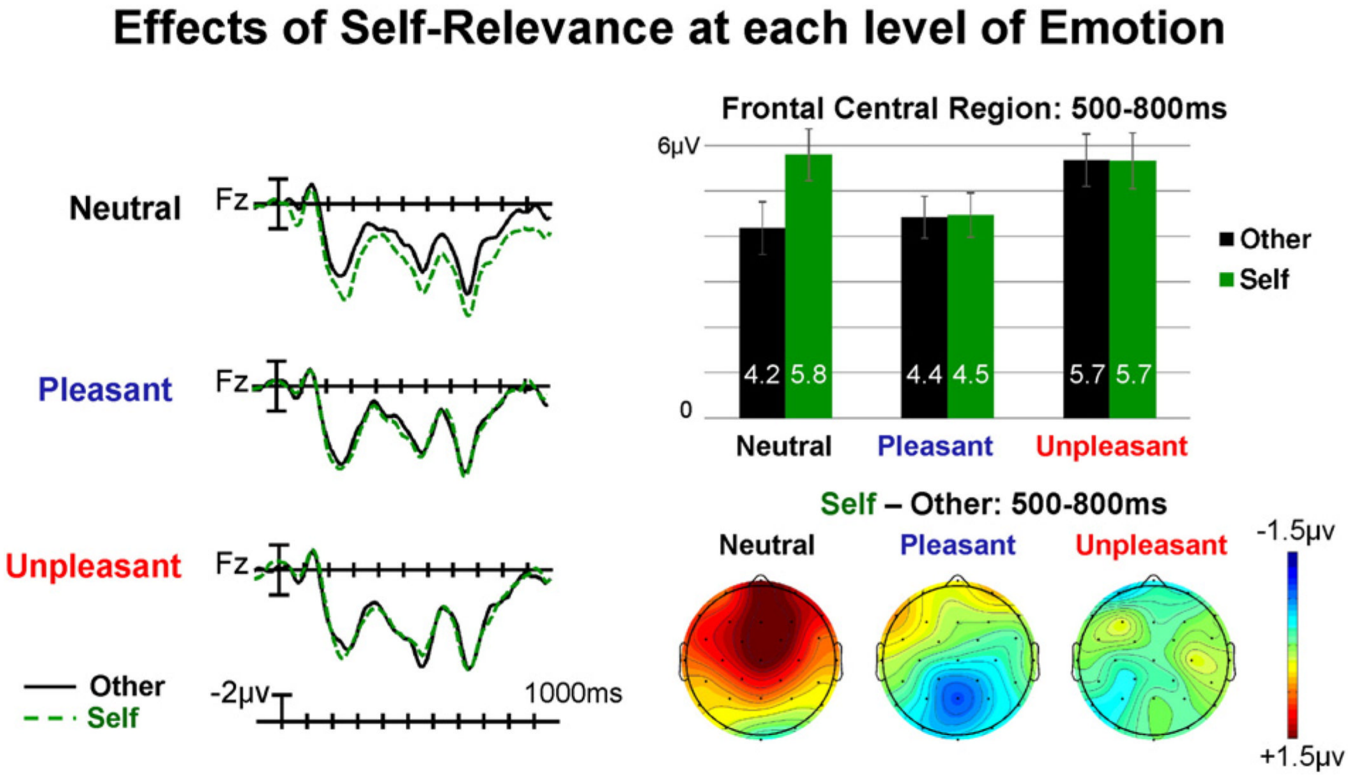

Fig. 4. Interactions between Self-Relevance and Emotion in the 500–800 ms time window: Effects of Self-Relevance at each level of Emotion

Neutral critical words in the self condition evoked a larger late positivity than neutral critical words in the other condition, particularly at frontal sites. The late positivity to pleasant and unpleasant critical words was not modulated by self-relevance. Mean voltages of all six conditions are shown at the frontal region (Fz, FC1, FC2) where the interaction effect was largest. Error bars show the standard error for each mean.

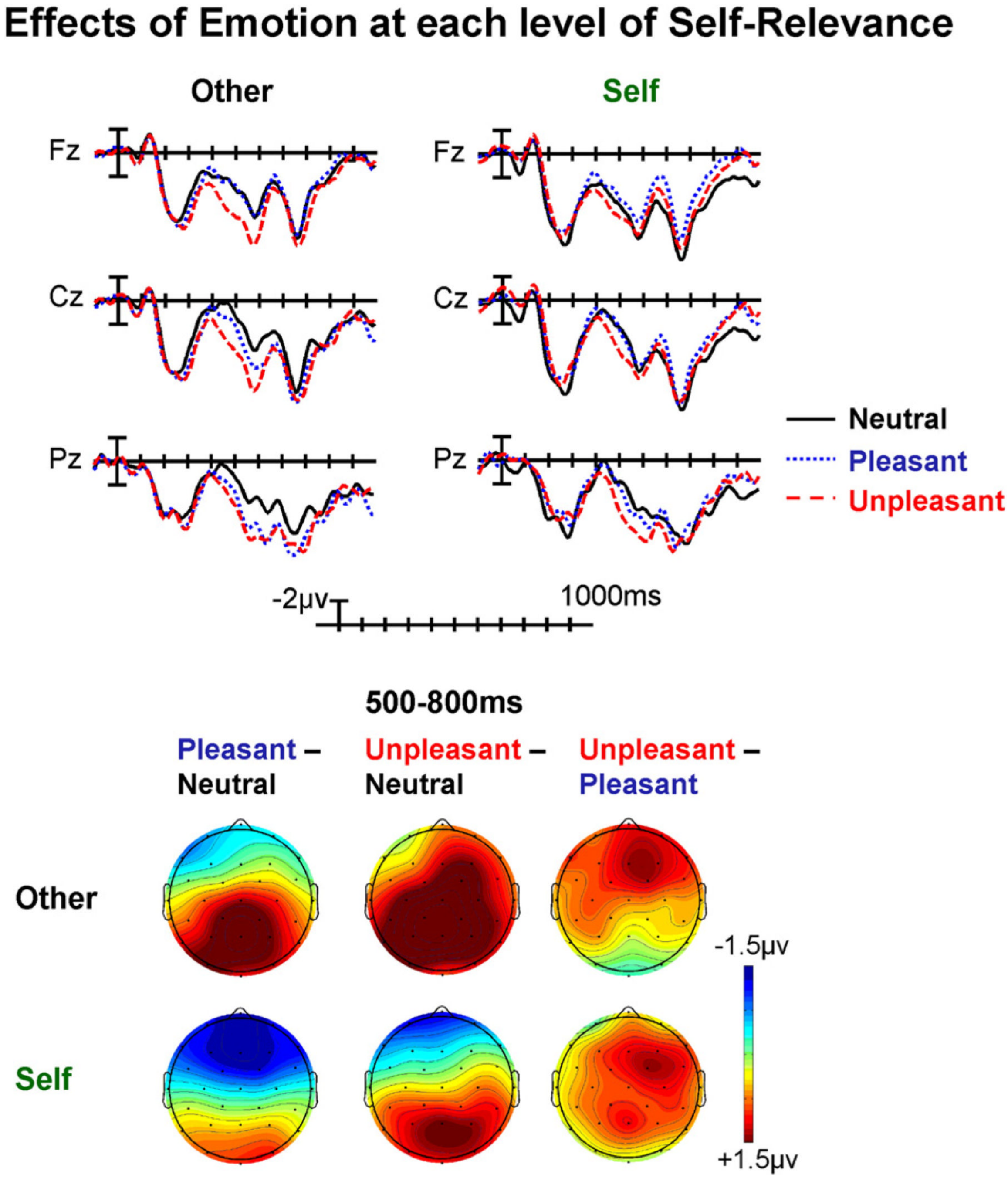

Fig. 5. Interactions between Self-Relevance and Emotion in the 500–800 ms time window: Effects of Emotion at each level of Self-Relevance

There was a main effect of Emotion on the late positivity in both the self and other conditions, although the effect was smaller for the self condition due to the larger anterior positivity evoked by neutral critical words.

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Table 1

Examples of two-sentence scenarios in each of the six conditions

Self			Other		
Pleasant	**Neutral**	**Unpleasant**	**Pleasant**	**Neutral**	**Unpleasant**
A man knocks on Sandra's hotel room door. She sees that he has a <u>gift</u> in his hand.	A man knocks on Sandra's hotel room door. She sees that he has a <u>tray</u> in his hand.	A man knocks on Sandra's hotel room door. She sees that he has a <u>gun</u> in his hand.	A man knocks on your hotel room door. You see that he has a <u>gift</u> in his hand.	A man knocks on your hotel room door. You see that he has a <u>tray</u> in his hand.	A man knocks on your hotel room door. You see that he has a <u>gun</u> in his hand.
Fletcher writes a poem for a class. His classmates think it is a very <u>beautiful</u> composition.	Fletcher writes a poem for a class. His classmates think it is a very <u>intricate</u> composition.	Fletcher writes a poem for a class. His classmates think it is a very <u>boring</u> composition.	You write a poem for a class. Your classmates think it is a very <u>beautiful</u> composition.	You write a poem for a class. Your classmates think it is a very <u>intricate</u> composition.	You write a poem for a class. Your classmates think it is a very <u>boring</u> composition.
Vince spends time with his relatives over the vacation. This turns out to be a <u>wonderful</u> experience for him in many ways.	Vince spends time with his relatives over the vacation. This turns out to be a <u>characteristic</u> experience for him in many ways.	Vince spends time with his relatives over the vacation. This turns out to be a <u>disastrous</u> experience for him in many ways.	You spend time with your relatives over the vacation. This turns out to be a <u>wonderful</u> experience for you in many ways.	You spend time with your relatives over the vacation. This turns out to be a <u>characteristic</u> experience for you in many ways.	You spend time with your relatives over the vacation. This turns out to be a <u>disastrous</u> experience for you in many ways.
After dinner, Lydia is involved in a discussion. Many of her remarks <u>impress</u> people.	After dinner, Lydia is involved in a discussion. Many of her remarks <u>surprise</u> people.	After dinner, Lydia is involved in a discussion. Many of her remarks <u>hurt</u> people.	After dinner, you are involved in a discussion. Many of your remarks <u>impress</u> people.	After dinner, you are involved in a discussion. Many of your remarks <u>surprise</u> people.	After dinner, you are involved in a discussion. Many of your remarks <u>hurt</u> people.
Carmelo has been in his current job for over a year. He learns that he is getting a <u>bonus</u> this month.	Carmelo has been in his current job for over a year. He learns that he is getting a <u>transfer</u> this month.	Carmelo has been in his current job for over a year. He learns that he is getting a <u>pay-cut</u> this month.	You have been in your current job for over a year. You learn that you are getting a <u>bonus</u> this month.	You have been in your current job for over a year. You learn that you are getting a <u>transfer</u> this month.	You have been in your current job for over a year. You learn that you are getting a <u>pay-cut</u> this month.

The critical word is underlined (but did not appear underlined in the actual stimulus lists). Additional examples can be found at www.nmr.mgh.harvard.edu/kuperberglab/materials.htm or by request from the first author.

Table 2

Stimuli ratings and characteristics

	Other Pleasant	Other Neutral	Other Unpleasant	Self Pleasant	Self Neutral	Self Unpleasant
Cloze Probability	3% (9%)	3% (7%)	3% (9%)	3% (8%)	3% (8%)	3% (7%)
Constraint	22% (13%)	22% (13%)	22% (13%)	22% (12%)	22% (12%)	22% (12%)
(log) HAL Frequency *	8.39 (2.04)	8.47 (1.89)	8.28 (1.72)	-	-	-
Number of letters	7.67 (2.38)	7.48 (2.20)	7.14 (2.47)	-	-	-
Concreteness	3.45 (0.85)	3.72 (0.92)	3.54 (0.84)	-	-	-
Valence (word)	5.69 (0.55)	4.32 (0.56)	2.34 (0.57)	-	-	-
Arousal (word)	4.48 (0.80)	3.38 (0.64)	3.80 (0.63)	-	-	-
Valence (scenario)	5.25 (0.48)	4.12 (0.51)	2.37 (0.48)	5.40 (0.52)	4.17 (0.55)	2.24 (0.53)
Arousal (scenario)	3.61 (0.77)	3.22 (0.66)	3.84 (0.74)	3.87 (0.79)	3.49 (0.75)	4.11 (0.75)

Means are shown with standard deviations in parentheses. Cloze probability and constraint are represented as the percentage of total responses from 29 subjects. Concreteness, valence, and arousal were all rated on seven point scales from least concrete (most abstract), very unpleasant, and least arousing, to most concrete, very pleasant and most arousing respectively. "-" indicates that the values were the same in the self conditions as in the other conditions since the identical critical words were used, except for in six scenarios in which the verb was conjugated differently.

* Some words did not exist in the HAL database and these were represented as null values in our calculations.

Table 3

Main effects of Self-Relevance and interactions between Self-Relevance, Region, and/or Hemisphere in early time windows (P1: 50–100 ms, N1: 100–150 ms, and P2: 200–300 ms) and the late positivity time window: 500–800 ms

	Effect	*df*	P1(50–100ms)			N1 (100–150 ms)			P2 (200–300 ms)			Late Positivity (500–800 ms)		
			F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Mid-regions omnibus ANOVA	S	1,25	0.69	0.415	0.027	0.16	0.689	0.007	7.69	**0.010**	0.235	1.85	0.186	0.069
	SxR	4,100	7.93	**0.001**	0.241	3.43	**0.030**	0.121	12.34	<**.001**	0.331	5.41	**0.007**	0.178
Prefrontal	S	1,25	5.66	**0.025**	0.185	5.42	**0.028**	0.178	16.35	<**.001**	0.395	5.37	**0.029**	0.177
Frontal	S	1,25	0.13	0.725	0.005	0.01	0.915	0.000	19.79	<**.001**	0.442	4.99	**0.035**	0.166
Central	S	1,25	0.36	0.556	0.014	0.53	0.472	0.021	5.41	**0.028**	0.178	2.57	0.122	0.093
Parietal	S	1,25	2.92	0.100	0.104	1.44	0.242	0.054	1.24	0.277	0.047	0.01	0.918	0.000
Occipital	S	1,25	10.18	**0.004**	0.289	1.82	0.190	0.068	3.04	0.093	0.109	1.62	0.215	0.061
Peripheral regions omnibus ANOVA	S	1,25	0.29	0.595	0.011	0.62	0.438	0.024	5.17	**0.032**	0.171	3.22	0.085	0.114
	SxR	4,100	13.03	**0.001**	0.343	3.86	0.061	0.134	15.37	**0.001**	0.381	7.69	**0.010**	0.235
	SxH	1,25	0.00	0.971	0.000	0.94	0.341	0.036	1.76	0.197	0.066	0.17	0.688	0.007
	SxRxH	2,50	3.44	0.076	0.121	0.01	0.924	0.000	0.63	0.435	0.025	2.00	0.170	0.074
Frontal (left & right)	S	1,25	1.48	0.235	0.056	-	-		13.14	**0.001**	0.344	7.91	**0.009**	0.240
Parietal (left &right)	S	1,25	3.73	0.065	0.130	-	-		0.05	0.831	0.002	0.02	0.901	0.001

Significant interactions between Self-Relevance and Region were followed up at individual regions. Effects significant at an alpha of .05 are shown in bold font. S=Self-Relevance, R=Region, H=Hemisphere.

Table 4

Main effects of Emotion and interactions between Emotion, Region, and/or Hemisphere in the late positivity (500–800 ms) time window

	Effect	*df*	Late Positivity (500–800 ms)			
			F	***p***	η^2	**Pairwise comparisons**
Mid-regions	E	2,50	9.78	**<.001**	0.281	U>N, P = N, U>P
omnibus ANOVA	ExR	8,200	9.85	**<.001**	0.283	
Prefrontal	E	2,50	3.57	**0.036**	0.125	U = N,P<N,U = P
Frontal	E	2,50	7.77	**0.002**	0.237	U = N,P = N,U>P
Central	E	2,50	11.78	**<.001**	0.320	U>N, P = N, U>P
Parietal	E	2,50	19.16	**<.001**	0.434	U>N, P>N, U>P
Occipital	E	2,50	11.77	**<.001**	0.320	U>N, P>N, U = P
Peripheral regions	E	2,50	12.29	**<.001**	0.330	U>N, P = N, U>P
omnibus ANOVA	ExR	2,50	13.47	**<.001**	0.350	
	ExH	2,50	1.13	0.330	0.043	
	ExRxH	2,50	5.85	**0.006**	0.190	
Frontal	E (right)	2,50	7.20	**0.002**	0.224	U = N,P = N,U>P
	E (left)	2,50	4.72	**0.015**	0.159	U = N,P<N,U>P
Parietal	E (right)	2,50	17.89	**<.001**	0.417	U>N, P>N, U>P
	E (left)	2,50	23.11	**<.001**	0.480	U>N, P>N, U>P

Interactions with Region and/or Hemisphere were followed up at individual regions. Effects significant at an alpha of .05 are shown in a bold font. Fisher LSD pairwise comparisons were conducted to follow up significant and marginally significant effects of Emotion. E = Emotion, R = Region, H = Hemisphere, U = Unpleasant, N = Neutral, P = Pleasant.

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Table 5

Effects of Self-Relevance at each level of Emotion within the late positivity (500–800 ms) time window

	Effect	*df*	Late Positivity (500–800 ms)								
			Neutral			Pleasant			Unpleasant		
			F	***p***	η^2	***F***	***p***	η^2	***F***	***p***	η^2
Mid-regions omnibus ANOVA	S	1,25	20.18	**0.000**	0.447	0.36	0.554	0.014	0.11	0.741	0.004
	SxR	4,100	5.94	**0.008**	0.192	2.53	0.095	0.092	0.33	0.757	0.013
Prefrontal	S	1,25	11.15	**0.003**	0.308	1.19	0.285	0.046	-	-	-
Frontal	S	1,25	23.20	**0.000**	0.481	0.02	0.901	0.001	-	-	-
Central	S	1,25	19.60	**0.000**	0.439	0.32	0.577	0.013	-	-	-
Parietal	S	1,25	7.54	**0.011**	0.232	2.66	0.115	0.096	-	-	-
Occipital	S	1,25	0.04	0.837	0.002	1.40	0.247	0.053	-	-	-
Peripheral regions omnibus ANOVA	S	1,25	15.12	**0.001**	0.377	0.01	0.916	0.000	0.00	0.956	0.000
	SxR	1,25	3.66	0.067	0.128	2.52	0.125	0.092	0.52	0.477	0.020
	SxH	1,25	0.01	0.926	0.000	1.71	0.203	0.064	0.14	0.710	0.006
	SxRxH	1,25	0.99	0.330	0.038	2.81	0.106	0.101	2.27	0.145	0.083
Frontal (left & right)	S	1,25	14.50	**0.001**	0.367	-	-	-	-	-	-
Parietal (left & right)	S	1,25	3.55	0.071	0.124	-	-	-	-	-	-

We resolved significant Emotion × Self-Relevance interactions by examining effects of Self-Relevance at each level of Emotion (see Table 6 for effects of Emotion at each level of Self-Relevance). Follow-up analyses were carried out in individual regions only when the mid-regions omnibus ANOVA showed a significant or marginally significant (<.10) interaction between Self-Relevance and Region. Follow-up analyses were carried out in peripheral regions (collapsed over the left and right hemisphere) only when the peripheral regions omnibus ANOVA showed a significant or marginally significant (<.10) interaction between Self-Relevance and Region (as can be seen, there were no significant effects involving Hemisphere). Effects significant at an alpha of .05 are shown in a bold font. S=Self-Relevance, R=Region, H=Hemisphere.

Table 6

Effects of Emotion at each level of Self-Relevance within the late positivity (500–800 ms) time window

	Effect	*df*	Late Positivity (500–800 ms)							
			Other				**Self**			
			F	***p***	**η^2**	**pairwise comparisons**	***F***	***p***	**η^2**	**pairwise comparisons**
Mid-regions omnibus ANOVA	E	2,50	12.05	<**.001**	0.325	U>N, P>N, U>P	2.32	0.111	0.085	
	ExR	8,200	5.38	**0.003**	0.177		7.96	<**.001**	0.242	
Prefrontal	E	2,50	2.66	0.082	0.096	U = N,P = N,U>P	4.54	**0.016**	0.154	U<N, P<N, U = P
Frontal	E	2,50	9.08	<**.001**	0.266	U>N,P = N,U>P	4.54	**0.019**	0.154	U = N, P<N, U>P
Central	E	2,50	11.91	<**.001**	0.323	U>N,P>N,U = P	2.93	0.065	0.105	U = N,P = N,U>P
Parietal	E	2,50	13.45	<**.001**	0.350	U>N,P>N,U = P	4.65	**0.015**	0.157	U>N,P = N,U>P
Occipital	E	2,50	7.96	**0.001**	0.241	U>N,P>N,U = P	5.59	**0.011**	0.183	U>N,P>N,U = P
Peripheral regions omnibus ANOVA	E	2,50	11.48	<**.001**	0.315	U>N,P = N,U>P	3.39	**0.044**	0.120	U = N,P = N,U>P
	ExR	2,50	6.32	**0.006**	0.202		10.27	<**.001**	0.291	
	ExH	2,50	0.34	0.709	0.013		1.53	0.228	0.058	
	ExRxH	2,50	6.53	**0.004**	0.207		1.33	0.273	0.051	
Frontal	E (right)	2,50	5.49	**0.007**	0.180	U>N,P = N,U>P	4.98	**0.011**	0.166	U = N, P<N, U>P
	E (left)	2,50	3.60	**0.035**	0.126	U = N,P = N,U>P	3.06	0.059	0.109	U = N, P<N, U = P
Parietal	E (right)	2,50	10.17	<**.001**	0.289	U>N,P>N,U = P	6.07	**0.004**	0.195	U>N,P = N,U>P
	E (left)	2,50	16.97	<**.001**	0.404	U>N,P>N,U = P	7.05	**0.002**	0.220	U>N,P = N,U = P

We resolved significant Emotion × Self-Relevance interactions by examining effects of Emotion at each level of Self-Relevance (see Table 5 for effects of Self-Relevance at each level of Emotion). Interactions with Region and/or Hemisphere were followed with analyses at individual regions. Effects significant at an alpha of .05 are shown in a bold font. Fisher LSD pairwise comparisons were conducted to follow up significant and marginally significant effects of Emotion. E=Emotion, R=Region, H=Hemisphere, U=Unpleasant, N=Neutral, P=Pleasant.