Event-related potential studies of the effects of mood, self-relevance, and task on the processing of emotional words in social vignettes

A thesis submitted by

Eric C. Fields

In partial fulfillment of the requirements for the degree of

Master of Science
in
Psychology

Tufts University

May 2015

Adviser: Gina Kuperberg, M.D., Ph.D.

ABSTRACT

This thesis presents research on the impact of self-relevance and emotion during the processing of social vignettes and the interaction of these effects with task and the mood state of the participant. Two-sentence social vignettes were presented either in second person (self-relevant) or third person (other-relevant). ERPs were time-locked to a critical word toward the end of the second sentence that was pleasant, neutral, or unpleasant. This paradigm was used to investigate two broad theoretical issues. In Part 1, the N400 is explored as a measure of social knowledge and social cognition, in particular the positive-bias associated with the self-concept. In Parts 2 and 3 the effects of self-relevance, task, and mood state on the late positive potential (LPC) to emotional stimuli are investigated. The general implications of these findings for the study of social cognition and a functional account of the LPC are discussed.

ACKNOWLEDGEMENTS

I first want to thank my committee members, Gina Kuperberg, Phil Holcomb, Heather Urry, and Tali Ditman, for all their help and feedback with every aspect of the research and writing that went into this thesis.

Camila Carneiro de Lima, Rohan Natraj, Erich Tusch, Sorabh Kothari, Wonja Fairbrother, and Matthew O’Connor were valuable research assistants who helped with many aspects of the studies described here, including stimuli creation and norming, creation of mood induction materials, data collection, data analysis, and literature reviews. Jeff Birk and the Tufts Emotion, Brain, & Behavior Lab helped with EMG aspects of this work. I also thank Tad Brunye and Holly Taylor for the use of their EMG data collection equipment. Finally I thank Nate Delaney-Busch, Allison Fogel, and other members of the NeuroCognition lab for their help and feedback with many aspects of the research and discussion in this thesis.

The studies in this thesis were supported by funding from NIMH (R01 MH071635) and NARSAD (with the Sidney Baer Trust) grants, as well as a Senior Faculty Research Award from Tufts University to Gina Kuperberg.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Event-related potential studies of the effects of mood, self-relevance, and task on the processing of emotional words in social vignettes

Eric C. Fields

GENERAL INTRODUCTION

Although the event-related potential technique has now been used for several decades in the investigation of language processing (Kutas & Federmeier, 2011; Swaab, Ledoux, Camblin, & Boudewyn, 2012), relatively few ERP studies have examined the role of emotional and social factors in language. Many of the studies that have looked at these factors have been single word studies, and only recently have researchers begun to examine the processing of emotional words in larger context or the influence of social cognition on the processing of language.

This work is important both for the cognitive neuroscience of language processing as and for social and affective neuroscience. With regard to psycholinguistics, much of the language we experience in our daily lives—from conversations, books, newspapers, TV, etc.—has emotional and social significance. Understanding how and at what point in the processing stream social and emotional factors influence language comprehension is important for a full understanding of language processing. From the perspective of social and affective neuroscience, language is a particularly flexible and natural way to manipulate social and emotional variables of interest, and much of what we have learned from decades of psycholinguistics studies using ERPs can be used to study longstanding questions in social psychology. As I will argue, such paradigms may allow us to answer questions that have proved quite difficult to answer with behavioral methods alone.

The research presented here investigates several distinct theoretical issues by examining the effects of social and affective context on the processing of emotional language. In particular, these studies examine the influence of mood, self-relevance, and task on the processing of emotional and neutral words in discourse context. Part 1 investigates effects of the self-positivity bias—the broad tendency to view oneself positively—on the neurocognitive mechanisms of online semantic processing by examining the N400 component. Part 2 compares the results of two experiments with identical stimuli and procedures, but different tasks, to examine the context sensitivity of the late positive component (LPC) generally seen to emotional stimuli. Part 3 then examines how each of these effects is modulated by the mood of the participant.

STUDY 1: THE N400 REVEALS ONLINE EFFECTS OF A SELF-POSITIVITY BIAS[1]

Introduction

Most of us think well of ourselves, often unrealistically so. For example, in one classic study, 94% of college instructors thought they were better than average in teaching ability and 68% placed themselves in the top 25%—obviously statistical impossibilities (Cross, 1977; for many other examples, see reviews by Alicke & Govorun, 2005; Dunning, Heath, & Suls, 2004; Taylor & Brown, 1988). This "self-positivity bias" has been widely studied and there are now numerous studies showing that we tend to evaluate ourselves more positively than others (the "better-than-average effect"; Alicke & Govorun, 2005), and that we believe good things are more likely (and bad things less likely) to happen to ourselves than to others (the "optimistic bias"; Armor & Taylor, 2002).

Positively biased self-views are argued to be a key component of healthy psychological functioning, influencing self-esteem, motivation, and determination (Taylor & Brown, 1988). Indeed, a lack of a self-positivity bias (or even a self-negativity bias) may contribute to mood and anxiety disorders (Beck, Rush, Shaw, & Emery, 1979; Goldin et al., 2013; Shestyuk & Deldin, 2010; Taylor & Brown, 1988). However, there are also negative effects of unrealistic self-assessment: for example, underestimating the likelihood of future health problems can stop us

[1] This study, with most of the same text as presented here, has been accepted for publication as Fields and Kuperberg (In press).

from taking preventative measures, and students' unrealistic views of how well they understand material can undermine effective studying (see Dunning et al., 2004 for a review).

Despite its importance and practical implications, there remains controversy about measurement of the self-positivity bias. The self-report questionnaires that are traditionally used often require subjects to explicitly compare themselves with others (either with a specific person or an "average person"), and it has been argued that self-positivity effects could be artifacts of this judgment process. For example, when rating a trait such as honesty, it may simply be easier to think of specific instances of honesty relating to ourselves than the comparison target, leading to artificially high ratings (for a comprehensive review of such "non-motivated" accounts of self-positivity effects, see Chambers & Windschitl, 2004). Perhaps even more importantly, responses on such questionnaires may not necessarily reflect our true self-views, but rather our desire to *present* ourselves well to others or even ourselves. Supporting this idea, measures that are designed to index self-presentation (such as impression management and self-deception) correlate with measures of self-positivity (Farnham, Greenwald, & Banaji, 1999).

In an effort to bypass conscious deliberation and tap into more automatic processes, implicit measures of self-esteem such as the Implicit Association Test (IAT; Greenwald & Farnham, 2000) and the Name-Letter Test (NLT; Koole & Pelham, 2003) have been developed. Self-positivity effects have been described using both these paradigms, and this has been taken as evidence for the existence of an automatic or implicit self-positivity bias that is unconfounded by controlled aspects of responding (for discussion, see Farnham et al., 1999; Fazio & Olson, 2003; Greenwald & Farnham, 2000; Olson, Fazio, & Hermann, 2007). However, concerns have also been raised about these measures. One concern is that by attempting to avoid motivated responses, implicit measures may reduce access to important aspects of the self-concept itself. For example, the IAT's emphasis on speedy responding may "deprive [participants] of the time they need to access and reflect upon autobiographical knowledge . . . that is potentially relevant to the associations they are making" (Buhrmester, Blanton, & Swann, 2011, p. 375). In a comprehensive review of the literature, Buhrmester et al. (2011) take this argument a step further: they conclude that currently existing implicit measures do not actually measure the self-concept at all and emphasize that these measures have repeatedly failed to correlate with socially important phenomena that self-esteem should predict. Finally, there is evidence that implicit measures may not be as successful as originally hoped in avoiding self-presentational confounds, possibly because they still require a behavioral response and self-enhancement tendencies can be automatized (see discussion in Buhrmester et al., 2011; see also Paulhus, 1993).

Thus, neither the explicit or implicit measures currently available have proven fully satisfactory in providing a measure with full access to the self-concept, while also avoiding self-presentational confounds. Put simply, it remains unclear whether the self-positivity bias emerges only through the process of making judgments or behavioral decisions about the self, or whether it acts as a schema that reflects a basic, implicit aspect of the way we comprehend the world. A measure showing that the self-positivity bias can directly influence the way we make sense of incoming events as they unfold in real time, in the absence of a behavioral response, would address this question and avoid many of the concerns raised in the previous paragraphs. Event-related potentials (ERPs), a direct measure of neural activity with excellent temporal resolution, are an ideal technique for this purpose (Luck, 2014).

Our focus in this study was on the N400, a negative-going, often centro-parietally distributed ERP component that peaks at around 400 ms after the onset of meaningful stimuli such as words or pictures. The N400 is thought to reflect semantic processing of a stimulus in relation to expectations set up by the preceding context and multiple types of information (including schemas) stored within memory (Kutas & Federmeier, 2011). A stimulus that is expected evokes a smaller N400 than a stimulus that is unexpected because the context preactivates (or leads people to predict) upcoming relevant features (Kuperberg, 2013; Lau, Holcomb, & Kuperberg, 2013). For example, in a sentence like "The children went outside to play/look", "play" elicits a smaller N400 than "look" (example from Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007). Although both these sentences are fully plausible, greater expectations for "play" (as can be shown via the cloze procedure) lead to an attenuated N400. If positively-biased aspects of the self-concept are available online, then people should expect more positive outcomes in sentences about themselves than about others, predicting a smaller N400 to positive words in self-relevant than other-relevant contexts. Testing this hypothesis was the goal of the present research.

A few ERP studies have asked how self-relevance influences the processing of incoming emotional information (Fields & Kuperberg, 2012; Herbert, Herbert, Ethofer, & Pauli, 2011; Herbert, Pauli, & Herbert, 2011; Li & Han, 2010; Shestyuk & Deldin, 2010). However, these studies primarily focused on how self-relevance influences a later allocation of attentional and/or processing resources to emotional stimuli, as indexed by a fairly late ERP component,[2] a positivity that generally peaks after 500ms (Citron, 2012; Hajcak, MacNamara, & Olvet, 2010).[3] In addition, in many of these studies the late positivity began before 500 ms, overlapping spatially and temporally with the N400 and therefore making it difficult to discern independent effects within the N400 time window.

---

[2] One previous study has reported what the authors suggest may be a self-positivity bias on the N400 (Watson, Dritschel, Obonsawin, & Jentzsch, 2007). However, because the N400 is a negative-going component with a fairly stable latency around 400 ms (Kutas & Federmeier, 2011) and the component in question was a positive-going component peaking after 500 ms, we think it is more likely that Watson et al.'s results reflect a modulation of the late positivity.

[3] It is not clear how a self-positivity bias would influence this late positive component. On the one hand, one might predict a larger late positivity to stimuli that are consistent with a self-positivity bias because they are preferred; on the other hand, one might argue that the positivity should be larger to incoming stimuli that are inconsistent with a self-positivity bias because they are unexpected (and may therefore require more processing resources to integrate).

The present study

In the present study, we presented two-sentence social vignettes with a neutral, pleasant, or unpleasant critical word. To manipulate self-relevance we exploited the fact that grammatical person directly influences the perspective of the mental model developed by comprehenders. Whereas second person leads to the engagement of a self-perspective, third person leads to the adoption of an "other" perspective (Brunyé, Ditman, Mahoney, Augustyn, & Taylor, 2009). Thus our study was a 3 (Emotion: neutral, pleasant, unpleasant) x 2 (Self-Relevance: self, other) design, e.g.: *A man knocks on Sandra's/your hotel room door. She/You see(s) that he has a* <u>*tray/gift/gun*</u> *in his hand.*

We recently carried out a study with these same stimuli using a different, more active task (Fields & Kuperberg, 2012), but in that study were unable to examine modulation on the N400 because the late positive component began within the N400 time window (~400 ms). Here we used a comprehension task, which did not draw attention to the emotional aspects of stimuli. Our lab (Holt, Lynn, & Kuperberg, 2009) and others (e.g., Fischler & Bradley, 2006) have shown that such comprehension tasks (compared to more explicit tasks such as emotional categorization) can reduce and delay the late positivity evoked by emotional words enough that independent effects on the earlier N400 can be observed.

If positively-valenced aspects of the self-concept are available online and influence our expectations about upcoming information, this should produce an interaction between emotion and self-relevance on the N400. Specifically, we hypothesized that participants' implicit expectations of positive outcomes in sentences about themselves would lead to facilitated processing of pleasant words in self-relevant than other-relevant contexts reflected by an attenuated N400. In contrast, we predicted no N400 effects of self-relevance on the neutral words or unpleasant words. This is because the amplitude of the N400 is generally *facilitated* by words whose semantic features *match* prior expectations; it is not a direct measure of incongruence or implausibility per se (Kutas & Federmeier, 2011; Paczynski & Kuperberg, 2012). Thus, an effect of self-relevance on unpleasant stimuli would only be predicted if the other-relevant contexts led to expectations for unpleasant outcomes. In fact, all else being equal, we tend to evaluate other people positively (Sears, 1983), and the self-positivity bias is thought to reflect even more positive views of ourselves than of others (Alicke, Klotz, Breitenbecher, Yurak, & Vredenburg, 1995).

Methods

Participants

Twenty-eight Tufts University students originally participated in the ERP study. Four were excluded from analysis due to excessive artifact in the EEG, leaving 24 participants (17 females) in the final analysis. Self-reported race and ethnicity was non-Hispanic White (n = 21), mixed Asian/White (n = 1), Hispanic (race not otherwise indicated, n = 1), and unreported (n = 1). All participants were right-handed native English speakers (age 18-23, $M = 19.3$, $SD = 1.6$) who reported no history of psychiatric or neurological disorders and were not currently taking psychoactive medications. We also administered the Beck Depression Inventory (BDI-II) and the State-Trait Anxiety Inventory (STAI) in order to rule out participants with symptoms of mood and anxiety disorders (none scored outside the lower range of each scale, and so none were excluded for this reason). Participants were paid for their participation and provided informed consent in accordance with the procedures of the Institutional Review Board of Tufts University.

Stimuli

Stimuli were the same as those used in Fields and Kuperberg (2012). 222 sets of two-sentence scenarios were developed with Emotion (pleasant, neutral, and unpleasant) and Self-Relevance (self and other) conditions crossed in a 3 x 2 factorial design. The scenarios were written to include a broad range of situations that would be familiar and/or plausible to our subject population (e.g., many were about school or professional jobs). The first sentence introduced a situation involving one or more people, only one of which was specifically named (evenly split between male and female names), and which was always neutral or ambiguous in valence. The second sentence continued the scenario and was the same across all emotion conditions except for the critical word, which was pleasant, neutral, or unpleasant. To create the self condition, the named protagonist was changed to “you”. See Table 1 for examples.

Other			**Self**		
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.

Table 1. *Examples of two-sentence scenarios in each of the six conditions*. The critical word is underlined (but did not appear underlined in the actual stimulus lists). Additional examples can be found in the supplementary materials for Fields and Kuperberg (In press).

A series of norming studies, summarized below, were carried out via the internet, with inclusion criteria for participants that were the same as for the ERP study. All means and standard deviations are reported in Table 2.

	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)

Table 2. *Stimuli ratings and characteristics*. 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.

Length, concreteness, cloze, and constraint

Stimuli were matched across conditions for critical word length (number of letters) and HAL word frequency (Balota et al., 2007; Lund & Burgess, 1996) [*F*s < 2.9, *p*s > .05]. Critical words differed in concreteness across conditions [$F(2, 660) = 7.13$, $p = .001$], with neutral critical words being rated as slightly, but significantly, more concrete than pleasant or unpleasant critical words, which did not differ from one another. In a cloze study, scenarios were cut off before the critical word and 29 participants per scenario gave the word they thought most likely to come next. Stimuli were matched across conditions for cloze probability (percentage of responses matching the critical word) and constraint (frequency of the modal response) [*p*s > .5].

Valence and arousal

Valence and arousal ratings were gathered for both the critical words in isolation and the scenarios up until the critical word. Valence ratings were as expected for both critical words and scenarios: the pleasant condition was rated as more positive than the neutral condition, which was rated as more positive than the unpleasant condition [*F*s > 1000, *p*s < .001]. In the scenarios, self-relevance amplified these differences, making pleasant scenarios more positive and unpleasant scenarios more negative [Emotion x Self-Relevance interaction: $F(2, 442) = 26.50$, $p < .001$].

As expected, there was a main effect of arousal for the both the critical word and scenario ratings [*F*s > 70, *p*s < .001], with pleasant and unpleasant stimuli being rated as more arousing than neutral stimuli. For the critical word ratings pleasant were rated as more arousing, but for the scenario ratings unpleasant were rated as more arousing. For the scenario ratings, 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 self-relevant scenarios being rated as more arousing than other-relevant scenarios.

Procedure

Stimulus presentation

All stimuli were counterbalanced such that each of the 222 scenarios appeared in a different condition in each of six lists (thus appearing in all conditions across lists). Participants were randomly assigned to a list (with the provision that there were an equal number of participants for each list). Trials were presented in random order, both within and across lists.

Trials were self-paced: they each began with the word “READY” until the participant pressed a button to begin the trial. In each trial, the first sentence then appeared in full until the participant pressed a button to advance to the second sentence. 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 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. Participants were asked to refrain from blinking during the second sentence of each scenario (which contained the critical word), but no restrictions were given for other parts of the trial.

Task

To ensure that participants were attending to the scenarios and comprehending them for meaning, forty scenarios (randomly interspersed in each list) were followed by a yes-or-no comprehension question that stayed on the screen until the participant gave his/her answer via button press. Each question and its correct answer was the same across all conditions of a particular scenario except where the self-relevance manipulation required changes to names/pronouns and verb conjugations and no question directly referred to the valenced aspects of the scenarios. For example, the scenario "Casper/You is/are new on campus. Everyone thinks he/you is/are quite idiosyncratic/clever/dumb compared to most people." was followed by the question "Did Casper/you go to this school last year?" with the correct answer being "no".

ERP acquisition and processing

The EEG response was recorded from 29 tin electrodes in an elastic cap (Electro-Cap International, Inc., Eaton, OH; see Figure 1). Additional electrodes were placed below the left eye and at the canthus of the right eye to monitor vertical and horizontal eye movements. The impedance was kept below 2.5 kΩ for mastoid electrodes, 10 kΩ for EOG electrodes, and 5 kΩ for all other electrodes. The EEG signal was amplified by an Isolated Biometric Amplifier (SA Instrumentation Co., San Diego, California), band pass filtered online at 0.01-40 Hz, and continuously sampled at 200Hz. ERPs were referenced online to the left mastoid.

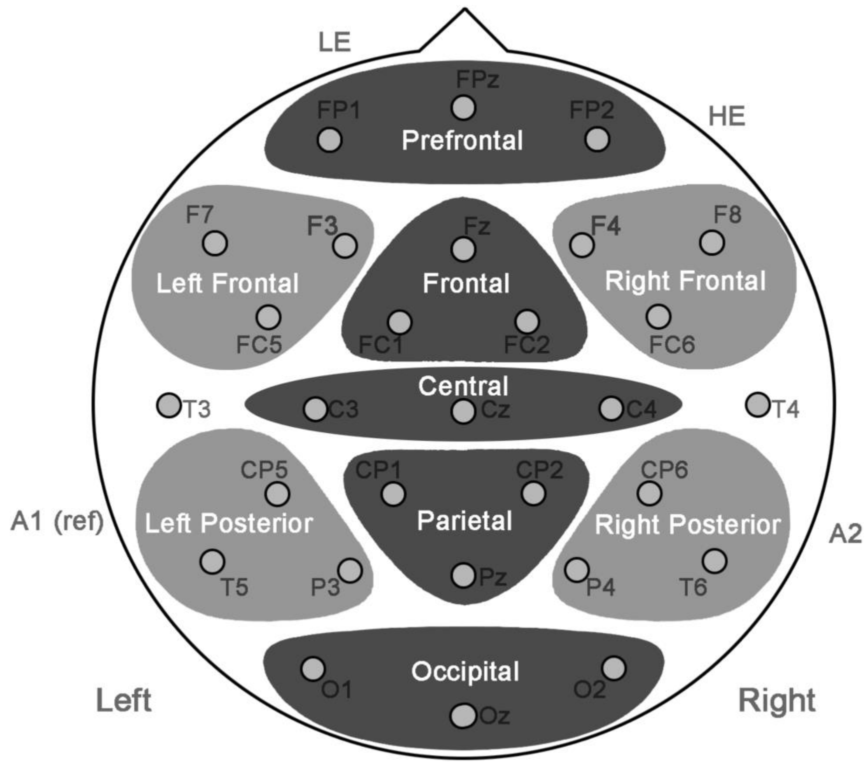

Figure 1: *Electrode montage with regions used for analysis*. For the purposes of statistical analyses, the scalp was divided into three-electrode regions. Regions in dark gray were part of the mid-regions omnibus ANOVA and regions in light gray were part of the peripheral regions omnibus ANOVA.

The EEG was collected and processed using in-house software (available at: http://neurocoglaboratory.org/ERPSystem.htm). Segments from 100 ms before onset to 1100 ms after onset of each event were obtained. The 100 ms period immediately preceding stimulus onset was used as the baseline for all amplitude measurements. Trials with muscular and ocular artifact were identified and discarded using three algorithms: the first returns the number of time points within a given amplitude range of the minimum or maximum point of an epoch and is used to monitor for amplifier blocking or signal loss (i.e., a flat line); the second returns the difference between the maximum and minimum point of an epoch at the vertical and horizontal eye channels (independently) to monitor for eye movement and other large deflections unlikely to be neural activity; the third returns the difference of the mean difference and maximum difference between the electrode under the left eye and the electrode on the forehead above this eye and is used to identify blinks (which are characterized by opposite polarity shifts in these two channels). Appropriate thresholds for each of these algorithms were determined for each subject via visual inspection of the raw data, but were the same across all events within each subject (i.e., they were the same across all experimental conditions due to the within-subjects design).

ERP statistical analysis

The scalp was subdivided into three-electrode regions along its anterior–posterior distribution, at both mid-line and peripheral sites. Two omnibus ANOVAs, one covering mid-regions (dark gray in Figure 1) and another covering peripheral regions (light gray in Figure 1), were conducted using SPSS 21 (IBM) with Emotion, Self-Relevance, Region, and Hemisphere (peripheral regions only) as within-subjects factors. For all tests of significance the Greenhouse and Geisser (1959) estimation of ε was used to correct the degrees of freedom (the original degrees of freedom are reported in the text along with the corrected p values). A significance level of $\alpha = .05$ was used for all analyses.

Results

Participants were quite accurate in answering the comprehension questions, indicating that they were engaged in reading and comprehending the scenarios. The average accuracy was 94% and no participant was below 85%, except for one participant who expressed confusion during the experiment about which buttons corresponded to yes and no (as there were no other problems with this participant's data, it was included in subsequent ERP analyses).

After examination of the raw EEG, 7.5% of critical word trials were rejected for artifact with at least 28 trials averaged for each condition for every subject, and the rejection rate did not differ across conditions [$Fs < 1$, $ps > .4$]. Averaged ERPs were calculated from trials remaining after artifact rejection.

	Effect	*df*	Neutral *F*	Neutral *p*	Neutral η²	Pleasant *F*	Pleasant *p*	Pleasant η²	Unpleasant *F*	Unpleasant *p*	Unpleasant η²
Mid-regions omnibus ANOVA	S	1,23	0.35	0.562	0.015	5.51	**0.028**	0.193	0.02	0.893	0.001
	SxR	4, 92	0.26	0.755	0.011	3.26	**0.040**	0.124	0.68	0.526	0.029
Prefrontal	S	1,23	--	--	--	3.76	0.065	0.141	--	--	--
Frontal	S	1,23	--	--	--	7.66	**0.011**	0.250	--	--	--
Central	S	1,23	--	--	--	5.43	**0.029**	0.191	--	--	--
Parietal	S	1,23	--	--	--	4.39	**0.047**	0.160	--	--	--
Occipital	S	1,23	--	--	--	1.45	0.241	0.059	--	--	--
Peripheral regions omnibus ANOVA	S	1,23	0.79	0.383	0.033	4.45	**0.046**	0.162	0.03	0.872	0.001
	SxR	1,23	0.45	0.510	0.019	0.23	0.634	0.010	2.56	0.124	0.100
	SxH	1,23	0.11	0.742	0.005	0.57	0.457	0.024	0.02	0.877	0.001
	SxRxH	1,23	0.05	0.828	0.002	0.65	0.428	0.027	0.00	0.970	0.000
Frontal	S	1,23	--	--	--	--	--	--	--	--	--
Parietal	S	1,23	--	--	--	--	--	--	--	--	--

Table 3. *Effects of Self-Relevance at each level of Emotion within the N400 (300-500 ms) time window*. We resolved the significant Emotion x Self-Relevance interaction by examining effects of Self-Relevance at each level of Emotion. Follow-up analyses were carried out in individual regions only when the omnibus ANOVA showed a significant or marginally significant (<.10) interaction between Self-Relevance and Region. Effects significant at an alpha of .05 are shaded gray and shown in a bold font. S = Self-Relevance, R = Region, H = Hemisphere.

The N400 was defined a priori as the mean amplitude between 300 and 500 ms.[4] Analyses of this time-window revealed significant interactions between Emotion and Self-Relevance in both the mid-regions [$F(2, 46) = 4.50$, $p = .018$, $\eta^2 = .164$] and peripheral regions [$F(2, 46) = 3.87$, $p = .029$, $\eta^2 = .144$] ANOVAs. In line with our a priori hypothesis, we broke down this interaction by examining the effect of Self-Relevance at each level of Emotion. Results are reported in Table 3, Figure 2, and Figure 3. There were no significant differences between the self and other contexts on the N400 evoked by neutral or unpleasant critical words. However, pleasant critical words evoked a smaller negativity in the self-relevant contexts than the other-relevant contexts.[5] This effect was significant in the mid-regions and marginally significant in the peripheral regions ANOVA. In the mid-regions ANOVA, there was a further

[4] Analyses of other time windows are available in the supplementary materials for Fields and Kuperberg (In press).

[5] This effect cannot be attributed to an overlapping late positivity to the self-relevant (versus other-relevant) words, as it was not significant either in the full late positivity time window (500 – 800 ms) or in the 500 – 600 ms, 600 – 700 ms, or 700 – 800 ms time windows [all Fs < 4.3, ps > .05]. In addition, the self-other contrast for pleasant words showed a different (more posterior) scalp distribution in these later time windows than in the 300-500 ms time window.

interaction with Region, and follow-ups showed that the effect of self-relevance on pleasant words was significant in frontal, central, and parietal regions, was marginally significant in the prefrontal region, but was not significant in the occipital region.

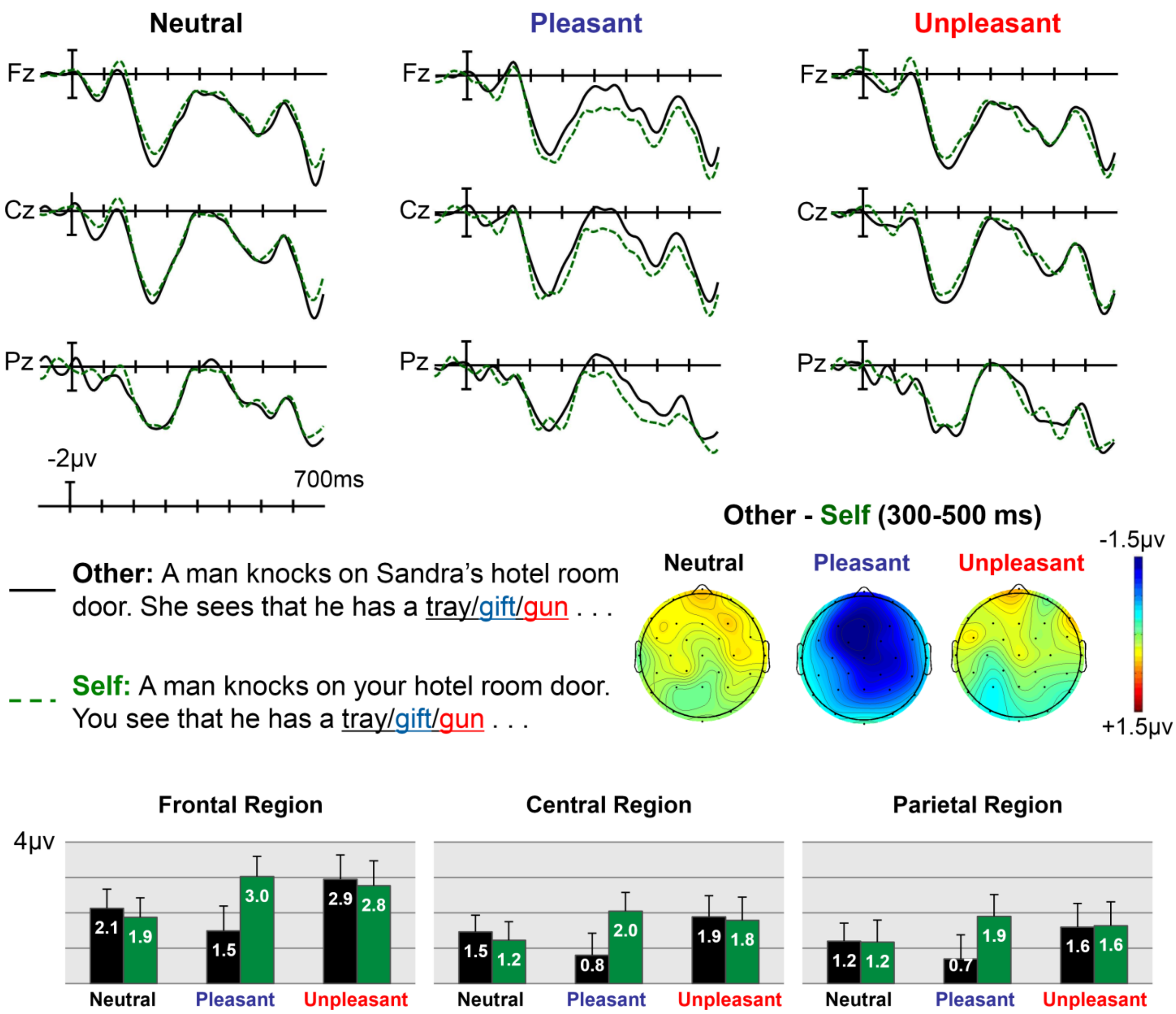

Figure 2: *Effects of Self-Relevance at each level of Emotion*. Waveforms are time-locked to the critical word (underlined). They are low-pass filtered with a half-amplitude cutoff at 15 Hz for viewing purposes. Voltage maps show mean voltage across the N400 (300-500 ms) time window. Tables show mean voltage for the midline Frontal, Central, and Parietal regions in the N400 (300-500 ms) time window and error bars represent the standard error of the mean.

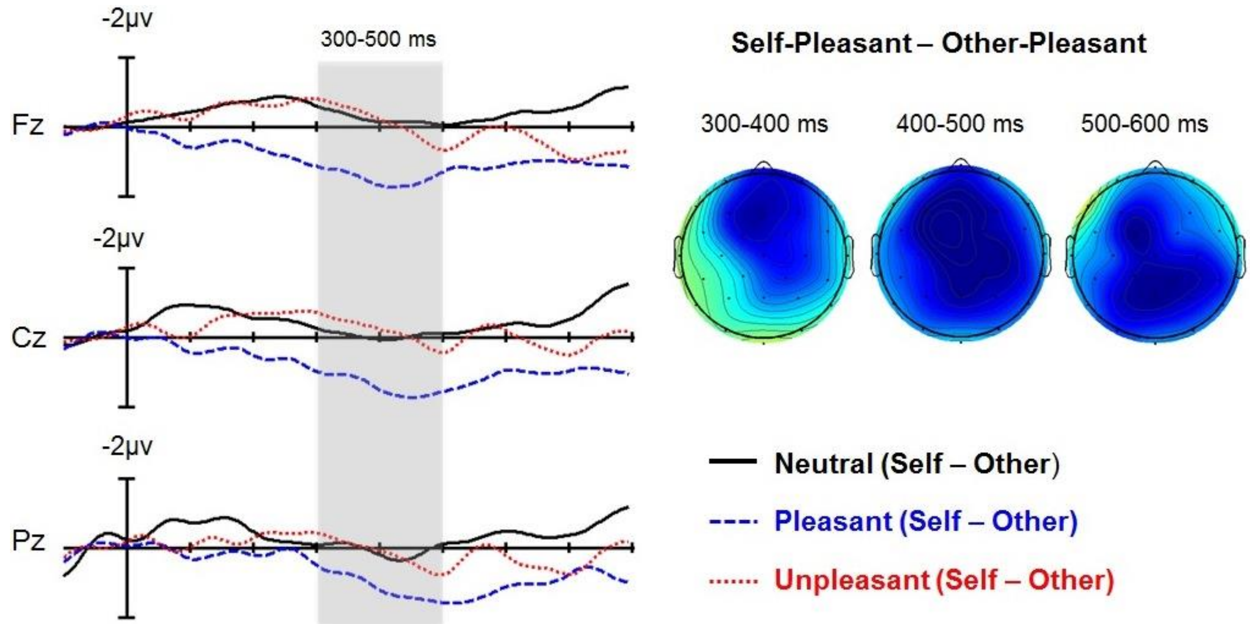

Figure 3. *Self – other difference waves*. Waveforms show the effect of Self-Relevance (self – other) for each Emotion condition. They are low-pass filtered with a half-amplitude cutoff at 5 Hz for viewing purposes.

Discussion

We used ERPs to determine whether positively biased aspects of the self-concept are available online and whether they influence the processing of incoming stimuli as they unfold in real time. We found that pleasant words elicited a reduced negativity between 300-500ms in self-relevant contexts compared to other-relevant contexts.

This effect cannot be explained by any differences in the critical words themselves, as these were identical across the self-relevant and other-relevant conditions within each Emotion condition. Cloze probability was also the same across the six conditions and the contexts were not highly constraining. It is therefore unlikely that the effect seen here was driven by a pre-activation (or prediction) of the *specific* words that were presented. Rather, we suggest that that a self-relevant context activated subjects' (generally positive) self-schema, along with its associated positive features. This made it easier to retrieve the positively valenced properties of the pleasant critical words, reflected by activity within the N400 time window (cf. Federmeier & Kutas, 1999; Paczynski & Kuperberg, 2012; for discussion, see Kuperberg, 2013).

As noted in the Introduction, some theorists have argued that the better-than-average effect and optimistic bias could be artifacts of certain types of judgments, including the process of explicitly comparing oneself with others (Chambers & Windschitl, 2004). Others have proposed that self-positivity effects could be primarily a function of impression management—that is, attempts to present oneself in a good light (Alicke & Govorun, 2005; Farnham et al., 1999; Paulhus, 1993, 2002). Under either account, the self-positivity bias should only emerge when making a judgment or behavioral response with regard to the self, as is done in traditional explicit measures and implicit measures (although designed to avoid impression management, implicit measures may be sensitive to automated self-enhancement tendencies, see Buhrmester et al., 2011; Paulhus, 1993). The current findings show that this is not the case: in our paradigm, participants were not asked to make any kind of self-related judgment and nothing in our instructions indicated that we were assessing self-views. Nonetheless, we saw evidence of a self-positivity bias within a few hundred milliseconds of processing incoming words.

Our paradigm also avoids another potential drawback of implicit measures of self-esteem, which, by attempting to bypass conscious processing altogether, may fail to index important aspects of the self-concept (see Buhrmester et al., 2011 for discussion). Because self-relevance was introduced in the first sentence of the context in our stimuli, participants had sufficient time to access and activate scenario-relevant self-knowledge. Thus we would expect ERP effects in our paradigm to be sensitive to any relevant stored information about the self.

With these characteristics of the paradigm in mind, there are two important implications of our findings. First, our results suggest that the self-positivity bias quickly influences how we make sense of incoming information at early stages of comprehending meaning. This provides evidence that a positively biased self-concept is a basic, relatively automatic aspect of the way we view the world. Thus, whatever the role of impression management in unrealistic self-positivity, it appears the self-positivity bias cannot be fully attributed to socially desirable responding, whether conscious or automated (Paulhus, 1993, 2002). Second, if our interpretation is correct, the ERPs in this paradigm covertly measure whatever expectations subjects naturally generate about themselves as they comprehend the scenarios, and these expectations are not necessarily explicitly, intentional, or even fully consciously generated by participants. Our paradigm may therefore provide a more accurate measure of what subjects fundamentally believe and feel about themselves than traditional explicit or implicit measures.

Open questions

Of note, the scalp distribution of the effect within the N400 time window was fairly widespread, but it had a more anterior focus than the more central-posterior (and sometimes right-lateralized) N400 effect that is typically associated with lexically expected versus unexpected words in sentences. Some researchers have argued that emotional words elicit a more frontal N400 than non-emotional words (Egidi & Nusbaum, 2012; see also Delaney-Busch & Kuperberg, 2013; Kanske & Kotz, 2007; Pratt & Kelly, 2008). The N400 is likely generated by multiple underlying sources (Federmeier & Laszlo, 2009). It is therefore possible that words that match (versus mismatch) emotional expectations may elicit additional contributing sources, or that such words fail to generate activity in some of the sources that are active in response to words that match on other types of semantic features. Indeed, other factors, including imageability and concreteness, are also known to shift the N400 anteriorly and these effects have been explained in similar ways (Holcomb, Kounios, Anderson, & West, 1999; Lee & Federmeier, 2008; Swaab, Baynes, & Knight, 2002; see also Sitnikova, Kuperberg, & Holcomb, 2003; West & Holcomb, 2002).[6] However, it is important to note that N400 effects with a more

[6] Another possibility is that emotion (and self-relevance) may make readers more likely to form mental images of the scenarios they are reading, leading to a more frontal distribution. However, this explanation remains speculative.

canonical posterior distribution have also been seen to emotional words in discourse contexts (e.g., Holt et al., 2009; Leon, Diaz, de Vega, & Hernandez, 2010). Future research will be needed to more fully understand this pattern.

More generally, it will be important for future work to test the properties of our effect as a measure of the self-concept (and social schemas more generally, see below). For example, how does it correlate with common explicit and implicit measures (and does this correlation increase under situations where participants are expected to be more honest)? Regardless of its precise interpretation, however, for all the reasons discussed above, the pattern of results suggest the observed effect is related to emotionally valenced aspects of the self-concept. The broader implications of this finding are returned to in the General Discussion.

PART 2: THE INTERACTION OF TASK, SELF-RELEVANCE, AND EMOTION ON THE LATE POSITIVE COMPONENT (LPC) OF THE ERP

In Part 1 we examined how ERPs, and the N400 component in particular, can be used to examine social schemas, in particular the positivity-bias in the self-schema. However, the paradigm used in this study is also quite relevant to the ERP literature on the processing of emotional words, which has examined different components and been concerned with different theoretical questions than those discussed above (see Citron, 2012). In Part 2, the interaction of emotion and self-relevance on the late positive component (LPC) is compared between the study presented in Part 1 and a previous study using the same stimuli with a different task.

Introduction

Emotions have been described as “relevance detectors” (Frijda, 1986): if something in the environment is detected as being emotionally valenced, this indicates that it requires attention and further evaluation. However, what is salient and deemed relevant is not solely a function of bottom-up stimulus factors. Instead, it is determined by a complex interaction of the properties of a particular emotional stimulus, its local and global context (including its self-relevance), and its relevance for current goals. In the present work we used event-related potentials (ERPs) to examine the interactions between emotion, the self-relevance of the context, and task on processing words in socially relevant contexts.

It is well established that emotional stimuli capture attention (Compton, 2003). For example, faces with emotional expressions “pop out” and are more easily recognized in a crowd (Hansen & Hansen, 1988; Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001), emotional stimuli are looked at more often and for longer than neutral stimuli (Calvo & Lang, 2004; even when participants are instructed not to look at the emotional stimuli: Nummenmaa, Hyona, & Calvo, 2006), and the “attentional blink” phenomenon (reduced identification of a target stimulus that is immediately preceded by another stimulus) can be reduced if the preceding stimulus is emotionally valenced (Anderson, 2005). Such effects have often been investigated with pictures, but similar attentional effects have been reported on emotional words using paradigms such as the emotional Stroop task (MacKay, 2004; McKenna, 1995; Pratto, 1991) and spatial orienting tasks (Fox, Russo, Bowles, & Dutton, 2001; Stormark, Nordby, & Hugdahl, 1995). Moreover, these effects can lead to deeper processing and encoding as indexed by better memory retrieval for emotional than neutral stimuli (Hamann, 2001; Laney, Campbell, Heuer, & Reisberg, 2004).

At a neural level, the capture of attention and enhanced processing to emotional stimuli can be indexed by components of the event-related potential (ERP; for a review, see Hajcak, Weinberg, MacNamara, & Foti, 2012). In particular, emotional stimuli have most consistently modulated a parietally-distributed late positive component (LPC) that begins at around 400-500 ms from stimulus onset and that extends for several hundred milliseconds.[7] This LPC is generally larger to emotional than neutral stimuli and it is seen to both pictures (Hajcak et al., 2010; Olofsson, Nordin, Sequeira, & Polich, 2008) and words (Citron, 2012; Kissler, Assadollahi, & Herbert, 2006).

The exact neurocognitive function represented by the emotion-sensitive LPC is not clear. However, it has often been viewed as being related to the P300, an extensively studied ERP component that is larger to unexpected or surprising stimuli as well as to task-relevant stimuli (Donchin & Coles, 1988; Polich, 2012). The P300 is associated with the capture and allocation of attention, increased processing, and stimulus encoding, and it is strongly dependent on environmental context and task demands: for example, it is most likely to be evoked when the detection of an unexpected stimulus is relevant to performing a given task (although this is neither sufficient nor necessary for a P300 to be produced).

Unlike “target” stimuli in traditional oddball paradigms (those that require a response), an emotional stimulus does not need to be either unexpected in its wider experimental context or task-relevant to evoke an LPC. In this sense, emotional stimuli have been argued to be “natural targets” (Hajcak et al., 2010): that is, they capture attention as a result of their *inherent* motivational significance rather than task-defined motivational significance. However, like the P300, the LPC evoked by emotional stimuli is significantly influenced by both task requirements and experimental context. For example, tasks that draw attention to emotional features lead to larger LPC effects (e.g., Fischler & Bradley, 2006; Holt et al., 2009; Naumann, Maier, Diedrich, Becker, & Bartussek, 1997; Schupp et al., 2007). Task can also influence the sensitivity of the

---

[7] Some research suggests there may be multiple related emotion-sensitive late positivities (Delplanque, Silvert, Hot, Rigoulot, & Sequeira, 2006; Foti, Hajcak, & Dien, 2009; Hajcak et al., 2012; MacNamara, Foti, & Hajcak, 2009). In practice this is often difficult to distinguish and most widely-distributed later components of the ERP have multiple underlying neural sources (Luck, 2014). Here we use the term “late positive component” as a general term for an emotion-sensitive positivities peaking after approximately 400 ms. We assume that any such components are functionally related, but we do not take a stance on the neurobiological unity of these components.

LPC to different dimensions of emotional stimuli: in a well-controlled set of words, in which valence and arousal were orthogonally manipulated, our lab found an effect of arousal (but no effects of valence) when a semantic categorization task was used, but found an effect of valence (but not of arousal) when a valence categorization task was used (Delaney-Busch, Wilkie, Kim, Yacoubian, & Kuperberg, 2012).

This sensitivity of the emotional LPC to context and task suggests that we allocate processing to emotional stimuli in a highly dynamic fashion that is calibrated to the demands of a given situation. Although to date most of the evidence supporting this idea comes from studies of sequences of single emotional pictures and words, it has important implications for understanding how we process emotional situations in different social contexts, where what is motivationally relevant will depend on contextual factors such as self-relevance, the wider environment, and the demands of the particular situation. For example, the word “gun” may have negative connotations for many people in isolation, but it will have positive connotations for others. However, almost anyone will find a gun being pointed at herself to be a negative experience, and this will likely feel significantly different than a gun being pointed at a stranger (see the example stimulus below).

In a recent study using the same stimuli described in Part 1, we examined how contextual self-relevance influenced the LPC evoked by emotional and neutral words in short, socially relevant vignettes (Fields & Kuperberg, 2012). Participants read scenarios that ended with neutral, pleasant, or unpleasant information, for example: “A man knocks on Sandra's hotel room door. She sees that he has a <u>gift/tray/gun</u> in his hand.” In half of these scenarios, the situations were made self-relevant by changing them to second-person (see Brunyé et al., 2009), for example: “A man knocks on your hotel room door. You see that he has a <u>gift/tray/gun</u> in his hand.” To actively engage participants in comprehending these scenarios, they were asked to verbally produce a third sentence that would sensibly continue the scenario (e.g., for the self-relevant unpleasant version of the above example a participant might say, "I was very scared"). As expected, ERPs recorded to the critical word (underlined above) showed a main effect of emotion with the pleasant and unpleasant words evoking a larger LPC than the neutral words. However, the interaction of emotion and self-relevance showed an unexpected but interesting result: the LPC to *neutral* words was larger in the self-relevant condition than in the other-relevant condition, but self-relevance had no effect for pleasant or unpleasant words.

We argued that, with the production task, the interaction between emotion and self-relevance was driven by participants' attempts to assess the valence of the neutral words. Neutral stimuli are often more ambiguous in valence than pleasant or unpleasant stimuli (consider, for example, the word "surprise"). It has been previously argued that ambiguous stimuli can demand more attention than emotional stimuli because any ambiguous aspects of a situation need to be understood before it is clear where attention and resources should be directed (Hirsh & Inzlicht, 2008; Sokolov, Spinks, Näätänen, & Lyytinen, 2002). This idea has been supported by previous ERP studies showing that ambiguous stimuli can evoke a larger feedback-related negativity (Gu, Ge, Jiang, & Luo, 2010; Hirsh & Inzlicht, 2008) and a larger LPC (Tritt, Peterson, & Inzlicht, 2012) than emotional stimuli. More specifically, we suggested that the effect of self-relevance in the LPC time window produced by neutral words may have reflected the demands of building a representation of an event that allowed for a congruent continuation in the face of this ambiguity. As a concrete example, consider the scenario "After dinner, you are involved in a discussion. Many of your remarks surprise/impress/hurt people." Here it is relatively clear what is happening in the pleasant and unpleasant conditions. However, in order to continue the scenario plausibly in the neutral condition, an ambiguity probably needs to be resolved: were people surprised because your comments were unexpectedly good, bad, or just unusual? Importantly, resolving this question likely required additional consideration in the self-relevant condition because of participants' desire to produce a verbal continuation consistent with their self-concept (Swann, 2011). In the other-relevant condition (involving a perfect stranger), on the other hand, there was no motivation to go beyond the easiest or most salient interpretation of the valence of the situation.

If this interpretation is correct, the pattern we saw on the LPC should be closely tied to the task requirement of participants to verbally continue each scenario. We should therefore see a different pattern in a task in which participants are simply asked to read the scenarios. In this situation, there would be no particular demand on participants to interpret or disambiguate the valence of neutral critical words, and we should therefore see a different allocation of processing resources. The most straightforward hypothesis is that attention and processing resources would simply be directed to the most inherently motivationally relevant stimuli: in this case the self-relevant emotional words. We would therefore expect that self-relevance would amplify the classic effect of emotion on the LPC. Such a finding would be in line with previous studies examining the effects of self-relevance in two-word noun phrases with no overt task, which reported effects of emotion in the self-relevant condition, but not the other-relevant conditions (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011; see discussion later in this manuscript).

To test this hypothesis, we used the same stimuli as Fields and Kuperberg (2012) in a different group of participants. However, instead of asking participants to produce a verbal continuation for each scenario, they simply read for comprehension and answered intermittent questions that did not refer to valenced aspects of the scenarios (cf. Holt et al., 2009, Exp. 2). In order to directly compare the pattern of findings on the late positivity under these task demands with those seen in our previous study with different task demands (Fields & Kuperberg, 2012), we combined the results of the two studies in a model in which task was analyzed as a between-subjects factor.

Methods

Participants

Participants were recruited from postings on a university community website (tuftslife.com) in 2010 (production task) and 2011 (comprehension task). Twenty-nine people originally participated in the production task experiment; three participants were excluded from analysis due to excessive artifact in the EEG, leaving 26 participants in the final analysis (15 females) between the ages of 18 and 29 (M = 20.7, SD = 2.30). The comprehension task experiment was the same study as described in Part 1. Twenty-eight people originally participated; four participants were excluded from analysis due to excessive artifact in the EEG, leaving 24 participants (17 females) between the ages of 18 and 23 (M = 19.3, SD = 1.6). No individual participated in both experiments. All participants were right-handed native English speakers (having learned no other language before age 5) 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.

Stimuli and procedures

The comprehension task study was the same experiment as described in Part 1. Thus, all stimuli and procedures where the same as described above. For the production task all stimuli and procedures were the same except that instead of 40 comprehension questions there were only 11 and there was also an additional task for every scenario. Participants were instructed to verbally produce a single short sentence that followed naturally from the sentences they had just read (i.e., that continued the story). Participants were instructed to continue second-person (self-relevant) scenarios as if they were about themselves (i.e., in first person). 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.

Results

Artifact rejection procedures were the same for both studies and were as described above. Overall, 7.7% and 7.5% of trials were rejected for artifact for the production and comprehension tasks respectively. The rejection rate did not differ across the Self-Relevance, Emotion, or Task conditions and there were no interactions between these factors [Fs < 2.5, ps > .09].

The LPC was quantified by calculating the mean amplitude from 500 to 800 ms relative to a 100 ms prestimulus baseline.[8] The Emotion x Self-Relevance x Task interaction was significant in both the mid-regions omnibus [$F(2, 96) = 7.49$, $p = .001$, $\eta^2 = .135$] and the peripheral regions omnibus [$F(2, 96) = 5.90$, $p = .004$, η2 = .109]. The Emotion x Self-Relevance x Task x Region interaction was marginally significant in the mid-regions omnibus [$F(8, 384) = 2.32$, $p = .063$, η2 = .046] and not significant in the peripheral regions omnibus [$F(2, 96) = 0.72$, $p = .489$, η2 = .015]. Neither of these effects was further modulated by hemisphere in the peripheral regions ANOVA [Fs < 1.6, ps > .20]. We followed-up these interactions by examining the Emotion x Self-Relevance interaction and Emotion x Self-Relevance x Region interaction in each task group separately.

Production task

As previously reported (Fields & Kuperberg, 2012), the Emotion x Self-Relevance interaction was significant in the mid-regions omnibus ANOVA [$F(2, 50) = 4.02$, $p = .026$, $\eta^2 = .138$] and marginally significant in the peripheral regions omnibus [$F(2, 50) = 2.70$, $p = .078$, η^2

[8] Analyses of other time windows are available in Fields and Kuperberg (2012) for the production task. For the comprehension task analysis of the N400 time window is presented in Part 1 and analysis of other time windows is available in the supplementary materials for Fields and Kuperberg (In press).

= .098]. Both the mid-regions and peripheral regions omnibus ANOVAs showed significant effects of Emotion and/or significant Emotion x Region interactions in both the self-relevant and other-relevant scenarios, but these effects were larger in the other-relevant scenarios, see Figure 4.

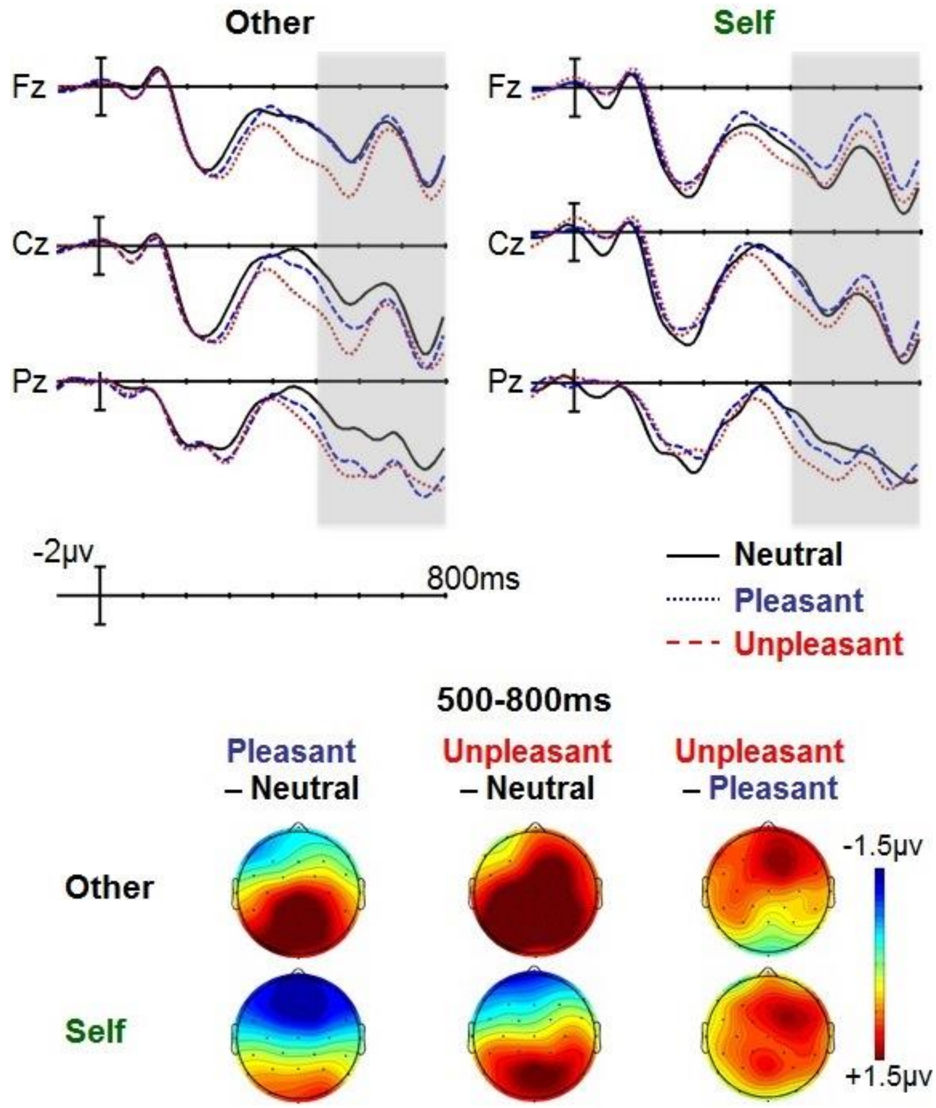

Figure 4. *Production task: Effects of emotion at each level of self-relevance*. Effects of emotion were seen in both other-relevant and self-relevant scenarios, but were smaller to self-relevant stimuli. This difference was driven entirely by a larger positivity to neutral words in the self-relevant versus other-relevant condition. The 500-800 ms time window is shaded. The waveforms are low-passed filtered with a half-amplitude cut-off of 10 Hz for viewing purposes.

This pattern, however, was driven entirely by the neutral words: self-relevant neutral words elicited a larger LPC than other-relevant neutral words (thus making them more similar to pleasant and unpleasant words) [mid-regions omnibus: $F(1, 25) = 20.18$, $p < .001$, η2 = .447]. In contrast, pleasant and unpleasant words did not differ by self-relevance [*F*s < 0.4, *p*s > .55]. The effect of self-relevance for neutral words further interacted with Region [F(4, 100) = 5.94, p = .008, η2 = .192] and follow-up ANOVAs in individual regions showed that the effect was strongest in the frontal region and also significant in the prefrontal, central, and parietal regions. See Fields & Kuperberg (2012) for additional details.

Comprehension task

In the comprehension task study, the interaction of Emotion and Self-Relevance was significant in both the mid-regions ANOVA [$F(2, 46) = 3.73$, $p = .032$, $\eta^2 = .140$] and the peripheral regions ANOVA [$F(2, 46) = 3.32$, $p = .045$, $\eta^2 = .126$]. However, the pattern of the effect was quite different, and the interaction was primarily driven by a significant effect of Emotion in the self-relevant scenarios [mid-regions: $F(2, 46) = 3.86$, $p = .029$, $\eta^2 = .144$; peripheral regions: $F(2, 46) = 5.09$, $p = .011$, $\eta^2 = .181$], with no significant effect of Emotion in the other-relevant scenarios [mid-regions: $F(2, 46) = 2.26$, $p = .117$, $\eta^2 = .089$; peripheral regions: $F(2, 46) = 2.96$, $p = .064$, $\eta^2 = .114$], see Figure 5. Fisher-Hayter comparisons within the self-relevant scenarios confirmed that both pleasant and unpleasant critical words elicited a larger LPC than neutral critical words, but that the amplitude of the LPC to pleasant and unpleasant words did not differ.[9]

This effect of Emotion (within self-relevant scenarios) had a centro-parietally centered, but broad, distribution (see Figure 5). It did not interact with the Region factor in the mid-regions

[9] When we broke down this interaction by examining the effect of Self-Relevance at each level of Emotion, the effect of Self-Relevance did not reach significance at any level of Emotion: there was a marginally significant effect of Self-Relevance on the pleasant words [$F(1, 23) = 3.47$, $p = .075$, $\eta^2 = .131$] and no effect on neutral or unpleasant words [*F*s < 1.4, *p*s > .25], see Figure 2.

ANOVA [$F(8, 184) = 2.05$, $p = .110$, $\eta^2 = .082$]. In the peripheral regions, the Emotion x Region interaction was significant [$F(2, 46) = 4.16$, $p = .023$, $\eta^2 = .153$] and follow-ups showed that the effect of Emotion was significant in the posterior region [$F(2, 46) = 7.60$, $p = .002$, $\eta^2 = .248$], but not the frontal region [$F(2, 46) = 1.77$, $p = .184$, $\eta^2 = .071$]. There were no significant interactions with the hemisphere factor [Fs < 2.6, ps > .09].

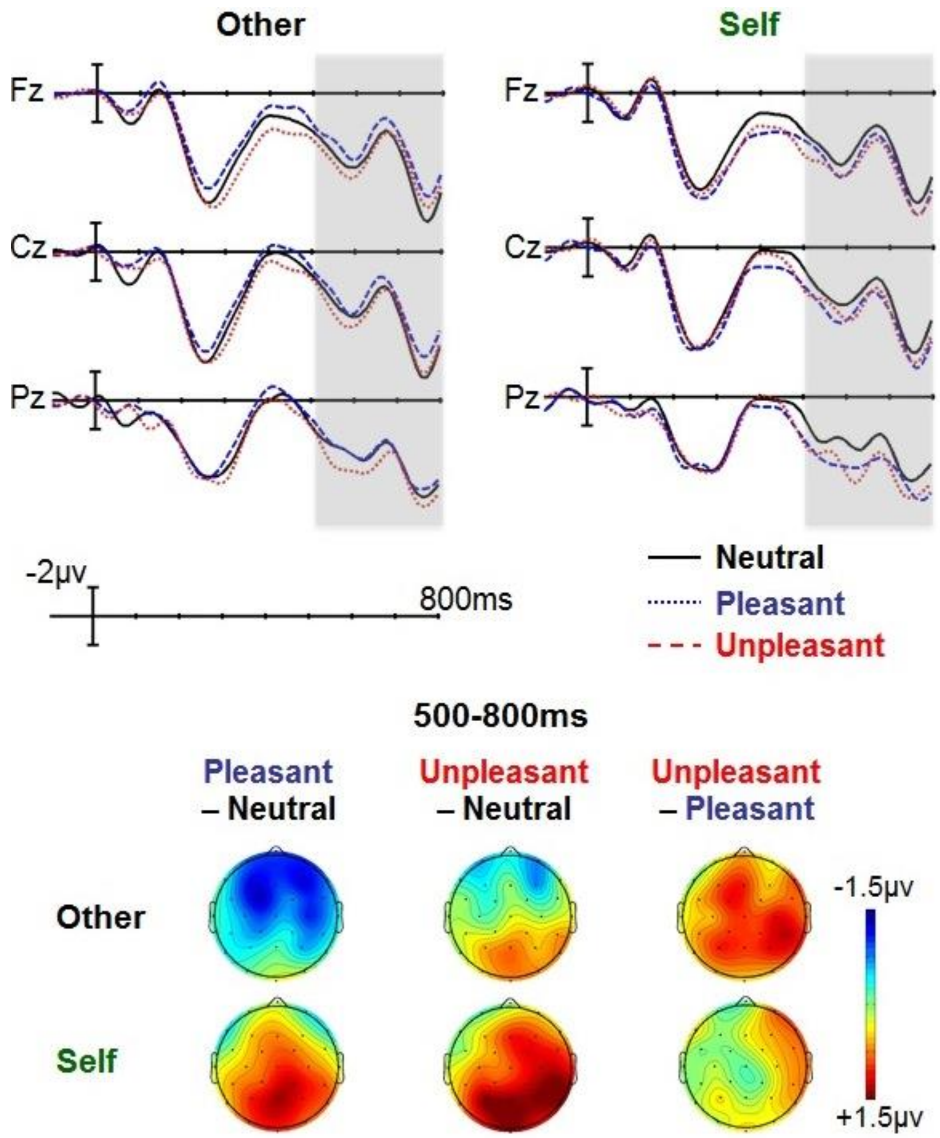

Figure 5. *Comprehension task ERP results: Effects of Emotion at each level of Self-Relevance*. Effects of Emotion were seen in self-relevant scenarios, but not other-relevant scenarios. The 500-800 ms time window is shaded. The waveforms are low-passed filtered with a half-amplitude cut-off of 10 Hz for viewing purposes.

Discussion

The aim of this study was to examine the influence of task demands on processing emotional words in short socially relevant contexts. We presented two-sentence social vignettes that were either contextually self-relevant or other-relevant, and that contained a neutral, pleasant, or unpleasant critical word in the second sentence. Participants performed either a production task in which emotional aspects of the scenarios, particularly valence, were relevant to task performance (the types of continuations produced), or a comprehension task in which emotion was not directly relevant for task performance. We saw quite different patterns of modulation on the LPC across these two tasks. First, whereas with the production task self-relevance enhanced the LPC evoked by neutral words (but not emotional words), with the comprehension task self-relevance enhanced the typical effect of emotion on the LPC. Second, whereas with the production task, an LPC effect was seen on all emotional (versus neutral) words, with the comprehension task, an LPC effect was only seen on self-relevant emotional (versus neutral) words. We discuss each of these findings before considering their general implications for how we allocate neural resources to whatever is assessed as motivationally significant in a given situation.

The effect of self-relevance on the LPC evoked by emotional and neutral stimuli

As described in the Introduction and our previous work (Fields & Kuperberg, 2012), we suggest that when participants were asked to produce a continuation for each scenario, the enhanced effect of self-relevance on neutral (but not emotional) words was driven by prolonged attempts to assess the valence of the neutral words, which were inherently more ambiguous in valence than the pleasant or unpleasant words (see also Gu et al., 2010; Hirsh & Inzlicht, 2008; Tritt et al., 2012).[10] We argued that the production task used in our previous study was critical in

[10] It is worth noting that this effect had a more frontal distribution than the standard posterior effect of emotion on the LPC. This suggests that the nature of the further processing induced by these particular stimulus and task conditions may have been distinct from that usually seen to emotional stimuli that are

inducing such an effect because it encouraged participants to disambiguate the valence of these words in order to produce a sensible and consistent continuation. This was particularly important in the self-relevant condition because of participants' desire to produce a continuation consistent with their self-concept (Swann, 2011).

We saw quite a different pattern under the comprehension task, in which emotion was not directly relevant to answering the comprehension questions. We argue that, in a situation such as this that does not invoke particular task demands beyond the reading of the scenario, processing resources were allocated to the stimuli that were most inherently motivationally-relevant and attention-grabbing. In this case, these were the stimuli that were both emotional and self-relevant. As predicted these critical words produced the largest LPC amplitude.

This enhancement of the typical emotion effect on the LPC by self-relevance is consistent with previous work. For example, previous behavioral studies report greater changes in participants' emotional states after they read self-relevant emotional texts versus non-self-relevant emotional texts (Brunyé, Ditman, Mahoney, & Taylor, 2011). Similarly, the results of our ratings studies (see the Methods section) showed that self-relevance lead to pleasant stimuli being rated as more positive and unpleasant stimuli being rated as more negative. Our results are also consistent with a handful of other studies that have examined the interaction of self-relevance and emotion with ERPs. Shestyuk and Deldin (2010) saw differences between pleasant and unpleasant words (this study did not include neutral words) on the LPC when words were judged for self-relevance but not when they were judged for relevance to Bill Clinton. In a related study, Schindler, Wegrzyn, Steppacher, and Kissler (2014) showed participants trait adjectives under either a) a condition where a second person was supposedly judging the whether the adjective applied to the participant or b) a computer was simply randomly presenting the words. They only found effects of emotion for words that participants

---

not ambiguous. For discussion of this issue, see Fields and Kuperberg (2012).

thought they were being judged in relation to. In work more similar to our own, Herbert and colleagues (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011) report two studies in which participants passively read (with no additional task) emotional and neutral words preceded by first-person and third-person pronouns and found effects of emotion on the LPC only for words preceded by the first person pronouns (see also Li & Han, 2010).

The LPC to emotional stimuli that are not self-relevant

As noted above, we saw a difference between the two tasks in the effects of emotion on the LPC within the non-self-relevant stimuli. Under the production task, we saw a larger posterior LPC to emotional versus neutral stimuli in both self-relevant and other-relevant contexts. As discussed in the introduction, these effects are consistent with a large body of ERP studies that have reported emotion effects on the LPC in single words (reviewed in Citron, 2012; Kissler et al., 2006) and to emotional words in non-self-relevant contexts (e.g., Bartholow, Fabiani, Gratton, & Bettencourt, 2001; Bayer, Sommer, & Schact, 2010; Delaney-Busch & Kuperberg, 2013; Holt et al., 2009). Thus, it is striking that under the comprehension task, as well as in the previous studies of the interaction of emotion and self-relevance that were just discussed (which also used tasks in which emotion was not directly relevant for performance; Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011; Li & Han, 2010; Schindler et al., 2014; Shestyuk & Deldin, 2010), effects of emotion on the LPC were only seen in self-relevant stimuli, not in other-relevant stimuli

We argue that this apparent discrepancy can be explained in the broad dynamic framework outlined above. Specifically, we suggest that allocation of resources is not only a function of the inherent salience of stimuli and overt task demands, but *also* the more general context. A stimulus that seems salient and important in one context may garner little attention in another: while a spider discovered in your living room may dominate your attention under normal circumstances, if your house is on fire you may not notice it at all. This more general effect of context is illustrated in a recent study by Fogel, Midgley, Delaney-Busch, and Holcomb (2012), who showed that the effects of emotion on emotional words completely disappeared when they were intermixed with high-arousal taboo words, presumably because the standard emotional words lost their ability to draw special attention in the presence of the more arousing taboo words (see also, Crites, Cacioppo, Gardner, & Bernston, 1995). On this account, with the comprehension task used in Experiment 2 (or with no task as in the Herbert et al. studies) the non-self-relevant scenarios, even when emotional, lost their ability to draw additional attention in the presence of self-relevant emotional scenarios. When emotional properties were task-relevant on the other hand, as we have argued they were for the production task, attention was allocated to emotional words, leading to an enhanced LPC, regardless of their self-relevance.

Summary and conclusions

In sum, we have shown a complex three-way interaction of the emotional properties of a stimulus, self-relevance, and task demands. When emotion was relevant to task demands, self-relevance enhanced the LPC specifically for neutral words. When emotion was not relevant to task demands, self-relevance enhanced the canonical emotion effect on the LPC. These results suggest that there is no one-to-one relationship between the emotional properties (or self-relevance) of an eliciting event and its effects on cognitive processing. They support the view that the LPC is triggered by a highly dynamic computational mechanism. The nature of this mechanism is discussed further in the General Discussion.

PART 3: EFFECTS OF MOOD ON THE INTERACTION OF SELF-RELEVANCE AND EMOTION IN DISCOURSE PROCESSING

In the preceding studies, we examined how multiple properties of stimuli and task interact to influence goals and expectations and thereby modulate the ERPs elicited by words in discourse scenarios. In those studies, we examined both goals given to the participant by the task, as well as motivations and expectations generated from more longstanding predispositions to see the self positively and to view particular words as pleasant or unpleasant. In Part 3, we examined how a transient psychological state would impact the processing of socially relevant emotional stimuli. In particular, we were interested in how mood would modulate the effects described in the previous sections. To examine this question, we replicated the comprehension task study reported in Part 1 and Part 2 with the addition of a between subjects mood induction procedure to put participants in either a happy or sad mood.

Introduction

Mood has effects on many aspects of information processing, judgment, and decision making (Martin & Clore, 2001). One major effect of mood is its relatively direct influence on affective processes such as judgments, expectations, and the relative salience or accessibility of affective information. When a person is in a happy mood she assess people, objects, and situations more positively, and when in a sad mood she tends to evaluate them more negatively (reviewed in Clore & Huntsinger, 2007). For example, in one classic study participants in a telephone survey reported greater life satisfaction when responding on a sunny day than a rainy day (Schwarz & Clore, 1983).

However, mood can also have more general influences on information processing through effects on cognitive processing style. Generally speaking, “when people are made happy they engage in global, category-level, relational processing, whereas when they are sad they engage in local, item-level, stimulus-specific processing” (Clore & Huntsinger, 2007, p. 395). Because many classic effects in psychology result from the use of schemas, heuristics, biases, and analogical processing, many effects are increased by a happy mood and decreased by a sad mood (reviewed in Clore & Huntsinger, 2007). For example, semantic priming effects are larger under a happy mood than a sad mood (Hanze & Hesse, 1993). People are also more likely to make use of schemas under a happy mood (Bless, Schwarz, Clore, Golisano, & Rabe, 1996), including social schemas such as stereotypes (Bodenhausen, 1993; Bodenhausen, Kramer, & Susser, 1994; Isbell, 2004).

Several ERP effects have also been shown to be modulated by mood, including classic effects in the language processing literature. For example, paralleling behavioral effects, the effects of semantic priming on the N400 have been found to be larger under a happy mood and smaller or eliminated under a sad mood (Chwilla, Virgillito, & Vissers, 2011; Federmeier, Kirson, Moreno, & Kutas, 2001). Sad mood has also been shown to attenuate the effect of syntactic violations on the P600 (Vissers, Chwilla, Egger, & Chwilla, 2013; Vissers et al., 2010) and ERP effects associated with referential processing (Van Berkum, De Goede, Van Alphen, Mulder, & Kerstholt, 2013).

A few studies have used ERPs to look at the interaction of mood and the emotional properties of stimuli. In an early study Chung et al. (1996) reported that the N400 was reduced to mood congruent words in discourse contexts, and Egidi and Nusbaum (2012) have recently replicated this effect. However, in a single word paradigm, Pratt and Kelly (2008) observed a somewhat later anterior negativity that was larger to mood-congruent words. Unfortunately, none of these studies examined the LPC time window.

The present study: Research questions and hypotheses

In the present work, we were interested in how mood might affect both the N400 and LPC effects reported in the previous two studies. I discuss these in turn.

<u>Mood effects on the self-positivity bias and the N400</u>

Mood might be expected to influence the self-positivity effect we observed on the N400 in two different ways, but both lead to the same prediction. First, mood may directly influence the way we think about ourselves. The self-concept is both stable and dynamic. Obviously some aspects of how we view ourselves are long-term representations that are stable across time and circumstance. On the other hand, a person's self-confidence, optimism about her future, etc. can clearly change over relatively short periods of time. Some of these changes are simply a matter of which information about the self is active or most salient in a given context: theorists have distinguished between active self-knowledge and stored self-knowledge and have noted that the working self-concept can be highly sensitive to context (Markus & Kunda, 1986; Swann & Bosson, 2010). One example is that we are likely to feel less positively about ourselves and to be less optimistic when we are in a sad mood, and this has been confirmed by experimental evidence showing less positive self-appraisals under negative moods (Brown & Mankowski, 1993; Helweg-Larsen & Shepperd, 2001). Similarly, a reduced self-positivity bias has long been associated with mood disorders (Bargh & Tota, 1988; Beck et al., 1979; Blackburn & Eunson, 1989; Bradley & Matthews, 1983; Goldin et al., 2013; Kuiper & Derry, 1982; Moretti, Segal, McCann, & Shaw, 1996; Shestyuk & Deldin, 2010; Taylor & Brown, 1988; Wang, Brennen, & Holte, 2006). Thus, one possibility is that mood will affect the relative salience and accessibility of mood congruent self-knowledge. In this case, a happy mood would be expected to increase the self-positivity effect observed in the previous study and a sad mood would be expected to attenuate, eliminate, or even reverse this effect.

The second way that mood may modulate the self-positivity effect on the N400 is through its general effects on processing style. As discussed above a happy mood generally increases, and a sad mood decreases, the use of schemas, heuristics, and biases. Thus, whether one regards the self-positivity bias as a heuristic, bias, or simply part of the self-schema, it may be expected that a happy mood will increase the effect we have observed on the N400 and a sad mood will attenuate or eliminate this effect.

Mood effects on the LPC

It is less clear what effects mood might have on the LPC, partly because of the diverse effects of mood, and partly because the neurocognitive function represented by the LPC is less clear.

One possibility is that mood will affect LPC amplitude by influencing stimulus assessment. As discussed above, stimuli are more likely to be judged as positive in a happy mood and negative in a sad mood (Clore & Huntsinger, 2007). Given that the LPC varies with subjective valence and arousal, this could lead to a larger LPC for mood congruent stimuli (because their perceived valence is enhanced by mood effects) and a smaller LPC to mood incongruent stimuli (because their perceived valence is attenuated by mood). In this case, neutral stimuli may be particularly affected by mood (because their valence is more open to interpretation in the first place) and would be expected to elicit a larger LPC under either mood condition than under a neutral mood (because they would be perceived as more emotional).

Another possible effect of mood on the LPC is through effects on processing styles. As has been discussed, it is well established that we have an attentional bias to emotional stimuli (Compton, 2003), and the LPC is often seen as being associated with increased attention and processing allocated to emotional stimuli. Since a happy mood generally increases, and a sad mood decreases, cognitive biases, the effects of mood on cognitive styles would predict a larger effect of emotion on the LPC (i.e., a larger difference in amplitude between emotional and neutral words) under a happy mood than a sad mood.

Finally, the LPC has often been compared to the P300, a component that is strongly modulated by expectancy or “surprise” (Donchin & Coles, 1988; Polich, 2012). In fact, a number of studies have observed a larger LPC to stimuli that violate valence expectancies. For example, Bartholow et al. (2001) presented social vignettes where a behavior described in the last sentence violated the valence expectations set up by the context and reported a larger LPC to expectancy violations (see also Bartholow, Pearson, Gratton, & Fabiani, 2003; Crites et al., 1995; Van Duynslaeger, Sterken, Van Overwalle, & Verstraeten, 2008; Van Duynslaeger, Van Overwalle, & Verstraeten, 2007; Van Overwalle, Van den Eede, Baetens, & Vandekerckhove, 2009; but see Delaney-Busch & Kuperberg, 2013). To the extent that participants expect stimuli congruent with their present mood (see discussion of mood congruency effects on the N400 above), the LPC may be larger to mood incongruent stimuli. This prediction is, of course, the opposite of the pattern predicted on the basis of the effects of mood on judgment (see above).

Methods

Participants

59 Tufts University students who responded to an advertisement on an online community site (tuftslife.com) or were contacted based on participation in previous studies originally participated in the ERP study. 5 participants were excluded due to excessive artifact in the EEG and/or technical problems with EEG acquisition, 1 participant was excluded because she was found to be ineligible due to use of psychoactive medication, and 1 participant quit the experiment before completion due to tiredness. An additional 4 participants were excluded from analysis because they did not respond to the mood induction procedure as indicated by their self-reported mood (i.e., they reported being in a happy mood despite being in the sad mood induction condition). This left 48 participants (24 in each Mood condition) that were included in the final analysis.

Because it is difficult to successfully induce mood consistently in the laboratory and because previous research has shown that women respond to mood induction better than men (e.g., Federmeier et al., 2001), all participants were female (see also Chwilla et al., 2011; Vissers et al., 2013; Vissers et al., 2010). Self-reported race was White (n=37), Black or African-American (n=3), more than one race (n=5), and unreported (n=3). 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 (M = 20.5, SD = 1.9). They had no history of psychiatric or neurological disorders and were not taking any psychoactive medications. Participants were paid for their participation and provided informed consent in accordance with the procedures of the Institutional Review Board of Tufts University.

Stimuli and procedure

All stimuli and procedures were the same as described in Part 1, except for the addition of the mood induction procedure and the recording of facial EMG.

Mood induction

Participants were randomly assigned to either a happy or sad mood induction condition. Before the experiment began (immediately before the beginning of stimulus presentation) participants watched a video that consisted of 22 images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) presented for 9 seconds each and paired with music that matched the images in valence. Between each of the 6 blocks of the experiment participants saw a refresher video of 6 images (2 of which hadn't previously been seen) presented for 13 seconds each, also accompanied by music.

Based on ratings from the IAPS database (female participants only), the images were matched for arousal (rated 1 to 9, with 9 being most arousing) between the happy (M = 5.2, SD = 0.9) and sad (M = 5.1, SD = 0.9) conditions [$t(62) = 0.60$, p = .551]. The mean valence rating (on a 1 to 9 scale, with 9 being the most positive) for happy pictures was 8.3(0.3) and for sad pictures was 2.6(0.6).[11] For the happy condition, pictures in the initial video were set to an excerpt of Mozart's Divertimento in D Major, K. 136 played at a reduced speed (in order to

[11] The happy images were IAPS numbers: 1440, 1441, 1460, 1610, 1710, 1750, 1920, 2040, 2045, 2050, 2057, 2070, 2071, 2080, 2150, 2154, 2260, 2340, 2347, 2530, 2550, 2660, 5760, 5833, 5910, 7502, 8080, 8190, 8370, 8420, 8470, and 8501.

The sad images were IAPS numbers: 2039, 2053, 2276, 2278, 2301, 2312, 2345.1, 2375.1, 2455, 2456, 2457, 2700, 2703, 2799, 2900, 6010, 7520, 9000, 9001, 9041, 9046, 9050, 9075, 9220, 9470, 9471, 9480, 9600, 9611, 9620, 9621, and 9900.

better match it in arousal to the sad condition) and the refreshers alternated excerpts from the Divertimento and a solo piano version of Satie's "Je te veux". For the sad condition, pictures in the initial video were set to an excerpt from the first movement (*Largo*) of Dmitri Shostakovich's 8^{th} String Quartet and the refreshers alternated excerpts from this piece and Chopin's Prelude in B minor, Op. 28, No. 6. We also collected valence and arousal ratings on the videos as a whole from online participants (Amazon Mechanical Turk; see Paolacci & Chandler, 2014) who met the same criteria as the ERP subjects with the exception that raters were both male and female. The happy and sad videos were matched for arousal [ts < 1, ps > .4] and the music used in the two conditions was matched for familiarity [ts < 1.6, ps > .1].

Instructions to participants were as follows: "Before each block, you will be watching a video intended to induce a particular mood. Part of what we are interested in for this study is how mood affects basic cognitive processes like reading. You will be watching [happy/sad] videos. What we want you to do is to pay attention to the video and to try to use it to get into a [happy/sad] mood."

Just before the initial mood induction participants completed the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) and they completed the BMIS again at the end of the experiment with the instruction to respond according to how they had felt *during* the experiment. In addition, immediately after watching each mood induction video (and just before the beginning of stimulus presentation) participants indicated their mood using the overall mood rating scale of the BMIS. To reduce demand characteristics, participants were told: "Because we're asking you to get into a [happy/sad] mood, you may feel some pressure to rate your mood that way. But we just want an honest answer for how you feel at that moment so we know how well the procedure worked for different people."

EMG recording and processing

Although we attempted to use the instructions above to minimize demand characteristics in participants' self-reported mood, we also wanted a more covert manipulation check. We therefore recorded the electromyogram over the corrugator supercilii muscle during presentation of the mood induction videos as a manipulation check. Previous work has shown the corrugator EMG to covary with the valence of stimuli (Cacioppo, Bush, & Tassinary, 1992; Lang, Greenwald, Bradley, & Hamm, 1993; Larsen, Norris, & Cacioppo, 2003). EMG was recorded separately during each mood induction video yielding six measures for each participant, one before each experimental block (see below). In addition, a baseline measurement, consisting of the participant sitting still while a fixation cross was on the screen for 78 seconds (the same length as each refresher video), was taken before the experiment began. To reduce self-awareness and effects of demand characteristics, participants were not informed before the experiment that we were recording facial expressions—the EMG electrodes were simply placed on the face at the same time as the mastoid and EOG electrodes.

Ag/AgCl electrodes were placed according to the standards outlined in Fridlund and Cacioppo (1986) and connected to a BioPac Systems, Inc. (Goleta, CA) MP150 amplifier. EMG data were recorded and analyzed with BioPac Systems' AcqKnowledge 4.1.1 software. The signal was band pass filtered online from 1 Hz to 500 Hz and continuously sampled at 1,000 Hz. Offline, data was high-passed filtered with a half-amplitude cut-off of 10 Hz. The data were then rectified and corrugator activity was measured as the average amplitude across the entire recording period (that is, throughout each mood induction video).

Results

Behavioral results

Participants were quite accurate in answering the comprehension questions. The average accuracy was 93% and no participant's accuracy was below 75%. There was no difference in performance between the happy and sad mood groups [$t(46) = 1.58$, $p = .121$].

Self-report and EMG mood manipulation checks

Self-reported mood

Means for self-reported overall mood for pre- and post-experiment BMIS and each block are presented in Table 4.

	pre	initial	R1	R2	R3	R4	R5	post
Happy	2.2 (1.4)	3.1 (0.9)	3 (0.9)	3.5 (0.8)	3.1 (1.3)	3.3 (1)	3.3 (1.1)	2.8 (0.8)
Sad	1.7 (1.5)	-0.8 (1.4)	-1.1 (1.3)	-1.5 (1.2)	-1.4 (1.3)	-1.8 (1.2)	-2 (1.5)	-1.4 (1.4)

Table 4. *Self-reported mood*. Means are shown with standard deviation in parentheses. Ratings are on a scale from -5 ("Very Unpleasant") to 5 ("Very Pleasant") with 0 labelled as "Neutral".

I first examined participants' self-reported mood by directly comparing the two groups. Independent samples t-tests showed that the groups did not differ in the pre-experiment ratings for overall mood (valence) or arousal [*t*s < 1.1, *p*s > .25]. However, the groups differed as expected in their overall mood ratings for every experimental block as well as in the post-experiment rating [*t*s > 10, *p*s < .001]. The sad group also reported slightly higher arousal in the post-experiment BMIS [$t(46) = 2.24$, $p = .030$].

I next compared each group's self-reported mood for each block, as well as the post experiment questionnaire, to the mood they reported before the experiment to examine whether the mood induction video was successful in changing moods. For the happy group overall mood was reported as higher than baseline for all time points [*t*s > 3.5, *p*s < .01] and for the sad group overall mood was reported as lower than baseline for all time points [*t*s > 7, *p*s < .001]. There was no significant change in arousal for either group [*ts* < 1.7, *p*s > .1].

Finally, I compared the means of all ratings to 0 (defined as neutral mood in the BMIS overall mood scale) via single sample t-tests. Both groups showed a significant difference from 0 in the pre-experiment rating, showing that participants came to the lab in a moderately positive mood. Importantly, the happy group reported their mood to be significantly above 0 for all blocks [*t*s > 7, *p*s < .001] and the sad group reported their mood to be significantly below zero for all blocks [*t*s > 2.8, *p*s < .02].

Thus, self-reported mood indicates that the two groups differed significantly from each other in mood, that the mood induction procedure in both groups successfully changed mood in the intended direction, and that happy group was in a positive mood while the sad group was in a negative mood.

<u>EMG</u>

In contrast to the self-report data, there is no objective baseline for corrugator activity signaling a neutral mood. In addition, the EMG data were quite variable. I therefore only examined EMG data in relation to each participant’s baseline.

	initial	**R1**	**R2**	**R3**	**R4**	**R5**
Happy	**-1.0 (2.2)**	-0.7 (1.6)	-0.7 (2.0)	**-1.3 (2.0)**	-0.7 (2.3)	-1.0 (3.0)
Sad	**4.3 (4.3)**	**2.3 (5.1)**	1.3 (6.0)	0.8 (3.7)	0.9 (4.6)	1.4 (3.5)

Table 5. *EMG results*. The mean of the difference between each block and the baseline measurement is shown with standard deviation in parentheses. Means that differ significantly from zero are bolded and shaded in dark gray; means that are marginally significantly different ($p < .1$) from zero are shaded in lighter gray.

Table 5 shows the differences between EMG for each block and the baseline measurement for each mood group. As can be seen, all means were in the expected direction with the happy mood induction reducing corrugator activity and the sad mood induction increasing it. However, due to high variability, this difference only reached significance in some blocks.

To compare the two groups directly, I conducted an independent samples t-test on the difference between EMG activity in each block and the baseline measurement. This effect was significant for the initial video and the first, third, and fifth refreshers [ts > 2.4, ps < .05], but not for the second or fourth refresher [ts < 1.6, ps > .10].

In sum, although EMG effects were in the expected direction for all comparisons, relatively high variability meant these differences were only significant in some blocks.

ERP results

Based on the results of the studies reported in Parts 1 and 2, I first examined effects in two a priori time windows: 300-500 ms and 500-800 ms.

<u>300-500 ms time window</u>

There were no significant main effects or interactions involving the Self-Relevance or Mood factors in the either omnibus ANOVA [all Fs < 4.1, ps > .05].

	Effect	*df*	*F*	*p*	η^2	Post hoc Tests
Mid-regions omnibus ANOVA	E	2, 92	8.76	**<.001**	0.160	U>N, P=N, U>P
	ExR	8, 368	2.82	**0.026**	0.058	
Prefrontal	E	2, 92	8.66	**<.001**	0.159	U>N, P=N, U>P
Frontal	E	2, 92	12.23	**<.001**	0.210	U>N, P=N, U>P
Central	E	2, 92	6.29	**0.003**	0.120	U>N, P=N, U>P
Parietal	E	2, 92	4.01	**0.023**	0.080	U>N, P=N, U=P
Occipital	E	2, 92	2.54	0.090	0.052	U=N, P=N, U>P
Peripheral regions omnibus ANOVA	E	2, 92	4.23	**0.020**	0.084	U>N, P=N, U>P
	ExR	2, 92	0.16	0.846	0.004	
	ExH	2, 92	3.78	**0.027**	0.076	
	ExRxH	2, 92	1.44	0.242	0.030	
Left Hemisphere	E	2, 92	2.69	0.075	0.055	U>N, P=N, U=P
Right Hemisphere	E	2, 92	5.40	**0.008**	0.105	U>N, P=N, U>P

Table 6. *Main effects of Emotion and interactions between Emotion, Region, and/or Hemisphere in the 300-500 ms time window*. Interactions with Region and/or Hemisphere were followed up at individual regions. Effects significant at an alpha of .05 are shaded gray and are shown in a bold font. Fisher-Hayter 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.

Effects of Emotion and its interactions with spatial factors are shown in Table 6. There were significant effects of Emotion in both the mid-regions and peripheral ANOVAs. In the mid-regions ANOVA, the interaction between Emotion and Region was significant, while in the peripheral regions ANOVA the Emotion x Hemisphere interaction was significant. No other main effects or interactions were significant in the omnibus ANOVAs.

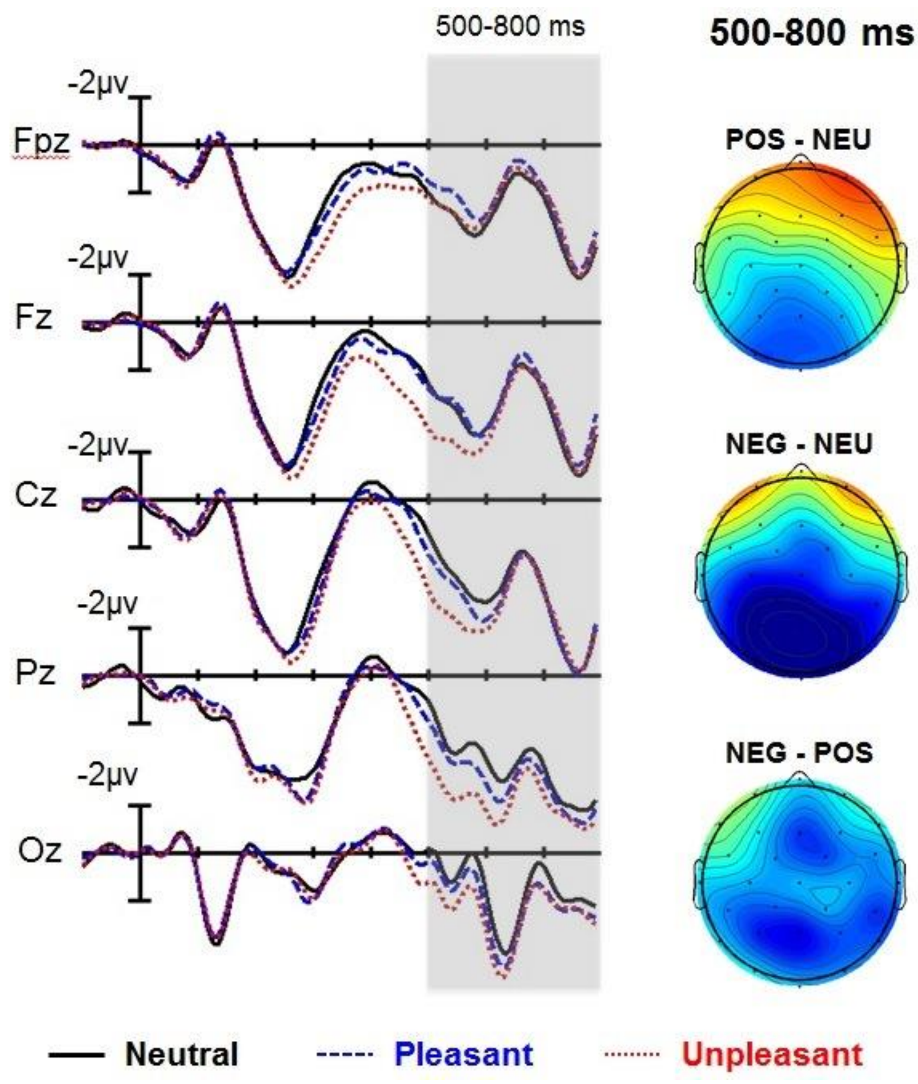

Figure 6. *Main effects of Emotion*. An anterior negativity was reduced to unpleasant words between 300 and 500 ms. At posterior sites a positivity extending approximately 450 to 700 ms was larger unpleasant words. Waveforms are low-pass filtered with half-amplitude cutoff of 15 Hz for viewing purposes.

Fisher-Hayter comparisons showed that the main effect of Emotion was driven by a smaller negativity to Unpleasant words than Pleasant or Neutral words (which did not differ). This effect had a fronto-central distribution (see Figure 6 and Figure 7). Follow-up tests in each mid-line region showed that the effect of Emotion was largest in the Frontal region, was also significant in the Prefrontal, Central, and Parietal regions, and was not significant in the Occipital region. In all regions Fisher-Hayter pairwise comparison showed the same pattern as in the omnibus ANOVAs: a smaller negativity to Unpleasant words than Pleasant or Neutral words (which did not differ). Follow-up ANOVAs in the peripheral regions showed that the effect of Emotion was significant in the right hemisphere, but only marginally significant in the left hemisphere.

<u>500-800 ms time window</u>

As in the previous time window, there were no significant main effects or interactions involving the Self-Relevance or Mood factors. However, there was a marginally significant main effect of Self-Relevance in both the mid-regions [$F(1, 46) = 3.26$, $p = .078$, $\eta^2 = .066$] and peripheral regions [$F(1, 46) = 3.85$, $p = .056$, $\eta^2 = .077$] ANOVAs, due to a slightly larger positivity to the Self condition than the other condition in the early portion of the time window.

Effects of Emotion and interactions between Emotion and spatial factors are summarized in Table 7. There was a significant main effect of Emotion in the mid-regions ANOVA and a marginally significant effect of Emotion in the peripheral ANOVA. The Emotion x Region interaction was significant in both ANOVAs. No other main effects or interactions were significant in the omnibus ANOVAs.

Fisher-Hayter pairwise comparisons in both mid- and peripheral regions showed that there was a larger positivity to unpleasant words than to pleasant or neutral words (which did not differ from each other). In contrast to the preceding time window, this effect had a parieto-occipital distribution (see Figure 6 and Figure 7). Follow-up ANOVAs in each region showed that the effect of Emotion was significant in all regions except for the Frontal and peripheral Frontal regions, and these effects were largest in the Parietal and Occipital regions. In the parietal region the positivity followed the same pattern as in the omnibus: it was larger to unpleasant than pleasant or neutral, which did not differ. In the occipital region all three conditions differed with unpleasant eliciting a larger positivity than pleasant words, which elicited a larger positivity than neutral words.[12]

	Effect	*df*	*F*	*p*	η^2	Tests
Mid-regions omnibus ANOVA	E	2, 92	3.93	**0.023**	0.079	U>N, P=N, U>P
	ExR	8, 368	10.05	**<.001**	0.179	
Prefrontal	E	2, 92	3.37	**0.039**	0.068	U=N, P>N, U=P
Frontal	E	2, 92	2.56	0.083	0.053	U=N, P=N, U>P
Central	E	2, 92	3.20	**0.045**	0.065	U>N, P=N, U=P
Parietal	E	2, 92	8.66	**<.001**	0.158	U>N, P=N, U>P
Occipital	E	2, 92	12.45	**<.001**	0.213	U>N, P>N, U>P
Peripheral regions omnibus ANOVA	E	2, 92	3.07	0.052	0.063	U>N, P=N, U>P
	ExR	2, 92	15.94	**<.001**	0.257	
	ExH	2, 92	1.49	0.231	0.031	
	ExRxH	2, 92	0.88	0.419	0.019	
Frontal	E	2, 92	1.16	0.318		
Posterior	E	2, 92	9.82	**<.001**	0.176	U>N, P=N, U>P

Table 7. *Main effects of Emotion and interactions between Emotion, Region, and/or Hemisphere in the 500-800 ms time window*. Interactions with Region and/or Hemisphere were followed up at individual regions. Effects significant at an alpha of .05 are shaded gray and are shown in a bold font. Fisher-Hayter 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.

<u>Exploratory analyses: 300-400 ms</u>

The preceding time windows were chosen a priori based on the results of the studies in Parts 1 and 2, and were reported for direct comparisons with those studies. However, visual examination of the waveform suggests that the results of the present study may have had a somewhat different component structure than our previous studies. Figure 7 presents difference waves of the emotion effects in this study. These waveforms reveal a negativity peaking slightly

[12] Visual examination of the waveform suggested the effects in this study occurred earlier than in the previous studies, extending approximately 450-700 ms. However, analyses in the 500-700 ms time window (450-500 ms was excluded to avoid overlap from the preceding negativity), showed a nearly identical pattern of effects. These analyses are presented along with the analyses of earlier time windows in the appendix.

before 350 ms that is largest at the most anterior electrodes. This is followed by a posterior positivity that begins around 450 ms and extends to approximately 700 ms. In the 400-500 ms time window these effects appear to overlap, particularly at frontal and central electrodes. Thus, whereas the 500-800 ms time window appears to be an appropriate measure of the LPC in this study (the effect appears to extend only to around 700 ms, but results were nearly identical in the 500-700 ms time window; see footnote 12), the 300-500 ms time window may reflect the averaging together of the earlier anterior negativity and the early portion of the late positivity effect.

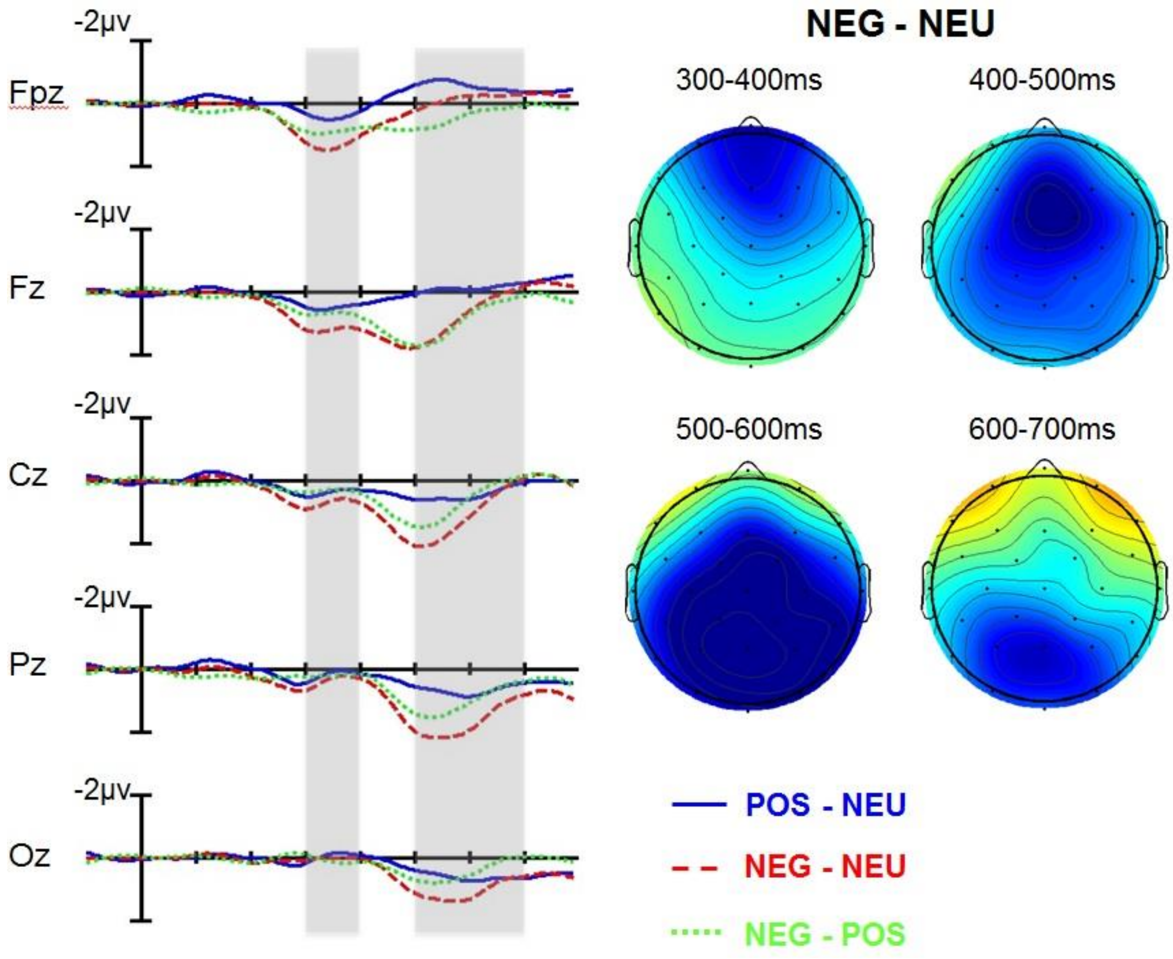

Figure 7. *Difference waves for the main effect of Emotion*. The 300-400 ms and 500-700 ms time windows are shaded. Waveforms are low-pass filtered with a half-amplitude cut-off at 5 Hz for viewing purposes. Voltage maps show the difference between unpleasant and neutral words in 100 ms time intervals.

I therefore conducted statistical analyses within the 300-400 ms time window to obtain a less confounded measure of the anterior negativity. In the peripheral regions ANOVA there was a significant Self-Relevance x Region x Mood interaction [$F(1, 46) = 4.70$, $p = .035$, $\eta^2 = .093$]. Follow-ups within each Mood group showed Self-Relevance x Region interaction in the happy mood condition [$F(1, 23) = 6.79$, $p = .016$, $\eta^2 = .228$], but not the sad mood condition [$F(1, 23) = 0.24$, $p = .630$, $\eta^2 = .010$]. However, within the happy mood condition, the effect of Self-Relevance did not reach significance in either the frontal or posterior peripheral regions [*F*s < 1.6, *p*s >.20].

Effects of Emotion and its interaction with spatial factors are presented in Table 8. Both the main effect of Emotion and the Emotion x Region interaction were significant in the mid-regions ANOVA. In the peripheral regions ANOVA the Emotion x Region interaction was marginally significant and the Emotion x Hemisphere interaction was significant.

	Effect	*df*	*F*	*p*	η^2	Tests
Mid-regions omnibus ANOVA	E	2, 92	6.01	**0.004**	0.116	U>N, P=N, U>P
	ExR	8, 368	4.84	**0.001**	0.095	
Prefrontal	E	2, 92	14.75	**<.001**	0.243	U>N, P=N, U>P
Frontal	E	2, 92	7.62	**0.001**	0.142	U>N, P=N, U>P
Central	E	2, 92	2.86	0.064	0.059	U>N, P=N, U=P
Parietal	E	2, 92	1.40	0.253	0.029	
Occipital	E	2, 92	0.71	0.489	0.015	
Peripheral regions omnibus ANOVA	E	2, 92	2.06	0.135	0.043	
	ExR	2, 92	3.16	0.051	0.064	
	ExH	2, 92	3.61	**0.031**	0.073	
	ExRxH	2, 92	0.31	0.693	0.007	
Left Hemisphere	E	2, 92	1.33	0.271	0.028	
Right Hemisphere	E	2, 92	2.98	0.058	0.061	U>N, P=N, U=P
Frontal	E	2, 92	3.52	**0.034**	0.071	U>N, P=N, U=P
Posterior	E	2, 92	0.40	0.657	0.009	

Table 8. *Main effects of Emotion and interactions between Emotion, Region, and/or Hemisphere in the 300-400 ms time window*. Interactions with Region and/or Hemisphere were followed up at individual regions. Effects significant at an alpha of .05 are shaded gray and are shown in a bold font. Fisher-Hayter 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.

Like in the 300-500 ms time window, these effects were driven by a reduced negativity to unpleasant words compared to pleasant and neutral words (which did not differ). Fisher-Hayter pairwise comparisons confirmed this pattern both in the mid-regions ANOVA and in the individual regions in which the effect of Emotion was significant. However, this effect was more anteriorly distributed (see Figure 6 and Figure 7): the effect of Emotion was largest in the Prefrontal Region and only reached significance in this region and the Frontal regions. In the peripheral regions, the effect of Emotion was marginally significant in the right hemisphere and non-significant in the left hemisphere.

There were for the first time in this time window significant interactions involving the Mood factor in the omnibus ANOVAs. These were confined to the peripheral ANOVA where there was a significant Emotion x Hemisphere x Mood interaction [$F(2, 92) = 3.31$, $p = .041$, $\eta^2 = .067$] and a marginally significant Emotion x Mood interaction [$F(2, 92) = 2.46$, $p = .092$, $\eta^2 = .051$]. These were examined by conducting follow-ups within each Mood condition. In the happy mood condition, the peripheral ANOVA showed a significant main effect of Emotion [$F(2, 46) = 6.09$, $p = .007$, $\eta^2 = .209$], which Fisher-Hayter pairwise comparisons showed was due to the negativity being significantly smaller for unpleasant words than neutral words and marginally significantly smaller to unpleasant words than pleasant words. The Emotion x Hemisphere interaction was not significant [$F(2, 46) = 1.52$, $p = .229$, $\eta^2 = .062$]. In the sad mood condition, the peripheral ANOVA showed a non-significant main effect of Emotion [$F(2, 46) = 0.02$, $p = .975$, $\eta^2 = .001$], but the Emotion x Hemisphere interaction was significant [$F(2, 46) = 7.17$, $p = .002$, $\eta^2 = .238$]. However, the effect of Emotion was not significant in either hemisphere [Fs < 1, ps $> .5$].

Summary of results

I interpret the ERP waveforms and statistical analyses as showing two primary effects. First, there was an anterior negativity peaking around 350 ms, which was reduced to unpleasant words compared to pleasant or neutral words. Second, there was a posterior positivity peaking around 550 ms, which I interpret as the late positive component described in Part 2 and seen in many other studies using emotional stimuli (Citron, 2012; Hajcak et al., 2012). The LPC was larger to unpleasant words than pleasant or neutral words, and larger to pleasant words than neutral words at the most posterior sites. These two effects may have overlapped, primarily in the 400-500 ms time window, but can be discerned relatively independently before 400 ms and after 500 ms. For the most part, these effects did not interact with the Self-Relevance and/or Mood factors, although there was some limited evidence that the effect on the anterior negativity may have been stronger in the happy condition, at least at peripheral sites.

Discussion

The results showed a reduced anterior negativity to unpleasant words and increased LPC for unpleasant words. In general, these effects were not different across mood or self-relevance conditions. However, it would be inaccurate to say that the mood induction procedures had no effect: Parts 1 and 2 report different results for the same paradigm—with the same stimuli, task, EEG recording equipment, and processing parameters—with no mood induction procedure.. Thus, the mood induction procedure in this study does seem to have had an effect, but that effect was the same for both mood conditions.

It is not entirely clear how to characterize this effect. One possibility is that it is mediated by arousal, which is known to have a number of psychological effects (e.g., Mather & Sutherland, 2011). In the present study, there was no significant difference in the BMIS arousal sub-scale before the experiment and after (when participants were asked to complete the BMIS for how they felt *during* the experiment). However, in the studies reported in Parts 1 and 2, there was a significant *decrease* in arousal from the pre-experiment to post-experiment ratings. Thus, it is reasonable to assume that the mood induction procedure caused participants in the current study to be in a higher arousal state than the participants in the previous studies. Unfortunately, it is difficult to compare arousal states directly between the samples because the questionnaires assessing arousal were not the same.

What can be said about our mood induction procedure, based on both self-report measures and EMG, is that it did have some effect on affective states. Although it is difficult to specify the exact nature of this effect on the basis of the current data, in the following I work from the general assumption that the affective states induced in the present study affected processing by increasing the salience or relevance of the emotional properties of words. I now turn to discussing each of the effects we observed in turn.

Anterior negativity

The first question about the anterior negativity effect observed in the present results is how it relates to the negativity described in Part 1. Determining when two ERP components are the same or different is notoriously difficult (see discussion in Luck, 2014), but there are three factors that can be used to distinguish components: scalp distribution, timing, and sensitivity to experimental manipulations. I consider three possible interpretations of the anterior negativity observed in the present study.

The first possibility is that the effects in the present study reflect a modulation of the same component as the effect described in Part 1, and that this component is the N400 (in line with our interpretation in Part 1). In Part 1, we interpreted the observed negativity as the N400 because it displayed the same timing as the N400 (which is known for its strong temporal stability: Kutas & Federmeier, 2011) and showed sensitivity to a semantic manipulation that we had a priori predicted would modulate the N400. The center of the effect on the scalp was more frontal than most commonly seen for the N400, but it was widespread and analyses in the individual regions showed it was significant in the central and parietal regions where the N400 effect is most often largest. In addition, there are factors known to shift the N400 effect anteriorly, and, in general, the scalp distribution of the N400 is not quite as stable as its timing. However, the effect in the present study was further anterior than the effect seen in Part 1: it was largest at the most anterior electrodes and was only significant in the prefrontal and frontal regions. While studies in various domains have reported N400s centered around Cz or Fz (Delaney-Busch & Kuperberg, 2013; Egidi & Nusbaum, 2012; Holcomb et al., 1999; Kanske & Kotz, 2007; Lee & Federmeier, 2008; Sitnikova et al., 2003; Swaab et al., 2002; West & Holcomb, 2002), the literature offers less support for prefrontally-distributed N400 effects. In addition, the N400 is known to have a relatively stable temporal peak around 400 ms, but the effect in the current study peaked before 350 ms and was more short-lived than the usual N400 effect. Finally, while the effect seen in Part 1 accorded well with the theoretical and empirical literature on the N400 (and was in fact predicted a priori on the basis of this literature), it is difficult to make sense of the current effect as an N400. That is, why would a happy mood lead to greater expectations for unpleasant information than neutral or pleasant information? For all these reasons, it is difficult to construe the anterior negativity effect in the present study as a modulation of the N400.

The second possibility is that the anterior negativity in the present study is a modulation of the same component as the effect described in Part 1, but our previous interpretation was wrong. It is possible that the both negativities represent the same non-N400 component, a component that can be frontally or prefrontally distributed and that has less stable temporal characteristics than the N400. There are clearly differences between these effects in timing and distribution, but the difference within each of these domains is small enough that it remains plausible to interpret them as the same component. However, the effects also show quite different sensitivity to experimental manipulations. The effect seen in Part 1 was primarily driven by an effect of self-relevance that was modulated by emotion, with no overall main effect of emotion. The effect in the present study was a main effect emotion that was not modulated by self-relevance, and there was no main effect of self-relevance in this time window. In addition, even putting aside the specific theoretical literature of the N400, a single-component interpretation of the two effects would require that a given cognitive process is reduced specifically to pleasant words in self-relevant contexts in one study, but in the same paradigm under an induced mood (either happy or sad) it is reduced to unpleasant words generally. It's hard to imagine what neurocognitive process would show this pattern, and therefore theoretical motivations suggest the effects are probably more easily explained as reflecting distinct components and cognitive mechanisms.

Thus, I believe that temporal and spatial characteristics of the effect, experimental sensitivity, and theoretical concerns converge to support the third possibility: that the effects seen in Part 1 and the present study are on distinct components of the ERP. In this case, how might we interpret the anterior negativity in the present study? It is not clear that this component can be related to any of the components most commonly seen in the language (Swaab et al., 2012) or emotion (Hajcak et al., 2012) literatures. Our interpretation is therefore necessarily speculative. However, some as-yet unpublished studies of emotional words in our lab (Delaney-Busch, 2013) and the Cognition and Brain Lab at the University of Illinois (personal communication from K. Federmeier to N. Delaney-Busch; Frost & Federmeier, 2012) have shown a similar effect (see also Pratt & Kelly, 2008). In these studies, an anterior negativity in the N400 time window was interpreted as reflecting working memory and/or decision making processes and was argued to be sensitive to emotional dimensions of stimuli that were specifically relevant to task performance (see discussion in Delaney-Busch, 2013). Given that emotional aspects of the scenarios were not task-relevant in the present study, that interpretation is not directly translatable. However, the effect in the present study may have had something to do with the increased salience/relevance of emotional properties of stimuli after mood induction: in the next section, I argue that by making emotional properties of stimuli salient and/or relevant, mood had effects on the LPC similar to tasks that require attention to emotional properties.

Late positive component

Results on the LPC clearly differed from those seen in the comprehension task study reported in Part 2, which was identical to the present study with exception of the mood induction procedure. First, in Part 2 the LPC effect was only seen to self-relevant stimuli, whereas in the present study self-relevance did not interact with the emotion effect on the LPC. Second, the effect in the present study began and peaked earlier than in Part 2. Third, in Part 2 the LPC was larger to emotional words than neutral words, but unpleasant and pleasant words did not differ whereas in the present study, the LPC was larger to unpleasant words than pleasant or neutral words. Notably, this is the same pattern of differences that was seen between the two studies reported in Part 2. That is, although the present study used the comprehension task described in Part 2, the results more closely resembled those seen in the production task study.

We argued that the differences between the comprehension and production task studies was due in part to the fact that the emotional properties of stimuli were task-relevant under the production task, but not the comprehension task. Previous studies have shown that tasks that draw attention to emotional properties of stimuli lead to earlier and larger effects of emotion (e.g., Fischler & Bradley, 2006; Holt et al., 2009). This stronger effect of emotion, in turn, may have eliminated the anchoring effect whereby the presence of self-relevant stimuli eliminated the effect of emotion for other-relevant stimuli (see further discussion in Part 2).

I believe the present results can be interpreted within the same general framework. The process of being shown emotional videos and being asked to adopt a particular mood likely made participants more aware that the study was in part about emotion. The affective state induced by the mood induction procedure likely also contributed to the emotional properties of stimuli being more salient. Thus, the present results suggest that *any* aspect of an experimental paradigm that makes the emotional properties of stimuli more salient and relevant to participants can have similar effects on the LPC.

Finally, it is interesting that both the production study and the present results showed a larger LPC to unpleasant than pleasant words, whereas the comprehension task study in Part 2 did not. Many researchers have argued for a “negativity bias”, the idea that negative emotion generally has stronger effects than positive emotion (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rozin & Royzman, 2001; Taylor, 1991). Although a number of ERP studies have shown this pattern, many others have not, and the present work is not the first to show that task and context can determine whether the negativity bias is observed. For example, using single words Delaney-Busch (2013) saw a negativity bias on the LPC when participants performed a valence categorization task but not a semantic task. However, Fischler and Bradley (2006) found a negativity bias with a semantic task, but not a valence categorization task, also with a single word paradigm. And Holt et al. (2009), in discourse scenarios similar to the present stimuli, found a negativity bias with both a valence categorization task and a semantic task. Thus, while it is clear that valence differences on the LPC are sensitive to context, it is not clear exactly how to characterize this sensitivity.

Open questions

A major question raised by our results is why there were no differences in the ERP results between the happy and sad mood groups. Although the mood induction procedure did modulate ERP effects as discussed above, this modulation was the same in both the happy and sad conditions. The fact that the mood induction procedure did have general effects on the ERPs, combined with the results of our manipulation checks, suggest that the null effects here cannot be attributed entirely to a failure of our procedure to induce moods at all. What then might account for the lack of differences between the mood conditions?

One possibility comes one of the major theoretical accounts of mood effects. Clore and colleagues’ (Clore & Huntsinger, 2007; Clore et al., 2001) affect-as-information hypothesis integrates both the effects of mood on judgment and processing styles into one theoretical framework. This account assumes that mood effects are largely the result of the misattribution of affect. We are often not fully aware of the source of a mood or affective experience, and ambiguous affective experiences are often attributed to whatever is most salient in the environment, whether this is the actual cause of the affect or not. In the case of effects on judgment, mood is misattributed directly to the object of judgment (leading to more positive judgments in happy moods and vice versa). In the case of mood effects on processing styles, it is assumed that affect is misattributed to cognitive processes. Generally speaking we would experience affect in response to successes and failures as we perform a task and this gives feedback as to whether out strategies are working or not. When mood from other sources is misattributed to cognitive processing, a happy mood leads to the assumption that current or default strategies are working, thus leading to greater reliance on heuristics, biases, schemas, etc., and sad mood has the opposite effect. As would be predicted by this framework, making participants aware of the source of their mood often eliminates mood effects of both types (reviewed in Clore & Huntsinger, 2007).

In the present study, participants were explicitly asked to use the mood induction videos to adopt a happy or sad mood. They were then reminded of this task via instructions on the screen before each block. This likely made participants particularly aware of the source of their mood, and thus may have eliminated the effects hypothesized in the Introduction. On the other hand, it is worth noting that previous ERP studies investigating mood effects have also explicitly asked participants to adopt a mood and were still able to find differences between mood conditions (Chwilla et al., 2011; Vissers et al., 2013; Vissers et al., 2010). These studies used film clips to induce mood, which previous work has generally shown to be the most effective mood induction procedure (Rottenberg, Ray, & Gross, 2007; Westermann, Spies, Stahl, & Hesse, 1996). We did not use this approach because it is more difficult to control film clips for factors such as arousal, length, lexical and semantic content, etc. However, it is possible that the more emotionally powerful film clips did not actually require subjects to put any effort into adopting a mood, in contrast to our procedure, leaving the source of their mood to be less salient despite the explicit instructions.

These explanations currently remain speculative. It is of course possible that we did not see effects of mood simply because the specific ERP effects we investigated are not sensitive to differences in sad versus happy mood. It would require further research to determine whether the lack of happy-sad differences in the present study are due to our mood induction procedure or are more general. Importantly, to the extent that our null effects are related to something specific to the mood induction procedure we used, the theoretical questions outlined in the Introduction remain open.

Summary and conclusions

The present study did not show differences in ERP results as a function of happy versus sad mood. The mood induction procedure nevertheless produced effects that differed from the same study with no mood induction, and these results were interesting. First, there was an anterior negativity that was reduced specifically for unpleasant words. The meaning of this effect is unclear on the basis of current data, but it shows some similarities to effects observed in other studies of emotional words (Delaney-Busch, 2013; Frost & Federmeier, 2012; Pratt & Kelly, 2008). Second, it appears that mood can have effects on the LPC similar to tasks that draw attention to emotional features of words: possibly because mood lead to increase salience for emotional features of words, the emotion effect on the LPC began and peaked earlier, a negativity bias was produced, and the emotion effect was present for both self-relevance conditions (as opposed to only the other-relevant condition as in the comprehension task study reported in Part 2). These results add to evidence of the context sensitivity and dynamic nature of the late positive component, which will be discussed further in the next section.

General Discussion

Taken together, the studies reported here show two broad, theoretically interesting results. First, we have shown an online effect of the self-positivity bias on the N400 component of the ERP. Second, we have shown that mood, task, self-relevance, and emotional properties of stimuli interact in complex ways to determine LPC amplitude. In this section, we discuss the general implications of these findings for theory and future research.

Self-positivity and the N400: Implications for social cognitive neuroscience

In Part 1, we found a robust effect of the self-positivity bias on the N400. However, the results of the production study in Part 2 and the mood induction study reported in Part 3 show that this effect is not observed in all contexts. Future research should further examine the conditions under which this effect, and other effects of social schemas (see below), can be observed on the N400.

To the extent that further research supports our paradigm as a useful measure of the self-concept, it may be helpful in determining how the self-positivity bias varies both within and between individuals and populations. In Study 1, our sample was a group of Western, largely white students at a private university, who were screened to exclude psychiatric disorders. These participants are probably particularly likely to show evidence of a self-positivity bias (Heine, Lehman, Markus, & Kitayama, 1999; Henrich, Heine, & Norenzayan, 2010). It is important to recognize, however, that a self-positivity bias may not be universal for all people at all times, and it will be important for follow-up studies to examine variability in self-positivity both within and between individuals and populations. For example, our paradigm may be useful for examining how the self-concept is altered in psychiatric disorders, including whether negative cognitions and attitudes about the self reflect implicit and relatively automatic effects or whether they result from effortful and elaborative rumination (Shestyuk & Deldin, 2010). It could be used to address debates in cultural psychology about whether a self-positivity bias is universal versus specific to Western cultures, which, for many of the same reasons discussed in this paper, current self-report and implicit measures have not been able to fully resolve (Heine, Kitayama, & Hamamura, 2007; Heine et al., 1999; Sedikides, Gaertner, & Toguchi, 2003; Sedikides, Gaertner, & Vevea, 2007; see also Kitayama & Park, 2010, 2014).

Our findings also have some more general methodological implications. Social psychologists have long sought methods to measure attitudes in ways that are not affected by social norms and impression management, and we are not the first to think that neurophysiological techniques (because they are a direct measure of mental activity not relying on a subject response) may be one way to do this. In some previous ERP work, researchers have attempted to use the LPC as such a measure (e.g., Crites et al., 1995). However, as we have seen, the LPC is highly sensitive to task and context, and generates less clear predictions for the effects of social schemas. The N400 is a relatively implicit neural measure of online comprehension, and it has now been shown to be sensitive to various types of social schemas and biases (e.g., gender stereotypes: White et al., 2009; moral beliefs: Van Berkum et al., 2009; and class and culture based differences in trait inference: Na & Kitayama, 2011; Varnum et al., 2012). The present study adds to this evidence by suggesting the N400 may also be sensitive to the self-positivity bias. Taken together, these studies suggest that ERPs and the N400 can prove a valuable addition to current implicit and explicit behavioral measures in the social psychologist's toolbox.

Dynamic context effects on the late positivity: Toward a functional theory of the LPC

Across three studies, we have observed a complex interaction of task, self-relevance, mood, and emotional properties of words on the amplitude of the LPC. Taken together, our results add to a growing body of data showing that we cannot use simple subtraction-based experimental designs to extract a full picture of how we process emotional stimuli. While previous work has suggested the LPC may reflect or be modulated directly by the emotional properties of stimuli (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Olofsson et al., 2008), it is now clear that there is no one-to-one relationship between the emotional properties of a stimulus (valence, arousal, etc.) and LPC amplitude. Nor can we state categorically that emotional, self-relevant, or ambiguous stimuli invariably capture attention and evoke an LPC. Rather, it is becoming clear that the cognitive process reflected by the LPC is highly dynamic and is modulated by several interacting factors.

In this work, we have discussed the potential influence of five such factors: 1) the "inherent" emotional salience of the stimulus itself (a function of enduring biological and social motivations), 2) the immediate context in which a particular incoming stimulus is encountered (in the present work, the self-relevance of the discourse social vignettes), 3) the wider overall experimental context (in the present work, the influence of self-relevant stimuli on emotion effects in non-self-relevant stimuli; see also Fogel et al., 2012; Schindler et al., 2014), 4) the situation-specific goals provided by a particular task, and 5) the psychological state of the perceiver (in the present work, mood). Importantly, none of these five factors is either sufficient or necessary to evoke an LPC effect; rather, we suggest that they act in combination to influence its amplitude.

These observations support the idea that the emotional LPC is related to the P300, which, as discussed previously, is evoked by affectively neutral stimuli when they are surprising or task-relevant (Donchin, 1981; Polich, 2012), and that is also dynamically influenced by task relevance and overall context. While links between the emotional LPC and P300 have often been noted (e.g., Hajcak et al., 2012), the functional relationship between these components has not been a topic of direct investigation or in-depth theoretical discussion. One possibility is that the LPC and the P300 share common underlying neuroanatomical sources. Because of their poor spatial resolution, ERPs alone cannot address this question. What we do suggest, however, is that the emotional LPC and the P300 may share a common underlying computational mechanism.

The major functional theory of the P300 is Donchin and colleagues' context updating account (Donchin, 1981; Donchin & Coles, 1988). This theory suggests that the P300 is related to building accurate and useful models of a given context. Clearly at any given time we must have some model or schema or our current environment. This model allows us to predict what is likely to happen, which actions are strategic for pursuing our goals, etc. Since our environment constantly changes, often in ways that are not fully predictable, we must make use of incoming sensory information to update our model. The context updating account of the P300 asserts "that the P300 is elicited by processes associated with the maintenance of our model of the context of the environment" (Donchin & Coles, 1988, p. 370). Unexpected events elicit context updating because they provide more information than expected events and act as signals that our environment may be different than we thought it was. Task relevance modulates this effect because our model of the environment is tailored to our goals and motivations—that is, processing resources and memory are limited, and we are trying to build a model of the environment that helps to achieve our goals in whatever task we have.

It is intuitive that emotional stimuli might also be associated with this sort of context updating process. First, emotions are often elicited by events that are surprising: events that are better than expected elicit positive emotions while events that are worse than expected elicit negative emotions. Second, in a complex and noisy environment, emotions act as "relevance detectors" (Frijda, 1986), telling us what information is relevant to our goals and motivations and thus which information is most important to integrate into our context model. Thus, whereas the P300 is often said to be modulated by "task relevance", perhaps it is more accurate to say that context updating is modulated more broadly by "motivational relevance", a factor that has often been associated with the emotional LPC and which would subsume task relevance as one component.

If this way of thinking about the LPC is correct, it suggests that the empirical and theoretical literature on the P300 may provide insights into building a functional theory of the LPC. Future research should further investigate similarities between these components and the extent to which the LPC is modulated by factors that are known to modulate the P300 (e.g., Johnson, 1988). This account may also help link the emotional literature to the increasingly influential literature on Bayesian models of cognition, which is also fundamentally concerned with the way in which incoming stimuli are used to update internal models that improve predictions of future events (Clark, 2013; Conrad, Recio, & Jacobs, 2011; Friston, 2005; Huang & Rao, 2011; Perfors, Tenenbaum, Griffiths, & Xu, 2011). This approach could lead to computational models of the LPC, which could aid in understanding both the factors that elicit an LPC and the functional correlates of the LPC. It also may help to integrate our understanding of the LPC with other ERP components (including the P300) that have also been interpreted within a Bayesian predictive coding account of neural functioning (Feldman & Friston, 2010; Friston, 2005; Garrido, Kilner, Stephan, & Friston, 2009; Kopp, 2008; Kuperberg, 2013, In press; Wacongne et al., 2011; Yu & Dayan, 2005).

References

Alicke, M. D., & Govorun, O. (2005). The better-than-average effect. In M. D. Alicke, D. Dunning & J. Krueger (Eds.), *The Self and Social Judgement* (pp. 85-106). New York: Psychology Press.

Alicke, M. D., Klotz, M. L., Breitenbecher, D. L., Yurak, T. J., & Vredenburg, D. S. (1995). Personal contact, individuation, and the better-than-average effect. *Journal of Personality and Social Psychology, 68*(5), 804-825.

Anderson, A. K. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General, 134*(2), 258-281.

Armor, D. A., & Taylor, S. E. (2002). When predictions fail: The dilemma of unrealistic optimism In T. Gilovich, D. Griffin & D. Kahneman (Eds.), *Heuristics and Biases: The Psychology of Intuitive Judgement* (pp. 334-347). New York: Cambridge University Press.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., et al. (2007). The English Lexicon Project. *Behavior Research Methods, 39*(3), 445-459.

Bargh, J. A., & Tota, M. E. (1988). Context-dependent automatic processing in depression: Accessibility of negative constructs with regard to self but not others. *Journal of Personality and Social Psychology, 54*(6), 925-939.

Bartholow, B. D., Fabiani, M., Gratton, G., & Bettencourt, B. A. (2001). A psychophysiological examination of cognitive processing of and affective responses to social expectancy violations. *Psychological Science, 12*(3), 197-204.

Bartholow, B. D., Pearson, M. A., Gratton, G., & Fabiani, M. (2003). Effects of alcohol on person perception: A social cognitive neuroscience approach. *Journal of Personality and Social Psychology, 85*(4), 627-638.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5*(4), 323-370.

Bayer, M., Sommer, W., & Schact, A. (2010). Reading emotional words within sentences: The impact of arousal and valence on event-related potentials. *International Journal of Psychophysiology, 78*, 299-307.

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

Blackburn, I. M., & Eunson, K. M. (1989). A content analysis of thoughts and emotions elicited from depressed patients during cognitive therapy. *British Journal of Medical Psychology, 62*(1), 23-33.

Bless, H., Schwarz, N., Clore, G. L., Golisano, V., & Rabe, C. (1996). Mood and the use of scripts: Does a happy mood really lead to mindlessness? *Journal of Personality and Social Psychology, 71*(4), 665-679.

Bodenhausen, G. V. (1993). Emotions, arousal, and stereotypic judgments: A heuristic model of affect and stereotyping. In D. M. Mackie & D. L. Hamilton (Eds.), *Affect, Cognition, and Stereotyping: Interactive Processes in Group Perception* (pp. 13-37). San Diego, CA: Academic Press.

Bodenhausen, G. V., Kramer, G. P., & Susser, K. (1994). Happiness and stereotypic thinking in social judgment. *Journal of Personality and Social Psychology, 66*(4), 621-632.

Bradley, B. P., & Matthews, P. (1983). Negative self-schemata in clinical depression. *British Journal of Clinical Psychology 22*, 173-181.

Brown, J. D., & Mankowski, T. A. (1993). Self-esteem, mood, and self-evaluation: Changes in mood and the way you see you. *Journal of Personality and Social Psychology, 64*(3), 421-430.

Brunyé, T. T., Ditman, T., Mahoney, C. R., Augustyn, J. S., & Taylor, H. A. (2009). When you and I share perspectives: Pronouns modulate perspective taking during narrative comprehension. *Psychological Science, 20*(1), 27-32.

Brunyé, T. T., Ditman, T., Mahoney, C. R., & Taylor, H. A. (2011). Better you than I: Perspectives and emotion simulation during narrative comprehension. *Journal of Cognitive Psychology, 23*(5), 659-666.

Buhrmester, M. D., Blanton, H., & Swann, W. B., Jr. (2011). Implicit self-esteem: Nature, measurement, and a new way forward. *Journal of Personality and Social Psychology, 100*(2), 365-385.

Cacioppo, J. T., Bush, L. K., & Tassinary, L. G. (1992). Microexpressive facial actions as a function of affective stimuli: Replication and extension. *Personality and Social Psychology Bulletin, 18*(5), 515-526.

Calvo, M. G., & Lang, P. J. (2004). Gaze patterns when looking at emotional pictures: Motivationally biased attention. *Motivation and Emotion, 28*(3), 221-243.

Chambers, J. R., & Windschitl, P. D. (2004). Biases in social comparative judgments: The role of nonmotivated factors in above-average and comparative-optimism effects. *Psychological Bulletin, 130*(5), 813-838.

Chung, G., Tucker, D. M., West, P., Potts, G. F., Liotti, M., Luu, P., et al. (1996). Emotional expectancy: Brain electrical activity associated with an emotional bias in interpreting life events. *Psychophysiology, 33*(3), 218-233.

Chwilla, D. J., Virgillito, D., & Vissers, C. T. W. M. (2011). The relationship of language and emotion: N400 support for an embodied view of language comprehension. *Journal of Cognitive Neuroscience, 23*(9), 2400-2414.

Citron, F. M. M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language, 122*(3), 211-226.

Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and Brain Sciences, 36*(3), 181-204.

Clore, G. L., & Huntsinger, J. R. (2007). How emotions inform judgment and regulate thought. *Trends in Cognitive Sciences, 11*(9), 393-399.

Clore, G. L., Wyer, R. S., Jr., Dienes, B., Gasper, K., Gohm, C., & Isbell, L. (2001). Affective feelings as feedback: Some cognitive consequences. In L. L. Martin & G. L. Clore (Eds.), *Theories of Mood and Cognition: A User's Guidbook* (pp. 63-84). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Compton, R. J. (2003). The interface between emotion and attention: A review of evidence from psychology and neuroscience. *Behavioral and Cognitive Neuroscience Reviews, 2*(2), 115-129.

Conrad, M., Recio, G., & Jacobs, A. M. (2011). The time course of emotion effects in first and second language processing: a cross cultural ERP study with German-Spanish bilinguals. *Frontiers in Psychology, 2*(351).

Crites, S. L., Cacioppo, J. T., Gardner, W. L., & Bernston, G. G. (1995). Biolectrical echoes from evaluative categorization: II. A late positive brain potentail that varies as function of attitude registration rather than attitude report. *Journal of Personality and Social Psychology, 68*(6), 997-1013.

Cross, P. (1977). Not can but will college teachers be improved. *New Directions for Higher Education, 17*, 1-15.

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52*(2), 95-111.

Delaney-Busch, N. (2013). *The processing of emotional features in single and primed words* (Master's Thesis). Tufts University, Medford, MA.

Delaney-Busch, N., & Kuperberg, G. R. (2013). Friendly drug-dealers and terrifying puppies: Affective primacy can attenuate the N400 effect in emotional discourse contexts. *Cognitive Affective & Behavioral Neuroscience, 13*(3), 473-490.

Delaney-Busch, N., Wilkie, G., Kim, J. H., Yacoubian, A., & Kuperberg, G. R. (2012). *Valence evaluations override innate salience of high-arousal words: The late positivitiy as a dynamic measure of emotional salience*. Poster presented at the 19th Annual Meeting of the Cognitive Neuroscience Society, Chicago, IL.

Delplanque, S., Silvert, L., Hot, P., Rigoulot, S., & Sequeira, H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology, 60*(3), 315-322.

Donchin, E. (1981). Surprise! . . . Surprise? *Psychophysiology, 18*(5), 493-513.

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*(3), 357-374.

Dunning, D., Heath, C., & Suls, J. M. (2004). Flawed self-assessment: Implications for health, education, and the workplace. *Psychological Science in the Public Interest, 5*(3), 69-106.

Egidi, G., & Nusbaum, H. C. (2012). Emotional language processing: How mood affects integration processes during discourse comprehension. *Brain and Language, 122*(3), 199-210.

Farnham, S. D., Greenwald, A. G., & Banaji, M. R. (1999). Implicit self-esteem. In D. Abrams & M. A. Hogg (Eds.), *Social Identity and Social Cognition* (pp. 230-248). London: Blackwell Publishing.

Fazio, R. H., & Olson, M. A. (2003). Implicit measures in social cognition research: Their meaning and use. *Annual Review of Psychology, 54*, 297-327.

Federmeier, K. D., Kirson, D. A., Moreno, E. M., & Kutas, M. (2001). Effects of transient, mild mood states on semantic memory organization and use: An event-related potential investigation in humans. *Neuroscience Letters, 305*(3), 149-152.

Federmeier, K. D., & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language, 41*(4), 469-495.

Federmeier, K. D., & Laszlo, S. (2009). Time for meaning: Electrophysiology provides insights into the dynamics of representation and processing in semantic memory. *Psychology of Learning and Motivation, 51*, 1-44.

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

Feldman, H., & Friston, K. J. (2010). Attention, uncertainty, and free-energy. *Frontiers in Human Neuroscience, 4*.

Fields, E. C., & Kuperberg, G. R. (2012). It's all about you: An ERP study of emotion and self-relevance in discourse. *NeuroImage, 62*(1), 562-574.

Fields, E. C., & Kuperberg, G. R. (In press). Loving yourself more than your neighbor: ERPs reveal online effects of a self-positivity bias. *Social Cognitive and Affective Neuroscience*.

Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: Words, phrases, and task effects. *Progress in Brain Research, 156*, 185-203.

Fogel, A. R., Midgley, K. J., Delaney-Busch, N., & Holcomb, P. J. (2012). F#©K! Processing emotion and taboo in a native versus a second language: An ERP study. *Psychophysiology, 49*(Suppl. 1), S41.

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology, 46*(3), 521-530.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology-General, 130*(4), 681-700.

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23*(5), 567-589.

Frijda, N. H. (1986). *The Emotions*. New York: Cambridge University Press.

Friston, K. J. (2005). A theory of cortical responses. *Philosophical Transactions of the Royal Society B: Biological Sciences, 360*(1456), 815-836.

Frost, D. J., & Federmeier, K. D. (2012). *Event-related brain potentials of semantic access and memory for emotional language*. Poster presented at the 19th Annual Meeting of the Cognitive Neuroscience Society, Chicago, IL.

Garrido, M. I., Kilner, J. M., Stephan, K. E., & Friston, K. J. (2009). The mismatch negativity: A review of underlying mechanisms. *Clinical Neurophysiology, 120*(3), 453-463.

Goldin, P. R., Jazaieri, H., Ziv, M., Kraemer, H., Heimberg, R. G., & Gross, J. J. (2013). Changes in positive self-views mediate the effect of cognitive-behavioral therapy for social anxiety disorder. *Clinical Psychological Science, 1*(3), 301-310.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*(2), 95-112.

Greenwald, A. G., & Farnham, S. D. (2000). Using the Implicit Association Test to measure self-esteem and self-concept. *Journal of Personality and Social Psychology, 79*(6), 1022-1038.

Gu, R. L., Ge, Y., Jiang, Y., & Luo, Y. J. (2010). Anxiety and outcome evaluation: The good, the bad and the ambiguous. *Biological Psychology, 85*(2), 200-206.

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: An integrative review. *Developmental Neuropsychology, 35*(2), 129-155.

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2012). ERPs and the study of emotion. In S. J. Luck & E. S. Kappenman (Eds.), *The Oxford Handbook of Event-Related Potential Components* (pp. 441-474). New York: Oxford University Press.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences, 5*(9), 394-400.

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917-924.

Hanze, M., & Hesse, F. W. (1993). Emotional influences on semantic priming. *Cognition & Emotion, 7*(2), 195-205.

Heine, S. J., Kitayama, S., & Hamamura, T. (2007). Which studies test whether self-enhancement is pancultural? Reply to Sedikides, Gaertner, and Vevea, 2007. *Asian Journal of Social Psychology, 10*(3), 198-200.

Heine, S. J., Lehman, D. R., Markus, H. R., & Kitayama, S. (1999). Is there a universal need for positive self-regard? *Psychological Review, 106*(4), 766-794.

Helweg-Larsen, M., & Shepperd, J. A. (2001). Do moderators of the optimistic bias affect personal or target risk estimates? A review of the literature. *Personality and Social Psychology Review, 5*(1), 74-95.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences, 33*(2-3), 61-83.

Herbert, C., Herbert, B. M., Ethofer, T., & Pauli, P. (2011). His or mine? The time course of self-other discrimination in emotion processing. *Social Neuroscience, 6*(3), 277-288.

Herbert, C., Pauli, P., & Herbert, B. M. (2011). Self-reference modulates the processing of emotional stimuli in the absence of explicit self-referential appraisal instructions. *Social Cognitive and Affective Neuroscience, 6*(5), 653-661.

Hirsh, J. B., & Inzlicht, M. (2008). The devil you know: Neuroticism predicts neural response to uncertainty. *Psychological Science, 19*(10), 962-967.

Holcomb, P. J., Kounios, J., Anderson, J. E., & West, W. C. (1999). Dual-coding, context-availability, and concreteness effects in sentence comprehension: An electrophysiological investigation. *Journal of Experimental Psychology: Learning Memory and Cognition, 25*(3), 721-742.

Holt, D. J., Lynn, S. K., & Kuperberg, G. R. (2009). Neurophysiological correlates of comprehending emotional meaning in context. *Journal of Cognitive Neuroscience, 21*(11), 2245-2262.

Huang, Y. P., & Rao, R. P. N. (2011). Predictive coding. *Wiley Interdisciplinary Reviews: Cognitive Science, 2*(5), 580-593.

Isbell, L. M. (2004). Not all happy people are lazy or stupid: Evidence of systematic processing in happy moods. *Journal of Experimental Social Psychology, 40*(3), 341-349.

Johnson, R., Jr. (1988). The amplitude of the P300 component of the event-related potential: Review and synthesis. In P. K. Ackles, J. R. Jennings & M. G. H. Coles (Eds.), *Advances in Psychophysiology*: JAI Press.

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research, 1148*, 138-148.

Kissler, J., Assadollahi, R., & Herbert, C. (2006). Emotional and semantic networks in visual word processing: Insights from ERP studies. *Progress in Brain Research, 156*, 147-183.

Kitayama, S., & Park, J. (2010). Cultural neuroscience of the self: Understanding the social grounding of the brain. *Social Cognitive and Affective Neuroscience, 5*(2-3), 111-129.

Kitayama, S., & Park, J. (2014). Error-related brain activity reveals self-centric motivation: Culture matters. *Journal of Experimental Psychology: General, 143*(1), 62-70.

Koole, S. L., & Pelham, B. W. (2003). On the nature of implicit self-esteem: The case of the name letter effect. In S. Spencer, S. Fein & M. P. Zanna (Eds.), *Motivated Social Perception: The Ontario Symposium* (Vol. 9, pp. 93-116). Mahwah, NJ: Erlbaum.

Kopp, B. (2008). The P300 component of the event-related brain potential and Bayes' theorem. In M. Sun (Ed.), *Cognitive Sciences at the Leading Edge*. New York: Nova Science Publishers.

Kuiper, N. A., & Derry, P. A. (1982). Depressed and nondepressed content self-reference in mild depressives. *Journal of Personality, 50*(1), 67-80.

Kuperberg, G. R. (2013). The proactive comprehender: What event-related potentials tell us about the dynamics of reading comprehension. In B. Miller, L. Cutting & P. McCardle (Eds.), *Unraveling Reading Comprehension: Behavioral, Neurobiological, and Genetic Components*. Baltimore, MD: Paul H Brookes Publishing.

Kuperberg, G. R. (In press). What event-related potentials tell us about predictive coding in language comprehension: A commentary on Rabovsky & McRae, "Simulating the N400 ERP component as a semantic error network: Insights from a feature-based connectionist attractor model of word meaning". *Cognition*.

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

Laney, C., Campbell, H. V., Heuer, F., & Reisberg, D. (2004). Memory for thematically arousing events. *Memory & Cognition, 32*(7), 1149-1159.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8.* Unpublished manuscript, University of Florida, Gainesville, FL.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*(3), 261-273.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology, 40*(5), 776-785.

Lau, E. F., Holcomb, P. J., & Kuperberg, G. R. (2013). Dissociating N400 effects of prediction from association in single-word contexts. *Journal of Cognitive Neuroscience, 25*(3), 484-502.

Lee, C. L., & Federmeier, K. D. (2008). To watch, to see, and to differ: An event-related potential study of concreteness effects as a function of word class and lexical ambiguity. *Brain and Language, 104*(2), 145-158.

Leon, I., Diaz, J. M., de Vega, M., & Hernandez, J. A. (2010). Discourse-based emotional consistency modulates early and middle components of event-related potentials. *Emotion, 10*(6), 863-873.

Li, W., & Han, S. (2010). Perspective taking modulates event-related potentials to perceived pain. *Neuroscience Letters, 469*(3), 328-332.

Luck, S. J. (2014). *An Introduction to the Event-Related Potential Technique* (2nd ed.). Cambridge, MA: The MIT Press.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods: Instruments & Computers, 28*(2), 203-208.

MacNamara, A., Foti, D., & Hajcak, G. (2009). Tell me about it: Neural activity elicited by emotional pictures and preceding descriptions. *Emotion, 9*(4), 531-543.

Markus, H., & Kunda, Z. (1986). Stability and malleability of the self-concept. *Journal of Personality and Social Psychology, 51*(4), 858-866.

Martin, L. L., & Clore, G. L. (Eds.). (2001). *Theories of Mood and Cognition: A User's Guidebook*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6*(2), 114-133.

Mayer, J. D., & Gaschke, Y. N. (1988). The experience and meta-experience of mood. *Journal of Personality and Social Psychology, 55*(1), 102-111.

Moretti, M. M., Segal, Z. V., McCann, C. D., & Shaw, B. F. (1996). Self-referent versus other-referent information processing in dysphoric, clinically depressed, and remitted depressed subjects. *Personality and Social Psychology Bulletin, 22*, 68-80.

Na, J. Y., & Kitayama, S. (2011). Spontaneous trait inference is culture-specific: Behavioral and neural evidence. *Psychological Science, 22*(8), 1025-1032.

Naumann, E., Maier, S., Diedrich, O., Becker, G., & Bartussek, D. (1997). Structural, semantic, and emotion-focussed processing of neutral and negative nouns: Event-related potential correlates. *Journal of Psychophysiology, 11*(2), 158-172.

Nummenmaa, L., Hyona, J., & Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion, 6*(2), 257-268.

Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*(3), 466-478.

Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381-396.

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77*(3), 247-265.

Olson, M. A., Fazio, R. H., & Hermann, A. D. (2007). Reporting tendencies underlie discrepancies between implicit and explicit measures of self-esteem. *Psychological Science, 18*(4), 287-291.

Paczynski, M., & Kuperberg, G. R. (2012). Multiple influences of semantic memory on sentence processing: Distinct effects of semantic relatedness on violations of real-world event/state knowledge and animacy selection restrictions. *Journal of Memory and Language, 67*(4), 426-448.

Paolacci, G., & Chandler, J. (2014). Inside the Turk: Understanding Mechanical Turk as a participant pool. *Current Directions in Psychological Science, 23*(3), 184-188.

Paulhus, D. L. (1993). Bypassing the will: The automatization of affirmations. In D. M. Wegner & J. W. Pennebaker (Eds.), *Handbook of Mental Control* (pp. 573-587). Hillsdale, NJ: Psychology Press.

Paulhus, D. L. (2002). Socially desirable responding: The evolution of a construct. In H. I. Braun, D. N. Jackson & D. E. Wiley (Eds.), *The Role of Constructs in Psychological and Educational Measurement* (pp. 49-69). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Perfors, A., Tenenbaum, J. B., Griffiths, T. L., & Xu, F. (2011). A tutorial introduction to Bayesian models of cognitive development. *Cognition, 120*(3), 302-321.

Polich, J. (2012). Neuropsychology of P300. In S. J. Luck & E. S. Kappenman (Eds.), *The Oxford Handbook of Event-Related Potential Components* (pp. 159-188). New York: Oxford University Press.

Pratt, N. L., & Kelly, S. D. (2008). Emotional states influence the neural processing of affective language. *Social Neuroscience, 3*(3-4), 434-442.

Rottenberg, J., Ray, R. R., & Gross, J. J. (2007). Emotion elicitation using films. In J. A. Coan & J. J. B. Allen (Eds.), *The handbook of emotion elicitation and assessment*. New York: Oxford University Press.

Rozin, P., & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review, 5*(4), 296-320.

Schindler, S., Wegrzyn, M., Steppacher, I., & Kissler, J. (2014). Its all in your head: How anticipating evaluation affects the processing of emotional trait adjectives. *Frontiers in Psychology, 5*(1292), 1-10.

Schupp, H. T., Stockburger, J., Codispoti, M., Junghofer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *Journal of Neuroscience, 27*(5), 1082-1089.

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45*(3), 513-523.

Sears, D. O. (1983). The person-positivity bias. *Journal of Personality and Social Psychology, 44*(2), 233-250.

Sedikides, C., Gaertner, L., & Toguchi, Y. (2003). Pancultural self-enhancement. *Journal of Personality and Social Psychology, 84*(1), 60-79.

Sedikides, C., Gaertner, L., & Vevea, J. L. (2007). Evaluating the evidence for pancultural self-enhancement. *Asian Journal of Social Psychology, 10*(3), 201-203.

Shestyuk, A. Y., & Deldin, P. J. (2010). Automatic and strategic representation of the self in major depression: Trait and state abnormalities. *American Journal of Psychiatry, 167*(5), 536-544.

Sitnikova, T., Kuperberg, G., & Holcomb, P. J. (2003). Semantic integration in videos of real-world events: An electrophysiological investigation. *Psychophysiology, 40*(1), 160-164.

Sokolov, E. N., Spinks, J. A., Näätänen, R., & Lyytinen, H. (2002). *The Orienting Response in Information Processing*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Stormark, K. M., Nordby, H., & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioral and ERP data. *Cognition & Emotion, 9*(5), 507-523.

Swaab, T. Y., Baynes, K., & Knight, R. T. (2002). Separable effects of priming and imageability on word processing: An ERP study. *Cognitive Brain Research, 15*(1), 99-103.

Swaab, T. Y., Ledoux, K., Camblin, C. C., & Boudewyn, M. A. (2012). Language-related ERP components. In S. J. Luck & E. S. Kappenman (Eds.), *The Oxford Handbook of Event-Related Potential Components*. New York: Oxford University Press.

Swann, W. B., Jr. (2011). Self-verification theory. In P. A. M. V. Lange, A. W. Kruglanski & E. T. Higgins (Eds.), *Handbook of Theories of Social Psychology* (Vol. 2, pp. 23-42). Thousands Oak, CA: SAGE Publications.

Swann, W. B., Jr., & Bosson, J. (2010). Self and identity. In S. T. Fiske, D. T. Gilbert & G. Lindzey (Eds.), *Handbook of Social Psychology* (5th ed., pp. 589-628). New York: McGraw Hill.

Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization minimization hypothesis. *Psychological Bulletin, 110*(1), 67-85.

Taylor, S. E., & Brown, J. D. (1988). Illusion and well-being: A social psychological perspective on mental health. *Psychological Bulletin, 103*(2), 193-210.

Tritt, S. M., Peterson, J. B., & Inzlicht, M. (2012). *The uncertainty bias: Brain evidence that ambiguity is more captivating than threat or reward*. Poster presented at the Annual Meeting of the Social and Affective Neuroscience Society, New York, NY.

Van Berkum, J. J. A., De Goede, D., Van Alphen, P. M., Mulder, E. R., & Kerstholt, J. H. (2013). How robust is the language architecture? The case of mood. *Frontiers in Psychology, 4*.

Van Berkum, J. J. A., Holleman, B., Nieuwland, M., Otten, M., & Murre, J. (2009). Right or wrong? The brain's fast response to morally objectionable statements. *Psychological Science, 20*(9), 1092-1099.

Van Duynslaeger, M., Sterken, C., Van Overwalle, F., & Verstraeten, E. (2008). EEG components of spontaneous trait inferences. *Social Neuroscience, 3*(2), 164-177.

Van Duynslaeger, M., Van Overwalle, F., & Verstraeten, E. (2007). Electrophysiological time course and brain areas of spontaneous and intentional trait inferences. *Social Cognitive and Affective Neuroscience, 2*(3), 174-188.

Van Overwalle, F., Van den Eede, S., Baetens, K., & Vandekerckhove, M. (2009). Trait inferences in goal-directed behavior: ERP timing and localization under spontaneous and intentional processing. *Social Cognitive and Affective Neuroscience, 4*(2), 177-190.

Varnum, M. E. W., Na, J. Y., Murata, A., & Kitayama, S. (2012). Social class differences in N400 indicate differences in spontaneous trait inference. *Journal of Experimental Psychology: General, 141*(3), 518-526.

Vissers, C. T. W. M., Chwilla, U. G., Egger, J. I. M., & Chwilla, D. J. (2013). The interplay between mood and language comprehension: Evidence from P600 to semantic reversal anomalies. *Neuropsychologia, 51*(6), 1027-1039.

Vissers, C. T. W. M., Virgillito, D., Fitzgerald, D. A., Speckens, A. E. M., Tendolkar, I., van Oostrom, I., et al. (2010). The influence of mood on the processing of syntactic anomalies: Evidence from P600. *Neuropsychologia, 48*(12), 3521-3531.

Wacongne, C., Labyt, E., van Wassenhove, V., Bekinschtein, T., Naccache, L., & Dehaene, S. (2011). Evidence for a hierarchy of predictions and prediction errors in human cortex. *Proceedings of the National Academy of Sciences, 108*(51), 20754-20759.

Wang, C. E., Brennen, T., & Holte, A. (2006). Automatic and effortful processing of self-statements in depression. *Cognitive Behavioral Therapy, 35*, 117-124.

Watson, L. A., Dritschel, B., Obonsawin, M. C., & Jentzsch, I. (2007). Seeing yourself in a positive light: Brain correlates of the self-positivity bias. *Brain Research, 1152*, 106-110.

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Cognitive Brain Research, 13*(3), 363-375.

Westermann, R., Spies, K., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology, 26*(4), 557-580.

White, K. R., Crites, S. L., Jr., Taylor, J. H., & Corral, G. (2009). Wait, what? Assessing stereotype incongruities using the N400 ERP component. *Social Cognitive and Affective Neuroscience, 4*(2), 191-198.

Yu, A. J., & Dayan, P. (2005). Uncertainty, neuromodulation, and attention. *Neuron, 46*(4), 681-692.