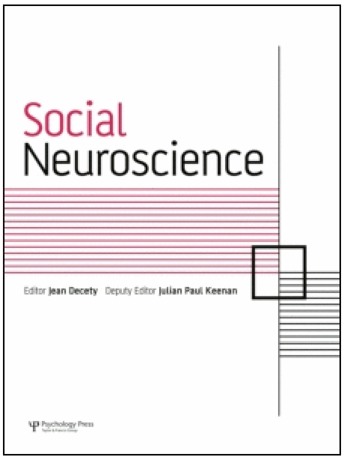

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Emotional states influence the neural processing of affective language

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Emotional states influence the neural processing of affective language

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The present study investigated whether emotional states influence the neural processing of language. Event-related potentials recorded the brain's response to positively and negatively valenced words (e.g., love vs. death) while participants were directly induced into positive and negative moods. ERP electrodes in frontal scalp regions of the brain distinguished positive and negative words around 400 ms poststimulus. The amplitude of this negative waveform showed a larger negativity for positive words compared to negative words in the frontal electrode region when participants were in a positive, but not negative, mood. These findings build on previous research by demonstrating that people process affective language differently when in positive and negative moods, and lend support to recent views that emotion and cognition interact during language comprehension.

INTRODUCTION

Recent studies in emotion and cognition suggest that changes in emotion may subsequently alter the neurocognitive processing (Atchley, Ilardi & Enloe, 2003; Chung et al., 1996; Compton, 2003; Lang et al., 1998; Schupp et al., 2006; Vuilleumier, Armony, & Dolan, 2003). Positive and negative stimuli mediate cognition through subjective evaluation of the motivational relevance of incoming stimuli (Compton, 2003). Assessing the significance of stimuli, therefore, rests on current mood states as associated with motivation and goals. The current study investigates how mood may modify the neural processing involved in viewing positive or negative words.

Recent theories of embodied cognition claim that high-level cognitive processes are deeply rooted in the body (Barsalou, 1999; Damasio, 1999; Decety & Grezes, 2006; Dolan, 2002; Glenberg & Kaschak, 2002; Tucker, 2001). These theories view cognition not as a detached processor of abstract and arbitrary symbols, but rather as an embedded process grounded in meaningful physical experiences gathered through perception and action. Previous research supports an embodied-cognition view of mood and language processing (Atchley et al., 2003; Barsalou, 1999; Glenberg & Kaschak, 2002; Glenberg, Havas, Becker, & Rinck, 2005). Behavioral evidence suggests that subjective emotional states influence language comprehension. For example, Glenberg and colleagues induced positive or negative moods in participants and then asked them to respond to positive and negative sentences (Glenberg et al., 2005). Participants

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were faster to comprehend the sentences when their mood was congruent versus incongruent with the meaning of the sentences.

Previously, researchers indicated that lexical representations are mediated by current motivations and underlying mood (Kissler, Assadollahi & Herbert, 2006). Emotional states enhance certain cortical connections representing lexical knowledge (Kissler et al., 2006). Insight from neuroscience reveals the prefrontal cortex (PFC) assesses stimuli with regard to subjective appraisal and motivation (Bechara, Tranel, Damasio & Damasio, 1996; Luu, Collins, & Tucker, 2000). The incoming information is assessed by current drives and motivation. Top-down processing, initiated in the PFC, mediates attention and cognition by evaluating emotional relevance (Mayberg, 1997; Taylor & Fragopanagos, 2005).

Evidence from event-related potentials (ERPs) suggests that positive and negative linguistic stimuli are differentiated around 400 ms (Dietrich et al., 2001; Dillon, Cooper, Grent-'t-Jong, Woldorff, & LaBar, 2006; Schupp, Junghofer, Weike, & Hamm, 2003). In assessing the significance of emotional words, Schapkin, Gusev, & Kuhl (2000) found that positive words compared to negative words produced a larger component at approximately 400 ms. Other researchers note changes in the brain response in a similar time window when emotional words are encoded (Dietrich et al., 2001; Dillon et al., 2006). Around 450 to 700 ms, emotional words (both positive and negative) produced larger effects in the frontal region compared to encoding neutral words (Dietrich et al., 2001; Dillon et al., 2006). These findings suggest that forming decisions about the affective valence of emotional words engages rather slow-developing (late ERP components) cognitive processes in the frontal region.

Because language is a pervasive and effective tool for expressing and comprehending emotional meaning, it is possible that the comprehension of emotionally valenced language recruits or activates brain areas involved in the actual physical experience of emotion. Electrophysiological research on the interaction of mood and language has demonstrated that certain ERP components reflect the processing of emotional information while in an emotional state (Chung et al., 1996; Dietrich et al., 2001; Federmeier, Kirson, Moreno & Kutas, 2001). In one study, Chung et al. (1996) placed participants in a positive or negative mood and then presented emotional passages of real-life events. ERPs recorded brain responses to the final word of the text revealing the emotional meaning of the passage. The relevant result in that study was that participants in a negative mood showed larger amplitude changes in the N400 to passages with a mood-incongruent—in this case, positive—ending. This suggests that current mood states influence high-level language processing and provides preliminary evidence supporting Glenberg et al.'s (2005) embodiment view for the interaction of mood and language processing.

Building on previous research in emotion and language processing (Chung et al., 1996; Schapkin et al., 2000), the present study investigates how a more *direct* mood induction affects emotional word processing. Specifically, whereas previous research required participants to "imagine" being in a specific mood state (Chung et al., 1996; Damasio et al., 2000; Esslen et al., 2004), the present study used feedback based on an appraisal of the participants' mental ability and psychological state, to directly induce changes in current mood state. Providing participants with positive and negative feedback has previously been shown to alter mood and interfere with performance (Anshel, 1988), and previous research indicates that using feedback to alter an emotional state is a more effective and ecologically valid way to induce mood than indirect methods (Nummenmaa & Niemi, 2004).

The current study examined the neural underpinnings of emotionally valenced language while participants were induced in different mood states. The hypotheses were structured around examining differential processing of positive or negative words in congruent or incongruent mood states. Based on previous findings with emotional language, we predicted that mood-congruent stimuli will produce an enhanced effect around 400 ms in the frontal regions (Chung et al., 1996; Dietrich et al., 2001; Federmeier et al., 2001). Specifically, we predicted that a positive mood will enhance the processing of positive words, and a negative mood will enhance the processing of negative words.

METHODS

Participants

Thirteen right-handed, Caucasian college undergraduates (5 males, 8 females; mean age: 20) participated for course credit. All participants had normal or corrected-to-normal vision. Prior to testing, each participant signed an informed consent approved by the university's Institutional Review Board.

Materials

The word stimuli were selected from a list of emotionally valenced nouns used in previous research (Rubin & Friendly, 1984). In a stimulus norming session, a small group of undergraduates ($n=8$), not included in the ERP testing session, rescaled the selected words by ranking them according to how positive and negative they were. In addition, they rated the words on a 7-point scale (1 being the least emotionally charged, 7 the most). From this norming session, we selected the 20 words with the most extreme emotional valance (10 positive and 10 negative words). The words were then placed into the MRC Psycholinguistic Database: Machine Usable Dictionary: Version 2.00 (Wilson, 1987). Independent samples *t*-tests found that there were no differences between the two groups of words for concreteness, $t(18) = -0.662$, *ns*; familiarity, $t(18) = 1.148$, *ns*; number of syllables, $t(18) = -1.282$, *ns*; Kucera-Francis written frequency, $t(18) = 0.784$, *ns*; and meaningfulness: pavio norms, $t(18) = -1.005$, *ns*. See Table 1 for a list of 10 positive and 10 negative words.

Procedure

ERP specifications and stimulus presentation

Participants were fitted with a 128-electrode Geodesic ERP net. The EEG was sampled at 250 Hz using a band pass filter of $0.1-30$ Hz. Impedances were kept below 50 kΩ using high-impedance amplifiers. Previous research indicates that using high-impedance amplifiers allows for accurate detection of signal (Ferree, Luu, Russel, & Tucker, 2001). Eye artifacts were monitored with four electro-oculography (EOG) electrodes. Trials with artifacts were removed offline. Individual ERPs were segmented starting 100 ms before, and continuing 900 ms following stimulus onset.

TABLE 1
Word stimuli: 10 positive and 10 negative words

Positive words	*Negative words*
Love	Anxiety
Passion	Tragedy
Joy	Panic
Happiness	Agony
Friend	Anger
Hope	Hatred
Miracle	Grief
Kindness	Murder
Freedom	Misery
Pleasure	Death

Participants sat 3 feet (0.914 m) from a 13 inch (0.33 m) LCD screen. The words were visually presented for 500 ms in 36pt Arial Black font on a white background. The ten positive and ten negative words were each presented five times in random order for a total of 100 trials per mood condition. The variable interstimulus interval ratio varied between 1.5 s to 2.5 s. Participants were instructed to press one key on a button box if the stimulus was a positive word and another key if the stimulus was a negative word. Reaction times and ERPs were measured at the presentation of the word.

Mood induction

Prior to stimulus presentation, the experimenter induced either a positive or negative mood in the participants. The mood induction was based on an appraisal of the participants' mental ability and psychological state—a procedure that is a successful and ecologically valid mood induction technique (Nummenmaa & Niemi, 2004). Participants were randomly assigned to begin with one of the two mood conditions, the order of which was counterbalanced across subjects. All subjects received both mood inductions and received the same instructions and comments. The only difference was the order in which the mood conditions occurred.

To induce mood, the experimenter explained that a printout of the participant's brainwaves would be used to "verify" whether he or she was suitable for data collection. After the experimenter returned, she brought the printout to the participant and had a conversation with the second experimenter and the participant regarding the brainwaves. Unknown to the participants, the printouts were fabricated and the same for everyone.

In the positive mood condition, the first experimenter explained to the second that the brainwaves were very impressive and, in fact, the best so far in this experiment. The experimenter also commented that the brainwaves would make excellent data and add to the results of the study. Finally, the experimenter presented to the participant the fabricated printout of brainwaves that were very clean and clear (see Figure 1 (top)).

In the negative mood condition, participants saw a different printout and heard different comments, but the procedure remained the same as the positive mood induction. The first experimenter explained that there was a concern about the participant's "unusual" brainwaves and that the professor was wary about proceeding with the experiment. This was followed by comments concerning the participant's stress or anxiety level. The experimenter then showed the participant a printout with erratic and incoherent brainwaves (see Figure 1 (bottom)).

Following the mood induction, the experimenter asked a series of questions about the participant's mood. The cover story was that these questions were standard procedure to ensure that results across different participants were comparable. Participants were asked to rate current emotional states on four emotional levels (happy, sad, positive, negative) on a scale of 1 through 7 (1 = do not feel this way at all to 7 = feeling this way to a great degree).

After participants viewed the positive and negative words following the first mood induction (approximately 8–10 min), the experimenter

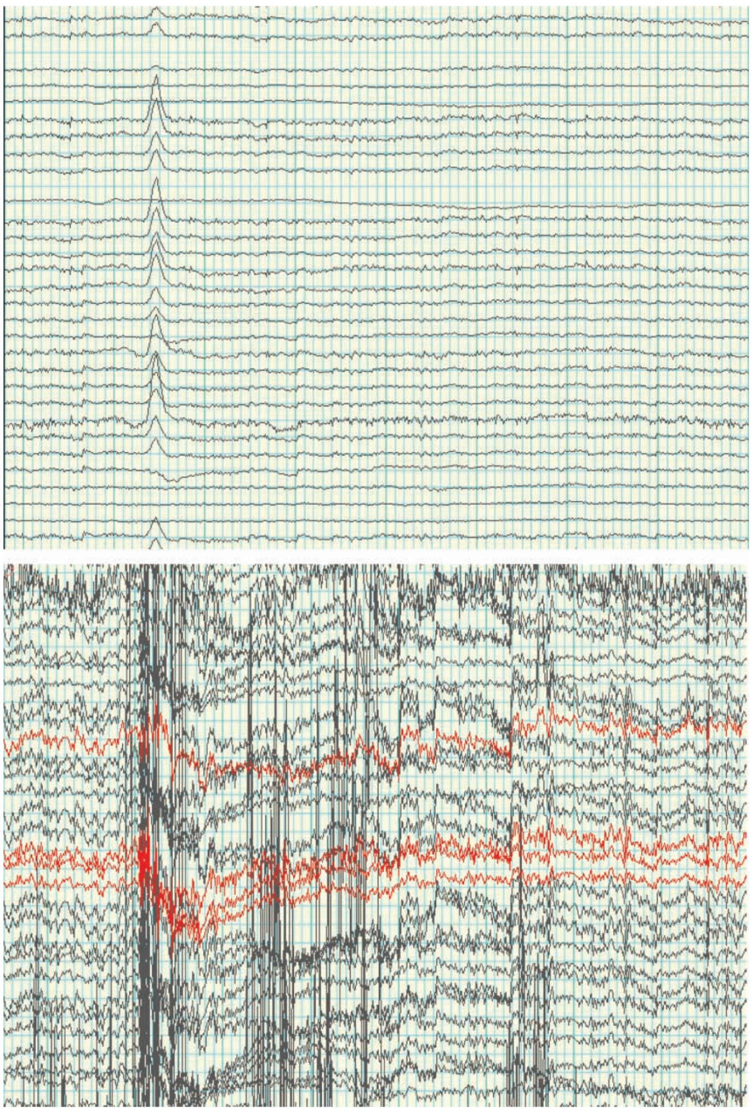

Figure 1. (Top) The fabricated brainwave picture used to induce the positive mood condition. (Bottom) The fabricated brainwave picture used to induce the negative mood condition.

induced the second mood. To do this, the experimenter entered the testing room and explained that there had been a problem with the software collecting the brainwaves. Therefore, the computer system was rechecked and the brainwave data was reassessed. After correcting the problems, another brainwave printout—this time, ''correct''—would be checked before proceeding. At this point, participants received the *opposite* mood induction. To account for the switch in the cover story, the experimenter explained that the faulty software misrepresented the participant's brainwaves in the first session. If the participant had been in the positive mood condition first, the experimenter explained that the brainwaves were actually much worse than they first appeared, and proceeded with the ''negative'' cover story. If the participant had been in the negative mood condition first, the experimenter explained that the brainwaves were actually much better than they first appeared, and proceeded with the ''positive'' cover story. Again, the participants filled out the behavioral questionnaire regarding mood, and the stimuli were presented again in random order for a total of 100 trials.

After the experiment, the experimenter debriefed all participants and explained the reason for the deception. The majority of participants indicated that they had believed the cover story and anecdotally expressed that it had affected their mood.

Design and analysis

Behavioral analyses examined mood by assessing the ratings from the questionnaire. Emotion ratings were averaged before and after each brainwave recording session. Each question (happy, sad, positive, negative) was assessed using paired *t*-tests between mood conditions.

In addition, the other behavioral analysis examined the reaction times and error rates during the ERP portion of the experiment. These data were analyzed using a 2 (Mood) × 2 (Word) repeated-measures ANOVA.

Because we had such a small number of participants, we analyzed the ERP data using a small number of *a priori* contrasts (planned *t*-tests) rather than a four-way omnibus ANOVA. Specifically, we focused on a cluster of bilateral frontal electrodes (Schapkin et al., 2000) and compared ERP responses (amplitude and latency) within the time window of 350 to 600 ms to positive and negative words within each mood

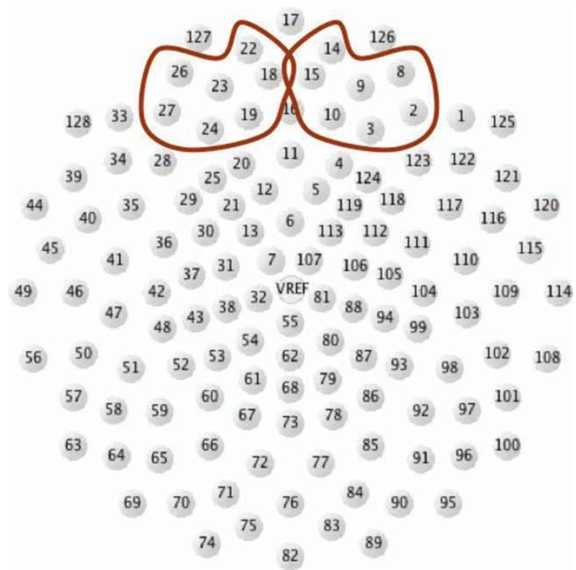

Figure 2. Layout of the 128-electrode net and the cluster of frontally distributed channels used for the ERP analysis.

condition for the right and left hemispheres. The electrode clustering configuration is shown in Figure 2.

The analysis quantified a negative waveform in a window between 350 and 600 ms. Analysis of the peak amplitude included an 8 ms (inclusive) window extending around the negative peak. The peak averaged the selected channels in the left and the right hemispheres. Contrasts were used to compare the effects of viewing positive and negative words in either positive or negative mood states within the left and right hemispheres.

RESULTS

Behavioral data

Mood manipulation

A paired *t*-test compared the subjective mood measures across the positive and negative mood conditions. Subjective ratings were significantly more sad in the negative mood condition compared to the positive, $t(12) = -2.132$, $p = .05$). Ratings for the happy condition were marginally more happy in the positive mood condition than the negative mood condition, $t(12) = -2.007$, $p = .068$. No other rating values were significant between the two mood states: positive mood rating, $t(12) = -0.64$, *ns*; negative mood rating, $t(12) = -1.148$, *ns*.

Reaction time data

The reaction time data were submitted to a two-way repeated-measures ANOVA with Mood (2) $\times$ Word (2) as the conditions. No significant effects were found for Mood, $F(1, 12) = 0.48$, *ns*; Word, $F(1, 12) = 1.65$, *ns*; or Mood $\times$ Word, $F(1, 12) = 0.01$, *ns*, interaction. Thus, no changes occurred in response time due to mood or word manipulations.

ERP data

Peak amplitude

The ERP analysis used planned contrasts to compare the difference between positive and negative words in the positive and negative mood conditions between 350 and 600 ms in the frontal leads. Positive words were more negative in amplitude than negative words when participants were in the positive mood state in both the left hemisphere, $t(12) = 2.162$, $p = .05$, the right hemisphere region, $t(12) = 3.918$, $p = .002$. In contrast, there were no significant differences between positive and negative words in the negative mood condition in either the left, $t(12) = -0.115$, *ns*, or right hemisphere, $t(12) = -0.265$, *ns* (see Figure 3).

DISCUSSION

The results indicated that pleasant and unpleasant feedback influenced the neural processing of affective language. Participants' subjective ratings of their emotional states suggested that they did feel a change in their mood based on our induction technique. The electrophysiological changes indicated that when participants were placed in the positive mood state, positive words generated a larger negative response compared to negative words. The results in the positive mood condition are consistent with the hypothesis that one's emotional state differentially influences the neural processing of positive and negative words.

Previous research suggests that contextual analysis of emotional words influences the brain response at approximately 400 ms (Kissler et al., 2006). In the Kissler et al. (2006) study, participants in a positive mood state produced more negative peaks to positive words compared to negative words. This result suggests that the positive mood induction influenced the neural activity associated with evaluating positive and negative words. The present study extended this work by using a more direct and ecologically valid mood induction procedure. Together, this body of work fits well with research on neural mechanisms for subjective experience of emotions interacting with cognition (De Pascalis & Morelli, 1990; Federmeier et al., 2001). Federmeier et al. (2001) found that positive mood facilitated processing the last word of a sentence, which was either an expected or unexpected ending, as revealed by a negative waveform around 400 ms. Indeed, other researchers conclude that positive moods tend to improve our ability to form semantic connections (Bolte, Goschke, & Kuhl, 2003). As with the current study, positive and negative words were processed differently while subjects were in the positive mood state. Findings from Bolte et al. (2003) and Federmeier et al. (2001) suggest that positive mood may facilitate semantic processing. This lends support to the fact that the differential processing of positive and negative words occurred only in the positive mood state. The current study suggests that even with slight changes in subjective ratings of feeling ‘‘happy’’, the neural response generated an increase to the presentation of positive words, compared to negative words, while in a positive mood state.

The present effect of mood and language is interesting because of the simplicity and directness of our induction technique. A meta-analysis by Nummenmaa and Niemi (2004) suggested that mood inductions that are direct, ecologically valid and based on performance appraisals may be highly effective in inducing mood in participants. Indeed, our mood induction technique was very direct in that it did not require participants to imagine being in a mood state—rather, it put them in that state directly. It was ecologically valid because it avoided demand characteristics by inducing mood without artificially drawing attention to the goals of the experiment. The mood was also a powerful type of performance appraisal because it highlighted an aspect of neurocognitive functioning (quality of one's brain functioning) that is certainly a sensitive topic for college students.

Although there were no significant findings for differentiating positive and negative words in the negative mood state, the plotted waveforms suggest that negative words produce a more negative wave in the left hemisphere while participants were in the negative mood

Figure 3. ERP waveforms to positive and negative words within frontal left and right hemisphere regions and different mood conditions. The top panels display the negative-going peak to positive and negative words within the negative mood condition; the bottom panels display the negative-going peak to positive and negative words within the positive mood condition The boxes indicate the significant results found between positive and negative word processing from 350 to 600 ms. The *y*-axes show µV.

state (see Figure 3). The lack of a significant effect suggests that the negative mood may not have been as effective as the positive mood manipulation across all of the subjects. In the future, further research is needed to investigate the effect of transient negative mood changes using a direct mood manipulation.

A notable limitation of the study concerns the lack of a neutral mood condition. Although this condition would have established a baseline for participants, the mood induction procedure was meant to determine that *any change* in mood would influence the neural comprehension of words. Because our mood induction was exploratory, future research is needed to understand the full effects of a direct mood manipulation. Moreover, additional studies should incorporate a neutral mood condition to further clarify the specific influences of different moods on language processing.

CONCLUSION

The current results extend the behavioral research of Glenberg et al. (2005) and provide preliminary electrophysiological support for an embodied view of emotion and language processing. One interpretation of our findings is that directly eliciting a positive mood enhances the meaning of congruent emotional words over the frontal region. These results suggest that just as we recruit neural areas associated with producing actions when comprehending action words (Pulvermuller, 1999), neural regions associated with emotional experience may be activated when one is comprehending emotionally valenced language. The novelty of the present study is that it is one of the first to use a direct mood induction technique (see Nummenmaa & Niemi, 2004) to explore how the brain processes emotionally valenced language differently in varying emotional mental/

physical states. Building on this work, future research should continue to explore how underlying emotions and mental states serve as ubiquitous contexts for how people comprehend language in everyday, naturalistic and situated face-to-face interactions.

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