The impact of verbal framing ("Negative?" vs. "Positive?")
on brain activity evoked by emotional images

Michael A. Kisley
Alana M. Campbell
Jenna M. Larson
Andrea E. Naftz
Jesse T. Regnier
Deana B. Davalos

1University of Colorado at Colorado Springs
2Colorado State University

Correspondence: Michael A. Kisley, Ph.D.
Department of Psychology
University of Colorado at Colorado Springs
1420 Austin Bluffs Parkway
Colorado Springs, CO 80918
Phone: 719-255-4177
Email: mkisley@uccs.edu

Running head: IMPACT OF EMOTIONAL FRAMING ON ERPS
Abstract

Emotional stimuli generally command more brain processing resources than non-emotional stimuli, but the magnitude of this effect is subject to voluntary control. Cognitive reappraisal represents one type of emotion regulation that can be voluntarily employed to modulate responses to emotional stimuli. Here, the late positive potential (LPP), a specific event-related brain potential (ERP) component, was measured in response to neutral, positive and negative images while participants performed an evaluative categorization task. One experimental group adopted a “negative frame” in which images were categorized as negative or not. The other adopted a “positive frame” in which the exact same images were categorized as positive or not. Behavioral performance confirmed compliance with random group assignment, and peak LPP amplitude to negative images was affected by group membership: brain responses to negative images were significantly reduced in the “positive frame” group. This suggests that adopting a more positive appraisal frame can modulate brain activity elicited by negative stimuli in the environment.
Acknowledgments

We gratefully acknowledge the thoughtful insights of John Chavis, Jesse Regnier and Stacey Wood, as well as data collection assistance provided by Barbara Banz and Elizabeth Burnette. Financial support was generously provided to the first author by the National Institute on Aging (1 R15 AG037393-01).
The impact of verbal framing ("Negative?" vs. "Positive?")
on brain activity evoked by emotional images

Emotional stimuli command attention (Ohman, Flykt, & Esteves, 2001; Pratto & John, 1991) and correspondingly evoke a proportionately greater amount of brain activity than non-emotional stimuli. This has been demonstrated in humans with non-invasive measures of brain response including event-related brain potentials (ERPs) (Begleiter & Platz, 1969; Hajcak, Macnamara, & Olvet, 2010; Schupp et al., 2000) and regional cerebral blood flow (Keil, Bradley, Hauk, Rockstroh, Elbert et al., 2002; Sabatinelli, Lang, Keil, & Bradley, 2007).

However, it has also been shown that individuals can voluntarily modulate the amplitude of brain responses to emotional images. In general this has been accomplished through attempts to direct attention allocation towards non-emotional aspects of the images (Hajcak, Moser, & Simons, 2006; Ito & Cacioppo, 2000) or alternatively regulate the subsequent emotional response to the image (Krompinger, Moser, & Simons, 2008; Moser, Hajcak, Bukay, & Simons, 2006).

One ERP component in particular, the late positive potential (LPP), has been employed to study brain processing of emotional images. This waveform has been consistently shown to exhibit larger amplitude in response to emotionally-valenced images, both positive and negative, compared to neutral images (Ferrari, Codispoti, Cardinale, & Bradley, 2008; Kisley, Wood, & Burrows, 2007; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp et al., 2000). The scalp-recorded LPP corresponds to neural activity distributed across multiple cortical regions, predominantly visual association areas in the occipital, temporal and parietal lobes (Keil et al., 2002; Sabatinelli et al., 2007). Thus, observation of a larger LPP waveform in response to emotional images is consistent with the idea that stimulus emotionality and consequential
attention allocation lead to enhanced neural processing within sensory association areas of the cerebral cortex (Vuilleumier, 2005).

It is becoming increasingly clear that the relative degree of neural resource allocation to processing emotional images – that is, the amplitude of the LPP waveform – can be modulated by emotional regulation strategies (Hajcak et al., 2010). This importantly includes “cognitive reappraisal” strategies defined by Ochsner and Gross (2005) as reinterpreting the meaning attributed to an emotional stimulus. For example, it has been shown that the valence (negative vs. neutral) of a short verbal description immediately preceding a negative emotional image can modulate LPP amplitude in response to that image (Foti & Hajcak, 2008; Macnamara, Foti, & Hajcak, 2009). As a variation on this approach, the present study was designed to test whether the emotional “frame” adopted by an individual can modulate the amplitude of LPP responses to emotional images. Specifically, we asked participants to adopt a negative frame – by categorizing images as negative or not-negative – or conversely a positive frame – by categorizing images as positive or not-positive. This general approach is based on the work of Tversky and Kahneman (1981), although they conceptualized negative/positive framing in terms of losses/gains in the context of risky decision making. Here the appraisal frame was specified by the wording of the categorization response options, and this remained unchanged throughout the experimental session for each participant (i.e., this was a between-subjects manipulation). Also, in addition to neutral and negative images that have been utilized in other studies of appraisal-induced modulation of the LPP (e.g., Macnamara et al., 2009), emotionally positive images were also encountered and appraised within the experimentally-assigned frame here. Based on previous work showing that negatively-valenced verbal descriptions preceding negatively-valenced images tend to increase the amplitude of cortical response to those images (Hajcak et
al., 2010), we predicted that peak LPP amplitude in response to negative images would be larger in the negative frame condition compared to the positive frame condition in this paradigm. Secondarily, because it has been shown that neural responses to positive images can also be modulated by task instructions (Hajcak et al., 2006; Krompinger et al., 2008), we predicted modulation of LPP amplitude in response to positive images such that the largest response would occur within the positive frame condition.

Of final note concerning the present study, previous investigations of reappraisal effects on LPP amplitude have employed an ERP paradigm during which images from each valence category (negative, neutral, and sometimes positive) are presented in a relatively balanced proportion and typically in blocks of similarly-valenced images (Hajcak et al., 2010). However, emotional stimuli are often encountered in isolation, within an otherwise emotionally neutral context. Therefore another experimental approach to investigating neural responses to motivationally relevant stimuli, and that employed here, involves the emotional “oddball” ERP paradigm (Ito, Larsen, Smith, & Cacioppo, 1998; Kisley et al., 2007) where rarely-occurring emotional stimuli (both positive and negative) are presented sporadically within a “neutral context” in which the majority of images presentations are neutral. The present study is the first to manipulate the emotional frame through which images are appraised during such an emotional oddball ERP paradigm.

Method

Participants. A total of 118 undergraduate students at Colorado State University participated for course credit, but data for 10 were excluded due to the presence of excessive recording artifact commonly encountered in ERP studies (excessively high electrical resistance between scalp and electrodes, excessive blinking-related artifact during image presentation, and
muscle artifact due to jaw or neck movement). Statistical analyses were performed with the data from the remaining 108 adults (48 male) between 17 and 44 years of age ($M = 19.0$, $SD = 2.4$).

Before enrolling, all subjects tested 20/40 or better with corrected vision on the Snellen visual acuity chart and were screened by self-report for current use of psychoactive drugs including antidepressants. Subjects were randomly assigned to the “negative frame” group or the “positive frame” group. Originally composed of 59 subjects each, the “negative frame” group was reduced to 55 and the “positive frame” group was reduced to 53 after the exclusions mentioned above. The groups did not differ significantly on age or gender distribution.

Materials. Images were presented on a 17-in. LCD color monitor 2.5 ft from the subject. E-Prime (Psychological Software Tools, Inc., Pittsburgh, PA) was used for presenting the images and recording behavioral responses. Electroencephalographic activity was recorded from disposable silver/silver-chloride electrodes (Vermed, Bellows Falls, VT) with a Neuroscan NuAmps amplifier under control of a computer running Scan 4.3 (Compumedics Neuroscan, El Paso, TX).

Thirty images were taken from the International Affective Picture System (IAPS) on the basis of normative ratings (Lang, Bradley, & Cuthbert, 2005) and previous ERP studies (Ito et al., 1998; Kisley et al., 2007). This included 24 context neutral images and 6 “target” images (2 neutral, 2 positive, 2 negative). The context images were used to set an overall neutral context within which the oddball targets would be presented. ERP waveforms were computed only for the target images. For these targets each subject completed quantitative ratings of bipolar valence (from 1, most negative, to 9, most positive) and arousal (from 1, least arousing, to 9, most arousing) using the Self Assessment Manikin instrument (SAM; Lang et al., 2005) at the end of their participation in the study. Ratings from 3 participants were not available due to
missing or incomplete data. Image identities were as follows: target neutral images (IAPS pictures 6150, 7550: electrical outlet, man at computer), target positive images (7340, 7350: ice cream, pizza), and target negative images (9140, 9571: decomposing calf, dead cat).

Procedure and Analysis. Other than experimental manipulation of emotional framing, basic procedures for this study were the same as previous investigations of the LPP in our laboratory (Kisley et al., 2007; Wood & Kisley, 2006). Participants received specific instructions concerning performance of the evaluative categorization task before the electrophysiological recording began. During the task subjects viewed each image for 1 s and afterwards categorized it by pressing one of two buttons on a response pad. For the negative frame group the left button corresponded to a negative categorization and the right button to a not-negative categorization. For the positive frame group the left button corresponded to positive and the right button to not-positive. Participants were cued to these response choices by a response screen that appeared immediately after every image was presented. For the negative frame group the response screen read “Negative?” in the top half of the screen and the words “Yes” at bottom left and “No” at bottom right. An identical response screen was presented to the positive frame group except the phrase “Positive?” substituted for the top half of the screen. Aside from these different response screens the two framing groups were exposed to the exact same image presentation identity and order throughout the categorization task. After each categorization response was indicated a new image was presented after a 1.2 s pause.

Each of the 30 IAPS images (24 context neutral, 2 target neutral, 2 target positive, 2 target negative) were presented 15 times each for a total of 450 presentations during the entire task. Presentations occurred in blocks of 5 with a participant-controlled pause between blocks which was ended by a button press. The vast majority of image presentations were neutral in
order to set a neutral “context” (Ito et al., 1998). Pseudo-randomly, but only on the third, fourth or fifth trial of a block, the target images used to compute ERPs were presented. A total of 30 of these presentations were target neutral image presentations, 30 target positive presentations, and 30 target negative presentations. Of these 30 presentations for each valence category, only artifact-free trials were used to compute the average ERP waveforms as described below.

Behavioral responses were collected for all 90 target image presentations (i.e., 30 target neutral, 30 target positive, and 30 target negative presentation). This included response times (as opposed to “reaction times,” as this was not a speeded task) and response “accuracy.” The latter was specified as follows in order to test for task compliance: for the negative frame (“Negative?”) a “Yes” response was considered accurate for negative target images and a “No” response was considered accurate for positive images. The converse was true for the positive frame condition. Presumably the neutral target images were subjectively proximal to the “yes/no” categorization boundary in both framing conditions, and further we lacked an a priori hypothesis concerning how they would be rated. Therefore we did not consider these responses useful for assessing task compliance, and these data are not shown here.

During the evaluative categorization task, electrophysiological signals were recorded from standard scalp electrode sites (Fz – midline over frontal lobe, Cz – midline over central sulcus, PZ – midline over parietal lobe) and also sites near the eyes for the detection of eye movements and blinks. Prior to the recording, the skin was cleaned with beaded prep gel and alcohol before attaching the electrodes. Subjects for which adequate electrode contact with the skin could not be maintained (specifically impedances > 5 kΩ) were excluded because this can corrupt the electrophysiological signal. Specific recording details were as follows: 1000-Hz
sampling rate, 0.1-to-100 Hz band pass filter, signals referenced to the average of left and right mastoids (bony ridge behind the ear), ground electrode placed on forehead.

For each individual, average ERP waveforms were computed offline and analyzed separately for the target neutral, positive, and negative image presentations using standard procedures for ERP analysis. Single trials containing movement or blink artifact (i.e., signals exceeding ± 100 µV) were excluded from the average waveform computation. In order to avoid inclusion of unreliable average waveforms in the final analysis, participants for which an insufficient number of single trials (less than 10) were available for any average waveform after artifact rejection were excluded from the study. Subsequently the average number of trials used for computation of all waveforms across all participants was 22.4 (SD = 6.1; range = 12-30). Mean number of available trials did not differ significantly across valences, groups or any combination thereof (i.e., there were no significant interactions for this measure). The final analyzed waveforms spanned from 100 ms before image onset to 900 ms after image onset, and were smoothed with a low-pass filter (9 Hz corner frequency). LPP amplitude was recorded for each average waveform as the maximal peak amplitude between 400 and 900 ms after image onset on electrode Pz, over the parietal lobe, where LPP amplitude is largest (Ito et al., 1998; Wood & Kisley, 2006). LPP latency was recorded as the time, to the nearest millisecond, at which peak amplitude occurred.

To examine the hypothesis that framing modulates brain responses to emotional images a mixed design analysis of variance was performed (Wilks’ Lambda approximation, post-hoc comparisons Bonferroni-adjusted, \( p < .05 \)) with framing condition (negative or positive) as the between-subjects factor and image valence (neutral, positive, negative) as the within-subjects factor. Peak LPP amplitude and latency were analyzed with this model. Subjective ratings of
image valence and arousal collected with the SAMs instrument were also analyzed with this model to test for successful manipulation of image emotionality. Behavioral response accuracy and response times for negative and positive images, recorded during task performance, were also analyzed in order to ensure that participants were performing the task in a manner consistent with their assigned framing condition and also to check whether framing condition systematically affected behavioral responses.
Results

During performance of the ERP task behavioral response accuracy was very high, confirming that participants were generally employing the emotional response frame they were assigned to. For the negative frame, mean response accuracy to positive images (i.e., a “No” response to the cue “Negative?”) was 98.7% (SD = 6%) and mean response accuracy to negative images (i.e., “Yes”) was 95.8% (SD = 12%). For the positive frame, mean response accuracy to positive images (i.e., a “Yes” response to the cue “Positive?”) was 93.6% (SD = 14%) and mean response accuracy to negative images (i.e., “No”) was 99.7% (SD = 1%). No main effects of valence or frame were found. Concerning response times, there was a main effect of valence, $F(1,106) = 5.261, p < .05$, as responses were generally faster to the negative images than to the positive images. No other main or interaction effects reached significance. For the negative frame, mean response time to positive images was 548.0 ms (SD = 189.3 ms) and mean response time to negative images was 526.9 ms (SD = 213.8 ms). For the positive frame, mean response time to positive images was 565.2 ms (SD = 196.5 ms) and mean response time to negative images was 530.1 ms (SD = 202.8). Note that behavioral response times are relative to image offset, and therefore the movements related to button presses did not overlap with the ERP waveforms (which are relative to image onset) presented immediately below.

Peak amplitude of the LPP waveform was affected by image valence, but differentially depending upon how response options were framed. The overall pattern of response amplitude as a function of group assignment and image valence is shown in Figure 1. A main effect for valence was found, $F(2,105) = 51.840, p < .001$. Post-hoc comparisons revealed that overall LPP mean amplitude was smallest in response to neutral images (marginal $M = 6.9 \text{ µV}$), intermediate to positive images (marginal $M = 9.0 \text{ µV}$), and largest to negative images (marginal $M = 13.9$
µV). However, an interaction between valence and group was also detected, \( F(2, 105) = 12.237, p < .001 \). This effect was driven by a substantial and significant increase in LPP amplitude to the negative images from the positive framing condition \( (M = 11.3 \, \mu V, \, SD = 8.9 \, \mu V) \) to the negative framing condition \( (M = 16.4 \, \mu V, \, SD = 10.2 \, \mu V) \). This stands in contrast to the positive image response amplitude which showed a modest, non-significant increase from the negative framing \( (M = 8.4 \, \mu V, \, SD = 7.1 \, \mu V) \) to positive framing condition \( (M = 9.7 \, \mu V, \, SD = 6.7 \, \mu V) \). A modest, non-significant increase also occurred for neutral images from negative framing \( (M = 6.5 \, \mu V, \, SD = 5.2 \, \mu V) \) to positive framing condition \( (M = 7.3 \, \mu V, \, SD = 5.0 \, \mu V) \). In summary, the wording of the behavioral response options modulated the amplitude of the LPP waveform, and in the predicted direction: specifically, negative framing lead to larger brain responses to negative images.

LPP peak latency was affected by image valence, \( F(2, 105) = 4.222, p < .05 \), but not by framing condition. Specifically, peak latency was significantly shorter for negative images (marginal \( M = 512 \, ms \)) compared to both positive (marginal \( M = 529 \, ms \)) and neutral images (marginal \( M = 531 \, ms \)). No interaction was detected.

Analysis of participant ratings for target images measured by the SAM ratings confirmed successful manipulation of subjective emotionality for the images used to compute the ERPs. Across the 105 participants with available data mean valence for the target neutral images was 5.14 (\( SD = 0.96 \)) and the mean arousal rating was 2.19 (\( SD = 1.63 \)). For target positive images mean valence was 7.46 (\( SD = 1.30 \)) and mean arousal was 4.37 (\( SD = 2.24 \)). For target negative images mean valence was 1.54 (\( SD = 0.93 \)) and mean arousal was 5.34 (\( SD = 2.39 \)). There was a main effect of image type on subjective rating of valence, \( F(2,102) = 857.108, p < .001 \). In post-hoc comparisons, mean valence was significantly different between neutral, positive, and
negative image categories (all $p < .001$). There was also a main effect of image type on subjective arousal ratings, $F(2,102) = 91.644$, $p < .001$. Arousal was significantly lower for neutral images compared to both positive and negative images, $p < .001$. Arousal was also significantly lower for positive compared to negative images, $p < .05$. No main effects of framing group and no interactions were detected for any subjective rating variable.

Discussion

Based on the observed pattern of behavioral responding participants successfully adopted the assigned emotional frame, and based on the pattern of LPP waveforms the adopted frame affected the brain responses to emotional images. Most notably a negative appraisal frame was associated with a substantially larger amplitude brain response to negative images as compared to positive and neutral images. However this negative dominance was significantly reduced when images were appraised in the context of a positive frame. This suggests that the emotional regulation strategy of adopting a more positive appraisal frame can affect the amount of brain activity elicited by negative stimuli in the environment. This is generally consistent with recent demonstrations that verbal reappraisals emphasizing the neutrality of an otherwise negative image can reduce LPP amplitude in response to that image (Foti & Hajcak, 2008; Hajcak et al., 2010; Macnamara et al., 2009). Because of study design we cannot definitively rule out the possibility that the pattern of results observed here were due to “target” effects, whereby the amplitude of neural response to negative images was larger in the negative frame condition simply because participants were “looking for” negative images (see for example Ferrari et al., 2008). However, if that were the case, then we would have predicted a complimentary enhancement of neural responses to positive images in the positive frame condition. But no framing-induced modulation for positive image response was found here. Further, we cannot be
certain that the framing effects resulted only from top-down, voluntary efforts on the part of the
participants. Because each participant experienced many trials, it’s possible that the response
frame became relatively automatic and might even have affected brain processes preceding the
LPP waveform (i.e., < 500 ms). Due to a relatively low signal-to-noise ratio available for
measuring earlier ERPs (due to insufficient trials for analysis of such smaller, higher-frequency
waveforms), this idea was not tested in the present study.

At present it remains unclear why we did not detect a significant frame-related
modulation of response amplitude for positive images. In fact relatively few studies have
demonstrated significant modulation effects for neural responses to positive images, but those
that do involve substantive methodological differences from the present study. For example,
Hajcak et al. (2006) instructed participants to evaluate positive images on an affective dimension
in one condition (was the image “pleasant” or “unpleasant”) and a non-affective dimension in the
other condition (“how many people were in the picture?”). LPP amplitude in response to positive
images was larger in the affective rating condition. This approach stands in contrast to the
present study where both conditions involved an affective evaluation, but differed in the valence
of that evaluation (“positive?” in one condition vs. “negative?” in the other). Another study that
successfully demonstrated significant modulation of neural response to positive images involved
manipulation of specific emotion regulation instructions to “enhance” the emotional response in
one condition, “suppress” in another condition, or just “view” the emotional images in a third
condition (Krompinger et al., 2008). LPP amplitude evoked by positive images was significantly
reduced in the “suppress” compared to “view” condition. In the present study we did not
explicitly instruct participants to regulate their emotional response, but rather manipulated only
the verbal frame of the behavioral response options. Further studies will be required to determine
if these methodological differences might explain the discrepant findings, and further whether the types of emotional regulation that modulate neural responses differs in important ways for positive and negative stimuli.

The present findings have implications for research designs that implement the “emotional oddball” ERP paradigm, including the study of the lifespan development of changes in brain response to emotional stimuli. For example, adding to the literature on documented age-related shifts in attentional allocation towards positive and away from negative stimuli (Murphy & Isaacowitz, 2008), we have shown a significant decrease in LPP amplitude to negative images with relatively stable responding to positive images as adults age from the 20s to the 60s (Kisley et al., 2007; Wood & Kisley, 2006). However, the findings of the present study suggest that the magnitude and perhaps even detectable presence of this age-related reduction in negative responding might depend on the manner in which the relevant stimuli are appraised by the participants. In all past studies from our lab participants were given three response options for rating images: “neutral, positive, or negative.” No manipulation of appraisal options was previously implemented. By contrast in the current study we found a substantial reduction in the brain response to negative images within a very restricted younger adult sample ($M = 19$ years) by framing the response options in a specifically positive frame. This demonstration is important because it has been claimed that positivity effects in cognitive operations of older adults arise from voluntary efforts to optimize emotional well-being consistent with Socioemotional Selectivity Theory (Mather & Carstensen, 2005). More studies will be required to determine whether older adults are able to modulate neural responses to emotional stimuli through cognitive reappraisal including for example the framing paradigm presented here.
It has been hypothesized that negative stimuli in the environment are special, in that they convey information potentially important to survival (Ohman et al., 2001). Consistent with this theory, humans exhibit a so-called “negativity-bias” in many psychological domains (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) including for example peak amplitude of the LPP waveform in response to emotional images (Ito et al., 1998). Although LPP amplitude was largest in response to negative images overall here, it is premature to generalize these results to the potential impact of reappraisal on the negativity bias *per se*. The subjective ratings for the positive and negative images we used for the present study were not balanced: the negative images were significantly higher on subjective arousal ratings. This could explain why the neural responses to negative images were of larger amplitude here (Schupp et al., 2000). Further, we used a very limited stimulus set to operationalize positive (appetizing foods) and negative (dead animals) valence. It has recently been shown that the presence of the negativity bias might depend on the specific category of images presented (Weinberg & Hajcak, 2010). Replication with more varied image categories will be important. Nevertheless, we demonstrated here that valence-selective verbal framing can affect brain responses to emotional images in a valence-specific manner. Thus voluntary modulation of the negativity bias might be possible in a verbal framing paradigm through reduction of responding to negative images. But replication with refined procedures - in particular, more tightly controlled subjective image arousal levels and more varied image themes - will be important to test this idea. Also, further investigation will be required to determine the potential influence this modulation of brain response could have on overall emotional experience and well-being.
References


Figure Captions

Figure 1. Across-subjects average ERP waveforms separated by image valence (neutral, positive, negative), group (negative frame group, *left*, positive frame group, *right*) and electrode (*Fz, top*, *Cz, middle*, *Pz, bottom*). The LPP is the prominent waveform component reaching maximal amplitude near 500 ms after the image onset (at time = 0 ms) at electrode Pz. Note that these “grand-averaged” waveforms are for illustrative purposes and were not analyzed here. Cz and Fz are shown for comparison purposes: note that the LPP exhibits maximal amplitude at electrode Pz. Statistical analysis was performed on peak LPP amplitudes at Pz that were determined for each individual participant (presented in text and in Figure 2).

Figure 2. Mean peak LPP amplitudes recorded at electrode Pz as a function of image valence and group assignment. Response amplitude to valenced (i.e., positive and negative) images was consistently larger than to neutral images, but response amplitude to negative images in particular was affected by the manner in which response options were framed.
FIGURE 1
FIGURE 2

Image Valence

LPP Amplitude (µV)

neutral positive negative

neg. frame pos. frame