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Negative Expectancies in Posttraumatic Stress Disorder: Neurophysiological (N400) and Behavioral Evidence

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Abstract

Background—Posttraumatic stress disorder (PTSD) is a disorder that theoretically and clinically is thought to be associated with persistent and exaggerated negative expectancies. This study used the N400 event-related potential (ERP) to investigate expectancies for threatening endings to ambiguous sentence stems. The N400 ERP is thought to reflect the amount of effort required to integrate a stimulus into a given context. In sentence reading tasks, the N400 is reliably larger when a word is unexpected.

Method—In this study, fifty-seven trauma survivors of various types (22 with PTSD and 35 without) read ambiguous sentence stems on a computer screen. These sentence stems were completed with either an expected ("The unfortunate man lost his…wallet"), unexpected ("The unfortunate man lost his…artist"), or threatening word endings ("The unfortunate man lost his…leg").

Results—Participants with PTSD, as compared to those without, showed significantly smaller N400s to threatening sentence endings suggesting enhanced expectancies for threat. Behavioral responses supported this conclusion.

Conclusions—These findings are consistent with the clinical presentation of hypervigilance and proposed revisions to the DSM-V that emphasize persistent and exaggerated negative expectations about one's self, others, or the world. Relative to earlier behavioral studies, this work further suggests that this expectancy bias occurs automatically and at the early stages of information processing. The discussion focuses on the potential impact of a negative expectancy bias in PTSD and the value of the ambiguous sentence paradigm for studying PTSD as well as other disorders.

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Contributors Laura Batterink, Libby Marks, and Cordelia Ross all collected substantial portions of the data, analyzed subsets of the data, did careful literature reviews, and wrote academic theses on parts of the project. Kevin Fleming played an important role in the creation of the task, the discussion of theoretical issues, and consultation regarding interpretation and analyses.

Keywords

PTSD; negative appraisals; expectancy bias; attention; hypervigilance; threat; N400; event-related potentials

The DSM-IV-TR defines a psychological trauma as a "an event in which the person experienced, witnessed, or was confronted with actual or threatened death or serious injury, or a threat to the physical integrity of self or others"(p.467) (APA, 2000). While most recover, a proportion of those exposed to psychological trauma present with long standing negative psychological consequences. For example, a recent comprehensive study supported by the Rand Corporation reported that approximately fourteen percent of returning veterans from Iraq and Afghanistan are struggling with posttraumatic stress disorder (Tanielian, et al., 2008).

For those that do develop a chronic reaction to traumatic events, the impact on their lives is considerable. The effects of trauma can include a range of signs, symptoms, and behaviors that include increased arousal states, avoidant coping strategies, and recurrent distressing recollections of the event (APA, 2000). Included among these concerns is a tendency to have persistent and exaggerated negative expectations. Over the years, work in the area of negative expectancies has gained theoretical, clinical, and empirical support. Recently, it has been the cognitive model of Ehlers and Clark (2000) that has delineated the nature and effects of negative expectancy biases in trauma survivors. Ehlers and Clark argue that excessive negative appraisals of the trauma contribute to a sense of ongoing, serious threat, (p.319). It is a theory that expanded on those of others (Janoff-Bulman, 1989; Foa et al., 1989) that emphasized post trauma cognitions in which the trauma survivors see the world as completely dangerous and the self as completely negative.

Understanding negative appraisals is critical because they appear to be highly correlated with post traumatic pathology (Smith & Bryant, 2000; Warda & Bryant, 1998; Foa et al., 1999; Ehring et al., 2006, Hatcher et al., 2009; Moser et al., 2007; Karl et al., 2009; Agar, et al., 2006) and have been shown to predict subsequent PTSD (O'Donnell et al., 2007; Kleim et al., 2007; Ehring et al., 2008; Engelhard et al., 2009; Dunmore et al., 1999; Ehlers et al., 1998; Ehlers et al., 2003; Engelhard et al., 2002). In recognition of the central quality of these negative expectancies, the proposed revisions to the Diagnostic and Statistical Manual for the 5th edition include the following proposed symptom, "Persistent and exaggerated negative expectations about one's self, others, or the world."

Therefore, characterizing the nature and extent of these negative expectancies remains an important challenge for the field. Event related potentials, or ERPs, continue to hold promise as a technique that will help elucidate aspects of bias in PTSD. One ERP component that has never been investigated in PTSD is the N400 component, a negative going waveform that peaks approximately 400 ms after stimulus onset and is sensitive to incongruities in semantics and meaning. The N400 has been theorized to index the integration of a stimulus into a given context, with larger N400s occurring to stimuli that require more cognitive effort for integration (Kutas & Federmeier, 2000; Rugg et al., 1994). This effect is believed to occur because context serves to pre activate meaning and facilitates subsequent stimulus processing. When violations of context occur, more effort is needed to retrieve information from semantic memory, resulting in a larger N400.

The N400 effect has been most frequently and most reliably produced to unexpected final words in "garden path" sentences—sentences in which the preceding sentence context greatly constrains the number of choices that might sensibly finish a sentence. It was a garden path sentence paradigm that produced the first recorded N400 to sentences such as "He shaved off his mustache and city" (Kutas & Hillyard, 1980; Kutas & Hillyard, 1984). Therefore, words that may be harder to process—because they are unexpected in a context–elicit larger amplitude N400s while expected ending elicit small N400s.

Despite its potential, the N400 has not been widely used in the study of psychopathology, schizophrenia excepted (Salisbury et al., 2002; Kiang et al., 2007; Kiang et al., 2008; Nestor et al., 1997). There have been some investigations of the N400 in individuals with depressive disorders, however no difference in the amplitude of the N400 have been found in depression to unexpected final words in garden path type sentences (Deldin et al., 2006; Ruchsow et al., 2008; Moser et al., 2008). There have been no published N400 studies in anxiety disorders, although Moser and colleagues (Moser et al., 2008) did report differences in a related component (the P600) in low anxious individuals that suggested a positivity bias.

However in recent years (using non clinical samples), the N400 has been found in paradigms that extend beyond the typical garden path approach. N400 amplitude has been shown to vary during semantic priming paradigm (Franklin et al., 2007; Weisbrod et al., 1999; Rugg, 1985) and can be elicited by pictures, environmental sounds, faces, and odors (Kutas, 1997; Van Petten & Rheinfelder, 1995; Bobes et al., 1994; Sarfarazi et al., 1999) as long as the semantics of the stimulus is incongruous with the preceding context. Recently, the N400 was shown to index incongruent stereotypes (White et al., 2009), mood/word mismatches (Chung et al., 1996), and rejections words in the context of romance (Zayas et al., 2009).

This broader use of the N400 in non clinical samples suggests new possibilities for clinical investigations. For example, if individuals with PTSD are vigilant for threat, they might maintain different expectations for how ambiguous sentence stems might end. Support for this view comes from in a non-ERP study that showed that veterans with PTSD complete ambiguous sentences stems with military-relevant endings more frequently than veterans without PTSD (Kimble et al, 2002). How might those participants with PTSD respond to ambiguous sentence stems that were completed with word endings that were either expected (i.e., The field was littered with trash"), unexpected ("The field was littered with traffic"), or threatening ("The field was littered with bodies")? In theory, PTSD-related negative expectancies should be reflected in the amplitude of the N400--with smaller N400s to threatening sentence endings. We tested this hypothesis in the current study.

This study is the first of its kind to use the N400 to investigate negative expectancies in individuals with PTSD. While there have been many ERP, behavioral, and reaction time studies that have investigated attentional bias and hypervigilance in PTSD, these studies have tended to assess attentional bias in the present, not expectancies about outcomes in the future (for reviews see Bar-Haim, 2010; Bar-Haim et al, 2007; Kimble et al., 2009; Mobini & Grant, 2007; Buckley et al., 2000). Assessing these expectancies and negative appraisals are critical as it is these cognitive processes that have reliably predicted posttraumatic pathology. Doing so using ERP's is particularly valuable in that it minimizes fake good or fake bad biases on the part of the participants that could be impacting the validity of the current self report literature. Evidence of negative expectancies in the N400 would indicate biases in the processing stream that are both early and automatic and would suggest that ambiguous circumstances elicit a negativity bias in those with PTSD.

Methods

Participants

Participants for this study were recruited were recruited from the community using flyers and newspaper ads placed around Addison, Chittenden and Rutland counties in Vermont.

Flyers were posted at local stores and businesses, and American Legion centers within a 50-mile radius of Middlebury College and Norwich University. The flyers and advertisements provided basic information about the study, including monetary compensation for participation, and instructed interested individuals to contact the principle investigator (MK). An initial phone screening, conducted by the PI, took place in order to determine if the interested individual met inclusion criteria. Requirement for participation included that individuals were at least 18 years of age and had experienced a traumatic incident as defined by the Diagnostic and Statistic Manual of Mental Disorders (APA, 2000). Exclusion criteria included head and brain injury, psychosis, epilepsy, impaired hearing, mental retardation, and poor English language abilities. Those with a history of substance abuse within the past year or a history of substance dependence were excluded. Those individuals determined by the PI to be valid participants scheduled appointments with the research team to participate in the study. Over 133 participants were screened. Seventy two were screened out, most frequently for not achieving Criterion A1 and A2 for the PTSD diagnosis. There were 61 participants in total who were invited in and completed the study, however the data from three participants were excluded from the analysis due to poor quality EEG data. A fourth participant was not included due inaccurate behavioral responses indicating a poor understanding of the task. Thirty-two participants (56%) were male, while 25 participants (43.9%) were female. Ages of participants ranged from 18 – 65, and the average age was 36. Average level of education was consistent with “partial college.” Twenty two (38.6%) of the 57 participants had PTSD while 35 (61.4%) did not meet the criteria. Trauma types included combat exposure, motor vehicle accidents, industrial accidents, sexual and physical assault, childhood abuse, natural disaster, natural disaster, and witnessing violent death. Eleven of the twenty-two participants with PTSD were on either anxiolytics or antidepressants. One participant in the no PTSD group was on an SSRI.

Materials

Interviews—The Structured Clinical Interview for the DSM-IV (SCID-CV)-PTSD module (First et al., 1996) and Clinician Administered PTSD Scale (CAPS: Blake et al., 1995) were used to diagnose a participant with PTSD.

Sentence Paradigm—Sixty-three sentences were presented word by word, with sentence length ranging from 6 to 12 words. Each word appeared on the screen for 1000 ms with a 200 ms interstimulus interval between words. The final word of each sentence was presented for 3000 ms, followed by a 200 ms ISI, after which an asterisk appeared. The asterisk indicated that the participant should push the “Yes” button if the sentence made sense and a “No” button if it did not. Following the button-press from participants, a second asterisk was presented for 3000 ms before the next trial began. The ambiguous sentence stems were used in a previous study examining semantic biases in combat veterans (Kimble et al., 2002). All sentence stems could be completed sensibly with either a threatening or neutral word. The order of the trials throughout the paradigm was randomized to avoid confounding variables such as fatigue and order effects.

Sentences and Final Words—Sentence endings fell in one of three categories: expected, unexpected, or threatening. Expected endings made sense and were highly likely within the context of previously presented sentence stem and were grammatically, syntactically and semantically correct. Unexpected endings were words that made sense grammatically and syntactically, but not semantically. Threatening endings made sense syntactically, grammatically, and semantically but ended the sentence negatively.

Each sentence stem was used three times throughout the paradigm, with a different type of ending each time. All final words were nouns. The average length of the final words was

5.95 letters and 1.68 syllables. The final words for the three types of sentences (expected, unexpected, threatening) did not differ on average with respect to word length, number of syllables, singularity v. plurality, and word frequency (Francis et al., 1982).

Procedure

When participants arrived at the study location, they were first asked to sign a consent form. The PI (MK) then conducted a diagnostic interview, lasting approximately one hour, to determine whether or not the participant currently had PTSD.

To begin the EEG procedure, participants were asked to sit approximately 1.5 meters from a 21-inch computer monitor. They were hooked up, via an electrode cap on their heads, to EEG recording equipment. Electrode gel was placed in each electrode case to ensure optimal conductivity. The 32 electrodes and two mastoid reference electrodes were placed in electrode cases and connected to an amplifier. When the participant was ready to begin the task, the researchers explained the task. Participants were asked to remain still as they silently read each word that appeared on the computer screen. After the sentence was completed, participants pressed either a “yes” or “no” button to indicate if they thought the sentence “made sense”. These answers were recorded by the Superlab stimulus software (Cedrus, San Pedro, CA). The task took eighteen minutes. Upon completion of the task, the electrode cap was removed from the participant’s head. Participants were debriefed after they completed the task and were given the PI’s contact information if they had any further questions or concerns. Following the debriefing session, each participant was paid for participating in the study.

ERP acquisition, filtering, averaging, and analyses—EEG was continuously recorded from 32 channels using a BioSemi Active II amplifiers and electrodes manufactured by BioSemi (Amsterdam, Netherlands). Active electrodes were embedded in an elastic cap at standard distances consistent with American Electroencephalographic Society Guidelines (1994). The EEG was measured using a combined ground/reference (CMS/DRL) circuit. EEG was digitally sampled at 1024 Hz

Data was stored off line and analyzed using Brain Electrical Source Analysis Software (BESA: Megis Software, Grafelfing, Germany). The data was baseline corrected and filtered at .1 to 60 Hz. Continuous EEG was epoched with 100 ms prestimulus stimulus baseline and continued for 1000 ms post stimulus. Eye blinks were removed using BESA eye blink correction routines. Because of the relative scarcity of trails per condition (only 21), no additional artifact rejection routine was used. However, visual inspection of all data indicated three participants for whom there was excessive non-blink artifact in the data. These three participants were removed.

The N400 was measured to final words at a central montage that consisted of Cz and its four adjacent electrodes FC1, FC2, CP1, CP2. These electrodes were chosen because ERPs to the N400 were maximal at the Cz electrode and the four surrounding electrodes were added to avoid effects due to spurious results from a single electrode. For each participant’s EEG, averages were calculated for expected, unexpected, and trauma-relevant endings. The N400 was defined as the most negative peak within the 350 and 550 ms latency window.

ERP data were analyzed using a 2 (Group: PTSD v. No PTSD) × 3 (Condition: Congruent, Incongruent, Traumatic) × 5 (Electrode: FC1, FC2, Cz, CP1, CP2) ANOVA. Greenhouse-Geisser corrections for violations of sphericity are reported as needed.

RESULTS

Behavioral Data

On 99.0% of the congruent trials, participants pressed the "Yes" button indicating that the expected final words made sense. Participants pressed "Yes" only 11.6% of the time on unexpected trials. On threatening trials, participants pressed "Yes" on 84.8% of the trials. A 2 (PTSD) × 3 (Condition) ANOVA indicated a PTSD × Condition interaction [$F(2,53)=10.81$, $p<.01$] with the two groups differing only in how they responded to the threatening final words [$t(55)=5.33$, $p<.01$]. Those with PTSD, as compared to those without PTSD, were more likely to respond "YES", indicating that the threatening words completed the sentence sensibly. There was also a significant effect for Condition [$F(2,53)=5535$, $p<.001$] as all conditions differed from each other. Follow up t tests indicated that participants were more likely to respond "Yes" to the expected ending than the threatening ($p<.01$) and the unexpected endings ($p<.01$). "Yes" responses to the threatening endings were also more common than those to the expected ($p<.01$).

Manipulation Check

In order to confirm that the standard N400 effect was not influenced by the introduction of a third sentence type (i.e., the threatening condition), a manipulation check was performed to demonstrate that unexpected final words demonstrated significantly larger (more negative) N400 amplitudes than did the congruent sentences as if frequently found in the non clinical literature. The 2 (PTSD) × 2 (Condition: Congruent v. Incongruent) × 5 (Electrode) ANOVA showed a significant effect for Condition [$F(1,55)= 9.39$, $p<.01$] with more negative N400s to unexpected final words than expected final words (see Figure 1).

Group effects on N400 amplitude

Consistent with our hypothesis, there was a significant PTSD × Condition interaction [$F(1.87,331) = 3.47$, $p<.05$]. There was also a significant overall Condition effect [$F(1.88,331) = 6.13$, $p<.01$] with the unexpected condition significantly different from the expected and trauma conditions. There were no main effects for "Electrode" or "PTSD". (see Figures 2 and 3).

Three follow up ANOVA were conducted in order to discriminate the source of the PTSD × Condition interaction. This was completed with separate PTSD × Condition ANOVAs in which only two levels of the Condition were tested at a time. In the first ANOVA, the expected condition was compared to the unexpected; in the second, expected vs. threatening; in the third, unexpected vs. threatening. The difference between groups was present between the expected and threatening conditions [$F(1,55) = 7.33$, $p<.01$] but not the unexpected and threatening conditions [$F(1,55) = 1.13$, $p>.05$] nor the expected and unexpected conditions [$F(1,55)=2.15$, $p>.05$]. This indicates that PTSD participants differed in their response to the threatening condition relative to their response to the expected condition. In particular those with PTSD compared to those without PTSD showed larger amplitudes to expected final words but smaller amplitudes to the threatening endings. (see Figure 4). Medication status was also used as a covariate in the analyses however medication status did not impact on the findings, nor did it interact with either "Group" or "Condition".

Group effects on N400 latency

There was no Group effects nor any Group × Condition interactions in the latency of the N400.

Discussion

Overview

The purpose of this study was to investigate possible neurophysiological evidence consistent with theoretical and clinical models of biases in individuals with PTSD. It was hypothesized that compared to individuals without PTSD, those with PTSD would exhibit smaller N400 amplitudes in response to threatening sentence endings due to their increased expectancies for threatening information. Consistent with the hypothesis, individuals with PTSD showed smaller (less negative) N400s in response to threatening sentence endings in comparison to their responses to expected endings. This finding is consistent with models that would predict increased expectancies in those with PTSD for threatening cues and information (Ehlers & Clark 2000; Ehring et al., 2006; Ehring et al., 2008, Engelhard et al., 2009) as well as a body of empirical literature that has shown attentional bias in PTSD (Buckley et al., 2000; Bar-Haim et al, 2007).

This facilitation for threat was supported not only by smaller N400s to the threatening endings but relatively larger N400s to the expected endings in those with PTSD. It appears that, in a context where negative outcomes are possible (i.e., ambiguous sentence stems) those with PTSD have expectations for negative outcomes and are somewhat surprised by more expected, neutral outcomes. Given that Kimble et al. (2002) found that combat veterans with PTSD were more likely to complete ambiguous sentence stems with combat words as opposed to neutral words, there was already some indication that threatening endings may be more accessible than even highly probable neutral endings in PTSD. However, this study indicates that this effect occurs automatically and at the earliest stages of information processing.

This bias also affected behavioral responses. Individuals with PTSD were more likely to indicate that threatening final words sensibly completed the ambiguous sentences than did those without PTSD. This was not a general bias in PTSD as the group did not differ significantly from the no-PTSD participants in their behavioral responses to the unexpected and expected endings. The behavioral data supports the N400 data indicating that those with PTSD find threatening outcomes more probable.

These findings add considerably to our understanding of threat bias in PTSD. Much of the previous work had used behavioral paradigms such as the emotional Stroop or the dot probe task that are likely influenced by motivation, depression, demand characteristics, and motor speed. In such studies, effects such as interference and facilitation are inferred from reaction times. This ERP data provide direct neural evidence of bias in those with PTSD. Additionally, the findings in this study confirm the emerging data from a larger self report literature of negative expectancies and negative appraisals in PTSD. It is known that these biases predict and maintain post trauma pathology, however it is not clear how conscious these processes are. For example, is a negative appraisal produced after consideration of the possible options? Do individuals with PTSD arrive at a negative expectancy for the future after evaluating the possibilities and deciding that a negative outcome is the most likely outcome? This ERP data suggests that the negative appraisals are not the result of a rational, thoughtful process. Rather, those with PTSD appear to be primed to expect the negative and this happens automatically. To an extent, having negative expectancies appears to be a default mode .

Implications and Future Directions

This of course has implications for recovery and treatment. The fact that numerous studies have demonstrated that negative appraisals before or soon after a trauma predict subsequent PTSD (Ehring et al., 2008, Kleim et al., 2007; O’Donnell et al., 2007), suggest that negative appraisals and expectancies may be present in individuals before their trauma. This speaks to how automatic these thought processes may be for these individuals. Negative appraisals are not necessarily new cognitions that develop as a result of the trauma, but rather deeply ingrained cognitive processes that limit recovery, facilitate the development of PTSD, and exacerbate posttraumatic pathology. The automaticity of the processes suggest that those with this type of bias are likely to have little insight into their presence and the impact they have on their lives.

The data from this study particularly suggest that, when negative outcomes are possible, individuals with PTSD assume they will occur. In any circumstance in which signs and stimuli are ambiguous, an expectancy bias consistent with what was found in this study would lead to interpretations of danger and threat. An expectancy bias in which stimuli are interpreted as dangerous would lead individuals to “find” more threatening stimuli even when they don’t exist. This pattern could lead to an increase in re-experiencing symptoms like intrusive memories, and psychological and physiological reactivity. Expectation of future threat would also lead to persistent anxiety, even when no truly threatening stimuli exist. This is likely to be associated with intrusive memories, avoidance behavior, irritability, and poor sleep. Finally, many social stimuli are rarely unequivocally clear, and this could lead to the assumptions of harm, difficulties with trust, and the social dysfunction that often characterize the disorder.

Modifications of the standard N400 paradigm has value in studying cognition and expectation in psychopathology. This study represents a significant advance methodologically in that previous N400 studies manipulated the size of the N400 by varying the expectancy of the stimuli. To our knowledge, this is the first study to investigate whether N400 is manipulated by pre existing expectancies on the part of the participants. While this study looked at semantic expectancy in those with trauma, similar work could be completed in depression and in other anxiety disorders. For example in depression, sentence stems could be designed to be completed with either positively or negatively valenced final words. The work would be able to establish underlying implicit bias in the disorders that may be created by negative schema or play a role in maintaining them.

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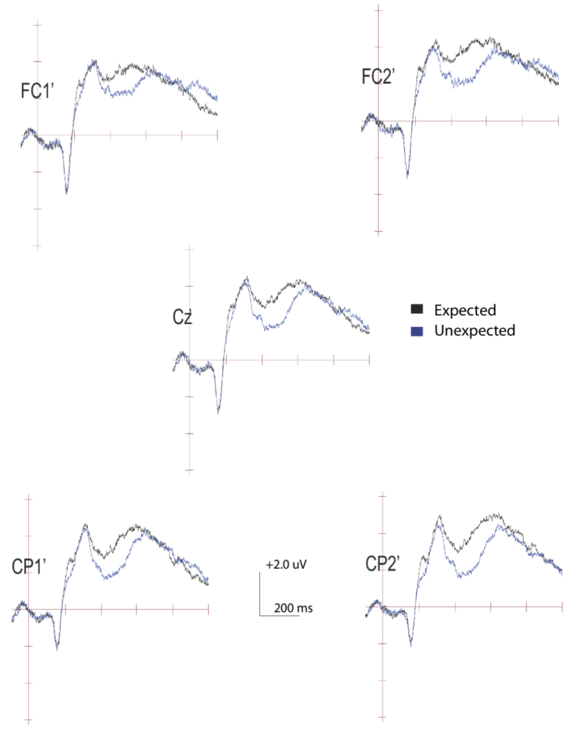

Figure 1.
Expected and unexpected waveforms in all 57 participants

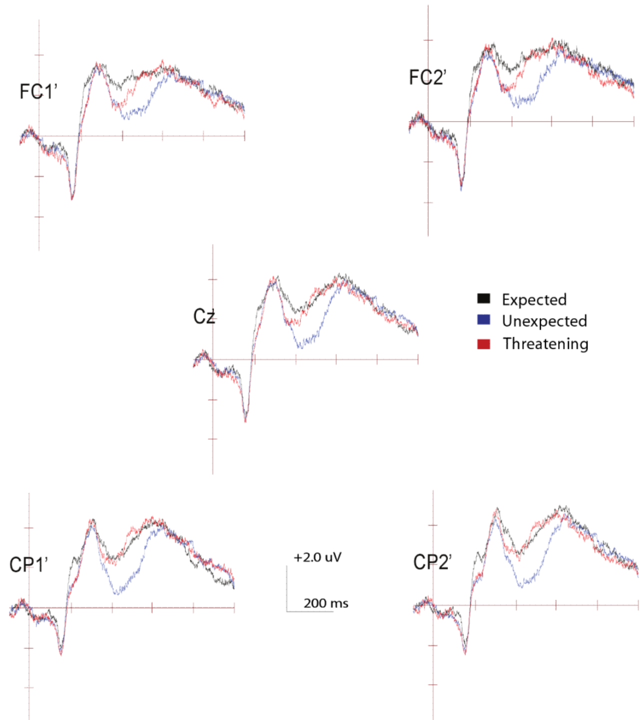

Figure 2.
No PTSD participants ERPs to expected, unexpected, and threatening endings.

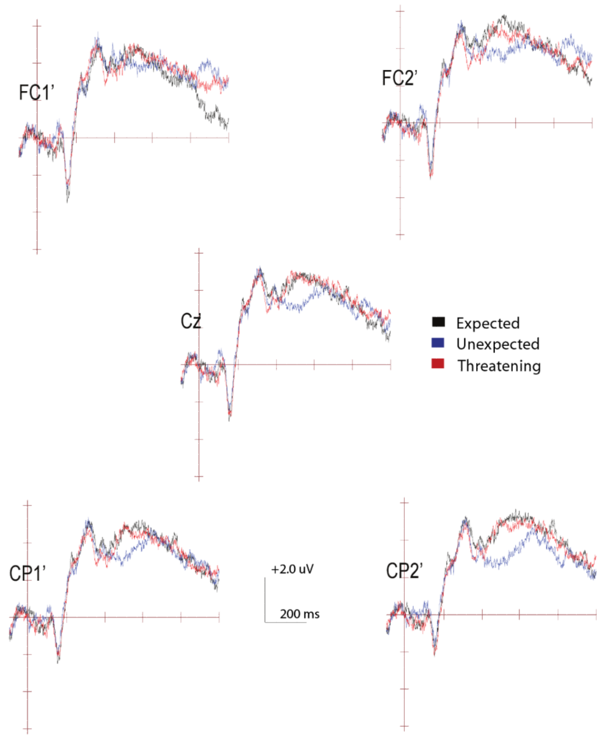

Figure 3.
PTSD participant ERPs to expected, unexpected, and threatening endings

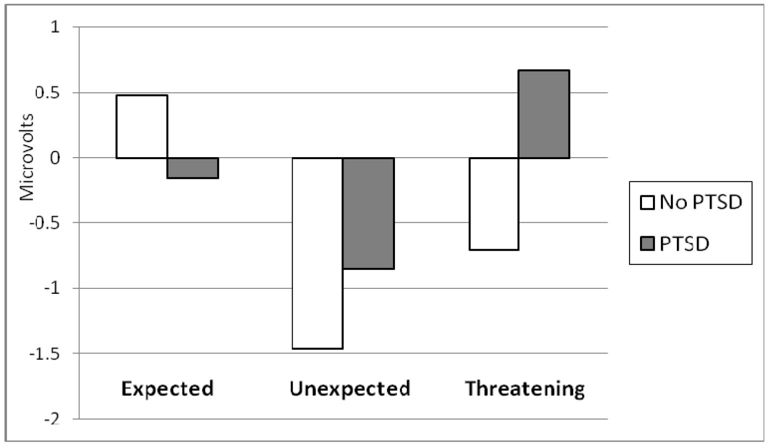

Figure 4.

Peak N400 amplitudes to the central montage (Cz, FC1, FC2, CP1, CP2) as a function of PTSD status and condition.