Neuropsychologia xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Emotion regulation to idiographic stimuli: Testing the Autobiographical Emotion Regulation Task

Brittany C. Speed[a,*], Amanda R. Levinson[a], James J. Gross[b], Dimitris N. Kiosses[c], Greg Hajcak[a]

[a] Department of Psychology, Stony Brook University, United States
[b] Department of Psychology, Stanford University, United States
[c] Department of Clinical Psychiatry, Weill Cornell Institute of Geriatric Psychiatry, United States

ARTICLE INFO

Keywords:
Emotion regulation
Cognitive reappraisal
Late positive potential
Idiographic

ABSTRACT

Mounting evidence suggests that the ability to regulate emotion is crucial for psychological well-being. However, one important limitation of prior emotion regulation studies is that they rely on standardized stimuli low in personal relevance. To address this limitation, the current study employed a novel event-related potential (ERP) paradigm designed to investigate the late positive potential (LPP) as a measure of emotional reactivity and regulation to idiographic stimuli in 49 young adults. The Autobiographical Emotion Regulation Task (AERT) is a word-viewing task in which participants identify neutral and emotionally-charged autobiographical memories and generate keywords unique to each memory. First, participants are instructed to simply view the keywords. Then, participants are presented with keywords from negative memories and are either instructed to react normally (react condition), or to use cognitive reappraisal to decrease negative emotion (reappraise condition). Results indicate that the LPP was potentiated when initially viewing keywords for negative compared to neutral memories. Furthermore, the LPP was reduced during reappraise compared to react trials, demonstrating successful down-regulation of neural activity to negative idiographic stimuli. These findings suggest that the AERT is a feasible and effective probe of emotion regulation to idiographic stimuli.

1. Introduction

Emotions may be conceptualized as transient changes in one's subjective experience, behavior, and physiology that result from motivationally salient internal or external cues (Gross, 2015; Lang, 1995). Emotion *regulation* refers to the activation of a goal to alter one's experiential, behavioral, and/or physiological emotional response tendencies (Gross, 1998b; Gross et al., 2011). According to the process model of emotion regulation (Gross, 2015), different types of emotion regulation can be distinguished by the stage at which they are implemented within the emotion-generation process, and by the outcomes they produce. Emotion regulation research has largely focused on the stage of *cognitive change*, which refers to the modification of cognitions related to a situation or one's ability to manage it (Gross and Thompson, 2007).

One specific form of cognitive change, cognitive reappraisal, has garnered increasing attention because of its associations with a range of positive health outcomes (Gross, 2002). Cognitive reappraisal is an antecedent-focused cognitive linguistic strategy which involves reinterpreting the meaning of a situation in order to change its emotional intensity. Typically cognitive reappraisal is employed to decrease the intensity of negative emotions or increase the intensity of positive emotions (Ochsner and Gross, 2005). The tendency to use cognitive reappraisal has been associated with reduced negative emotions and increased positive emotions (Gross, 1998a; Feinberg et al., 2012; Lieberman et al., 2011; Ray et al., 2010; Webb et al., 2012), and decreased physiological arousal (Gross, 1998a; Jackson et al., 2000; Kim and Hamann, 2012; Shiota and Levenson, 2012), and positive mental health outcomes (Gross and John, 2003; Nezlek and Kuppens, 2008; Richards and Gross, 2000).

Neuroimaging studies examining the neural bases of cognitive reappraisal utilizing standardized emotional stimuli have yielded largely consistent findings (for a review see Ochsner et al., 2012). Meta-analyses of these neuroimaging studies have found that cognitive reappraisal is associated with activation in brain regions associated with cognitive control, including the dorsolateral prefrontal cortex (dlPFC), ventrolateral PFC (vlPFC), and parietal cortex, as well as deactivation in brain regions associated with emotion-generation, such as the amygdala and insula (Buhle et al., 2014; Kalisch, 2009; Kohn et al., 2014). In addition, greater reappraisal use in daily life has been

* Corresponding author.
E-mail address: brittcspeed@gmail.com (B.C. Speed).

http://dx.doi.org/10.1016/j.neuropsychologia.2017.04.032
Received 19 January 2017; Received in revised form 30 March 2017; Accepted 26 April 2017

associated with greater decreases in amygdala activity and increases in prefrontal and parietal activity during the processing of negative emotional facial expressions, suggesting that greater reappraisal use may facilitate greater top-down processing of negative information (Drabant et al., 2009).

Given that important changes in emotional processing occur on the order of milliseconds, electrocortical measures of emotional processing derived from the event-related potential (ERP) are ideally suited to study engagement with emotional stimuli, allowing for the examination of discrete changes in neural functioning in response to emotion regulation across time (Weinberg et al., 2013). One promising biomarker of emotional processing is the late positive potential (LPP) which is evident as a positive deflection maximal at central-parietal midline recording sites; the LPP begins approximately 200 ms after stimulus onset and is potentiated for pleasant and unpleasant compared to neutral stimuli (Hajcak and Olvet, 2008). Unlike most ERPs, the LPP is sustained for the duration of stimulus presentation—and appears to index sustained attention toward, and engagement with, emotional content (Hajcak et al., 2010). Notably, the LPP is sensitive to changes in stimulus meaning, such as when emotion regulation strategies including cognitive reappraisal are used (Hajcak and Nieuwenhuis, 2006; Foti and Hajcak, 2008; Thiruchselvam et al., 2011). Previous research has found that cognitive reappraisal resulted in an attenuated LPP to negative pictures, which was associated with decreases in self-reported negative emotion (Hajcak and Nieuwenhuis, 2006). To further clarify the mechanism between a reduced LPP following reappraisal, one study provided auditory reappraisal frames before picture viewing (i.e., preappraisal), and found that the LPP was significantly reduced in response to unpleasant pictures that followed neutral descriptions, compared to the LPP elicited by unpleasant pictures that followed negative descriptions (Foti and Hajcak, 2008). Alternatively, the LPP can be potentiated when a neutral stimulus is pre-appraised in negative terms (MacNamara et al., 2009). These findings indicate that altering the meaning of an emotional stimulus, via reappraisal or preappraisal, can modify the amplitude of the LPP.

One broad limitation of prior emotion regulation studies is that they have primarily relied on standardized emotional words, picture sets, or films (Buhle et al., 2014; Dillon et al., 2006; Gross, 2002; Hajcak et al., 2010; Schupp et al., 2006). Appraisal theories argue that the self-relevance of a stimulus influences the intensity of the resulting emotion, which likely impacts the success of the regulation attempt (Ellsworth and Scherer, 2003). Thus, though there is strong evidence that adults can successfully utilize cognitive reappraisal to alter emotional responding to standardized emotional stimuli, there may be important differences in one's ability to use reappraisal to self-relevant versus standardized stimuli.

A growing literature utilizing self-relevant emotional stimuli suggests that cognitive reappraisal may also be effectively used to modulate emotional responses to autobiographical information. One self-report study utilized anger-inducing autobiographical memories, and found that cognitive reappraisal resulted in decreased re-experiencing of anger and negative emotion (Kross et al., 2005). Furthermore, Kross et al. (2009) found that cognitive reappraisal during negative autobiographical memory retrieval resulted in activation in brain regions associated with cognitive control, including the left PFC, as well as activation in a network of regions thought to be involved in autobiographical memory and self-referential processing, including the subgenual ACC and medial PFC. Activation in these regions mirrored participants' self-reported negative emotion (Kross et al., 2009). Other studies utilizing emotional autobiographical memories have largely replicated these findings (Cooney et al., 2007; Fabiansson et al., 2012; Holland and Kensinger, 2013; Joormann et al., 2012), suggesting that cognitive reappraisal to self-relevant stimuli results in activation of brain networks associated with cognitive control and self-referential processing, and decreases subjective negative emotion. However, it is currently unclear how cognitive reappraisal to self-relevant stimuli may influence other measures of emotional processing, such as the LPP.

As dysfunction in emotion regulation ability plays a key role in many forms of psychopathology (Gross and Jazaieri, 2014; Kring and Werner, 2004), studies have utilized the LPP as an individual difference measure, associating variability in the LPP to psychopathology (e.g. Foti et al., 2010; Weinberg et al., 2016). An essential criterion for conducting studies of trait-like individual differences and clinical problems is reliability in the measures used. To the best of our knowledge, no studies have examined psychometric properties of fMRI measures of emotion regulation, and only a single study has examined internal consistency of the LPP during emotion regulation. Specifically, Moran et al. (2013) found that the internal consistency reliability of the LPP during emotion regulation was in the good range (*r*s between 0.66 and 0.79). However, no studies have examined psychometric properties of neural correlates of regulation in response to idiographic stimuli that vary from participant to participant.

The primary goal of the current study was to examine the neural correlates of emotional reactivity and regulation to idiographic information (i.e. autobiographical memories) utilizing a novel ERP paradigm. The Autobiographical Emotion Regulation Task (AERT) utilizes idiographic keywords tied to negative and neutral autobiographical memories as emotional cues. In this task, participants are presented with the negative and neutral idiographic keywords, and asked to view them while thinking vividly of the situation, or to use cognitive reappraisal to decrease the intensity of negative emotions. Previous ERP studies utilizing standardized affective words as stimuli have found that the LPP is potentiated when viewing positive and negative words compared to neutral words (Dillon et al., 2006; Inaba et al., 2005; Maratos et al., 2000; McNeely et al., 2004; Naumann et al., 1992). Consistent with previous studies utilizing standardized stimuli, we hypothesized that the LPP would be potentiated when viewing keywords that serve as cues to negative autobiographical memories, compared to keywords that serve as cues to neutral autobiographical memories. Further, when viewing keywords that serve as cues to negative autobiographical memories we hypothesized that the LPP would be reduced during cognitive reappraisal compared to normal reactivity. Finally, as the current study utilizes a novel task that employed idiographic stimuli, internal reliability of the LPP was evaluated; based on previous work (Moran et al., 2013), we expected the LPP to have good internal consistency.

2. Method

2.1. Participants

Participants were 49 Stony Brook University undergraduate students recruited from the psychology department research participation pool (age $M = 19.47$, $SD = 2.84$, $n = 27$ females). The ethnic distribution of the sample was 40.8% Caucasian, 6.1% African American, 34.7% Asian, and 18.4% Hispanic. This study was approved by Stony Brook University's Internal Review Board. All participants provided informed consent and received course credit for their participation. Inclusion criteria were English fluency and ability to read and comprehend questionnaires.

2.2. Procedure

Participants came to the lab for a 1-h individual session. They first completed consent forms, provided basic demographic information, and then provided personal information pertaining to the Autobiographical Emotion Regulation Task (AERT). The AERT is a computerized word-viewing task that was designed to investigate ERPs during emotional reactivity and regulation in relation to idiographic information. First, participants were asked to write down four recent (i.e. in the past 2 years) autobiographical situations: two reflecting a neutral experience (e.g., grocery shopping, folding laundry) and two

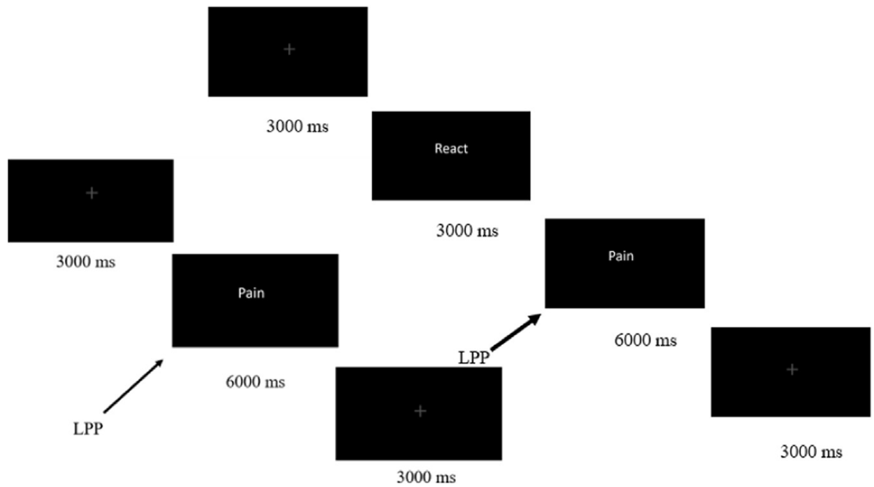

Fig. 1. Displayed on the left is an example of a single trial during block 1 of the AERT, which involved the passive viewing of keywords from each negative and neutral situation, grouped by situation and counterbalanced. Displayed on the right is an example of a single trial during a 'React' or 'Reappraise' block, which involved the viewing of keywords from the negative situations while reacting naturally (react block) or using cognitive reappraisal (reappraise block), as indicated by the preceding cue.

reflecting events that triggered intense negative emotions (e.g., relationship break-up, death of a loved one; see Appendix I). After writing about each situation, participants were asked to rate its emotional intensity using a Likert-scale ranging from 1 to 5 (1 = *completely neutral/not negative*, 2 = *a bit negative*, 3 = *moderately negative*, 4 = *very negative*, 5 = *extremely negative*). In addition, participants were asked to identify 10 keywords that were both unique and tightly linked to each situation. These keywords were then presented to participants during the task.

In the first portion of AERT, participants were asked to simply view the keywords associated with each of the four situations (see Fig. 1; 40 words total: 20 neutral, 20 negative). Participants were first reminded of a situation, and then were instructed to view all of the keywords associated with that situation while thinking vividly of that situation. The order in which situations were presented was counterbalanced across participants (i.e., Neu, Neg, Neu, Neg or Neg, Neu, Neg, Neu), and keywords within a situation were presented in a random order. Next, participants completed separate "react" and "reappraise" blocks of trials that focus only on negative situations.

In the react block, participants were first reminded of one of the negative situations they identified, and were told that they would again be viewing the keywords associated with that situation. Each word was preceded by a "React" cue, which was intended to serve as a reminder for participants to think vividly of the situation (see Fig. 1). Each keyword was presented twice in random order (20 negative react trials).

In the reappraise block, participants were likewise reminded of a negative situation, and were given instructions for how to engage in cognitive reappraisal when viewing the keywords for that situation. Specifically, participants were instructed to "*think about the situation that applies to the words from a different perspective, in a way that decreases negative emotion. For example, you might try to see this situation from the perspective of an impartial observer.*" Two practice trials were conducted with mock situations, where participants used reappraisal out-loud, to ensure that participants understood the reappraisal instructions (see Appendix II for detailed instructions and practice situations). During reappraisal trials, each word was preceded by a "Reappraise" cue which was intended to serve as a reminder for participants to decrease their negative emotion using cognitive reappraisal when viewing the upcoming word. Again, each word was presented twice in random order (20 negative reappraise trials).

React and reappraise blocks were presented in counterbalanced order across participants (i.e. React, Reappraise or Reappraise, React), and all cues (i.e., React, Reappraise) were presented for 3000 ms whereas all keywords in AERT were presented for 6000 ms each and followed by a 3000 ms fixation. The viewing distance was approximately 65 cm, words were presented in white font on a black background on the center of the screen in Calibri 60 pt. font. The AERT was presented using Presentation software (Neurobehavioral Systems Inc., Albany, CA).

Upon completion of each block, participants were asked to rate their overall subjective emotion when viewing the words in that block on a 5-point Likert scale (1 = *completely neutral/not negative* to 5 = *extremely negative*).

2.3. Physiological recording and data processing

Continuous electroencephalography (EEG) was recorded while participants completed the AERT. The ActiveTwo BioSemi was used and included 34 electrodes, including FCz and Iz, positioned according to the 10/20 system (BioSemi, Amsterdam, Netherlands). In addition, electrodes were placed above and below the left eye, adjacent to the outer canthi of the left and right eyes, and on the right and left mastoid bone. In order to improve the signal-to-noise ratio the EEG signal was preamplified at the electrode, and data were digitized at a 24-bit resolution with a sampling rate of 1024 Hz using a low pass fifth order sinc filter with a half-power cut-off of 204 Hz. EEG was measured online with respect to a common mode sense active electrode, forming a monopolar channel. Raw EEG data was re-referenced offline to the average of the left and right mastoids, and band pass filtered from 0.01 to 30 Hz. Artifacts due to eye blink and ocular movements were corrected using established standards described by Gratton et al. (1983). All EEG data processing was completed using BrainVision Analyzer (Version 2.1.1.327).

The EEG was segmented for each trial beginning 200 ms before the presentation of each ideographic keyword and continuing for 6200 ms (i.e., the full keyword presentation duration). A semiautomatic procedure was used to reject artifacts on individual trials. Specifically, individual channels were marked for rejection if a voltage step greater than 50.0 μV was present between sample points, if a deflection greater than 300.0 μV occurred within an epoch, or if a voltage difference of less than 0.50 μV was detected within 100 sequential ms. Lastly, visual inspection of the remaining trials was conducted to detect and reject any other artifacts. The LPP is typically sustained for the duration of a stimulus presentation (Hajcak et al., 2010), and has been shown to be modulated relatively quickly by top-down processes, such as directed attention or cognitive reappraisal (Hajcak et al., 2009; Moser et al., 2006). Therefore, in order to examine differences in emotion modulation and regulation across time, the LPP was scored as the average activity where it was maximal, at central-parietal electrodes (i.e., average of Pz, Cz, CP1, and CP2) in three time windows: 400–1000 ms, 1000–3000 ms, and 3000–6000 ms. The LPP was scored separately for negative and neutral trials in the "view" block (i.e., view neutral, view negative), negative trials in the "react" block (i.e., react negative), and negative trials in the "reappraise" block (i.e., reappraise negative). Each LPP average was baseline-corrected relative to the activity in the 200 ms window before picture onset. The average number of view neutral ($M = 18.69$, $SD = 2.80$), view negative ($M = 18.78$, $SD = 2.16$), react negative ($M = 19.18$, $SD = 2.23$), and reappraise negative ($M = 19.29$, $SD = 1.37$) trials included in ERP averages were proportionate. Eight participants were excluded from analyses as a result of equipment malfunction ($n = 2$), or excessive EEG artifacts ($n = 6$), resulting in a final sample of 49 participants.

2.4. Data analysis

Self-report ratings of negative emotion were evaluated by means of paired-samples *t*-tests. To determine if the negative and neutral situations differentially modulated the LPP during word viewing in block 1, we conducted a repeated-measures analysis of variance (ANOVA) with situation (negative vs. neutral) and time window (400–1000 ms, 1000–3000 ms, 3000–6000 ms) as within-subjects factors. To examine emotion regulation of the LPP during the react and reappraise blocks, we conducted a repeated-measures ANOVA with condition (react vs. reappraise) and time window (400–1000 ms, 1000–3000 ms, 3000–6000 ms) as within-subjects factors.

Internal consistency reliability of the LPP during the AERT was evaluated by calculating the split-half reliability. Specifically, we examined the correlation between averages based on odd- and even-numbered trials (i.e. words) within each block, corrected using the Spearman-Brown Prophecy Formula (Nunnally et al., 1967). All analyses were conducted using IBM SPSS Statistics, Version 22.0 (Armonk, NY).

3. Results

Upon identifying and writing about each negative (word count $M = 126.51$, $SD = 69.82$) and neutral (word count $M = 77.39$, $SD = 44.77$) situation, participants rated the negative situations as significantly more negative ($M = 4.55$, $SD = 0.60$) than the neutral situations ($M = 1.01$, $SD = 0.07$), $t(48) = -41.75$, $p < 0.001$.[1] Neutral situations included the completion of chores (28.3%), commuting/travel (18.2%), personal hygiene (17.2%), meal preparation (16.2%), shopping (10.1%), school work (7.1%), and 'other' (3%). Negative situations involved interpersonal conflict (34.3%), health problems (21.2%), loss of a loved one (14.1%), school/work problems (13.1%), relationship ending (12.1%), and 'other' (5.1%). The length of keywords in the first ($M = 6.14$, $SD = 0.94$) and second ($M = 5.95$, $SD = 0.78$) neutral situation were not significantly different, $t(48) = 1.22$, $p > 0.22$, nor were keywords in the first ($M = 6.39$, $SD = 0.79$) and second ($M = 6.57$, $SD = 0.75$) negative situation, $t(48) = -1.29$, $p > 0.20$. Overall, keywords for the negative situations ($M = 6.48$, $SD = 0.61$) were significantly longer than keywords for the neutral situations ($M = 6.04$, $SD = 0.69$), $t(48) = 3.55$, $p < 0.001$.[2]

3.1. Emotion reactivity

3.1.1. Self-report

Following initial passive viewing of keywords from each situation, negative emotion was rated significantly higher when viewing negative ($M = 3.53$, $SD = 0.87$) compared to neutral idiographic words ($M = 1.06$, $SD = 0.24$), $t(48) = 19.38$, $p < 0.001$.

3.1.2. LPP

As shown in Fig. 2, results from the initial passive viewing of words from each situation reveal that the LPP was potentiated when viewing negative idiographic keywords ($M = 4.91$, $SD = 6.99$), compared to the LPP when viewing neutral idiographic keywords ($M = 2.19$, $SD = 5.64$), $F(1, 48) = 5.71$, $p < 0.05$, $\eta_p^2 = 0.11$. The magnitude of the LPP did not change across time windows, $F(2, 96) = 2.08$, $p > 0.10$, and the Condition × Time interaction was not significant ($p > 0.20$).

3.2. Emotion regulation

3.2.1. Self-report

Negative emotion was rated significantly higher when viewing negative idiographic keywords during the react trials ($M = 2.92$, $SD = 1.02$), compared to when viewing negative idiographic keywords during the reappraise trials ($M = 2.10$, $SD = 1.03$), $t(48) = 5.32$, $p < 0.001$.

3.2.2. LPP

Results indicated that the LPP was reduced during reappraise ($M = 0.02$, $SD = 3.67$) compared to react trials ($M = 2.31$, $SD = 5.99$), $F(1, 48) = 5.34$, $p < 0.05$, $\eta_p^2 = 0.10$, indicating successful down-regulation of neural activity during the reappraise trials (see Fig. 3). In addition, the LPP was largest during the early window (400–1000 ms; $M = 3.28$, $SD = 3.92$), and smallest during the late window (3000–6000 ms; $M = -0.30$, $SD = 7.54$), $F(2, 96) = 17.00$, $p < 0.001$, $\eta_p^2 = 0.26$. However, this finding was qualified by a significant Condition × Time interaction, $F(2, 96) = 3.15$, $p < 0.05$, $\eta_p^2 = 0.06$, which indicated that the difference in LPP magnitude between react and reappraise conditions became larger over time. Specifically, LPP magnitude between react and reappraise conditions was not differentiated in the early window (400–1000 ms), $t(48) = 1.42$, $p > 0.16$, but was significantly differentiated during the middle (1000–3000 ms), $t(48) = 2.33$, $p < 0.05$, and late windows (3000–6000 ms), $t(48) = 2.26$, $p < 0.05$.[3]

3.3. Reliability

As illustrated in Table 1, internal consistency of the LPP in the AERT varied from modest during passive viewing of negative and neutral idiographic words, to poor during react and reappraise trials. According to traditional criteria, the LPP showed good internal consistency during the passive viewing of words from the negative situations ($r = 0.73$). However, during neutral, react, and reappraise conditions internal consistency was poor (*r*s ranged from 0.46 to 0.00).

4. Discussion

The current study examined emotional reactivity and emotion regulation using a novel ERP paradigm that utilized idiographic key-

[1] Follow-up analyses examining potential associations between the LPP and self-reported emotion found no significant associations between self-report ratings of negative emotion during the task and the LPP (*ps* > 0.28). In addition, ratings of negative emotional intensity when writing about negative scenarios was not associated with the LPP during the AERT (*ps* > 0.29).

[2] As negative and neutral keywords were significantly different in length, we conducted a follow-up analysis to determine if keyword length impacted the LPP. Specifically, we conducted a repeated-measures analysis of covariance (ANCOVA) with situation (negative vs. neutral) and time window (400–1000ms, 1000–3000ms, 3000–6000ms) as within-subjects factors, and negative and neutral keyword length as mean-centered continuous covariates. Results again revealed that the LPP was poten-

(*footnote continued*)
tiated when viewing negative idiographic keywords compared to the LPP when viewing neutral idiographic keywords, $F(1, 46) = 5.50$, $p < 0.05$, $\eta_p^2 = 0.11$. There were no significant main effects or interactions of time or word length on the LPP (*p*'s > 0.15).

[3] When sex was included as a between-subjects factor in all analyses, the pattern of results did not change; all reported findings remained significant. In addition, there were no main effects of sex or interactions found between sex and the LPP (*p*'s > 0.20).

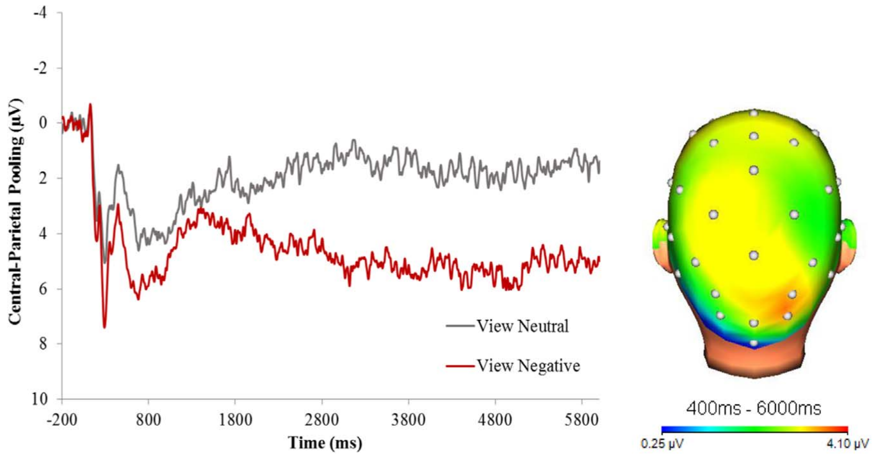

Fig. 2. Grand-average ERP waveforms and head maps to negative and neutral keyword presentation during the AERT in block 1. The LPP waveforms (left) were pooled across central-parietal (Pz, Cz, CP1, CP2) electrode sites. The head map (right) displays the difference between negative and neutral word presentation in block 1. Negative keywords were associated with a sustained increase in the late positive potential.

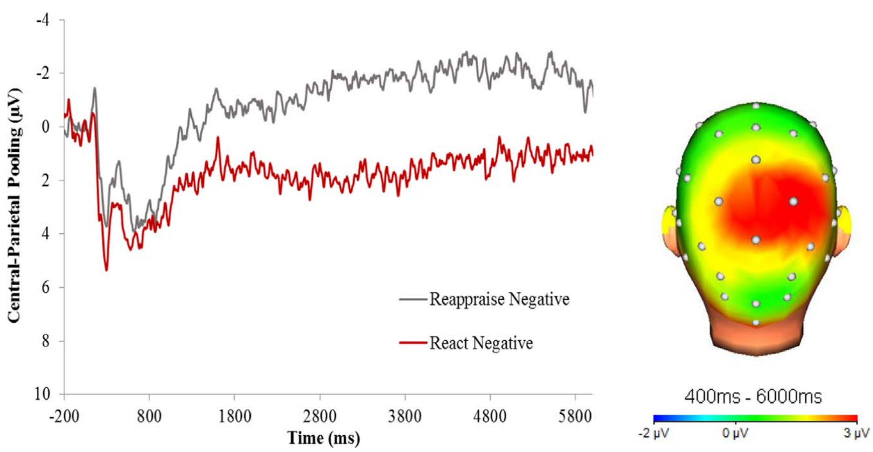

Fig. 3. Grand-average ERP waveforms and head maps to negative keyword presentation during the AERT in react and reappraise blocks. The LPP waveforms (left) were pooled across central-parietal (Pz, Cz, CP1, CP2) electrode sites. The head map (right) displays the difference between react and reappraise trials. Negative keywords presented in the reappraise condition were associated with a reduced late positive potential relative to negative keywords presented in the react condition.

Table 1
Odd vs. even trials split-half reliability of the LPP during the Autobiographical Emotion Regulation Task.

Time Window	View Neutral	View Negative	React Negative	Reappraise Negative
400–1000 ms	0.48	0.75	0.21	0.44
1000–3000 ms	0.57	0.63	0.20	0.00
3000–6000 ms	0.31	0.62	0.40	0.00
400–6000 ms	0.46	0.73	0.29	0.00

Note: The LPP was scored as the average activity at central-parietal electrodes (i.e., average of Pz, Cz, CP1, and CP2).

words as cues for autobiographical emotional memories. Consistent with our hypotheses, the LPP was potentiated when viewing keyword cues to negative autobiographical memories compared to word cues to neutral autobiographical memories. Furthermore, when viewing keyword cues to negative autobiographical memories, the LPP was attenuated during cognitive reappraisal trials compared to a control condition. This pattern of results was identical to what was found using self-report measures (i.e., self-reported negative emotion was increased when viewing negative keyword cues, and was reduced during reappraise trials compared to the control condition). Collectively, these findings demonstrate successful down-regulation of neural activity and subjective emotion to negative idiographic stimuli.

The majority of previous research examining emotional modulation of the LPP has focused on responsiveness to standardized affective picture sets, such as the International Affective Picture System (IAPS; Lang et al., 1999), finding that the LPP is potentiated to emotionally arousing compared to neutral pictures (Bernat et al., 2011; Cuthbert et al., 2000; Hajcak et al., 2010; Schupp et al., 2004). Studies utilizing standardized affective *words* have similarly found that the LPP is potentiated when viewing emotional (i.e. positive, negative) compared to neutral words (Dillon et al., 2006; Inaba et al., 2005; Maratos et al., 2000; McNeely et al., 2004; Naumann et al., 1992). Results from the current study replicate prior findings and extend them to non-standardized, idiographic stimuli. Specifically, the current study found that the LPP was potentiated to negative compared to neutral idiographic stimuli, using words that serve as cues to autobiographical memories.

Consistent with research on emotional modulation, the vast majority of research investigating the neural correlates of cognitive reappraisal have utilized standardized visual stimuli (Hajcak et al., 2010; Ochsner et al., 2012). Overall, these studies have found that cognitive reappraisal results in attenuation of the LPP when viewing negative pictures (Hajcak and Nieuwenhuis, 2006; Foti and Hajcak, 2008; Thiruchselvam et al., 2011). The current study found that the LPP elicited by negative idiographic keywords was decreased following reappraisal training and instructions, suggesting that cognitive reappraisal is an effective strategy in reducing the neural response to negative autobiographical memories. For the current study the size of this effect was in the small-to-moderate range ($d = 0.46$), which is notably smaller than the large effect size found by Hajcak and Nieuwenhuis ($d = 0.85$; 2006). Indeed, the increased personal salience of personally-relevant emotional events may make it more difficult to effectively utilize cognitive reappraisal as an emotion regulation strategy. The few neuroimaging studies that have been conducted using autobiographical emotional memories have found that in addition to cognitive control regions, activation is increased in areas of the brain associated with self-referential processing (Kross et al., 2009), suggesting that the self-relevance of emotional stimuli may influence neural activity associated with emotional processing and cognitive reappraisal. Therefore, the personal relevance of emotional information may be important, and may render emotion regulation more difficult. Future research should compare the AERT and a traditional standardized emotion regulation paradigm (e.g. Jackson et al., 2000) in the same subjects to better evaluate potential differences in effect size and internal consistency.

Given the growing interest in using ERPs and other neural measures to study individual differences in psychopathology, it is important to evaluate the psychometric properties of these measures (Patrick and Hajcak, 2016). In the current study, internal consistency of the LPP during the passive viewing of negative and neutral idiographic words was largely consistent with two previous studies that have examined reliability of the LPP while viewing standardized emotional pictures (Kujawa et al., 2013; Moran et al., 2013). However, the current study found that the internal consistency of the LPP to negative keywords during emotion regulation was poor. To date, only one study has investigated the reliability of the LPP during emotion regulation using standardized emotional stimuli, and findings suggest good internal consistency and test-retest reliability when compared to other psychophysiological measures (Moran et al., 2013). It should be noted that when conducting reliability analyses, Moran et al. (2013) only included participants with at least 20 artifact-free trials per condition, which resulted in them excluding 58 of the 87 participants (67%) in their sample. It is possible that the current study did not include enough trials to obtain adequate internal consistency. These findings suggest that the task was effective in producing the expected between-condition (i.e., within-subject) effects, but lacked sufficient internal consistency to be used to examine individual differences. Although disappointing and somewhat surprising given the previous research, these findings highlight a critical need for studies using psychophysiological measures to report the psychometric properties of those measures, as is common-practice when using self-report assessments.

There are several possibilities as to why internal consistency was lower than expected in the current study. As stated above, it may be that the current study did not include enough trials to obtain good internal consistency. In addition, participants' ability to reappraise negative scenarios may have changed during the course of the experiment, as they became more practiced. Future studies using idiographic stimuli may want to consider a providing participants with more practice using cognitive reappraisal to regulate negative emotion to self-relevant stimuli before beginning the AERT, as the current study involved reappraisal practice on only 2 mock scenarios. The current study utilized a novel task which involved viewing words as reminders of autobiographical memories; thus, each participant engaged with different stimuli. Measures of internal consistency were originally developed to evaluate psychometric properties of paper-and-pencil measures, in which all participants answer the same questions, typically with restricted response options (DeVellis, 2006). To improve internal consistency while maintaining external validity, future studies might consider using a single idiographic keyword cue, which is repeated across trials, for a given autobiographical memory. It may be that using multiple keyword cues per memory resulted in more varied responding across trials within a condition. For example, each keyword may have been linked to a different part of the autobiographical memory, and these parts may have varied significantly in their emotional content. In addition, during cognitive reappraisal trials it is possible that different cognitive strategies were engaged across participants, or across trials within participants, which may have resulted in poor internal consistency of the LPP. To overcome this potential problem, future research might encourage a more specific cognitive reappraisal strategy (e.g. distancing) in all participants. Lastly, future studies might examine test-retest reliability of the LPP during the AERT to determine whether variability in the LPP in this task is stable over time (i.e., trait like) overall. While test-retest reliability is more challenging to assess because it requires multiple assessments, it will be particularly important to determine for future research hoping to use the LPP as a trait-like biomarker of disease risk.

Overall, these findings suggest that the AERT is a feasible and effective probe of emotion modulation and emotion regulation to idiographic stimuli. Consistent with previous research using standardized affective visual stimuli, the current study found that cognitive reappraisal effectively reduces the LPP, a neural index of emotional processing, elicited during engagement with negative autobiographical memories. Future studies are needed to further evaluate and optimize the psychometric properties of the LPP, particularly when using idiographic stimuli, as internal consistency in the current study was low and inadequate for individual differences research. With the expansion of research on the neural correlates of emotion and emotion regulation comes a growing responsibility for researchers to critically evaluate the psychometric properties of their measurements. Unfortunately, the reporting of psychometric properties of psychophysiological measures is rare, and the current study indicates the need for this practice to become commonplace.

Appendix I

Neutral situation instructions: *Please recall and briefly describe below a recent autobiographical situation that did not elicit any strong emotions (e.g. making a meal, folding laundry, waiting for the bus). Try to recall the situation as vividly as possible.*

Negative situation instructions: *Please recall and briefly describe below a recent autobiographical situation that triggered significant or intense negative emotions (e.g. sadness, anxiety, anger, irritability, hopelessness, helplessness, guilt), preferable in the past 2 years. Try to recall the situation as vividly as possible.*

Instructions for generating keywords for a specific neutral or negative situation: *Considering the situation you just identified above, please identify 10 key words that are tightly linked to the situation. Please consider these words carefully, and do not choose any words you have chosen previously, you will be referencing them later on in the study.*

Appendix II

Reappraisal Instructions: *Before you see each word, you will see a screen that says "REAPPRAISE" – this cue indicates that we would like you to think about the situation that applies to the next word from a different perspective. We would like you to think in a way that decreases negative emotion. For example, you might try to see this situation from the perspective of an impartial observer – like it was a scene from a movie, or like it happened to a stranger.*

Practice Situation 1: *You raise your hand to answer a question in class, the professor indicates that your answer is not correct, and you think you hear other students in the class giggling.*

How might you reappraise your emotions in this situation?

If participant has difficulty, provide examples: *They were giggling at something else; the question was really difficult; it happened to someone else.*

Practice Situation 2: *You are supposed to be meeting a friend for dinner at 6 pm. At 6:30 pm they still have not arrived or tried to contact you.*

How might you reappraise your emotions in this situation?

If participant has difficulty, provide examples: *They are stuck in traffic; they got caught up atwork; people are often late or forgetful.*

If participant required prompts after the second practice situation, provide a 3rd example.

References

Bernat, E.M., Cadwallader, M., Seo, D., Vizueta, N., Patrick, C.J., 2011. Effects of instructed emotion regulation on valence, arousal, and attentional measures of affective processing. Developmental Neuropsychology *36* (4), 493–518.

Buhle, J.T., Silvers, J.A., Wager, T.D., Lopez, R., Onyemekwu, C., Kober, H., Ochsner, K.N., 2014. Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. Cerebral Cortex *24* (11), 2981–2990.

Cooney, R.E., Joormann, J., Atlas, L.Y., Eugène, F., Gotlib, I.H., 2007. Remembering the good times: Neural correlates of affect regulation. NeuroReport *18* (17), 1771–1774.

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.

DeVellis, R.F., 2006. Classical test theory. Medical Care *44* (11), S50–S59.

Dillon, D.G., Cooper, J.J., Grent-'t-Jong, T., Woldorff, M.G., LaBar, K.S., 2006. Dissociation of event-related potentials indexing arousal and semantic cohesion during emotional word encoding. Brain and Cognition *62* (1), 43–57.

Drabant, E.M., McRae, K., Manuck, S.B., Hariri, A.R., Gross, J.J., 2009. Individual differences in typical reappraisal use predict amygdala and prefrontal responses. Biological Psychiatry *65* (5), 367–373.

Ellsworth, P.C., Scherer, K.R., 2003. Appraisal processes in emotion. In: Davidson, R.J., Scherer, K.R., Goldsmith, H.H. (Eds.), Handbook of Affective Sciences. Oxford University Press, New York, NY, pp. 572–595.

Fabiansson, E.C., Denson, T.F., Moulds, M.L., Grisham, J.R., Schira, M.M., 2012. Don't look back in anger: Neural correlates of reappraisal, analytical rumination, and angry rumination during recall of an anger-inducing autobiographical memory. NeuroImage *59* (3), 2974–2981.

Feinberg, M., Willer, R., Antonenko, O., John, O.P., 2012. Liberating reason from the passions overriding intuitionist moral judgments through emotion reappraisal. Psychological Science *23* (7), 788–795.

Foti, D., Hajcak, G., 2008. Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. Journal of Cognitive Neuroscience *20* (6), 977–988.

Foti, D., Olvet, D.M., Klein, D.N., Hajcak, G., 2010. Reduced electrocortical response to threatening faces in major depressive disorder. Depression and Anxiety *27* (9), 813–820.

Gratton, G., Coles, M.G., Donchin, E., 1983. A new method for off-line removal of ocular artifact. Electroencephalography and Clinical Neurophysiology *55* (4), 468–484.

Gross, J.J., 1998a. Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. Journal of Personality and Social Psychology *74*, 224–237. http://dx.doi.org/10.1037/0022-3514.74.1.224.

Gross, J.J., 1998b. The emerging field of emotion regulation: An integrative review. Review of General Psychology *2*, 271–299. http://dx.doi.org/10.1037/ 1089-2680.2.3.271.

Gross, J.J., 2002. Emotion regulation: Affective, cognitive, and social consequences. Psychophysiology *39* (3), 281–291.

Gross, J.J., 2015. Emotion regulation: Current status and future prospects. Psychological Inquiry *26* (1), 1–26. http://dx.doi.org/10.1080/1047840X.2014.940781.

Gross, J.J., John, O.P., 2003. Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. Journal of Personality and Social Psychology *85* (2), 348–362.

Gross, J.J., Thompson, R.A., 2007. Emotion regulation: Conceptual foundations. In: Gross, J.J. (Ed.), Handbook of Emotion Regulation. Guilford Press, New York, NY, pp. 3–24.

Gross, J.J., Jazaieri, H., 2014. Emotion, emotion regulation, and psychopathology an affective science perspective. Clinical Psychological Science *2* (4), 387–401.

Gross, J.J., Sheppes, G., Urry, H.L., 2011. Emotion generation and emotion regulation: A distinction we should make (carefully). Cognition and Emotion *25* (5), 765–781.

Hajcak, G., Nieuwenhuis, S., 2006. Reappraisal modulates the electrocortical response to unpleasant pictures. Cognitive Affective & Behavioral Neuroscience 6, 291–297. http://dx.doi.org/10.3758/CABN.6.4.291.

Hajcak, G., Olvet, D.M., 2008. The persistence of attention to emotion: Brain potentials during and after picture presentation. Emotion *8* (2), 250–255.

Hajcak, G., Dunning, J.P., Foti, D., 2009. Motivated and controlled attention to emotion: Time-course of the late positive potential. Clinical Neurophysiology *120* (3), 505–510.

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

Holland, A.C., Kensinger, E.A., 2013. The neural correlates of cognitive reappraisal during emotional autobiographical memory recall. Journal of Cognitive Neuroscience *25* (1), 87–108.

Inaba, M., Nomura, M., Ohira, H., 2005. Neural evidence of effects of emotional valence on word recognition. International Journal of Psychophysiology *57* (3), 165–173.

Jackson, D.C., Malmstadt, J.R., Larson, C.L., Davidson, R.J., 2000. Suppression and enhancement of emotional responses to unpleasant pictures. Psychophysiology *37*, 515–522.

Joormann, J., Cooney, R.E., Henry, M.L., Gotlib, I.H., 2012. Neural correlates of automatic mood regulation in girls at high risk for depression. Journal of Abnormal Psychology *121* (1), 61–72.

Kalisch, R., 2009. The functional neuroanatomy of reappraisal: Time matters. Neuroscience & Biobehavioral Reviews *33* (8), 1215–1226.

Kim, S.H., Hamann, S., 2012. The effect of cognitive reappraisal on physiological reactivity and emotional memory. International Journal of Psychophysiology *83*, 348–356.

Kohn, N., Eickhoff, S.B., Scheller, M., Laird, A.R., Fox, P.T., Habel, U., 2014. Neural network of cognitive emotion regulation—an ALE meta-analysis and MACM analysis. NeuroImage *87*, 345–355.

Kring, A.M., Werner, K.H., 2004. Emotion regulation and psychopathology. In: Philippot, P., Feldman, R.S. (Eds.), The Regulation of Emotion. Lawrence Erlbaum, Mahwah, NJ.

Kross, E., Ayduk, O., Mischel, W., 2005. When asking “why” does not hurt distinguishing rumination from reflective processing of negative emotions. Psychological Science *16* (9), 709–715.

Kross, E., Davidson, M., Weber, J., Ochsner, K., 2009. Coping with emotions past: The neural bases of regulating affect associated with negative autobiographical memories. Biological Psychiatry *65* (5), 361–366.

Kujawa, A., Klein, D.N., Proudfit, G.H., 2013. Two-year stability of the late positive potential across middle childhood and adolescence. Biological Psychology *94* (2), 290–296.

Lang, P.J., 1995. The emotion probe: Studies of motivation and attention. American Psychologist *50* (5), 372–385.

Lang, P.J., Bradley, M.M., Cuthbert, B.N., 1999. International Affective Picture System (IAPS): Technical Manual and Affective Ratings. The Center for Research in Psychophysiology, University of Florida, Gainesville, FL.

Lieberman, M.D., Inagaki, T.K., Tabibnia, G., Crockett, M.J., 2011. Subjective responses to emotional stimuli during labeling, reappraisal, and distraction. Emotion *11* (3), 468–480.

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.

Maratos, E.J., Allan, K., Rugg, M.D., 2000. Recognition memory for emotionally negative and neutral words: An ERP study. Neuropsychologia *38* (11), 1452–1465.

McNeely, H.E., Dywan, J., Segalowitz, S.J., 2004. ERP indices of emotionality and semantic cohesiveness during recognition judgments. Psychophysiology *41* (1), 117–129.

Moran, T.P., Jendrusina, A.A., Moser, J.S., 2013. The psychometric properties of the late positive potential during emotion processing and regulation. Brain Research *1516*, 66–75.

Moser, J.S., Hajcak, G., Bukay, E., Simons, R.F., 2006. Intentional modulation of emotional responding to unpleasant pictures: An ERP study. Psychophysiology *43* (3), 292–296.

Naumann, E., Bartussek, D., Diedrich, O., Laufer, M.E., 1992. Assessing cognitive and affective information processing functions of the brain by means of the late positive complex of the event-related potential. Journal of Psychophysiology *6* 285-285.

Nezlek, J.B., Kuppens, P., 2008. Regulating positive and negative emotions in daily life. Journal of Personality *76*, 561–579.

Nunnally, J.C., Bernstein, I.H., Berge, J.M.T., 1967. Psychometric Theory 226 McGraw-Hill, New York.

Ochsner, K.N., Gross, J.J., 2005. The cognitive control of emotion. Trends in Cognitive Sciences *9* (5), 242–249.

Ochsner, K.N., Silvers, J.A., Buhle, J.T., 2012. Functional imaging studies of emotion regulation: A synthetic review and evolving model of the cognitive control of emotion. Annals of the N. York Academy of Sciences *1251* (1), E1–E24.

Patrick, C.J., Hajcak, G., 2016. RDoC: Translating promise into progress. Psychophysiology *53* (3), 415–424.

Ray, R.D., McRae, K., Ochsner, K.N., Gross, J.J., 2010. Cognitive reappraisal of negative affect: converging evidence from EMG and self-report. Emotion *10* (4), 587–592.

Richards, J.M., Gross, J.J., 2000. Emotion regulation and memory: The cognitive costs of keeping one's cool. Journal of Personality and Social Psychology *79* (3), 410–424.

Schupp, H., Cuthbert, B., Bradley, M., Hillman, C., Hamm, A., Lang, P., 2004. Brain processes in emotional perception: Motivated attention. Cognition and Emotion *18* (5), 593–611.

Schupp, H.T., Flaisch, T., Stockburger, J., Junghöfer, M., 2006. Emotion and attention: Event-related brain potential studies. Progress in Brain Research *156*, 31–51.

Shiota, M.N., Levenson, R.W., 2012. Turn down the volume or change the channel? Emotional effects of detached versus positive reappraisal. Journal of Personality and Social Psychology *103* (3), 416–429.

Thiruchselvam, R., Blechert, J., Sheppes, G., Rydstrom, A., Gross, J.J., 2011. The temporal dynamics of emotion regulation: An EEG study of distraction and reappraisal. Biological Psychology *87* (1), 84–92.

Webb, T.L., Miles, E., Sheeran, P., 2012. Dealing with feeling: A meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. Psychological Bulletin *138* (4), 775–808.

Weinberg, A., Ferri, J., Hajcak, G., 2013. Interactions between attention and emotion: Insights from the late positive potential. In: Robinson, M.D., Watkins, E.R., Harmon-Jones, E. (Eds.), Handbook of Cognition and Emotion. Guilford Press, New York, NY.

Weinberg, A., Perlman, G., Kotov, R., Hajcak, G., 2016. Depression and reduced neural response to emotional images: Distinction from anxiety, and importance of symptom dimensions and age of onset. Journal of Abnormal Psychology *125* (1), 26–39.