Biological Psychology 148 (2019) 107768

Contents lists available at ScienceDirect

Biological Psychology

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

# The late positive potential as a neurocognitive index of emotion regulatory flexibility

Sarah Myruski[a], George A. Bonanno[b], Hyein Cho[a,c], Boyang Fan[a,c], Tracy A. Dennis-Tiwary[a,c,*]

[a] Hunter College, The City University of New York, United States
[b] Teachers College, Columbia University, United States
[c] The Graduate Center, The City University of New York, United States

ARTICLE INFO

*Keywords:*
Emotion regulation
Regulatory flexibility
The late positive potential

ABSTRACT

A growing body of research has examined regulatory flexibility as the ability to dynamically modulate emotional expression and experience (Bonanno & Burton, 2013). The late positive potential (LPP), an event-related potential reflecting processing of emotionally-evocative stimuli, is sensitive to emotion regulation (ER) or the psychological processes that underlie the experience, expression, and management of emotions. However, few studies have used the LPP to index regulatory flexibility or tested its association with self-reported emotional well-being and ER. The results of the current study showed that regulatory flexibility indexed via the LPP was associated with self-reported use of specific ER strategies. Further, greater regulatory flexibility measured as the full LPP regulatory range (indexed following prompts to enhance and suppress emotional responses to stimuli) was specifically and uniquely associated with greater self-reported coping flexibility. Findings provide preliminary support for this neurocognitive approach to conceptualizing and assessing regulatory flexibility.

## 1. Introduction

Decades of research have highlighted the crucial role of emotion regulation (ER) in psychological adjustment and mental health. ER encompasses implicit and explicit psychological processes that underlie the experience, expression, and management of emotions (Campos, Campos, & Barrett, 1989; Gross & Thompson, 2007; Gross, 1998a, 1998b). While the majority of previous ER studies has focused on discrete strategies deemed as universally adaptive (e.g., reappraisal) versus maladaptive (e.g., suppression), a growing body of research (e.g., Bonanno & Burton, 2013) has instead conceptualized ER in terms of regulatory *flexibility*, or the ability to dynamically modify strategy use to fit situational demands. Yet, little is known about the biological underpinnings of individual differences in the ability to intentionally modulate emotional responses, nor how biologically-indicated regulatory flexibility may correspond to subjective report.

The current study assesses the late positive potential (LPP), an event-related potential sensitive to the modulation of emotional responses, as a neurocognitive signature of regulatory flexibility by examining it in relation to self-reported ER and emotional adjustment. Further, since ER has been shown to vary across individuals, with those showing greater symptoms of psychopathology or reduced psychological adjustment exhibiting maladaptive ER (e.g. Ehring, Tuschen-Caffier, Schnülle, Fischer, & Gross, 2010; Gross & John, 2003; Eftekhari, Zoellner, & Vigil, 2009), we target individual differences in regulatory flexibility as indexed via the LPP.

While a large body of work has shown that individual differences in the habitual use of specific ER strategies (e.g., reappraisal) is linked to fewer symptoms of psychopathologies including depression (Ehring et al., 2010; Gross & John, 2003) and post-traumatic stress disorder (Eftekhari et al., 2009), recent meta-analyses (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Webb, Miles, & Sheeran, 2012) indicate that use of discrete ER strategies (e.g. avoidance, reappraisal) predict outcomes with small to medium effect sizes, indicating that there is more variance to adaptive ER than is captured by these prior theoretical approaches. This finding suggests that classifying a specific ER strategy as either adaptive or maladaptive, also termed the "fallacy of uniform efficacy" (Bonanno & Burton, 2013) underestimates the impact of specific characteristics or components of ER on well-being. Bonanno and Burton (2013) highlight regulatory flexibility as a key characteristic of adaptive ER. How and when people use specific ER strategies will vary across time and situations; therefore effective regulation is that which allows people to flexibly respond to changing emotional challenges (Bonanno, Papa, Lalande, Westphal, & Coifman, 2004; Kashdan & Rottenberg, 2010; Tamir & Ford, 2009) including contexts that involve competing goals (Tamir & Ford, 2009) and for which distinct types of

* Corresponding author at: 695 Park Avenue, Hunter College, The City University of New York, New York, NY, 10065, United States.
*E-mail address:* tracy.dennis@hunter.cuny.edu (T.A. Dennis-Tiwary).

https://doi.org/10.1016/j.biopsycho.2019.107768
Received 8 April 2019; Received in revised form 9 August 2019; Accepted 9 September 2019
Available online 11 September 2019
0301-0511/ 

ER strategies might be more effective than others (Aldao et al., 2010).

In prior work (Myruski, Bonanno, Gulyayeva, Egan, & Dennis-Tiwary, 2017), we used behavioral and neurophysiological methods to measure a key component of regulatory flexibility, ER context sensitivity, or the ability to engage regulatory resources that are most suitable given contextual demands or opportunities (Bonanno & Burton, 2013). Using an emotional Go/No-Go task, we found that enhanced allocation of early attentional resources to pertinent pleasant and unpleasant emotional information, measured via the magnitudes of event-related potential responses (e.g., N170, N2) to emotion cues, was linked to greater reported emotional flexibility and fewer symptoms of psychopathology (Myruski et al., 2017).

In the present study, we focus on a second component of regulatory flexibility, repertoire. According to Bonanno and Burton (2013), a key aspect of repertoire is the ability to modify the breadth or magnitude of an emotional response. Few previous studies, however, have focused on individual differences in this magnitude component of regulatory flexibility, which captures not only whether individuals can modulate their emotions or not, but in what direction and to what degree (Gupta & Bonanno, 2011; Rodin et al., 2017; Westphal, Seivert, & Bonanno, 2010). In one study, however, Bonanno et al. (2004) showed that greater ability to modulate facial expressions and experiences of emotions when instructed to enhance, suppress, or simply view emotionally-unpleasant pictures was longitudinally associated with more positive adjustment. Specifically, greater breadth of emotional expression and subjective feelings across enhance *and* suppress conditions – that is, a full range of the magnitude of change – was more strongly related to well-being than either the ability to enhance or suppress on its own. In the present study, we measure repertoire in a similar way, as the ability to flexibly alter the magnitude of emotional responses when participants are instructed to enhance versus suppress emotional responses.

Building on these findings, Zhu and Bonanno (2017) developed and tested the Affective Flexibility Task in which facial muscular activity was recorded via EMG while participants were prompted to enhance, suppress, and view unpleasant images. They found that emotional responding indexed by EMG fluctuated appropriately to emotion modulation prompts, and that greater improvement in affective enhancement and suppression over the course of the study session was related to less self-reported depression. These studies demonstrated that regulatory flexibility can be captured by facial expressivity and subjective experience of emotion, and predicts emotional well-being (depression). Yet, little is known about the neural correlates of regulatory flexibility.

Scalp-recorded event-related potentials track dynamic changes in emotional responses and regulation with millisecond precision (Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Hajcak, Dunning, & Foti, 2009), and thus may provide a highly sensitive and complementary measurement approach to prior behavioral research on regulatory flexibility (Bonanno et al., 2004; Zhu & Bonanno, 2017). The late positive potential (LPP), an event-related potential emerging approximately 200–300 ms post-stimulus onset, has been used to study neural processes underlying ER. The LPP reflects elaborative attention to and processing of emotionally-evocative and motivationally-salient stimuli, such that the magnitude of the LPP is greater in response to affective (both positive and negative) versus neutral stimuli, and are positively correlated with affective arousal (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2000).

The magnitude of the LPP is reduced following the intentional regulation of emotion through strategies such as reappraisal and suppression in adults (Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006) and children (Babkirk, Rios, & Dennis, 2015; DeCicco, O'Toole, & Dennis, 2014; Dennis & Hajcak, 2009; Myruski et al., 2017), including clinical populations (Kudinova et al., 2016; Zhang et al., 2016). In one study, children's ability to modulate the LPP in response to directed reappraisal predicted greater use of ER behaviors employed during emotional challenges (Babkirk et al., 2015). In particular, those children showing successful LPP modulation via reappraisal tended to use ER strategies that actively shifted their attention away from the emotionally evocative challenge, both concurrently and after two-years, indicating that the LPP may capture enduring neurocognitive processes linked to ER.

However, few studies to date have directly examined the LPP in relation to measures of regulatory flexibility. Using the LPP to measure regulatory flexibility has the advantage of allowing temporally precise assessment of flexibility, including both the down-regulation and up-regulation of emotion. Another advantage of using the LPP as an index for regulatory flexibility is that ER is a temporally dynamic process (Gyurak, Gross, & Etkin, 2011). Since the LPP is a sustained event-related potential, lasting from about 200 ms post-stimulus onset throughout the duration of presentation, it can capture both relatively early attentional control processes (Hajcak et al., 2009; Hajcak, MacNamara, Foti, Ferri, & Keil, 2013; Mocaiber et al., 2010), as well as later elaborative processes (DeCicco, Solomon, & Dennis, 2012; Hajcak & Nieuwenhuis, 2006; Strauss et al., 2015). Thus, by examining early and late windows of the LPP, we can explore potential distinctions in regulatory flexibility that may emerge throughout the time-course of ER.

### 1.1. The present study

The goal of the present study was to assess the LPP as a metric of regulatory flexibility during the Affective Flexibility Task. Participants were healthy adults, instructed to enhance, suppress or maintain their emotional reactions to complex affective images that were pleasant, unpleasant or neutral. We examined individual differences in ER strategies and flexibility via two quantitative approaches: 1) unidirectional ER modulation (magnitude of LPP to enhance or suppress relative to LPP maintain baseline), and 2) regulatory flexibility (magnitude of LPP enhance relative to LPP suppress).

We tested the following two predictions: First, greater magnitude of unidirectional ER modulation will be associated with greater self-reported use of ER strategies (e.g., reappraisal). Second, greater magnitude of regulatory flexibility will be associated with greater self-reported coping flexibility and emotional well-being. We explored whether effects differed between early and later windows of the LPP, given the possibility that relatively automatic (early-emerging) versus deliberative (later-emerging) processes underlying the LPP may be associated with distinct aspects of ER and flexibility.

## 2. Method

### 2.1. Participants

Participants were recruited through the psychology participant pool at Hunter College, The City University of New York. An a priori power analysis (conducted via G*Power) revealed that a minimum sample size of 63 participants would be sufficient to detect small to medium effect sizes ($f$ = .15 and above) across the six target within-subject conditions (pleasant-enhance, pleasant-suppress, pleasant-maintain, unpleasant-enhance, unpleasant-suppress, and unpleasant-maintain) at 90% power. To account for anticipated data loss, 78 participants were recruited, and 6 were excluded due to missing or unusable EEG recordings. The resulting sample size consisted of 72 adults[1] ages 18–47 ($M$ = 20.69, $SD$ = 4.57), including 17 (23.6%) males and 55 (76.4%) females. Self-reported race/ethnicity included three (4.2%) African American, 13 (18.1%) Hispanic, 25 (34.7%) Caucasian, 21 (29.2%) Asian, one (1.4%) Pacific Islander, and nine (12.5%) identified as other.

[1] A subsample ($n$ = 66) of the current sample also completed an emotional go-nogo task, the results of which are published in Myruski et al., (2017).

### 2.2. Materials and procedure

Following informed consent, participants reported demographics and completed self-report questionnaires. Participants were then seated in an EEG recording booth approximately 65 cm away from a 17-inch monitor screen and EEG electrodes were applied for data acquisition. After EEG application, participants completed the Affective Flexibility Task (Zhu & Bonanno, 2017). Each study session lasted approximately two hours.

#### 2.2.1. Self-report of emotional well-being, emotion regulation, coping flexibility

*Beck Anxiety Inventory* (BAI; Beck, Epstein, Brown, & Steer, 1988) is a 21-item questionnaire that measures anxiety symptom severity. Each item is on a 4-point scale, with each assessing how much an individual has been affected by the described symptoms with 0 being "Not at all" and 3 being "Severely". Possible total scores range from 0 to 63 points, with higher total scores indicating more severe anxiety.

*Beck Depression Inventory* (BDI; Beck, Steer, & Brown, 1996) is a 21-item questionnaire that assesses depressive symptoms over the past 2-week period. Each item is on a 4-point scale, ranging from 0 to 3 based on how severe each item is rated, with total possible scores from 0 to 63, and higher scores indicating more severe depression.

*Emotion Regulation Questionnaire* (ERQ; Gross & John, 2003) is a 10-item scale that assesses the way in which individuals regulate their emotions, specifically their use cognitive reappraisal or expressive suppression. Each item is recorded on a 7-point scale, with 1 being "Strongly Disagree" and 7 being "Strongly Agree" to describe how they control their emotions. Six items are used to assess cognitive reappraisal and four items are used to assess expressive suppression. Higher scores in each subscale indicate higher use of that particular ER strategy.

*Perceived Ability to Cope with Trauma* (PACT; Bonanno, Pat-Horenczyk, & Noll, 2011) is a 20-item scale that measures individuals' flexibility to cope and the ability to use certain strategies and behaviors in response to events that are aversive or potentially traumatic, with two subscales assessing the focus of coping: trauma focus (8-item), forward focus (12-item) coping, as well as an overall coping flexibility. Each item is recorded on a 7-point scale, with 1 being "Not at all able" and 7 being "Extremely able". Only the overall flexibility score was used for this analysis, indicating the ability to flexibly shift between coping strategies.

#### 2.2.2. Affective flexibility task (adapted from Zhu & Bonanno, 2017)

Participants completed computerized Affective Flexibility Task during EEG was continuously recorded (Fig. 1).

Following a 10-trial practice session, participants completed seven condition blocks (pleasant-enhance, pleasant-suppress, pleasant-maintain, unpleasant- enhance, unpleasant-suppress, unpleasant-maintain, and neutral-maintain) presented in counterbalanced order with two break sessions. At the beginning of each block, participants were instructed that they would be presented with a series of pictures which would be either emotionally pleasant, unpleasant, or neutral. On each trial, a word prompt appeared in the center of the computer screen with black background for 200 ms, followed by a fixation cross for 100 ms. Prompts instructed participants to either simply view images, or to "enhance", or "suppress" their emotional responses to subsequently presented pleasant, unpleasant, or neutral images (view only for neutral images). Task instructions were adapted from Jackson, Malmstadt, Larson, and Davidson (2000) and Moser, Hajcak, Bukay, and Simons (2006). For example, an excerpt from the instructions for the suppress block reads: *"On the next set of trials, you will be asked to SUPPRESS your emotional response. By suppress we mean that we would like you to reduce the intensity of the emotion you feel in response to the picture… For example, if you are asked to suppress the fear you feel in response to a picture of a poisonous snake, do not think of something unrelated that generates a positive emotion. However, feel free to focus on a positive aspect of the picture or on a possible positive outcome of the situation in the picture. For example, you can imagine that the poisonous snake is about to be killed, which may help you to suppress the fear you may feel in response to the picture."*

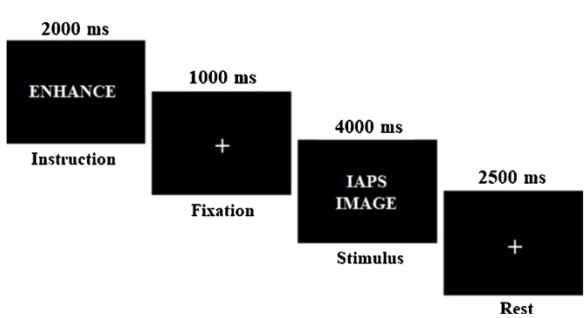


**Fig. 1.** The temporal sequence of a typical trial of the Affective Flexibility Task is depicted above.

Following the prompt, pleasant, unpleasant, or neutral pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) occupied the entire screen for 4,000 ms, followed by a 200 ms inter-trial interval in which the word "relax" appeared on the screen. Twenty-five pictures were presented in a random order for each block (total of 175 stimuli), and each picture was presented only once. Picture stimuli presented in each block were selected randomly from a master list (i.e., pleasant, unpleasant, and neutral) for each trial, and they were not repeated across instruction blocks for each participant. In other words, the pictures were not systematically tied to any one of the instruction blocks (e.g., pleasant-increase) but instead, each picture was equally likely to appear in any condition. The valence and arousal ratings for each picture category are as follows: Unpleasant: Valence ($M$ = 2.96, $SD$ = 0.81); Arousal ($M$ = 5.56, $SD$ = 0.90); Pleasant: Valence ($M$ = 7.02, $SD$ = 0.69); Arousal ($M$ = 4.77, $SD$ = .71); and Neutral: Valence ($M$ = 5.41, $SD$ = 0.54); Arousal ($M$ = 3.31, $SD$ = 0.67)[2] .

#### 2.2.3. EEG recording and data reduction

Continuous EEG was recorded during the Affective Flexibility Task via BioSemi system (BioSemi; Amsterdam, Netherlands) using 64 Ag/AgCl scalp electrodes, sampled at 512 Hz. Electrodes were applied to an EEG cap and arranged according to the International 10–20 system. Eye movements were monitored by electro-oculogram (EOG) placed 1 cm above and below the left eye for recording of vertical eye movements, as well as two electrodes that were applied 1 cm on the outer corner of each eye to record horizontal eye movements. Pre-amplification of the EEG signal took place at each electrode in order to improve the signal-to-noise ratio. During EEG acquisition, the voltage from each of the 64

[2] **List of Stimulus: Unpleasant ($n$ = 75)** 1050, 1111, 1120, 1201, 1270, 1274, 1300, 1301, 1310, 2276, 2312, 2458, 2691, 2700, 2750, 2811, 3053, 3160, 3180, 3181, 3301, 3500, 3530, 3550, 5130, 5940, 5971, 6010, 6211, 6212, 6230, 6241, 6360, 6570, 6821, 6834, 6838, 6940, 7360, 7380, 8230, 8231, 9008, 9041, 9042, 9050, 9160, 9181, 9250, 9265, 9290, 9373, 9402, 9404, 9410, 9415, 9421, 9430, 9433, 9440, 9452, 9480, 9490, 9520, 9530, 9561, 9571, 9584, 9611, 9622, 9635, 9800, 9911, 9920, 9921 **Pleasant ($n$ = 75)** 1410, 1440, 1460, 1463, 1510, 1601, 1610, 1650, 1710, 1722, 1920, 1942, 2002, 2030, 2040, 2055, 2057, 2060, 2075, 2080, 2152, 2155, 2160, 2299, 2306, 2314, 2339, 2344, 2352, 2362, 2375, 2506, 2530, 2598, 2660, 4006, 4071, 4150, 4537, 4538, 4542, 4559, 4574, 4604, 4610, 4616, 4617, 4624, 4628, 4643, 4653, 5199, 5202, 5250, 5621, 5623, 5829, 5831, 5833, 5836, 5910, 7330, 8031, 8120, 8162, 8300, 8330, 8350, 8380, 8461, 8496, 8497, 8500, 8502, 8540 **Neutral ($n$ = 75)** 1313, 1333, 1419, 1450, 1602, 1850, 2026, 2102, 2190, 2211, 2273, 2377, 2442, 2487, 2495, 2512, 2514, 2594, 2745, 2840, 5020, 5030, 5040, 5301, 5410, 5500, 5510, 5520, 5530, 5593, 5635, 5665, 5720, 5726, 5875, 5990, 6150, 7000, 7001, 7004, 7006, 7009, 7012, 7014, 7019, 7020, 7021, 7035, 7037, 7041, 7045, 7052, 7053, 7055, 7058, 7061, 7077, 7090, 7100, 7170, 7179, 7182, 7185, 7211, 7217, 7235, 7476, 7487, 7490, 7493, 7500, 7547, 7820, 7830, 7950.

electrodes was referenced online to the common mode sense active electrode, which produces a monopolar (nondifferential) channel. Acquired data were re-referenced offline the average of the mastoid electrodes (LPP) and filtered with the following cut-off frequency: low-cut off frequency of .1 Hz and a high cut off frequency of 30 Hz using Brain Vision Analyzer (Version 2.2, GmbH; Munich, Germany). Following ocular correction (Gratton, Coles, & Donchin, 1983), artifacts were identified using the following criteria and removed from analyses: voltage steps greater than 50 μV, changes within a given segment greater than 300 μV, and activity lower than .5 μV per 100 ms. In addition to this semi-automatic identification of artifacts, trials were also visually inspected for any further artifacts (i.e., trial-by-trial basis).

The LPP was generated for each of the six target Affective Flexibility Task conditions (pleasant-enhance, pleasant-suppress, pleasant-maintain, unpleasant- enhance, unpleasant-suppress, and unpleasant-maintain). Picture-locked data were segmented into epochs from 200 ms before stimulus presentation to 2000 ms after stimulus onset, with a 200 ms baseline correction. Following prior studies (Foti & Hajcak, 2008; Hajcak & Olvet, 2008; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), the LPP was examined in nine 200 ms segments (200–400, 400–600, 600–800, 800–1000, 1000–1200, 1200–1400, 1400–1600, 1600–1800, 1800–2000). The target period ranging from 200 ms post-stimulus onset to 2000 ms post-stimulus onset encapsulates periods have been shown to be sensitive to ER (Hajcak & Nieuwenhuis, 2006). While central-parietal recording sites have been examined by prior studies (e.g. Hajcak et al., 2009), the current study focused on parietal-occipital sites, which have been targeted in prior studies (e.g. Babkirk et al., 2015; DeCicco et al., 2012), and based on visual inspection of the grand average scalp distribution in the current study, regardless of condition, as suggested by Luck and Gaspelin (2017). Inspection of a portion of our individual participants (approximately 20%) confirmed that this time window (200–2000 ms) and electrode sites (parietal-occipital) consistently encompassed the maximal amplitude. Thus, the LPP was quantified as the mean voltage in the region of maximal signal: P3, P4, P5, P6, P7, P8, PO3, PO4, PO7, PO8, O1, and O2 (Fig. 2).

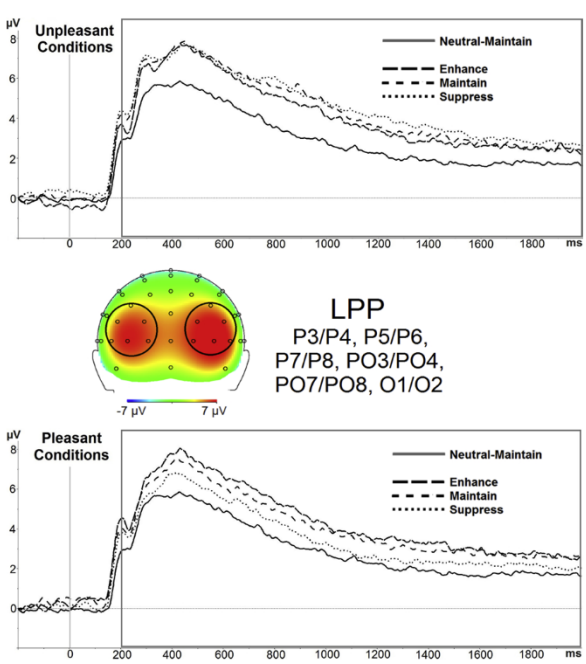


**Fig. 2.** Waveforms present LPP amplitudes for unpleasant (top) and pleasant (bottom) conditions, with LPP amplitudes to the neutral-maintain condition as a comparison.

### 2.2.4. *Quantifying unidirectional ER modulation and regulatory flexibility*

LPP difference scores were generated to quantify unidirectional ER modulation via suppression and enhancement for each of the seven conditions, for a total of six scores. ER unidirectional change was quantified by comparing LPP amplitudes to each enhance or suppress condition to emotional maintain conditions (pleasant enhance minus pleasant maintain, pleasant maintain minus pleasant suppress, unpleasant enhance minus unpleasant maintain, and unpleasant maintain minus unpleasant suppress). Regulatory flexibility was quantified as LPP difference scores reflecting the full range of regulatory change for pleasant and unpleasant emotions (i.e., for pleasant stimuli: pleasant enhance minus pleasant suppress; and for unpleasant stimuli: unpleasant enhance minus unpleasant suppress). For the four unidirectional ER modulation scores and two regulatory flexibility scores, positive LPP difference scores indicated an impact of prompt on the LPP in the predicted direction, while a negative LPP difference score indicated the opposite.

## 3. Results

### 3.1. *Descriptive statistics*

Descriptive statistics for LPP difference scores and self-reported dependent variables are presented in Table 1.

Independent-samples *t*-tests were conducted to examine sex differences for all study variables (i.e. LPP amplitudes and difference scores for each condition, BDI, BAI, ERQ, and PACT target subscales). In comparison to females ($M = -0.24$, $SD = 3.64$), males ($M = 1.96$, $SD = 3.66$) exhibited significantly greater reductions of the LPP in the pleasant-decrease vs pleasant-maintain conditions across the entire LPP segment (200–2000 ms), $t(26.46) = 2.17$, $p = .039$. Further, females ($M = 14.02$; $SD = 8.04$) reported significantly greater anxiety symptoms compared to males ($M = 8.47$; $SD = 5.04$), $t(4.081) = -3.455$, $p$

**Table 1**
Descriptive Statistics for Self-Reported Emotional Well-Being, ER, and Coping Flexibility.

| Questionnaire | Minimum | Maximum | *M*(*SD*) |
|---|---|---|---|
| *BDI* | | | |
| Depression symptoms | 0.00 | 44.00 | 12.52(9.03) |
| *BAI* | | | |
| Anxiety symptoms | 0.00 | 48.00 | 13.88(11.30) |
| *ERQ* | | | |
| Reappraisal | 6.00 | 42.00 | 28.40(7.46) |
| Suppression | 6.00 | 24.00 | 14.90(4.49) |
| *PACT* | | | |
| Overall coping flexibility | 4.25 | 12.75 | 8.62(1.75) |
| **LPP Difference Scores (μV)** | **Minimum** | **Maximum** | ***M*(*SD*)** |
| *Unidirectional LPP Enhancement* | | | |
| Unpleasant | −9.87 | 10.23 | 0.19(3.32) |
| Pleasant | −14.32 | 6.86 | −0.30(3.43) |
| *Unidirectional LPP Suppression* | | | |
| Unpleasant | −7.30 | 9.40 | 0.28(3.74) |
| Pleasant | −11.66 | 8.24 | −0.05(3.20) |
| *Regulatory Flexibility* | | | |
| Unpleasant | −9.92 | 11.24 | 0.47(3.77) |
| Pleasant | −13.21 | 7.54 | −0.36(3.45) |

*Note*. Questionnaire abbreviations are as follows: Beck's Depression Inventory (BDI), Beck's Anxiety Inventory (BAI), Emotion Regulation Questionnaire (ERQ), and Perceived Ability to Cope with Trauma (PACT). LPP difference scores are presented for the full 200–2000 ms window, and were computed as follows: LPP Enhancement: Pleasant-Enhance minus Pleasant-Maintain and Unpleasant-Enhance minus Unpleasant-Maintain; LPP Suppression: Pleasant Maintain minus Pleasant-Suppress and Unpleasant Maintain minus Unpleasant-Suppress; Regulatory Flexibility: Pleasant-Enhance minus Pleasant-Suppress and Unpleasant-Enhance minus Unpleasant-Suppress.

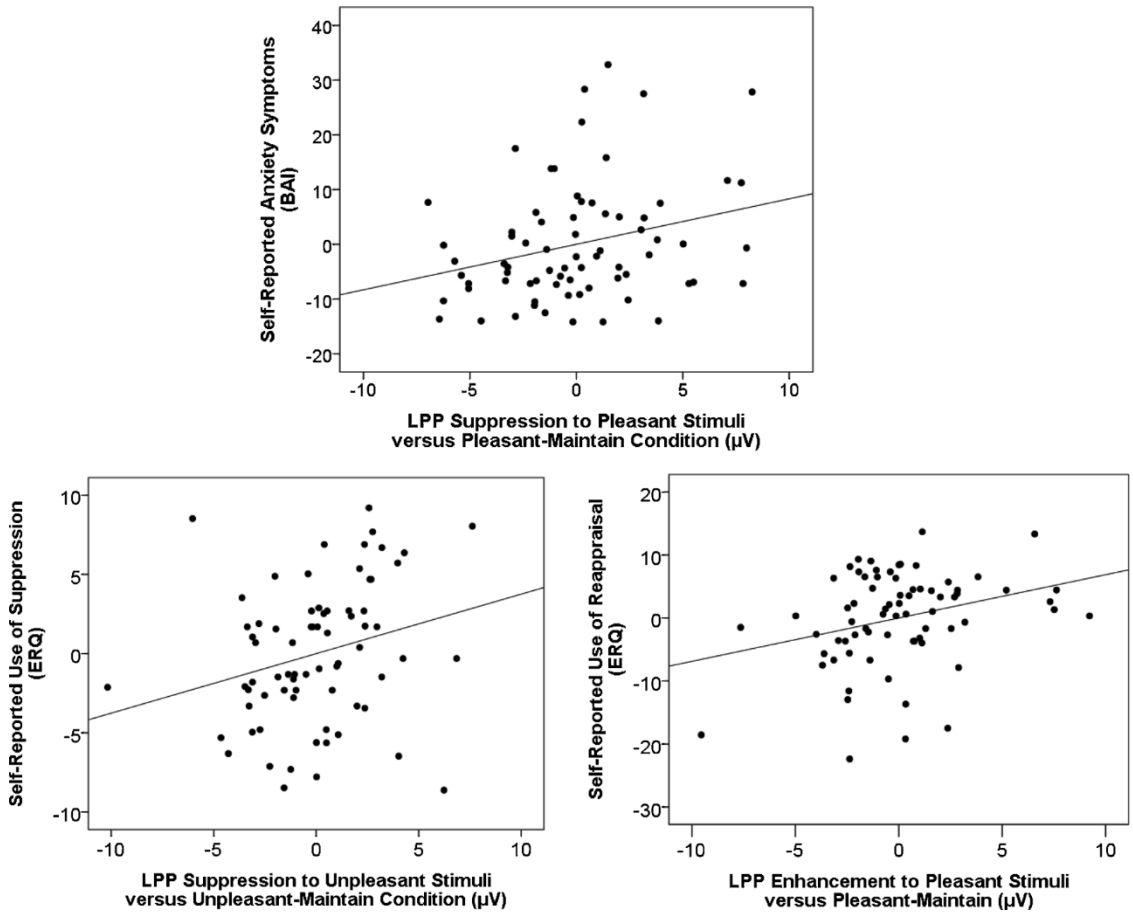


**Fig. 3.** Unidirectional ER modulation reflected via the LPP predicted self-reported anxiety and ER. Greater LPP suppression to pleasant stimuli was related to greater anxiety (top), greater LPP suppression to unpleasant stimuli was linked to increased self-reported suppression (bottom left), and greater LPP enhancement to pleasant stimuli was linked to greater use of reappraisal (bottom right).

= .001[3] . Due to these sex differences, since there were disproportionately more females ($f$ = 55) compared to males ($f$ = 17), and since prior studies have established sex-based differences in ER (e.g. Nolen-Hoeksema & Aldao, 2011), sex was entered into main analyses as a covariate.

Pearson correlations were conducted to examine associations among age and all study variables. Participant age was not significantly related to LPP amplitudes in any condition ($p$'s > .10), nor to self-report measure ($p$'s > .10) in the sample as a whole. However, LPP amplitudes in the unpleasant-maintain condition was significantly negatively correlated with age among males for the 400–600 ms ($r$ = −.518, $p$ = .033), 600–800 ms ($r$ = −.494, $p$ = .044), and 1800–2000 ms ($r$ = −.488, $p$ = .047) windows. Further, since the sample included a wide age range (18–47 years), and prior studies have established age-related difference in ER (e.g. Nolen-Hoeksema & Aldao, 2011), age was entered into main analyses as a covariate.

### 3.2. Effects of ER condition on the LPP

To examine the effect of prompts to modulate emotional responses to pleasant and unpleasant images on the LPP, a 2(Emotion: pleasant, unpleasant) x 3(Prompt: enhance, suppress, maintain) x 9(Window: 200–400, 400–600, 600–800, 800–1000, 1000–1200, 1200–1400, 1400–1600, 1600–1800, 1800–2000) repeated measures ANOVA was conducted.

The main effect of Emotion ($p$ = .268) or Prompt ($p$ = .921) on the LPP did not reach significance, nor did the Emotion X Prompt interaction ($p$ = .439). Thus, successful modulation of the LPP in the prompted direction was not exhibited in the sample as a whole.

There was a significant main effect of window [$F$(8, 64) = 2.394, $p$ = .025, $\eta_p^2$ = .230] such that mean LPP amplitudes were significantly different across all 200 ms window segments with the exception of the following: LPP amplitudes in the 200 to 400 ms window did not significantly differ from those in the 600 to 800 ms window. LPP amplitudes in the 1600 to 1800 ms window were not significantly different from those in the 1800 to 2000 ms window. This pattern is consistent with the expected shape of the LPP waveform.

There was also a significant Window X Emotion interaction, $F$(8, 64) = 31.05, $p$ = .015, $\eta_p^2$ = .795. However, follow-up tests failed to reveal significant differences between mean LPP amplitudes in pleasant versus unpleasant conditions while controlling for multiple comparisons (Bonferroni-corrected $p$ for 9 comparisons = .006). Thus, since there were no meaningful interactions between Window and any other construct, the nine 200 ms segments were condensed into a single aggregate window (200–2000 ms) similarly to prior studies (e.g. Thiruchselvam et al., 2011) and to reduce the number of comparisons for main analyses. As an alternative approach, two aggregate early (200–1000 ms) and late (1000–2000 ms) windows with the dividing point of 1000 ms [consistent with other previous studies (e.g. Foti & Hajcak, 2008] were also examined, results of which are footnoted in the main analyses section below.

[3] The Welch-Satterthwaite correction was used to account for unequal sample sizes between males and females.

### 3.3. Main analyses

We tested the main hypothesis that greater unidirectional ER modulation measured via the LPP would be associated with greater use of ER strategies (e.g., reappraisal). In addition, we examined whether greater magnitude of ER modulation measured via full range of LPP changes – or regulatory flexibility - would be associated with greater self-reported overall coping flexibility and emotional well-being (e.g., fewer signs of anxiety and depression).

#### 3.3.1. Unidirectional ER modulation

Hierarchical linear regressions were conducted as follows: 1st step: age and sex; 2nd step: One of the four ER modulation scores (enhance pleasant, enhance unpleasant, suppress pleasant, suppress unpleasant) dependent variables: self-report of coping flexibility, ERQ subscale (reappraisal and suppression), and emotional well-being (anxiety, depression) for a total of 16 regression models.

*3.3.1.1. LPP suppression.* Greater LPP suppression to pleasant stimuli was related to greater self-reported anxiety [$\beta = .275$; $R^2 = .146$; $t$ (70) = 2.368, $p = .021$; Fig. 3, top].[4] Greater LPP suppression to unpleasant stimuli was related to greater self-reported use of suppression [$\beta = .249$; $R^2 = .096$; $t$ (70) = 2.131, $p = .037$; Fig. 3, bottom left][5] .

*3.3.1.2. LPP enhancement.* In contrast, greater LPP enhancement to pleasant stimuli was related to greater self-reported use of reappraisal [$\beta = .310$; $R^2 = .098$; $t$ (70) = 2.674, $p = .009$; Fig. 3, bottom right].[6]

#### 3.3.2. Regulatory flexibility

Hierarchical linear regressions were conducted as follows: 1st step: age and sex; 2nd step: One of the two regulatory flexibility scores (pleasant, unpleasant); dependent variable: self-report of coping flexibility, ER subscale (reappraisal and suppression), and emotional well-being (anxiety, depression) for a total of 8 regression models.

Greater regulatory flexibility for pleasant images was related to greater overall coping flexibility [$\beta = .253$; $R^2 = .078$; $t$ (70) = 2.143, $p = .036$, Fig. 4].[7]

#### 3.3.3. Summary

Unidirectional ER modulation predicted self-reported emotional well-being (anxiety) and ER, with greater LPP enhancement to pleasant stimuli associated with increased self-reported reappraisal use, and greater LPP suppression to unpleasant stimuli associated with increased self-reported suppression use. Regulatory flexibility, in contrast, predicted greater self-reported use of coping flexibility.

## 4. Discussion

Previous studies document a connection between regulatory flexibility and mental health and well-being (e.g. Bonanno et al., 2004; Zhu & Bonanno, 2017). This study extends this line of research by assessing the LPP as a neurocognitive signature of individual differences in regulatory flexibility, with a particular focus on capturing the repertoire aspect of flexibility, or the breadth of emotional response modulation. We indexed regulatory flexibility measured via the LPP by computing LPP difference scores to quantify the magnitude of change for distinct regulatory goals (i.e. enhance pleasant, enhance unpleasant, suppress pleasant, suppress unpleasant), and also for the full range of regulatory change (i.e. enhance to suppress). Each measure yielded distinct associations with outcome measures, suggesting subtle differences in how the LPP can be used as a clinically-meaningful neurocognitive index of ER and regulatory flexibility.

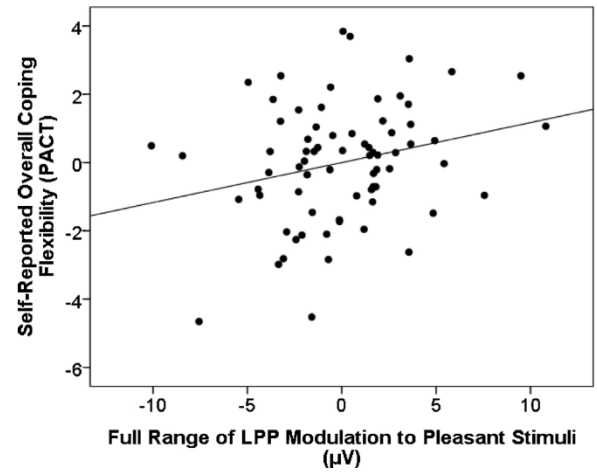


**Fig. 4.** Regulatory flexibility predicted self-reported coping flexibility. Greater full range of LPP modulation for pleasant images was related to greater overall coping flexibility.

We first examined associations between unidirectional ER modulation (enhance or suppress emotional responses) and self-report measures. We found that greater LPP suppression to pleasant stimuli was related to greater anxiety, whereas greater LPP enhancement to pleasant stimuli was linked to greater use of reappraisal. This suggests that the ability to modulate pleasant emotions may confer both psychological strengths and vulnerabilities, depending on the direction of modulation. Suppression of pleasant emotions, such as stifling enjoyment of an amusing film clip, has been linked to heightened arousal of the sympathetic nervous system (Gross & Levenson, 1997), a correlate of anxiety (e.g. Conrad, Isaac, & Roth, 2008; Andor, Gerlach, & Rist, 2008; Newman & Llera, 2011). This indicates that dampening of pleasant emotions in particular may coincide with anxious arousal. Indeed, Kashdan, Weeks, and Savostyanova (2011) argue that habitual self-control efforts associated with high anxiety may lead to blunted emotional processing of pleasant stimuli and events. In contrast, individuals who showed the ability to upregulate (enhance) pleasant emotions via the LPP tended to use reappraisal more frequently in daily life. This is consistent with McRae, Ciesielski, and Gross (2012), who documented that individuals use cognitive reappraisals to increase positive affect, despite most of the literature on cognitive reappraisal focused on the effect of reappraisal on decreasing negative emotions.

Unidirectional ER modulation in response to unpleasant stimuli also corresponded with self-reported ER. Individuals who demonstrated greater LPP suppression to unpleasant stimuli in particular, tended to report more frequent use of the ER strategy of suppression in daily life. These findings indicate a distinct linked between habitual ER strategy use and functional neurocognitive strengths. That is those individuals who habitually enlist suppression, as opposed to reappraisal, may also be better able to demonstrate neurocognitive down-regulation of unpleasant emotions. In contrast, those who habitually enlist reappraisal may be better able to exhibit neurocognitive up-regulation of pleasant emotions. Findings may also suggest that suppression might be more accessible when individuals need to decrease negative emotions, while

[4] This effect was significant in both the early [$\beta = .240$; $R^2 = .131$; $t$ (70) = 2.084, $p = .041$] and the late window [$\beta = .270$; $R^2 = .143$; $t$ (70) = 2.306, $p = .024$].

[5] This effect was significant in the late window [$\beta = .244$; $R^2 = .093$; $t$ (70) = 2.080, $p = .041$] and marginally significant in the early window [$\beta = .228$; $R^2 = .086$; $t$ (70) = 1.951, $p = .055$].

[6] This effect was significant in in both the early [$\beta = .271$; $R^2 = .077$; $t$ (70) = 2.328, $p = .023$] and late window [$\beta = .317$; $R^2 = .101$; $t$ (70) = 2.715, $p = .008$].

[7] This effect was significant in the early window [$\beta = .264$; $R^2 = .078$; $t$ (70) = 2.248, $p = .028$], and marginally significant in the late window [$\beta = .223$; $R^2 = .065$; $t$ (70) = 1.882, $p = .064$].

reappraisal is more accessible when individuals need to enhance their positive emotions. It has been argued that the specific strategy individuals deploy depends on the characteristics of the individual, the situation, and the goals an individual has in the situation (Gross, 2015). While the process of ER strategy selection is a topic that requires further investigation, our findings illustrate that the LPP may signal and shed light on individual differences in strategy use tendencies. Our findings demonstrate that the unidirectional change could reflect individual's ER strategy usage preference under different emotional contexts.

Regulatory flexibility, defined in terms of the full range of LPP change in response to enhancement versus suppression of emotion, was, as predicted, associated uniquely and specifically with self-reported coping flexibility. Similar to the finding presented in Zhu and Bonanno (2017), in which the greater enhancement *and* suppression were related to reduced symptoms of depression, our finding highlights that the range of LPP bidirectional modulation can serve as a specific neurocognitive index to measure an individual's regulatory flexibility. That is, the capacity to show varied responses to different emotional situations likely enables individuals to manage the diverse emotional demands in the environment.

In addition, we explored the temporal dynamics of the LPP as an index for regulatory flexibility of emotion, however this approach did not yield any new insights. Our results show that although LPP amplitudes were significantly different across the 200 ms segments, there were no significant interactions between time windows and other constructs (e.g. instruction, context). We anticipated that relatively automatic versus deliberative processes, reflected via the earlier and later LPP windows, may have been linked to unique variance in ER, regulatory flexibility, and emotional well-being. However, the current study did not support this notion, potentially indicating that the brain processes related to regulatory flexibility emerge throughout the full course of the LPP such that early automatic attentional control processes work cohesively with later emerging deliberate processes. While we had no strong indicators of temporally-specific patterns in the current study, we did find that certain effects became only marginally significant within the early or late window, in comparison to a statistically significant effects across the full aggregate window. Thus, future research should continue to examine automatic and deliberative ER processes via temporally-sensitive measures like event-related potentials in conjunction with complementary measurement approaches that vary in timescale (Myruski, Denefrio, & Dennis-Tiwary, 2018).

While this study has shown preliminary evidence that the LPP may reflect a portion of Bonanno and Burton (2013)'s proposed repertoire flexibility on the neurocognitive level, several limitations must be addressed. Importantly, there was no significant main effect of instruction (enhance, suppress) in the sample as a whole. This is in contrast to previous findings (Zhu & Bonanno, 2017) which indexed sample-wide selective enhancement and suppression of facial expressions and muscle activity. This discrepancy could be due to the fact that to generate the LPP, the present study used 25 pictures per condition block versus 10 in the prior study, which could have contributed to fatigue or inattention.

However, in line with the current study, one previous study of children's ER also failed to find an overall effect of reappraisal on the LPP, but identified individual differences such that the approximately 50% of participants who showed the predicted ER-induced reductions in the LPP, also showed adaptive observed ER concurrently and longitudinally (Babkirk et al., 2015). Thus, taking this type of individual differences approach, a focus of the current study, may yield the most powerful and clinically-meaningful metrics of ER and regulatory flexibility.

Similarly, in the current study, approximately one half of the sample showed LPP modulation in the predicted directions, while the other half demonstrated a reversal (e.g. *greater* LPP to decrease instructions versus maintain). This individual variation in the ability to successfully modulate the LPP in accordance with instructions is likely due to the design of the Affective Flexibility Task, such that individual differences in strategy choice were allowed by not restricting participants to any specific strategy (Zhu & Bonanno, 2017). This deliberate aspect of the task design conferred an advantage to assessing individual differences but may also present a limitation in terms of revealing the sample-wide main effect of instruction. For example, some individuals may have picked more adaptive strategies than others, and/or varied in how effective they were in implementing the strategy they choose, (e.g. they might be better a reappraising the situations). Some individuals, moreover, may have simply failed to enhance/suppress/maintain their emotions, despite their attempt to follow the instruction. However, the current study did not include any self-report measure of trial-by-trial arousal or regulatory success, so it is not possible to test whether participants' subjective experience was associated with the LPP, although prior studies have confirmed this link (Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2000). Future studies could assess specific strategy/strategies participant used during each trial and test if individuals with higher regulatory flexibility indeed use more variations of regulation strategies, or perhaps they are simply more effective at deploying the same strategy.

In addition, the stimuli we chose for the task were the IAPS, and while these are widely used and validated set of emotional stimuli used for emotion regulation research, the images vary in the intensity of valence and arousal (Lang et al., 2008). In our study, however, the participants were not asked to rate the intensity of arousal or valence of the image with which they were presented, thus it cannot be assumed that the IAPS elicited the level of emotional intensity as intended for each condition. It is also important to note that, following previous studies (Zhu & Bonanno, 2017), we implemented a block design rather than varying ER instructions on a trial-by-trial basis in the Affective Flexibility Task. This served several goals. First, a block design embeds a more consistent emotional context and anticipation of ER demand. Second, a block design minimizes the possibility of carry-over effects of the prior instruction (e.g., unpleasant-increase to unpleasant-decrease). Future studies could directly compare both block and trial-level designs to examine their impact on metrics of regulatory flexibility.

Finally, it will be important for future studies to examine the association between other traditional measures of emotional reactivity (e.g. SCR, EMG) and the LPP indices we examined in the current study. For example, it would also be interesting to examine how regulatory capacities measured via the LPP relate to other implicit forms of ER, such as threat bias (Myruski et al., 2018; Todd, Cunningham, Anderson, & Thompson, 2012). The LPP should also be examined in relation to objective measures of clinical treatment efficacy or adaptive ER.

In summary, the present study contributes to the literature on regulatory flexibility by extending the focus of analysis from emotional expression (e.g. Bonanno et al., 2004) and modulation of subjective affect (e.g. Zhu & Bonanno, 2017) to neurocognitive indices of regulatory flexibility in direct comparison with unidirectional change in neurocognitive responses associate with strategy use (enhance and suppress). Although further research is required to clarify the association between the LPP and multiple components of ER, the current study serves as a first important step towards a data-driven neurocognitive approach to conceptualizing and assessing regulatory flexibility.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This research was made possible by grant SC1MH104907 awarded to T. Dennis-Tiwary from the National Institute of General Medical Sciences, grant R56MH111700 awarded to T. Dennis-Tiwary from the National Institute of Mental Health, both of the National Institutes of

Health, and grant TR000457 of the National Center for Advancing Translational Sciences of the National Institutes of Health.

## References


Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review, 30*(2), 217–237. https://doi.org/10.1016/j.cpr.2009.11.004.

Andor, T., Gerlach, A. L., & Rist, F. (2008). Superior perception of phasic physiological arousal and the detrimental consequences of the conviction to be aroused on worrying and metacognitions in GAD. *Journal of Abnormal Psychology, 117*(1), 193–205. https://doi.org/10.1037/0021-843X.117.1.193.

Babkirk, S., Rios, V., & Dennis, T. A. (2015). The late positive potential predicts emotion regulation strategy use in school-aged children concurrently and two years later. *Developmental Science, 18*(5), 832–841. https://doi.org/10.1111/desc.12258.

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*(6), 893–897. https://doi.org/10.1037/0022-006X.56.6.893.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory–II (BDI-II)*. Toronto, Ontario, Canada: The Psychological Corporation.

Bonanno, G. A., & Burton, C. L. (2013). Regulatory flexibility: An individual differences perspective on coping and emotion regulation. *Perspectives on Psychological Science, 8*(6), 591–612. https://doi.org/10.1177/1745691613504116.

Bonanno, G. A., Papa, A., Lalande, K., Westphal, M., & Coifman, K. (2004). The importance of being flexible: The ability to both enhance and suppress emotional expression predicts long-term adjustment. *Psychological Science, 15*(7), 482–487. https://doi.org/10.1111/j.0956-7976.2004.00705.x.

Bonanno, G. A., Pat-Horenczyk, R., & Noll, J. (2011). Coping flexibility and trauma: The perceived Ability to cope with Trauma (PACT) scale. *Psychological Trauma: Theory, Research, Practice, and Policy, 3*(2), 117–129. https://doi.org/10.1037/a0020921.

Campos, J. J., Campos, R. G., & Barrett, K. C. (1989). Emergent themes in the study of emotional development and emotion regulation. *Developmental Psychology, 25*(3), 394–402. https://doi.org/10.1037/0012-1649.25.3.394.

Conrad, A., Isaac, L., & Roth, W. T. (2008). The psychophysiology of generalized anxiety disorder: 1 Pretreatment characteristics. *Psychophysiology, 45*(3), 366–376. https://doi.org/10.1111/j.1469-8986.2007.00601.x.

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. https://doi.org/10.1016/S0301-0511(99)00044-7.

DeCicco, J. M., O'Toole, L. J., & Dennis, T. A. (2014). The late positive potential as a neural signature for cognitive reappraisal in children. *Developmental Neuropsychology, 39*(7), 497–515. https://doi.org/10.1080/87565641.2014.959171.

DeCicco, J. M., Solomon, B., & Dennis, T. A. (2012). Neural correlates of cognitive reappraisal in children: An ERP study. *Developmental Cognitive Neuroscience, 2*(1), 70–80. https://doi.org/10.1016/j.dcn.2011.05.009.

Dennis, T. A., & Hajcak, G. (2009). The late positive potential: A neurophysiological marker for emotion regulation in children. *Journal of Child Psychology and Psychiatry, 50*(11), 1373–1383. https://doi.org/10.1111/j.1469-7610.2009.02168.x.

Eftekhari, A., Zoellner, L. A., & Vigil, S. A. (2009). Patterns of emotion regulation and psychopathology. *Anxiety, Stress & Coping: An International Journal, 22*(5), 571–586. https://doi.org/10.1080/10615800802179860.

Ehring, T., Tuschen-Caffier, B., Schnülle, J., Fischer, S., & Gross, J. J. (2010). Emotion regulation and vulnerability to depression: Spontaneous versus instructed use of emotion suppression and reappraisal. *Emotion, 10*(4), 563–572. https://doi.org/10.1037/a0019010.

Foti, D., & Hajcak, G. (2008). Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *Journal of Cognitive Neuroscience, 20*(6), 977–988. https://doi.org/10.1162/jocn.2008.20066.

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. https://doi.org/10.1016/0013-4694(83)90135-9.

Gross, J. J. (1998a). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74*(1), 224–237. https://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*(3), 271. https://doi.org/10.1037/1089-2680.2.3.271org.ezproxy.gc.cuny.edu.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry, 26*(1), 1–26. https://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. https://doi.org/10.1037/0022-3514.85.2.348.

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting negative and positive emotion. *Journal of Abnormal Psychology, 106*(1), 95–103. https://doi.org/10.1037/0021-843X.106.1.95.

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

Gupta, S., & Bonanno, G. A. (2011). Complicated grief and deficits in emotional expressive flexibility. *Journal of Abnormal Psychology, 120*(3), 635–643. https://doi.org/10.1037/a0023541.

Gyurak, A., Gross, J. J., & Etkin, A. (2011). Explicit and implicit emotion regulation: A dual-process framework. *Cognition & Emotion, 25*(3), 400–412. https://doi.org/10.1080/02699931.2010.544160.

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. https://doi.org/10.1016/j.clinph.2008.11.028.

Hajcak, G., MacNamara, A., Foti, D., Ferri, J., & Keil, A. (2013). The dynamic allocation of attention to emotion: Simultaneous and independent evidence from the late positive potential and steady state visual evoked potentials. *Biological Psychology, 92*(3), 447–455. https://doi.org/10.1016/j.biopsycho.2011.11.012.

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective & Behavioral Neuroscience, 6*(4), 291–297. https://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. https://doi.org/10.1037/1528-3542.8.2.250.

Jackson, D. C., Malmstadt, J. R., Larson, C. L., & Davidson, R. J. (2000). Suppression and enhancement of emotional responses to unpleasant pictures. *Psychophysiology, 37*(4), 515–522. https://doi.org/10.1017/S0048577200990401.

Kashdan, T. B., & Rottenberg, J. (2010). Psychological flexibility as a fundamental aspect of health. *Clinical Psychology Review, 30*(7), 865–878. https://doi.org/10.1016/j.cpr.2010.03.001.

Kashdan, T. B., Weeks, J. W., & Savostyanova, A. A. (2011). Whether, how, and when social anxiety shapes positive experiences and events: A self-regulatory framework and treatment implications. *Clinical Psychology Review, 31*(5), 786–799.

Kudinova, A. Y., Owens, M., Burkhouse, K. L., Barretto, K. M., Bonanno, G. A., & Gibb, B. E. (2016). Differences in emotion modulation using cognitive reappraisal in individuals with and without suicidal ideation: An ERP study. *Cognition & Emotion, 30*(5), 999–1007. https://doi.org/10.1080/02699931.2015.1036841.

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006a). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology, 43*(3), 292–296. https://doi.org/10.1111/j.1469-8986.2006.00402.x.

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

Luck, S. J., & Gaspelin, N. (2017). How to get statistically significant effects in any ERP experiment (and why you shouldn't). *Psychophysiology, 54*(1), 146–157. https://doi.org/10.1111/psyp.12639.

McRae, K., Ciesielski, B., & Gross, J. J. (2012). Unpacking cognitive reappraisal: Goals, tactics, and outcomes. *Emotion, 12*(2), 250–255. https://doi.org/10.1037/a0026351.

Mocaiber, I., Pereira, M. G., Erthal, F. S., Machado-Pinheiro, W., David, I. A., Cagy, M., ... de Oliveira, L. (2010). Fact or fiction? An event-related potential study of implicit emotion regulation. *Neuroscience Letters, 476*(2), 84–88. https://doi.org/10.1016/j.neulet.2010.04.008.

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006b). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology, 43*(3), 292–296. https://doi.org/10.1111/j.1469-8986.2006.00402.x.

Myruski, S., Bonanno, G. A., Gulyayeva, O., Egan, L. J., & Dennis-Tiwary, T. A. (2017). Neurocognitive assessment of emotional context sensitivity. *Cognitive, Affective & Behavioral Neuroscience, 17*(5), 1058–1071. https://doi.org/10.3758/s13415-017-0533-9.

Myruski, S., Denefrio, S., & Dennis-Tiwary, T. (2018). Stress and emotion regulation: The dynamic fit model. In K. Harkness, & E. P. Hayden (Eds.). *The Oxford handbook of stress and mental health*. Oxford: Oxford University Press.

Newman, M. G., & Llera, S. J. (2011). A novel theory of experiential avoidance in generalized anxiety disorder: A review and synthesis of research supporting a contrast avoidance model of worry. *Clinical Psychology Review, 31*(3), 371–382. https://doi.org/10.1016/j.cpr.2011.01.008.

Nolen-Hoeksema, S., & Aldao, A. (2011). Gender and age differences in emotion regulation strategies and their relationship to depressive symptoms. *Personality and Individual Differences, 51*(6), 704–708.

Rodin, R., Bonanno, G. A., Rahman, N., Kouri, N. A., Bryant, R. A., Marmar, C. R., ... Brown, A. D. (2017). Expressive flexibility in combat veterans with posttraumatic stress disorder and depression. *Journal of Affective Disorders, 207*, 236–241. https://doi.org/10.1016/j.jad.2016.09.027.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology, 37*(2), 257–261. https://doi.org/10.1017/S0048577200001530.

Strauss, G. P., Kappenman, E. S., Culbreth, A. J., Catalano, L. T., Ossenfort, K. L., Lee, B. G., ... Gold, J. M. (2015). Emotion regulation abnormalities in schizophrenia: Directed attention strategies fail to decrease the neurophysiological response to unpleasant stimuli. *Journal of Abnormal Psychology, 124*(2), 288–301. https://doi.org/10.1037/abn0000017.

Tamir, M., & Ford, B. Q. (2009). Choosing to be afraid: Preferences for fear as a function of goal pursuit. *Emotion, 9*(4), 488–497. https://doi.org/10.1037/a0015882.

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. https://doi.org/10.1016/j.biopsycho.2011.02.009.

Todd, R. M., Cunningham, W. A., Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences, 16*(7), 365–372. https://doi.org/10.1016/j.tics.2012.06.003.

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. https://doi.org/10.1037/a0027600.

Westphal, M., Seivert, N. H., & Bonanno, G. A. (2010). Expressive flexibility. *Emotion, 10*(1), 92–100. https://doi.org/10.1037/a0018420.

Zhang, B.-W., Xu, J., Chang, Y., Wang, H., Yao, H., & Tang, D. (2016). Impaired cognitive reappraisal in panic disorder revealed by the late positive potential. *NeuroReport: For Rapid Communication of Neuroscience Research, 27*(2), 99–103. https://doi.org/10.1097/WNR.0000000000000504.

Zhu, Z., & Bonanno, G. A. (2017). Affective flexibility: Relations to expressive flexibility, feedback, and depression. *Clinical Psychological Science, 5*(6), 930–942. https://doi.org/10.1177/2167702617717337.