THE EFFECTS OF EXPRESSIVE WRITING ON NEURAL MARKERS OF COGNITIVE PROCESSING IN WORRIERS

By

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ABSTRACT

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Individuals with excessive anxiety and worry often require additional effort to complete tasks, rendering their performance inefficient. Inefficient information processing in anxiety is evident by enlarged amplitude of the error-related negativity (ERN), an event-related brain potential (ERP) elicited after errors during simple reaction time tasks. Although enlarged ERN among worriers is well documented, few studies have examined the effects of interventions aimed at reducing it. Thus, it is unknown whether the ERN could be used to gauge anxiety treatment effects on information processing. The current study aimed to address this gap by recording ERPs among worried undergraduates following an expressive writing exercise (n=18) or a control writing condition (n=16). Expressive writing entails writing about one's deepest thoughts and feelings about a particular event, which can free up cognitive resources and promote more efficient performance among anxious individuals. I predicted that by off-loading worries and freeing up resources, worried individuals in the expressive writing condition would demonstrate reduced ERN and equivalent performance compared to those in the control condition, indicative of more efficient performance. Results supported these predictions. Moreover, a related ERP reflective of conflict-related cognitive control (N2) was also reduced in the expressive writing condition. These results suggest that error- and conflict- related brain activity during simple tasks might be promising markers of treatment response among individuals with clinical anxiety.

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INTRODUCTION

Anxiety is a common experience characterized by worrisome thoughts, physiologic arousal, and avoidance behaviors (Barlow, 2002). Although it serves an evolutionary purpose to detect and avoid threat, excessive anxiety can compromise performance in important situations (Beilock, 2008; Crocker et al., 2013; Yerkes & Dodson, 1908). Worrisome thoughts, in particular, detract important resources that are normally devoted to the task at hand, requiring an increase in effort to maintain adequate performance. This additional effort is thought to reflect a "hidden cost" of worry (Berggran & Derakshan, 2013). Cognitive neuroscience advances have revealed that one hidden cost of worry is excessive "cognitive control" brain activity without an increase in behavioral performance (e.g., Moser, Moran, Schroder, Donnellan, & Yeung, 2013). The current study aimed to understand how a simple intervention – expressive writing – impacts this excessive brain activity among individuals who habitually worry.

Neurophysiological Markers of the "Hidden Costs" of Worry

Although anxiety at times has detrimental consequences for high-stakes situations (Beilock, 2008) and difficult tasks (Eysenck & Calvo, 1992), the effects of anxiety on cognition and performance are not always obvious. In simple tasks, for example, anxiety does not influence accuracy or reaction time. Instead, anxious individuals require more effort to obtain optimal levels of performance, rendering their performance "inefficient". This pattern of inefficient processing is considered to be a "hidden cost" of anxiety (Berggren & Derakshan, 2013). Because of this, many researchers have turned to neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and event-related brain potentials (ERPs) to assess how worries impact the brain. One very promising neurobiological marker of cognitive inefficiency in anxiety is increased amplitude of the error-related negativity (ERN; Gehring, Goss, Coles, Meyer, & Donchin, 1993).

The ERN is an ERP elicited within 100ms of a response error in a simple two-choice task such as the Eriksen flanker task (Eriksen & Eriksen, 1974). The ERN has been localized to an area of the medial frontal cortex known as the anterior cingulate cortex (ACC; Dehaene, Posner, & Tucker, 1994; van Veen & Carter, 2002), which is involved in performance monitoring and action selection (Shackman et al., 2011; Shenhav, Botvinick, & Cohen, 2013; Ullsperger, Danielmeier, & Jocham, 2014). The ERN is thought to reflect ACC-mediated brain activity associated with monitoring for conflicts and errors in task performance (Yeung, Botvinick, & Cohen, 2004). As such, it is considered to be an index of cognitive control, which refers to the ability to detect and respond to conflicts and errors and implement appropriate adjustments to improve subsequent performance (Miller & Cohen, 2001). Indeed, larger ERN amplitudes often coincide with optimal performance (i.e., fewer errors, Gehring et al., 1993; Holroyd & Coles, 2002; Yeung et al., 2004).

However, the enhanced ERN among individuals with anxiety is almost always accompanied by average (unaffected) performance (Hajcak, 2012; Moser et al., 2013; Olvet & Hajcak, 2008). That is, larger ERN does not confer improvements in behavior among anxious individuals. Indeed, enhanced ERN but unaffected performance has been observed among individuals with symptoms of obsessive-compulsive disorder (Gehring, Himle, & Nisenson, 2000; Hajcak & Simons, 2002), generalized anxiety disorder (Weinberg, Klein, & Hajcak, 2012; Weinberg, Olvet, & Hajcak, 2010) as well as in non-clinical samples exhibiting similar anxiety-related traits (Aarts & Pourtois, 2010; Beste et al., 2013; Hajcak, McDonald, & Simons, 2003; Moser, Moran, & Jendrusina, 2012), suggesting this “neurobehavioral profile” is quite robust.

The pattern of enhanced error monitoring (ERN) but unaffected performance is somewhat unique to anxiety. In other related clinical disorders, such as depression, abnormal error monitoring often coincides with poorer task performance (e.g., Holmes & Pizzagalli, 2008; Schroder, Moran, Infantolino, & Moser, 2013).

Cognitive models of anxiety offer a mechanistic explanation of enhanced ERN among anxious individuals (Eysenck et al., 2007; Moser et al., 2013). The attentional control theory (ACT; Eysenck et al., 2007) posits that anxious apprehension, or the predisposition to worry, constrains working memory resources typically devoted to on-task processing. Because worries 'soak up' resources, compensatory effort – defined here as the engagement of attentional resources to the task at hand (Sarter, Gehring, & Kozak, 2006) - is required to maintain adequate levels of performance. ACT predicts that, during relatively simple tasks, anxiety does not affect performance *effectiveness* (overall accuracy or reaction time); rather, anxiety affects performance *efficiency* by requiring additional resources to maintain effectiveness. ACT has been supported by numerous neuroimaging studies linking anxiety with intact performance but enhanced activation of frontal cognitive-control networks (Basten et al., 2011, 2012; Fales et al., 2008; Sylvester et al., 2012). Integrating ACT and models of cognitive control, the Compensatory Error Monitoring Hypothesis (CEMH) suggests that enhanced ERN in anxiety reflects a compensatory effort response by which anxious individuals employ more effort/resources to maintain adequate levels of performance (Moser et al., 2013).

The extant ERN literature supports two additional assumptions of ACT and CEMH. First, the *anxious apprehension/ cognitive subtype* of anxiety – characterized by distracting and intrusive thoughts and worries – is most closely related to enhanced ERN (Hajcak, McDonald, & Simons, 2003; Moran et al., 2012; Moser, Hajcak, & Simons, 2005; Moser et al., 2012;

Vaidyanathan, Nelson, & Patrick, 2012). This contrasts with studies examining ERN and symtpoms of non-cognitive anxiety, such as *anxious arousal / physiologic anxiety* (Hajcak et al., 2003; Moser et al., 2005; Moser et al., 2013). Put another way, the ERN is enhanced only to the extent that anxiety is primarily expressed in the cognitive domain (i.e., worry). This is consistent with ACT's focus on the worry subcomponent that results in cognitive inefficiency. Second, the ERN is sensitive to manipulations of working memory load, such that additional load potentiates ERN amplitudes. For instance, ERN is enhanced when individuals are required to switch between stimulus-response mappings (Schroder, Moran, Moser, & Altmann, 2012) and when individuals are required to memorize digits before flanker stimuli (Moser et al., 2013). These studies provide evidence that by loading working memory – a neutral analog to the effects of worry – ERN is enhanced. Together, these two lines of evidence indicate that the ACT/CEMH can account for ERN enhancement in anxious individuals.

Although the past 13 years have shown that the ERN is consistently enhanced in anxious individuals, there has only been one study examining the effects of anxiety treatment on the ERN. Hajcak, Franklin, Foa, and Simons (2008) examined ERN in children diagnosed with pediatric obsessive-compulsive disorder (OCD) before and after cognitive behavioral therapy (CBT). Despite symptom reduction in the patient group, ERN amplitude remained significantly enhanced both before and after treatment compared to a non-anxious control group. Although this is the only anxiety treatment study of the ERN, these results are frequently used to support the interpretation that the ERN is a trait-like biomarker for anxiety (Hajcak, 2012; Olvet & Hajcak, 2008; Riesel et al., 2011) and that it is insensitive to treatment response (Proudfit, Inzlicht, & Mennin, 2013).

However, some important limitations of the Hajcak et al (2008) study prevent definitive conclusions regarding the ERN's sensitivity to treatment. First, they used a pediatric sample (ages ranged from 8 to 17 years). This is problematic because 1) the ERN is highly sensitive to development (Davies et al., 2004; Segalowitz & Dywan, 2009), 2) the anxiety-ERN relationship is moderated by age, with younger children's anxiety relating to *smaller* ERN and older adolescents' anxiety relating to *enhanced* ERN (Hanna et al., 2012; Meyer, Hajcak, et al., 2013; Meyer, Weinberg, Klein, & Hajcak, 2012; Torpey et al., 2013), and 3) the vast majority of anxiety-ERN studies used adult samples, making comparisons difficult. Second, there were nearly significantly more females in the OCD sample (relative to the control sample) at post-treatment (p = .07). This may have inflated the group differences at post-treatment, as the anxiety-ERN relationship is reliably stronger in females (Moran et al., 2012). Finally, the Simon task used in the Hajcak et al study is rarely used in error-monitoring studies (this is the only anxiety-ERN study I am aware of that used this task, cf. Moser et al., 2013). Thus, it is not entirely clear how ERNs elicited from the Simon task compare to the ERNs elicited from more commonly used tasks such as the flanker or Stroop task. Task choice is not trivial, as different types of tasks are associated with different psychometric properties of the ERN (Meyer et al., 2013; Riesel et al., 2013), and several studies have shown that subtle task differences (e.g., the presence or absence of trial-wise feedback or response ratings) affect ERN amplitudes and how the ERN relates to psychopathology (Foti et al., 2013; Grutzman, Endrass, Klawohn, & Kathmann, 2014; Gründler et al., 2009; Olvet & Hajcak, 2009b; Schroder et al., 2013). Taken together, the findings from Hajcak et al (2008) alone cannot provide definitive conclusions regarding the treatment sensitivity of the ERN. Crucially, no studies have examined how interventions influence the ERN in anxiety among an adult, sex-matched sample using a commonly used experimental paradigm.

Perhaps most important, the intervention of the Hajcak et al (2008) was designed to reduce anxiety symptoms, and not the underlying mechanism thought to reflect cognitive inefficiency (e.g., ERN). In this way, even though the patient group had reduced OCD symptoms after treatment, they still demonstrated anxiety-related inefficiency as reflected in enhanced ERN. The focus of the current study was not to reduce anxiety symptoms per se, but rather to reduce the functional relationship between worry and cognitive efficiency (cf. Ramirez & Beilock, 2011). That is, the focus of the expressive writing intervention described below was to target the *mechanism* thought to underlie this relationship between worry and enhanced ERN.

Another ERP associated with cognitive control is the N2, which peaks 200-400ms following stimulus onset (Falkenstein, Hoormann, & Hohnsbein, 1999; Folstein & van Petten, 2008) and is also localized to the ACC (van Veen & Carter, 2002; Yeung et al., 2004). The N2 is thought to reflect a process related to controlling incorrect response preparation (Folstein & van Petten, 2008) such as response inhibition (Falkenstein et al., 1999) and response conflict (Schroder et al., 2012; Yeung & Cohen, 2006). That is, even though the N2 is time-locked to the *stimulus,* it is thought to reflect processes associated with the preparation and control of the ensuing *response.* The N2 is sensitive to response conflict, such that its amplitude is enlarged on trials with incongruent stimuli (e.g., “MMNMM”) relative to congruent stimuli (e.g., “NNNNN”; Gehring, Gratton, Coles, & Donchin, 1992). Although the primary component of interest to the current study was the ERN, the N2 may also provide incremental information about cognitive control in anxiety. Because the ERN and N2 share a number of characteristics, including waveform shape, scalp distribution, source localization in ACC, and experimental manipulation effects, they have been considered to reflect similar yet dissociable outputs of a generic conflict-monitoring system (van Veen & Carter, 2002; Yeung & Cohen, 2006). To date, however, there is much less research examining the relationship between the N2 and anxiety compared to the ERN. Nevertheless, the relationship is similar to that of the ERN, with anxious individuals demonstrating increased N2 amplitudes (e.g., Dennis & Chen, 2007; Sass et al., 2010). Similarly, some research has found that individuals who have a predisposition to anxiety (behavioral inhibition) have increased N2 amplitudes (Amodio, Master, Yee, & Taylor, 2008; Leue, Lange, & Beauducel, 2012). Moreover, the N2 is enlarged with increasing working memory demands (Hsieh & Wu, 2011; Moran & Moser, 2012; Schroder et al., 2012). In sum, enhanced N2 may represent another hidden cost of worry.

The Expressive Writing Paradigm

The expressive writing paradigm was developed in the 1980s as a “mini-intervention" to alleviate mental and physical distress (Pennebaker & Beall, 1986). The standard instructions are for participants to write openly and freely about their emotions regarding past traumatic events. The largest meta-analysis to date (Frattaroli, 2006), which included all randomized expressive writing experiments using a variation of the original paradigm, found an overall effect size of d = .15. This seemingly small effect size is still likely to be meaningful given the low cost, ease of administration, and efficient nature of this intervention (Pennebaker & Chung, 2011). Indeed, this effect size is actually quite favorable compared to those of some other valued medical interventions such as daily aspirin intake to prevent heart attack (d = .04; Meyer et al., 2001).

Importantly, recent evidence also suggests that expressive writing curtails the negative effects of anxiety on cognitive performance. For instance, exam performance – which is highly susceptible to trait and state test anxiety (Beilock, 2008) - has been shown to improve substantially after expressive writing (Dalton & Glenwick, 2009; Frattaroli, Thomas, & Lyubomirsky, 2011). In fact, Ramirez and Beilock (2011) found that final exam performance improved after just a single (10-minute) session of expressive writing for individuals who were typically test-anxious as well as improved math performance for those who were exposed to a laboratory stress induction. Critically, the authors attributed their results to the fact that expressive writing increases working memory capacity by reducing intrusive thoughts (Klein & Boals, 2001; Yogo & Fujihara, 2008). This working memory improvement is particularly relevant to anxiety, as anxiousness and worry are theorized to detract resources from working memory (e.g., Eysenck & Calvo, 1992). This line of research suggests that expressive writing can relieve some of anxiety's effects on cognition (Maloney & Beilock, 2012; Maloney, Schaeffer, & Beilock, 2013; Ramirez & Beilock, 2011). However, the extent and nature of this improvement remains relatively unexplored and there have been no studies to date that have examined expressive writing's effects on potential mediating neural mechanisms in anxiety. The aim of the current study was to address this gap in the extant literature by exploring expressive writing's effects on neural markers of cognitive functioning in anxiety using the ERN and N2 components.

Current Study

The current study was designed to examine the extent to which expressive writing has effects on neural markers of error monitoring (ERN) and conflict-related cognitive control (N2) among individuals with elevated worry. "Cognitive efficiency" was assessed by examining both brain activity and behavior: I define increased efficiency as equivalent performance but reduced brain activity (Eysenck & Calvo, 1992; Gray & Braver, 2002; Gray & Burgess, 2004; Gray et al., 2005). Before performing a flanker task, worried subjects wrote about what they had done the day before (unrelated writing condition) or about the feelings they were experiencing as they prepared to perform the computer task (expressive writing condition). If enhanced ERN in anxiety reflects the cognitive inefficiency resulting from worries (Moser et al., 2013), I predicted that by off-loading worries and thereby reducing the burden they have on working memory (Klein & Boals, 2001; Yogo & Fujihara, 2008), individuals in the expressive writing condition would demonstrate reduced ERN yet intact performance. A similar reduction was predicted for the N2. Such findings would demonstrate that expressive writing has demonstrable effects on the hidden costs of worry.

METHODS

Participants

Undergraduates (N = 1,462) from a large Midwestern university completed the 16-item Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) as part of an online global screening procedure ($\alpha = .94$). Only participants scoring above a 61, which is the standard cutoff for Generalized Anxiety Disorder on this measure (Behar, Alcaine, Zuellig, & Borkovec, 2003), were asked to participate in the EEG experiment. Twenty-seven percent of respondents (N = 396) met the PSWQ score criterion, of which 44 right-handed undergraduate females (*M* age = 19.80, *SD* = 4.38) participated in the current study for course credit. Additional screening requirements included normal or corrected-to-normal vision, right-handedness, and no history of a loss of consciousness for over five minutes. Females were recruited because previous work indicates that the anxiety-ERN relationship is much greater in females (Moran et al., 2012). Upon arrival to the lab, participants were randomly assigned to the Expressive Writing (n =22) or the Unrelated Writing (n = 22) conditions. Participants in the two experimental conditions did not differ in terms of age or online PSWQ scores (*t*s < 1). The university's Institutional Review Board (IRB) approved all procedures.

Procedure

After providing written informed consent, EEG cap and sensors were applied (see below for details). All experimental procedures (questionnaires, writing task, flankers task) were presented on the computer using E-Prime 2.0 software. Participants first completed the State-Trait Anxiety Inventory-State Version (STAI-S; Speilberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; $\alpha = .94$). Next, participants were handed an envelope containing the specific instructions for their condition (experimenters were blind to the experimental condition). Instructions were nearly identical to those used in Study 2 of Ramirez & Beilock (2011):

Expressive Writing Group - *"Please take the next eight minutes to write as openly as possible about your thoughts and feelings regarding the computer task you are about to perform. In your writing, I want you to really let yourself go and explore your emotions and thoughts as you are getting ready to start. You might relate your current thoughts to the way you have felt during other similar situations at school or in other situations in your life. Please try to be as open as possible as you write about your thoughts at this time. Remember, there will be no identifying information on your essay. None of the experimenters, including me, can link your writing to you. Please start writing."*

Unrelated Writing Group – "*Please take the next eight minutes to write about how you spent your day yesterday. Describe how you spent your time as factually and unemotionally as possible from the time you got up in the morning until the time you went to sleep in the evening. Please be as detailed as possible about how you spent your day. You might write about how you spent your time yesterday in relation to how you spent your time the day prior. Remember, there will be no identifying information on your essay. None of the experimenters, including me, can link your writing to you. Please start writing."*

Using the computer, participants wrote for eight minutes. Care was taken to ensure that experimenters did not see the participants' writing at any time. As in Ramirez and Beilock (2011), after the eight minutes of writing, participants sat quietly for four minutes before they were given instructions about the computer task (participants were told that experimenters were setting up for the next part of the study). This additional time was provided for participants to reflect on what they had written, although this reasoning was not made explicit to participants. After the four minutes of rest, the experimenters returned to the experiment room and administered instructions for the computer task.

Flanker Task

The task was a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974). Participants were instructed to use the keyboard keys (left hand: "A" key; right hand: "L" key) to respond to the center (target) letter of a five-letter string in which the target was either congruent (for example: MMMMM or NNNNN) or incongruent (for example: NNMNN or MMNMM) with the distracter letters. For example, during the first block, participants were to respond with a left-hand keyboard response (the “a” button) if the target letter is “M”; a right-hand keyboard response (the “l” button) was required for target letter “N”. During each trial, flanking letters were presented 35ms prior to target letter onset, and all five letters remained on the screen for a subsequent 100 ms (total trial time was 135ms). Each trial was followed by a variable intertrial interval (1200-1700 ms) during which a fixation cross (+) was presented. Characters were displayed in a standard white font on a black background and subtended 1.3° of the visual angle vertically and 9.2° horizontally. All stimuli were presented using E-Prime software to control the presentation and timing of all stimuli, the determination of response accuracy, and the measurement of reaction times.

The experimental session included 480 trials grouped into twelve blocks of 40 trials during which accuracy and speed were equally emphasized. Across the entire task, the ratio of congruent to incongruent trials was kept at 1:1. To increase the number of errors and thus the number of error trials for reliable ERN analysis (Olvet & Hajcak, 2009a), letters making up the stimuli differed across the task (“M” and “N” in blocks 1 and 2, “E” and “F” in blocks 2 and 4, “O” and “Q” in blocks 5 and 6, “T” and “I” in blocks 7 and 8, “V” and “U” in blocks 9 and 10, and “P” and “R” in blocks 11 and 12) and stimulus-response mappings were reversed within each block pair (for example: target “M” in block 1 required left button response, whereas in block 2 target “M” required a right button response).

Immediately after the flankers task, participants completed the STAI-S again ($\alpha = .94$). After electrodes and cap were removed, participants completed the PSWQ (Meyer et al., 1990; $\alpha = .78$) as part of a larger battery of questionnaires.

Psychophysiological Recording and Data Reduction

Continuous encephalographic (EEG) activity was recorded using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands). Recordings were taken from 64 Ag-AgCl electrodes placed in accordance with the 10/20 system. In addition, two electrodes were placed on the left and right mastoids. Electro-oculogram (EOG) activity generated by eye movements and blinks was recorded at FP1 and three additional electrodes placed inferior to the left pupil and on the left and right outer canthi (all approximately 1 cm from the pupil). During data acquisition, the Common Mode Sense active electrode and Driven Right Leg passive electrode formed the ground, as per BioSemi's design specifications. All signals were digitized at 512 Hz using ActiView software (BioSemi). Offline analyses were performed using BrainVision Analyzer 2 (BrainProducts, Gilching, Germany). Scalp electrode recordings were re-referenced to the numeric mean of the mastoids and band-pass filtered with cutoffs of 0.1 and 30 Hz (12 dB/oct rolloff). Ocular artifacts were corrected using the method developed by Gratton, Coles and Donchin (1983). Response-locked data were segmented into individual epochs beginning 200 ms before response onset and continuing for 800 ms following the response. Stimulus-locked data were segmented into individual epochs beginning 200 ms before target stimulus onset and continuing for 800ms following the stimulus. Physiologic artifacts were detected using a computer-based algorithm such that trials in which the following criteria were met were rejected: a voltage step exceeding 50 μV between contiguous sampling points, a voltage difference of more than 200 μV within a trial or a maximum voltage difference less than 0.5 μV within a trial. The ERN and its correct-response counterpart (the correct-response negativity, CRN) were defined as the average activity in the 0-65ms post-response time window at electrode site FCz, where the ERN was maximal. The N2 was defined as the average activity in the 300-400ms post-stimulus time window at electrode Fz, where it was maximal. Per convention (Yeung et al., 2004), only correct trials were used for calculation of the N2.

Data from 10 participants were excluded prior to analysis due to a failure to follow task instructions. Specifically, these participants failed to properly switch stimulus-response mappings in one of the blocks, resulting in accuracy below 50% in one of the task blocks. This left a final analysis sample of 34 participants (*M* age = 18.85, *SD* = 1.05); 18 were in the expressive writing condition, and 16 were in the unrelated writing condition. Average PSWQ scores in the final sample (*M* = 68.56, *SD* = 5.94) were significantly higher than scores obtained from a "local norm" sample (N= 4,425) of individuals who completed this measure in our lab (*M* = 51.99, *SD* = 13.34); $t(4,457) = 7.24$, $p < .001$, $d = 1.25$). This suggests the individuals included in the current study were substantially more worried compared to typical undergraduates. The two writing groups did not differ in terms of online PSWQ scores or age (*t*s < 1).

Text Analysis

Participants' essays were analyzed with the Linguistic Inquiry and Word Count (LIWC2007; Pennebaker, Booth, & Francis, 2007). LIWC analyzes text documents and provides the percentage of different types of words (e.g., pronouns, affective words) used in a particular document. Previous work (Ramirez & Beilock, 2011) has identified the following linguistic categories as potentially related to writing-induced changes in anxiety: anxiety words (worried, fearful, nervous), affect words (happy, cried, abandoned), positive emotion words (love, nice, sweet), negative emotion words (hurt, ugly, nasty), inhibition words (block, constrain, stop) cause words (because, effect, hence), and insight words (think, know, consider). I predicted that individuals in the expressive writing condition would write a significantly higher percentage of these word categories than those in the Unrelated Writing condition. This analysis served primarily as a manipulation check.

Essays were also coded using an alternative coding scheme that was modeled after Creswell et al.'s (2007) study on expressive writing and breast cancer (cf. Ramirez & Beilock, 2011). This coding scheme analyzes the *content* of the essays (as opposed to the word use in LIWC). Statements were coded on four variables: on-task worries (any negative reflection related to the task (e.g., "I am nervous for this task")); off-task worries (any negative statement *not* related to the task (e.g., "I'm having a really bad time at school")); performance-monitoring (any statement related to monitoring their performance (e.g., "I wonder what my brain waves look like right now,")); and bodily sensations (any statement related to bodily functioning and/or states (e.g., "I can't keep my feet still.")). The definitions and coding schemes were adopted from Ramirez & Beilock (2011; Ramirez, personal communication, July 18, 2013). Statements of essays were coded individually. Independent coders (HS and a trained research assistant) coded 913 statements. Cohen's kappa (κ) for the coded variables was as follows: task worries = .76, off-task worries = .62, performance monitoring = .72, bodily sensations = .76. For analysis, the proportion of statements that fit into these categories was computed for each participant and averaged across coders. I predicted that individuals in the expressive writing condition would demonstrate higher proportions of sentences in all of these categories.

Behavioral Analysis

Behavioral analyses were conducted to assess differences in flanker task performance between the two conditions. I predicted that no such differences would emerge, given research and theory from Eysenck and colleagues (2007) indicating that anxiety does not impact behavioral performance in simple tasks (cf. Moser et al., 2013). A number of different behavioral effects have been observed in this and similar tasks, and all of them were analyzed in this study.

A univariate ANOVA with Writing Group (Unrelated vs. Expressive) as the independent variable was used to assess overall accuracy (% correct) differences. Reaction time (RT) data were submitted to a 2(Response Type: Error vs. Correct) X 2(Writing Group: unrelated vs. expressive writing) repeated-measures analysis of variance (rANOVA). Similarly, standard congruency effects [i.e., longer RTs and poorer accuracy on incongruent trials ("MMNMM") relative to congruent trials ("NNNNN")] were tested with a 2(Stimulus Type: Congruent vs. Incongruent) X 2(Writing Group; Unrelated vs. Expressive writing) rANOVA.

Post-error behavioral adjustments are integral to functional error monitoring (e.g., Danielmeier & Ullsperger, 2011; Schroder & Infantolino, 2013; Schroder & Moser, 2014). Post-error slowing is the most commonly observed post-error behavioral adjustment, and refers to the slowing of response times on trials that follow errors, relative to trials that follow corrects (Rabbitt, 1966). The extent to which participants increased their accuracy on trials following errors, relative to trials following correct responses (i.e., post-error accuracy) was also evaluated. Post-error performance (RT and accuracy) was assessed with a 2(Trial: Post-error vs. Post-correct) X 2(Writing Group: Unrelated vs. Expressive writing) rANOVA.

Finally, conflict-adaptation effects were assessed. Several studies have found that incongruent trials following incongruent trials are associated with faster RT and higher accuracy relative to incongruent trials following congruent trials (Botvinick et al., 2001; Gratton, Coles, & Donchin, 1992; Kerns et al., 2004). RT and Accuracy data were submitted to a 2 (Previous Congruency: Congruent vs. Incongruent) X 2(Current-trial Congruency: Congruent vs. Incongruent) X 2 (Writing Group: Unrelated vs. Expressive writing) ANOVA. Again, no behavioral adjustment differences were expected to emerge between writing group conditions.

ERP Analysis

The primary hypothesis of the current study was that individuals in the expressive writing condition would show greater cognitive efficiency (i.e., equivalent performance but reduced ERN and N2). The ERN was tested with a 2(Response Type: Error vs. Correct) X 2(Writing Group: Unrelated vs. Expressive writing) rANOVA. I predicted a significant interaction between Response Type and Writing Group, such that individuals in the Expressive Writing condition would demonstrate reduced ERN (relative to CRN) amplitudes compared to those in the Unrelated Writing condition. The N2 was tested with a 2 (Stimulus Type: Congruent vs. Incongruent) X 2 (Writing Group: Unrelated vs. Expressive writing) rANOVA. A similar result was predicted: a significant Stimulus Type X Writing Group interaction was predicted to show that individuals in the Expressive Writing condition would demonstrate reduced N2 difference amplitudes (Incongruent N2 minus Congruent N2).

RESULTS

Writing Results

Inspection of the essays suggested participants followed instructions in their respective conditions.

Descriptive statistics from the LIWC analysis are listed in Table 1. Analysis of the essay content indicated writing groups did not differ in terms of overall number of words in their essays (Expressive writing: M = 320.61, SD = 103.13; Unrelated writing: M = 341.25, SD = 101.19; $t(32) < 1$, $p = .56$). However, essays in the expressive writing condition had a significantly higher proportion of words in the categories of anxiety ($t(32) = 4.59$, $p < .001$, d = 1.62), affect ($t(32) = 6.87$, $p < .001$, $d = 2.43$), negative emotion ($t(32) = 6.03$, $p < .001$, d =2.13), positive emotion ($t(32) = 4.79$, $p < .001$, $d = 1.69$), cause ($t(32) = 5.81$, $p < .001$, $d = 2.05$), and insight ($t(32) = 6.94$, $p < .001$, $d = 2.45$). The writing groups did not significantly differ in the percentage of words used in the inhibition category ($t(32) = 1.46$, $p = .15$, d =.52). These results exactly mirror those found in the Ramirez and Beilock (2011) study.

Essay content from the alternative coding scheme is displayed in Table 2. The expressive writing group had a numerically, but not statistically, higher percentage of on-task worry statements compared to the unrelated writing group ($t(32) = 1.97$, $p = .06$, $d = 0.70$). The expressive writing group had a significantly higher percentage of statements of off-task worries ($t(32) = 2.08$, $p < .05$, $d = 0.74$), performance-monitoring ($t(32) = 4.43$, $p < .001$, $d = 1.57$), and bodily sensations ($t(32) = 3.34$, $p = .002$, $d = 1.18$). The expressive writing group also had a significantly higher percentage of worries overall (averaged across on- and off-task worries; $t(32) = 2.74$, $p = .01$, $d = 0.97$).

Self-Report Results

Self-report measures are listed in Table 3. As can be seen in the Table, there were no significant differences in experiment PSWQ or STAI-S scores between the two writing groups (*F*s < 1). The lack of difference in STAI-S scores between groups is consistent with Ramirez & Beilock (2011)'s study and suggests that the writing intervention had no direct bearing on subjective reports of anxiety.

Behavioral Performance Results

Behavioral measures are presented in Table 4. Consistent with previous studies using this version of the flanker task (e.g., Moran et al., 2012; Moser et al., 2012; Moser, Schroder, Heeter, Moran, & Lee, 2011), accuracy across the entire sample was quite high (percentage correct: M = 93.00, SD =4.15). Accuracy did not differ between writing groups ($F < 1$). RT was significantly shorter on error trials relative to correct trials ($F(1, 32) = 15.09$, $p < .0001$, $\eta^2_p = .32$), but did not differ between writing groups (*F*s < 1). Typical flanker-interference effects were observed, such that, relative to congruent trials, incongruent trials were associated with longer RT ($F(1, 32) = 175.22$, $p < .001$, $\eta^2_p = .85$) and lower accuracy ($F(1, 32) = 69.05$, $p < .001$, $\eta^2_p = .68$); these effects did not differ between writing groups (*Fs* < 2.30, *ps* > .14).

Behavioral adjustment effects are depicted in Figure 1. As can be seen in the Figure, correct trials that followed error trials had significantly longer RT (M = 471.64, SD = 61.77) compared to correct trials following correct trials (M = 443.21, SD = 33.01), consistent with a post-error slowing effect ($F(1, 32) = 10.80$, $p < .01$, $\eta^2_p = .25$). The difference between post-error and post-correct RTs was even more pronounced when only the post-correct trials that also preceded errors were used in calculating post-error slowing ($F(1, 32) = 35.60$, $p < .001$, η^2_p =

.53). This more "robust" calculation of post-error slowing (Dutilh et al., 2012) produced a post-error slowing estimate more than double in size (M = 56.25, SD = 54.27) than the traditional method (M = 28.43, SD = 51.72; $t(33) = 6.74$, $p < .001$, d = .53). Moreover, accuracy on trials following errors (M = 95.28%, SD = 5.14) was significantly greater than accuracy on trials following correct responses (M = 92.68%, SD = 4.29; $F\,(1, 32) = 17.01$, $p < .001$, $\eta^2_p = .35$). These results indicate that across the whole sample, participants were able to adjust from their errors adaptively by responding more slowly and accurately. However, PES was not correlated with post-error accuracy difference scores ($r = .10$, $p = .56$) suggesting these post-error adjustments were independent from one another (Danielmeier & Ullsperger, 2011; Schroder & Moser, 2014). None of the interactions involving Writing Group were significant (Fs < 1.37).

Typical conflict adaptation effects were observed, such that the Previous Congruency X Current Congruency interaction was observed for both RT ($F\,(1, 32) = 30.31$, $p < .001$, $\eta^2_p = .49$) and accuracy ($F\,(1, 32) = 42.56$, $p < .001$, $\eta^2_p = .57$). As can be seen in Figure 1, incongruent trials following incongruent trials had shorter RT (difference in RT: M = 7.44, SD = 12.81; $t(32) = 3.39$, $p = .002$, $d = 0.23$) and higher accuracy (difference in accuracy: M = 4.5%, SD = 3.8%; $t(32) = 6.85$, $p < .001$, $d = 0.86$) compared to incongruent trials following congruent trials. Thus, all participants were able to adjust their behavior following conflict trials adaptively. None of the interactions involving Writing Group reached significance (Fs < 1).

ERP Results

ERN. Response-locked waveforms are presented in Figure 2. The main effect of Response Type ($F\,(1, 32) = 56.82$, $p < .0001$, $\eta^2_p = .64$) in the 0-65ms post-response window confirmed that error trials had significantly larger (more negative) amplitude (M = -6.41, SD =

4.62) relative to correct trials (*M* =0.82, *SD* = 5.12). This is consistent with an ERN. Important for the present study and consistent with predictions, the interaction between Response Type and Writing Group was significant (F (1, 32) = 4.29, $p < .05$, $\eta^2_p = .12$). Follow-up tests confirmed that the ERN difference wave amplitude (ERN minus correct-response negativity, CRN) was significantly reduced in the expressive writing group (*M* = -5.32, *SD* = 4.56) compared to the unrelated writing group (*M* = -9.36, *SD* = 6.71; t (32) = 2.07, $p < .05$, $d = 0.73$). Neither the ERN alone ($t(32) = 1.00$, $p = .33$, $d = .36$) nor the CRN alone ($t(32) = 1.41$, $p = .17$, $d = .50$) were significantly different between writing groups. That is, the difference between error and correct ERN amplitudes is what distinguished the writing groups.

N2. Stimulus-locked waveforms are presented in Figure 3. The main effect of Stimulus Type was significant (F (1, 32) = 12.86, $p = .001$, $\eta^2_p = .29$), such that incongruent trials elicited a larger N2 relative to congruent trials. This is consistent with previous studies (Gehring et al., 1992; Schroder et al., 2012) and indicates the N2 was sensitive to conflict in the expected direction. Important for the present study, the interaction between Stimulus Type and Writing Group was also significant (F (1, 32) = 4.24, $p < .05$, $\eta^2_p = .12$). Follow-up tests indicated that N2 difference amplitudes (Incongruent N2 minus Congruent N2) were significantly reduced (less negative) in the expressive writing group (*M* = -0.46, *SD* = 1.15) relative to the unrelated writing group (*M* = -1.71, *SD* = 2.27; t (32) = 2.06, $p < .05$, $d = 0.73$). As was the case for the ERN, neither the N2 on congruent trials ($t(32) = 0.82$, $p = .42$, $d = 0.29$) nor the N2 on incongruent trials ($t(32) = .03$, $p = .98$, $d = 0.01$) was significantly different between the writing groups. That is, the difference between incongruent and congruent N2 amplitudes is what distinguished the writing groups.

ERP and Essay Content Analyses

The final analysis explored potential mechanisms underlying the significant ERP differences between writing groups. This analysis focused exclusively on the Off-Task worries variable from the alternative coding scheme because 1) worries have been theorized to account for enhanced ERN in anxiety (Moser et al., 2013), and 2) the proportion of off-task, and not on-task worries, was significantly different between the writing groups. To this end, I conducted a 2 (Response Type) x 2(Writing Group) x Off-Task Worries ANCOVA for the ERN and N2. For the ERN, including Off-Task Worries as a covariate reduced the Response Type x Writing Group interaction to non-significance ($F(1, 30) < 1$, $p = .33$, $\eta^2_p = .03$). For the N2, the interaction between Stimulus Type and Writing Group was similarly reduced to non-significance when Off-Task Worries was included as a covariate ($F(1, 30) = 1.51$, $p = .23$, $\eta^2_p = .05$). The three-way interaction between Stimulus Type, Writing Group, and Off-Task Worries was nearly significant ($F(1, 30) = 3.88$, $p = .058$, $\eta^2_p = .11$). Follow-up correlations indicated that off-task worries related to the N2 difference wave more strongly in the unrelated condition ($r(14) = -.39$, $p = .14$) than in the expressive condition ($r(16) = -.02$, $p = .93$; Fisher's r-to-z transformation: Z= 1.03, $p = .30$, two-tailed). Although preliminary and underpowered, these findings suggest that off-task worries might play a role in the significant ERP differences observed in this study.

DISCUSSION

This study assessed how expressive writing affected neural mechanisms important to error monitoring and conflict-related cognitive control in a sample of chronically worried college students. The design of the study was motivated by research and theory indicating that expressive writing alleviates the burden that worries put on working memory capacity, an essential element of executive functioning (Engle, 2002). Although previous work showed performance improvements following expressive writing for individuals with test anxiety (Ramirez & Beilock, 2011) no study to date has examined underlying neural mechanisms. Moreover, no studies to date have examined the ERN in an anxious adult sample following any intervention. I predicted that individuals in the expressive writing group would demonstrate equivalent performance but reduced error monitoring (ERN) and conflict-related control (N2) brain activity, consistent with a reduction in worry-related working memory load. The results were in line with these predictions. Below, I discuss these findings in the context of current theories of anxiety and cognitive control, and the implications that these results have for short-term interventions for worry and anxiety.

Reducing the ERN and N2: Reducing the costs of worry

The current findings are consistent with the above-mentioned ERN framework that considers enhanced error-monitoring activity among those with anxiety as a result of working memory-related constraints (Moser et al., 2013). Specifically, if the ERN represents the output of compensatory effort that these constraints instigate, an intervention designed to alleviate the burden of worries on working memory (expressive writing) should result in attenuated ERN amplitudes among those with high worry. Put another way, following an expressive writing exercise, anxious individuals should not have to work as hard in order to maintain adequate levels of performance. Reduced ERN but equivalent performance in the expressive writing group is entirely consistent with this prediction, and suggests for the first time that a single dose of expressive writing can alleviate the “hidden costs” of worry.

These results contrast with those of the only study to examine ERN after treatment for an anxiety disorder (Hajcak et al., 2008). However, that study differed in a number of ways from the current one that makes direct comparisons difficult. First, the current study examined worried adults, whereas Hajcak et al examined children diagnosed with OCD. Second, this study used a flankers task to examine ERN and the Hajcak et al study used a Simon task. Perhaps the most important difference is that the current intervention focused on improving cognitive efficiency with a one-time writing exercise whereas the Hajcak et al (2008) treatment was designed to reduce anxiety symptoms over several weeks. Given the dearth of studies examining intervention effects on the ERN, it is too early to make any definitive conclusions in this regard. Nonetheless, despite being the only treatment study to date, the Hajcak et al study has been used extensively to support the “trait” biomarker / endophenotype conceptualization of enhanced ERN in anxiety (Hajcak, 2012; Manoach & Agam, 2013; Olvet & Hajcak, 2008; Riesel et al., 2011; Weinberg et al., 2012). Clearly, more work in this area is needed (e.g., Moser, Moran, Schroder, Donnellan, & Yeung, 2014; Proudfit et al., 2013).

The current results are consonant with a growing number of studies suggesting that abnormalities of the ERN and ACC are not necessarily biomarkers of disease, but may instead reflect the online interaction between anxiety and cognitive control that is subject to changes. It has long been known that pharmacological interventions influence the ERN among healthy volunteers, including increased ERN after coffee intake (Tieges, Ridderinkhof, Snel, & Kok, 2004), noradrenaline (Riba, Rodriguez-Fornells, Morte, Munte, & Barbanoj, 2005), and reduced ERN after alcohol consumption (Ridderinkhof et al., 2002). Emerging research in clinical samples also suggests that the ERN is susceptible to change. Recent studies of children with attention-deficit hyperactive disorder (ADHD) – who typically have blunted ERN amplitudes and ACC activity (Liotti, Pliszka, Perez, Kothmann, & Woldorff, 2005) – showed significantly enhanced ACC activity following a brief bout of exercise (Pontifex, Saliba, Raine, Picchetti, & Hillman, 2013) or after a dose of methylphenidate (Rubia, Halari, Mohammad, Taylor, & Brammer, 2011). In adults, atypical antipsychotics enhance ERN amplitudes among patients with schizophrenia (Schneider et al., 2013), a disorder consistently associated with reduced ERN (Bates, Kiehl, Laurens, & Liddle, 2002; Foti, Kotov, Bromet, & Hajcak, 2012). Together, these studies suggest that the ERN is not inherently stable and indicate that there is room for this component to change.

In this vein, the current findings fit in well with our conceptualization of the anxiety-ERN relationship based on the interaction between cognition and affect, not purely affect alone. The relationship between the ERN and "state" affect is entirely unclear, with many studies suggesting the ERN may be modulated by state affect (e.g., Larson et al., 2006; Wiswede et al., 2009a; Wiswede et al., 2009b) and many studies showing that it is not (e.g., Clayson, Clawson, & Larson, 2012; Moser et al., 2005). That is, the current findings suggest that *affect* per se is not what influences the ERN in anxiety, but the interaction between a specific affect (worry) and cognition (i.e., working memory). Assuming future studies are able to corroborate these notions, the ERN may be a suitable marker for intervention response among those with anxiety. In support of this notion, a case study reported by Moser, Przeworksi, Schroder, and Dunbeck (2014) found that exposure therapy for an anxiety disorder lead to a monotonic decrease in ERN amplitude from pre-therapy, mid-treatment, one-month post-treatment, and five-month post-treatment.

Although the focus here was on the ERN – which has had much more research attention in general - the N2 reduction in the Expressive Writing condition is also important for several reasons. First, it indicates that expressive writing's effects on cognitive control are not limited to error monitoring, but also extend to conflict-related processes on correct trials as well. That is, individuals in the expressive writing condition performed the flanker task more efficiently both after conflict stimuli (N2) and after responses (ERN). Second, because the ERN and N2 have been thought to reflect the output of a common conflict-monitoring system within the ACC (Yeung et al., 2004; Yeung & Cohen, 2006), it suggests that overall, expressive writing has a more global effect of improving efficiency within this more generalized system for individuals with anxiety. Finally, that the N2 was also attenuated in the expressive writing condition suggests that it may too represent a viable index of treatment response among worriers.

Mechanisms and Applications of Expressive Writing

For the first time, the current findings shed light on the underlying neural mechanisms responsible for expressive writing's effects on cognition and performance. Reduced ERN and N2 are in line with research (Klein & Boals, 2001) and theory (Maloney & Beilock, 2012; Maloney, Schaeffer, & Beilock, 2013) that suggests expressive writing frees up working memory capacity, allowing for the optimization of performance. These studies consistently show that while anxiety per se is not reduced following expressive writing, the link between anxiety and performance is ameliorated. The current findings significantly extend past work by showing that a *hidden cost of worry* (the ERN) is also directly impacted by expressive writing. In this way, expressive writing results in more efficient performance for individuals with high worry. The exploratory analyses of essay content and ERP effects suggested that off-task worries had a different impact on conflict control for individuals in the two groups. In the unrelated group, in which participants were instructed to write about their time management, more off-task worries related to increased N2, similar to our recent framework of the interfering effects of worries on error monitoring (Moser et al., 2013). In contrast, within the expressive group, in which participants were instructed to let go and write about all of their emotions in the moment, writing about off-task worries had the opposite effect and related to reduced N2 amplitudes. In this way, the extent to which individuals in the expressive group were able to "off load" their off-task worries, the more efficient their conflict monitoring.

These findings also add to the extensive evidence base that expressive writing is an especially promising intervention for anxiety. Given the low costs, ease of dissemination, and broad range of effects on well-being (Pennebaker & Chung, 2011), expressive writing may be one solution to the problems of contemporary mental health treatment (e.g., Kazdin & Blase, 2011). Indeed, recent randomized controlled trials suggest expressive writing-like interventions may be promising for individuals with post-traumatic stress disorder (Sloan, Marx, Bovin, Feinstein, & Gallagher, 2012). Because anxiety disorders are the most common mental health problem and cost billions of dollars each year in treatment, management, and lost work productivity (Kessler et al., 2005a, 2005b), recent calls have been made to develop more time- and cost-effective treatment options for mental disorders (anxiety in particular) in order to have a wider societal impact than current treatment regimens allow (e.g., Baker et al., 2008; Kazdin & Blase, 2011; Kazdin & Rabbitt, 2013; Santucci, McHugh, & Barlow, 2012). The results from the current study further indicate that expressive writing may be one such intervention in that it acts directly on well-established neurobiological indices of cognition and performance in anxious individuals.

Limitations and Conclusions

There were several limitations that should be addressed in future studies. First, the sample size (N=34) was small for a between-subjects intervention study. Although this is unfortunately the norm for neuroimaging studies, future work will need to replicate these findings using much larger samples in order to confirm the effects observed here. Another limitation was that ERN/N2 was only measured after the writing intervention. Although the two groups were matched in terms of age, sex, state anxiety, trait worry, and behavioral measures, it is still possible that the observed ERP differences between groups were not a result of the writing intervention. Future studies assessing ERN/N2 before and after the writing intervention will be well suited to increment the current results and more directly suggest a causal role of writing. Third, only one writing session was used, as in previous work (Ramirez & Beilock, 2011). Future studies should implement additional writing sessions to match the most often-used protocol (e.g., 20 minutes of writing for 3-5 times), as is the norm for expressive writing paradigms (Pennebaker, 1997). However, a single session of writing may be sufficient to impact worry's effects on cognition, given that 1) Ramirez and Beilock (2011) found significant exam performance improvements after a single bout of writing, and 2) subtle, short, and theory-driven social-psychological interventions have profound effects on students' academic trajectories (Yeager & Walton, 2011). Therefore, one session might be sufficient to obtain beneficial effects in terms of error-monitoring and conflict-monitoring brain activity. A fourth limitation is that there was no control group of non-anxious individuals, so future studies should assess expressive writing's effects on neurocognitive processes among non-anxious individuals for a contrast.

Finally, future studies examining these effects in a clinical outpatient sample (as opposed to the student sample in the current study) will provide additional insight into the effects in a more severe population.

In conclusion, the current study found that worriers who wrote about their emotions concerning an upcoming computerized task showed more efficient brain activity during that task than those who wrote about time management. Specifically, those in the expressive writing condition demonstrated both reduced error-monitoring (ERN) and conflict control (N2) brain activity, but similar behavioral performance compared to those in the unrelated writing group. These results suggest that writing interventions target key cognitive control mechanisms that serve to detect and adapt to conflicting information and thus alleviate the cognitive burden of worry.

APPENDICES

APPENDIX A

TABLES

Table 1. Essay content results from the Linguistic Inquiry and Word Count.

Measure	Unrelated Writing (n=16)	Expressive Writing (n=18)
Anxiety***	.10 (.18)	1.21 (.96)
Affect***	1.85 (1.17)	6.52 (2.48)
Positive Emotion***	1.43 (.99)	3.85 (1.78)
Negative Emotion***	.42 (.45)	2.47 (1.29)
Cause***	.90 (.67)	2.90 (1.22)
Insight***	.81 (.77)	4.50 (1.99)
Inhibition	.43 (.30)	.26 (.38)

Note. Values are percentage of word category use in entire essay presented as Mean (Standard Deviation).
***p<.001

Table 2. Essay content results from the alternative coding scheme.

Measure	Unrelated Writing (n=16)	Expressive Writing (n=18)
On-task worries†	0.00	7.10 (14.42)
Off-task worries*	1.31 (2.68)	9.68 (15.89)
Performance Monitoring**	0.00	11.32 (10.20)
Bodily Sensations**	1.74 (2.69)	12.19 (12.22)
All Worries**	0.66 (1.34)	8.39 (11.19)

Note: Values are percentage of essays of coded category in the entire essay, presented as Mean (Standard Deviation).†p <.06, *p <.05, **p<.01

Table 3. Mean (Standard Deviation) of self-report measures of anxiety

Measure	Unrelated Writing (n=16)	Expressive Writing (n=18)
Pre STAI-S	31.38 (9.00)	36.11 (12.81)
Post STAI-S	33.19 (12.40)	36.50 (11.25)
PSWQ	66.50 (6.91)	65.22 (8.20)

Note: STAI-S: State-Trait Anxiety Inventory-State Version; PSWQ: Penn State Worry Questionnaire

Table 4. Behavioral measures presented as Mean (Standard Deviation).

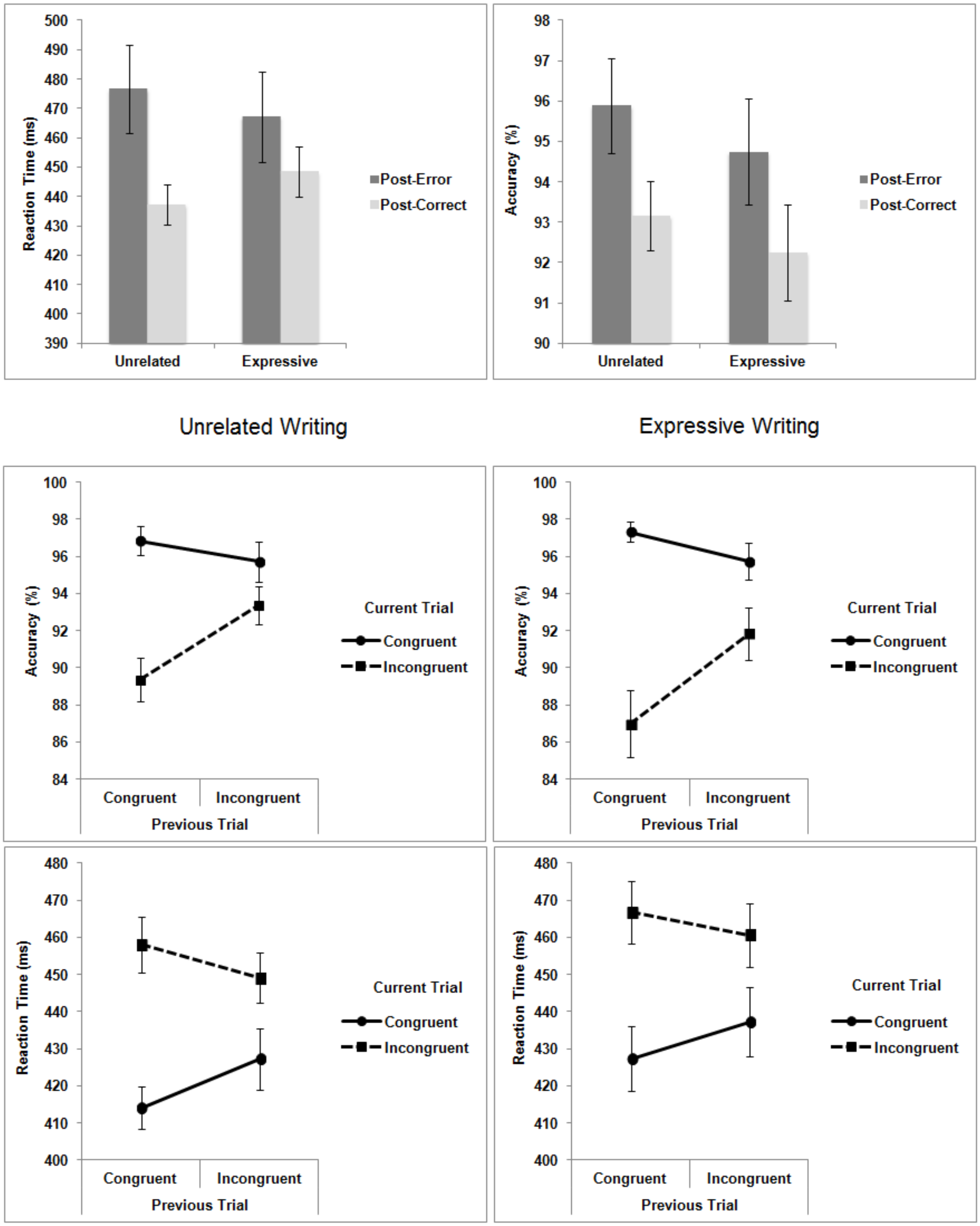
Measure	**Unrelated Writing (n=16)**	**Expressive Writing (n=18)**
Error RT	397.07 (70.79)	411.35 (49.14)
Correct RT	442.54 (28.50)	452.13 (36.23)
Accuracy (% Correct)	93.55 (3.32)	92.51 (4.81)
Congruent RT	426.95 (29.39)	437.56 (37.88)
Incongruent RT	459.24 (29.29)	468.20 (35.03)
Congruency Effect RT	32.29 (14.90)	30.64 (12.83)
Congruent Accuracy	96.16 (3.59)	96.30 (3.26)
Incongruent Accuracy	90.92 (4.03)	88.73 (6.95)
Congruency Effect Accuracy	5.24 (3.79)	7.57 (5.01)

Note: RTs are in milliseconds. All contrasts are non-significant (*p*s > .05).

APPENDIX B

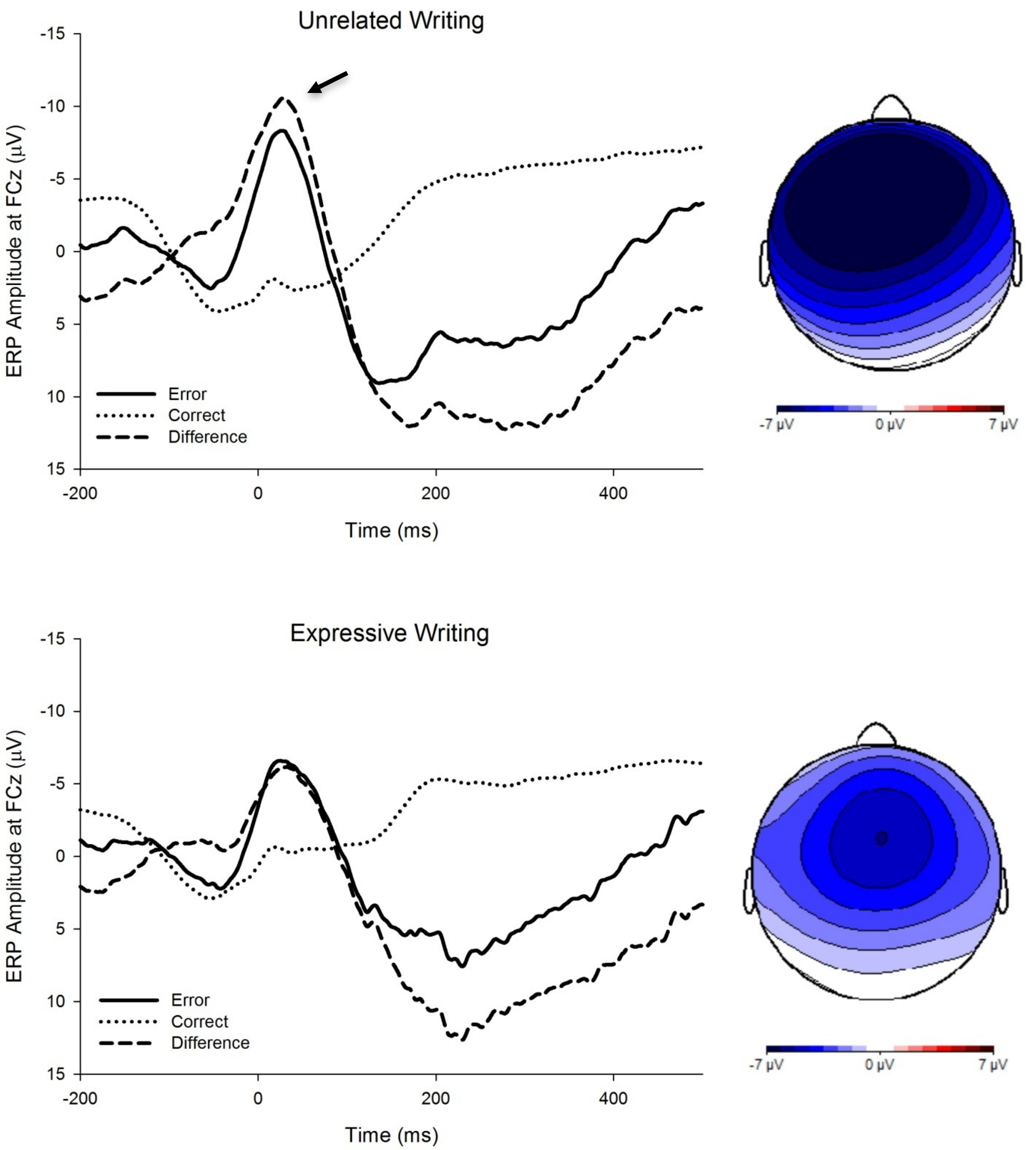
FIGURES

Figure 1. Behavioral data from the flankers task.



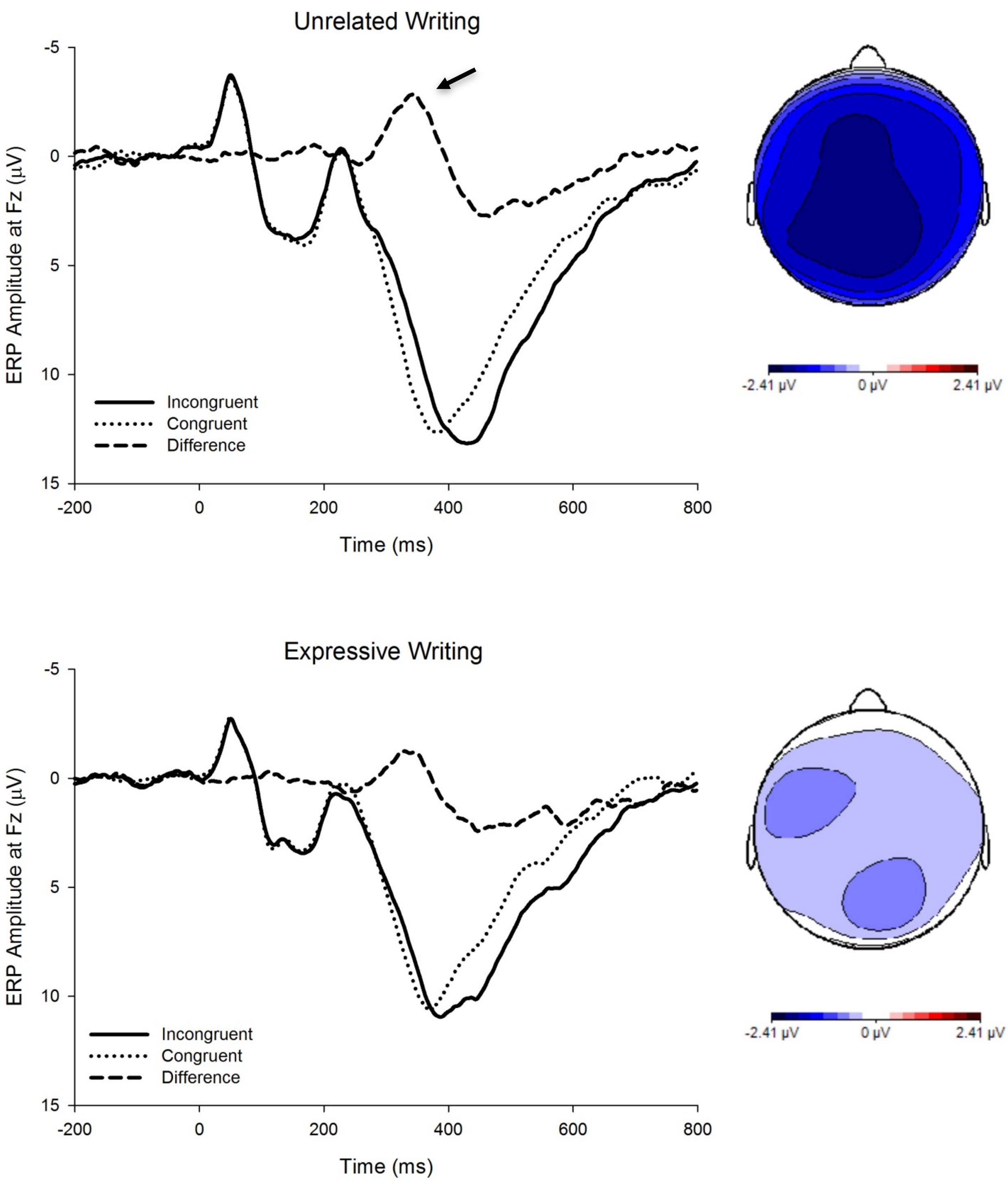
Top: Post-error adjustments for Unrelated and Expressive writing groups. Bottom: Conflict-adaptation effects for the Unrelated (left) and Expressive writing (right) groups. Error bars are ± 1 SEM.

Figure 2. Response-locked ERP data.



Note: Left: Grand average waveforms are depicted for error and correct trials, as well as the error minus correct difference wave. Arrow denotes ERN difference peak. Right: Scalp map topography of the difference waveform in the 0-65ms post-response time window.

Figure 3. Stimulus-locked ERP data.



Note: Left: Grand average waveforms are depicted for incongruent and congruent trials, as well as the incongruent minus congruent difference wave. Arrow denotes N2 difference peak. Right: Scalp map topography of the difference waveform in the 300-400ms post-stimulus time window.

APPENDIX C

SELF-REPORT MEASURES

Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990)

Rate each of the following statements on a scale of 1 ("not at all typical of me") to 5 ("very typical of me"). Please do not leave any items blank.

Not at all typical of me				Very typical of me
1	2	3	4	5

1. If I do not have enough time to do everything, I do not worry about it
2. My worries overwhelm me
3. I do not tend to worry about things.
4. Many situations make me worry.
5. I know I should not worry about things, but I just cannot help it.
6. When I am under pressure I worry a lot.
7. I am always worrying about something.
8. I find it easy to dismiss worrisome thoughts
9. As soon as I finish one task, I start to worry about everything else I have to do.
10. I never worry about anything.
11. When there is nothing more I can do about a concern, I do not worry about it any more.
12. I have been a worrier all my life.
13. I notice that I have been worrying about things.
14. Once I start worrying, I cannot stop.
15. I worry all the time.
16. I worry about projects until they are done.

State Trait Anxiety Inventory (Spielberger, 1983)

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	2	3	4
Not at all	**A little**	**Somewhat**	**Very Much So**

1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I feel tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I feel jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

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