IF AT FIRST YOU DON'T SUCCEED: EXAMINING HOW REFLECTING ON PAST FAILURES AFFECTS ATTENTION, LEARNING, AND MOTIVATION

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A Dissertation submitted to the

Graduate School – Newark

Rutgers, the State University of New Jersey

In partial fulfillment of the requirements

For the degree of Doctor of Philosophy Graduate Program in Psychology

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May 2018

ABSTRACT OF THE DISSERTATION

If at first you don't succeed: Examining how reflecting on past failures affects attention, learning, and motivation

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While positive psychology has suggested that focusing on the positive aspects of past experiences or current situations can result in greater success, some research has suggested that focusing on the negative can be a good thing. Specifically, writing about past traumas or current anxieties has been shown to result in improved performance and overall wellbeing; more recently, reflecting on past failures has been shown to increase self-reported persistence and performance on a task requiring persistence. Yet, it is unknown *why* reflecting on such strong negative experiences results in such positive outcomes, as there has been a lack of empirical evidence for many proposed explanations. Furthermore, it is imperative to examine the neural and physiological mechanisms of how expressive writing may lead to performance improvements in a variety of circumstances—including in the presence of a stressor or other challenging task—in order to shed light on the best way to utilize expressive writing in an educational or treatment setting. In 5 experiments, I examine whether reflecting on a past failure improves performance by altering physiological stress, modifying feedback processing, increasing attention, or affecting motivation, or some combination of these processes. The research aims to reveal more about the mechanisms of how expressive writing—specifically, writing about failures—leads to performance improvements.

Acknowledgments

First and foremost, I would like to thank my advisor Elizabeth Tricomi, who is one incredible, caring, and patient woman. Without her continued support, critical scientific eye, impeccable grammar skills, and humor, this work would not have been possible. I would also like to thank my committee members, Mauricio Delgado, Elizabeth Bonawitz, and Gabriele Otteingen, for their insightful comments, both pertaining to my dissertation and my general life journey. I am forever indebted my fantastic labmates (past and present): Karolina Lempert, Katya Dobryakova Kravtsov, Samantha Depasque Swanson, Holly Sullivan-Toole, Ahmet Ceceli, Christina Bejjani, Dina Mattern, and Chris Cagna; thank you for your endless help regarding my research, as well as putting up with the weird quirks that go along with sharing an office. No amount of words can fully express my gratitude for my family—specifically my parents, for their unwavering love and support. I also find it difficult to believe that I would still be submitting this document if it were not for the 26 years of influence of the late, “OG feminist”, Catherine Hullman.

Lastly, I would like to thank to my partner, Frank, for first coming into my life as a silver lining after a year chock full of my own “difficult times when I did not succeed”, and then remaining as my rock ever since.

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Chapter 1: Examining How Writing About Past Negative Experiences Can Lead to Positive Outcomes

Held on Patriot's Day every year since 1897, the Boston Marathon has become one of the most iconic and ruthless races of all time. Every year, thousands of marathon runners fight to even qualify, and on race day, those quick enough to make the cut run the grueling 26.2 miles from Hopkinton to Boston city center. In 2014, Meb Keflezighi won the 118th Boston Marathon with a time of just over 2 hours and 8 minutes. Keflezighi was the first American to win the Boston Marathon since 1985, and at just shy of 39 years old, the oldest winner in over 85 years (May, 2014). Fascinated by how someone at almost the age of a Masters athlete was able to outrun over a dozen other (mostly much younger) elite athletes, many trainers and running enthusiasts alike have questioned what about Meb's training program led to such a substantial victory.

When asked to reflect on which race he was most proud of, one would think that Meb Keflezighi would immediately cite his indelible 2014 Boston marathon victory, but unexpectedly, he answered with a polar-opposite race result from just 5 months earlier. In November of 2013, Meb ran another famous and competitive long distance race, the New York City Marathon. After a series of injuries, Meb was—at least by his standards—underprepared to compete against the other world class athletes at the starting line that day. After a particularly taxing first 19 miles, Keflezighi fell back, stopping to walk several times, and eventually finished with a time 2:23:47, his slowest on the course to date (Doyle, 2017).

Any competitive runner, elite or casual, fast or slow, knows that the 2012-2013 marathon circuit was a rough year, with both the 2012 NYC marathon cancellation due to Hurricane Sandy and the 2013 Boston Marathon bombings. Keflezighi decided to compete in the 2013 NYC marathon—despite health concerns—due to his desire to show support for his fellow Americans after such national tragedies, making his loss, paradoxically, ever the more tragic. When asked to reflect why then he found his 2013 disheartening failure to be the race he is proudest of, he elaborated, "I've finished plenty of races and immediately thought, *I'm never running in another marathon*. But then, here I am. I think as a runner, you generally feel as good as your last race. The thing is, running a good race feels *so good*, that it more than makes up for the disappointment of running a bad one. I live for that feeling" (emphasis original) (Keflezighi, 2015).

Although Keflezighi cites positive race experiences being his reasoning for his failures seeming not all that bad, perhaps the relationship is bidirectional: maybe experiencing a number of failures is what makes successes all the more enjoyable. Moreover, considering that Meb's 2014 Boston Marathon victory was just a few short months after his tremendous loss in New York, perhaps failures are necessary motivators for achieving many of our successes. Although it takes a unique individual to willingly subject oneself to over 26 miles of hills in April temperatures on the same course a year after a major terrorist attack—not to mention the hundreds of hours spent training to prepare for race day—Meb's experiences, as well as the experiences of many others who have succeeded after a major failure, may give us insight as to how and why people succeed, and how to use failures to improve performance.

A Common Explanation from Positive Psychology

From a scientific point of view, there may be a variety of reasons why an individual succeeds despite adversity. For example, positive psychology has postulated that "staying positive" is beneficial to psychological health, physical well-being, and lifetime achievement (Seligman & Csikszentmihalyi, 2000; Vaillant, 2000). Commonly, one method of suggested coping from positive psychology literature is cognitive reappraisal—that is, asking an individual to focus on how the potentially negative aspects of a situation can be seen in a positive light (Hofmann, Heering, Sawyer, & Asnaani, 2009; Ray, McRae, Ochsner, & Gross, 2010). This proposition from positive psychology has gained popularity in recent years, even spilling over into many mainstream arenas such as education, the workplace, clinical settings, and sports. Moreover, in the laboratory, positively reappraising negative situations has been shown to reduce rumination (Moore, Zoellner, & Mollenholt, 2008) and negative affect (Hofmann et al., 2009; Ray et al., 2010).

However, there is a lack of empirical evidence that cognitive reappraisal and "staying positive" initiatives can lead to improvements in actual performance, either in the lab or in the classroom or on the playing field. Moreover, many of the outcome measures examined within positive psychology interventions utilize non-empirical and/or self-reported measures (Seligman, Steen, Park, & Peterson, 2005; Sin & Lyubomirsky, 2009); positive psychology interventions do not appear to affect more empirical measures of behavior, or cognition, such as physiological or neural markers.

Self-Affirmation Theory

In self-affirmation research, which examines the effect of promoting one's positive individual self-concepts (Steele, 1988), participants are asked to describe why a specific positive personal trait is important to them in a detailed fashion (Cohen, Aronson, & Steele, 2000; Sherman, Nelson, & Steele, 2000). Having individuals "self-affirm" in this manner has been shown to lead to a variety of positive outcomes, such as decreasing an individual's self-defensiveness and increasing the likelihood that they will accept information that has factual support but conflicts with their own opinions (Cohen et al., 2000; Sherman et al., 2000).

Many have also suggested that reaffirming the self before a threat can lead to improvements in performance. For example, stereotype threat literature has suggested that priming individuals about a negative stereotype—e.g., "girls can't do math"—can lead to decrements in performance (Aronson, Quinn, & Spencer, 1998; Spencer, Steele, & Quinn, 1999; Steele & Aronson, 1995). However, asking an individual to self-affirm after experiencing a stereotype threat can result in reduced performance decrements (Martens, Johns, Greenberg, & Schimel, 2006; Schmeichel & Vohs, 2009; Sherman et al., 2013). Yet, although asking an individual to self-affirm improves performance in the presence of a threat, self-affirmation does not improve performance from baseline (i.e., in the presence of no threat). Therefore, individuals hoping to utilize an intervention that improves performance from baseline would not benefit from a self-affirmation intervention.

When Negative Experiences Lead to Positive Outcomes

If there is little to no empirical support for positive reflection or reappraisal leading to performance improvements, why is this something that is still posited by the mainstream? After all, the idea that positive thinking leads to positive outcomes makes logical sense. Moreover, even in my own research, I hypothesized that reflecting on a past success would lead to greater sustained attentional performance. Yet, this was simply not the case: participants randomly assigned to write about a difficult time in which they succeeded did not perform any better than control subjects. Surprisingly though, it was the individuals randomly assigned to reflect on a past *failure* that exhibited significant performance improvements, as well as improved self-reported motivation (DiMenichi & Richmond, 2015).

Time and time again, we often see failure occurring before any major success. Olympic athletes are more likely to break records after a close loss for a gold medal (Lewis, 2015). Abraham Lincoln experienced 8 major political defeats, one failed business, and the death of his first love before being elected President of the United States (Thomas, 2008). Samuel Morse invented the telegraph after a failed painting career (Morse & Morse, 2014), and Isaac Newton became a scholar only after failing as a farmer (Westfall, 1983).

In a laboratory setting, thinking deeply about a past failure may have similar effects on performance. For example, writing "expressively" about a past negative—i.e., writing about an important, emotional event or occurrence in a detailed manner (Lepore & Smyth, 2002; Pennebaker, Kiecolt-Glaser, & Glaser, 1988)—has been shown to lead to a variety of positive outcomes. Psychologically speaking, writing about a past trauma longitudinally can lead to reductions in anxiety and depression (Lepore & Smyth, 2002; Smyth, Hockemeyer, & Tulloch, 2008), as well as improvements in physical health (Harber, Pennebaker, & Christianson, 1992; Pennebaker et al., 1988). Cognitively speaking, writing about anxieties has been shown to increase working memory capacity (Klein & Boals, 2001) and improve test scores, both in the laboratory as well as in the classroom on actual high stakes exams (Ramirez & Beilock, 2011).

***Why* Does Expressive Writing Lead to Psychological, Physical, and Cognitive Benefits?**

The Stress Hypothesis

So, the question one naturally asks is: what is it about writing about negative experiences that leads to such benefits? Information about the mechanism by which expressive writing leads to benefits would be useful to therapists, educators, and coaches hoping to adapt expressive writing interventions for their various disciplines. Although some have posited that writing about a past negative experience can lead to decreases in physiological stress responses, which leads to observed benefits (Pennebaker, 1997; Pennebaker et al., 1988), this assertion has yet to be tested empirically. However, cortisol is a stress hormone that reliably peaks in the saliva approximately 20 minutes after one is exposed to an acute stressor (Dickerson & Kemeny, 2004), and this response can be altered by stress intervention techniques (Gaab et al., 2003). Therefore, examining cortisol after expressive writing and throughout a new task would offer an empirical way to observe if expressive writing really does affect physiological stress levels. Yet, physiological support for the assertion that stress levels mediate the effect of expressive writing has yet to be obtained.

The Working Memory Hypothesis

Others have posited that writing down negative feelings “frees up” attentional load on working memory to better focus on the task at hand (Klein & Boals, 2001; Ramirez & Beilock, 2011). However, there is little to no empirical evidence regarding how expressive writing relates to attentional processing in the brain, as well as other brain networks vital to cognition. For example, if writing about negative experiences like past traumas or current anxieties “frees up” space in working memory, one would expect to see decreased activation in areas of the brain typically correlated with load on working memory after writing and while working on a new task, such as the dorsolateral prefrontal cortex (Rypma, Berger, & D'esposito, 2002). Moreover, if expressive writing affects attentional processing, one might expect to see changes in activation in the dorsal attention network, a network of brain regions that is more active as an individual is more engaged in a task (Spreng, Sepulcre, Turner, Stevens, & Schacter, 2013; Stawarczyk, Majerus, & D'Argembeau, 2011). Yet, no expressive writing intervention initiatives have examined how expressive writing affects working memory and/or attentional processing in the brain, so it remains difficult to draw firm conclusions that changes in working memory load are the mechanism behind expressive writing's success.

Alternatively, writing about a negative event like a past failure might lead to performance improvements via changes to other cognitive processes other than those that primarily deal with attention, such as reward processing. For example, being reminded of a past negative experience may cause an individual to be more sensitive to a new negative experience, such as negative feedback about performance. Therefore, we might expect to see changes in activation in the striatum, an area of the brain primarily concerned with processing positive and negative rewards (Delgado, Locke, Stenger, & Fiez, 2003; Delgado, Nystrom, Fissell, Noll, & Fiez, 2000), as well as feedback learning (DePasque & Tricomi, 2015; Lempert & Tricomi, 2016; Tricomi & Fiez, 2012). Furthermore, writing expressively about negative events or current worries may evoke strong emotions, which may alter neural activation in areas of the brain that typically process strong negative emotion, such as the amygdala (Davis & Whalen, 2001; Hamann, Ely, Hoffman, & Kilts, 2002), or the cingulate cortex (Maddock, Garrett, & Buonocore, 2003; Shackman et al., 2011). Thus, changes in emotional processing may be responsible for the benefits of expressive writing. However, without empirical evidence from the brain, it is difficult to draw conclusions about this proposed mechanism behind the success of expressive writing. Evidence from fMRI may provide crucial evidence about mechanism, which may help therapists, sports psychologists, and educators hoping to utilize expressive writing interventions.

Insights from Longitudinal and Clinical Settings

Although many have suggested that writing itself is crucial to expressive writing's success, longitudinal studies about exposure to adversity suggest that experiencing the failure is what is important to cognition and behavioral. For example, exposure to moderate adversities results in more adaptive cognition (Frankenhuis and de Weerth (2013), more effective coping (Homberg, 2012), and better emotional resilience to a new stressor (Lyons, Parker, Katz, & Schatzberg, 2009). Moreover, athletes are more likely to win major events and break records after a close loss for a gold medal (Lewis, 2015). Therefore, perhaps being exposed to moderate levels of adversity helps better prepare an individual for new challenges.

Although it is difficult to induce a salient adversity experience in the lab, simply thinking critically about a past negative experience may allow an individual to focus on what may have gone wrong, and what changes must be made in order to result in future success. Although writing about a past failure can result in more careful, deliberate choices (DiMenichi & Tricomi, 2016; DiMenichi, Lempert, Bejjani, & Tricomi, 2018), which in turns results in performance improvements, it still remains unknown if writing about a past failure makes an individual more prepared in terms of physiological stress or neural processing.

Furthermore, some studies have utilized relatively enduring, longitudinal research paradigms (Harber et al., 1992; Klein & Boals, 2001; Pennebaker et al., 1988; Smyth et al., 2008), while some have found that the benefits of writing can have immediate effects on cognition (DiMenichi & Richmond, 2015; Ramirez & Beilock, 2011). Moreover, it is unknown if there are particulars about expressive writing itself that make it successful at improving performance, such as if the type of negative experience one writes about matters, or when an individual writes in relation to a new stressor. More information about the particulars of these writing techniques will guide clinical and educational interventions utilizing expressive writing.

Motivation

Although writing about past negative experiences has been shown to increase self-reported persistence (DiMenichi & Richmond, 2015), it remains a mystery whether or not expressive writing affects motivation directly, and which type of motivation may be involved. While extrinsic motivation is that which relates to external rewards, such as money, food, and even positive feedback (Deci, Koestner, & Ryan, 2001), intrinsic motivation relies on an individual’s own desire to complete a task for the sake of task mastery and/or pure enjoyment. Expressive writing about past negative experiences may result in improved performance due to a direct effect on motivation, either to receive positive feedback, or to do well for one’s own benefit.

Current Research Program

Five studies examine the effect of expressive writing—specifically, about a difficult time in which one did not succeed—on physiological stress, neural processing, attention, learning, and motivation. In Chapter 2, we examine if writing about a past failure affects cortisol levels directly, as well as in response to a new stressor. We also test whether expressive writing about past failures affects prolonged attentional performance while under stress, and if writing about a past failure *after* stress exposure has similar affects. In Chapter 3, we examine if writing about a past failure affects attentional, reward, and emotional processing in the brain on a new learning task. Finally, in Chapter 4, we examine how writing about a past failure affects performance on tasks offering extrinsic rewards vs lacking them, as well as intrinsic motivation directly.

Our research program is the first of its kind to examine *why* reflecting on a negative can lead to such positive outcomes. Details about the mechanism behind expressive writing's success may be valuable to individuals hoping to utilize writing interventions in their various disciplines. Broadly speaking, our results may be valuable to educators hoping to implement expressive writing interventions in the classroom to improve learning and attention, to improve motivation, or to reduce test anxiety. Moreover, our results may be valuable to therapists with a desire to utilize writing interventions with patients with trait and/or state anxiety, as well as sports psychologists hoping to train athletes after a major failure.

Chapter 2: Examining how reflecting on past failures buffers the effects of task distraction caused by psychosocial stress

Acute stress can be harmful to performance. In a real world setting, high levels of stress have been known to cause individuals to "choke under pressure," resulting in suboptimal performance (Beilock & Carr, 2005). "Choking under pressure" has been found to occur in both physical settings, such as high-stakes sporting events (Baumeister, 1984), and in classroom settings, such as during important exams (Beilock & Carr, 2005). Acute stress seems particularly detrimental to performance on tasks that require high levels of sustained attention. In the laboratory, acute stress has been shown to lead to higher rates of error on tasks requiring high levels of sustained attention (Qian et al., 2015).

Because acute stress is harmful to performance, there has been a recent interest in developing stress reduction interventions. Expressive writing, particularly about negative events such as current anxieties, has been shown to lead to *improvements* in performance (DiMenichi & Richmond, 2015), even in a high-stress environment (Ramirez & Beilock, 2011). Although this outcome is counterintuitive, it has been proposed that writing about negative life events leads to positive outcomes because it relieves stress that normally occurs as a result of attempting to inhibit thoughts about these negative life events (Pennebaker, 1997). However, the assertion that stress reduction is the mechanism by which expressive writing about negative events leads to positive outcomes has been understudied. Writing about failures has been shown to lead to performance improvements on tasks requiring sustained attention (DiMenichi & Richmond, 2015). However, it remains unknown whether writing about failures improves sustained attention because writing about failures reduces stress, or because it allows an individual to perform better *despite* experiencing physiological stress, perhaps by boosting psychological resources (Hemenover, 2003). If writing about past failures prior to an acute stressor reduces stress, then we would observe a reduction in endocrine response to that acute stressor, along with less of an impairment on performance in a sustained attention task following stress.

Acute stress has been shown to activate the hypothalamic-pituitary-adrenal (HPA) axis, resulting in the release of the hormone cortisol in both animals and humans (Hanson, Larson, & Snowdon, 1976). Furthermore, cortisol reliably peaks in the saliva in humans about 20 minutes after an individual experiences a stressor (Dickerson & Kemeny, 2004; Kirschbaum, Pirke, & Hellhammer, 1993). However, there is evidence that this response can be buffered with proper stress-reduction interventions (Smyth et al., 2008). Thus, measuring cortisol during and after a laboratory stressor may shed light on whether expressive writing about a negative event prior to stress can act as a stress-reduction intervention.

In two studies, we examined whether expressive writing affects performance while under stress. In Study 1, we examined if writing about a past failure reduced one's cortisol response to a new psychosocial stressor. We hypothesized that experiencing a psychosocial stressor would result in an increase in cortisol, but writing about a failure before experiencing the stressor would attenuate this cortisol response. We also examined whether expressive writing about past failures improves performance on a task requiring persistent, sustained attention directly after experiencing psychosocial stress. In Study 2, we examined if writing about a past failure significantly affected heart rate, a measure of the autonomic stress system (as opposed to the adrenal system measured by cortisol). We also tested if writing about a past failure *after* stress exposure also had a significant effect on performance under stress. Across both studies, we predicted that stress would harm performance, and that writing about a past failure would attenuate this effect.

Materials and Method: Study 1

Participants

One hundred and two participants were recruited from the surrounding area of Rutgers University, Newark. Our sample size was based on the performance effect of DiMenichi and Richmond (2015) and the cortisol effect of Kirschbaum et al. (1993). We also ran an additional power analysis based on the averaged effect size from two previous studies that utilized stress interventions ($f^2 = 0.28$) on cortisol after the Trier Social Stress Test (Gaab et al., 2003; Hammerfald et al., 2006). With stress group, writing group, and gender as factors, as well as an error probability of 0.05, this analysis suggests a total sample size of 86 participants. We are therefore confident that our sample size meets adequate power requirements.

The study was approved by the Institutional Review Board at Rutgers University. Participants (mean age=24.09, SD=7.36; 54% female; 21% white/Caucasian, 25% black/African American, 34% Asian, 1% Native American, 12% “other”) were paid $15 for 1.5 hours of participation. All participants completed the study between 1 p.m. and 5 p.m., in order to control for circadian fluctuations of cortisol (Dickerson & Kemeny, 2004). Subjects were naive to the purpose of why the saliva samples were being collected. Our saliva testing lab alerted us that two participants produced saliva samples that were contaminated (presumably from food content in the saliva); therefore, their data were not analyzed. Two additional participants’ data were removed from analyses after participants failed to follow instructions (i.e., did not write about their assigned writing prompt).

Task

Procedure timeline

Six cortisol samples were obtained throughout the experiment using salivary cheek swabs. After arriving at the laboratory and following giving written consent, participants provided the first salivary cortisol sample (T0), which served as a baseline measurement. Participants were then pseudo-randomly assigned to complete the "failure" or "control" writing manipulation (see below for a detailed description of the writing manipulation). After completing the 10-minute writing manipulation, a second salivary cortisol sample was obtained (T1; 15 minutes elapsed since T0; 20-25 minutes since arrival). Participants were then pseudo-randomly assigned to complete the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) or a control task. After completing the TSST or control task, a third saliva sample was taken (T2; 35 minutes elapsed since T0). Participants then completed the sustained attention to response task (SART; DiMenichi & Richmond, 2015; McVay & Kane, 2009) immediately after completing the TSST to examine the effect of psychosocial stress on attentional performance. Halfway through the SART, a fourth saliva sample was obtained (T3; 55 minutes elapsed since T0). Finally, the fifth saliva sample was collected at the conclusion of the SART (T4; 70 minutes elapsed) and the sixth was collected at the conclusion of the survey battery (T5; 85 minutes elapsed). See Figure 1 for experimental groups and cortisol timeline.

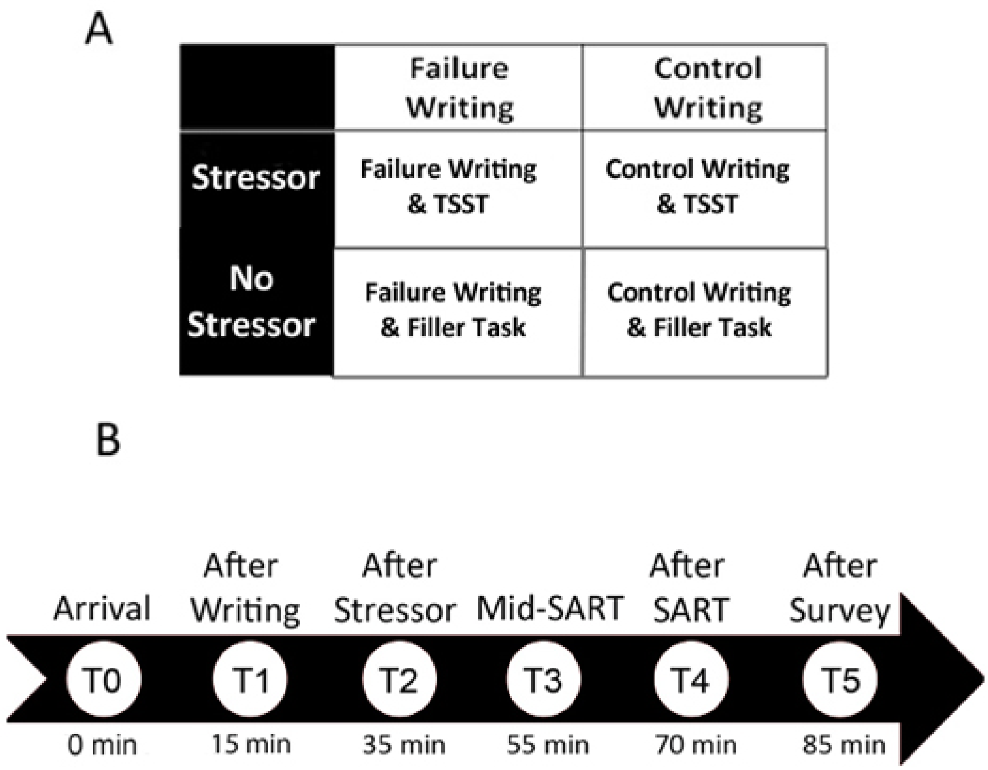

Figure 1. Study 1 Experimental Method. (a) Participants were assigned to one of four conditions in which they wrote about a failure or a control topic, and then experienced a stressor or control activity. (b) Six salivary cortisol samples were obtained throughout the experiment. Because previous research has found that cortisol peaks about 20 minutes after a stressor is experienced, all samples represent peak cortisol as a result of the previous event.

Cortisol Collection and Assay Procedures

Participants were asked to refrain from eating or drinking anything (besides water) at least 1 hour prior to participating in the study. Salivary cortisol samples were collected using Salimetrics Oral Swabs. Participants were asked to hold swabs in their cheek for approximately two minutes and to saturate each swab as much as possible with saliva. After this time elapsed, participants were asked to spit the swab into a Salivette vial. Vials were stored in a freezer at -20 degrees Celsius before being shipped on dry ice to Salimetrics LLC (Carlsbad, CA, USA), where each sample was assayed twice. The intra-assay variability was 4.66% and the inter-assay variability was 4.47%.

Writing Manipulation

Participants completed a writing manipulation adapted from DiMenichi and Richmond (2015). In the "failure" condition, participants saw a prompt on a computer screen that asked them to spend the next 10 minutes writing about a difficult time in which they did not succeed. They typed their response on the computer. Participants assigned to the "control" condition were prompted to write about the plot of a movie they had recently viewed. In order to control for the effect of mood, a follow-up study verified that asking participants to write about a sad movie did not have an effect on attentional performance, suggesting that mood alone is not likely to be the mechanism by which failure writing improves performance on the SART (see Appendix; Chapter 1).

Since previous research has found that individual differences within each writing sample (e.g., emotional intensity) can lead to individual differences in outcomes (Harber et al., 1992), two research assistants blind to cortisol and behavioral results read each participant's writing sample and coded the writing sample for the following five elements: valence (overall positive and negative tone of writing), emotional arousal (i.e., a rating pertaining to how emotional the sample was), compliance with the prompt, relation to oneself, and relation to persistence). Each category was rated with a single score from 1-5.

Trier Social Stress Test (TSST)

Immediately after completing the writing manipulation, participants assigned to the stress condition completed the Trier Social Stress Test (TSST) (Kirschbaum et al., 1993). The TSST proceeded as follows: the experimenter asked participants about their current career or major, and probed them about their “dream job.” Then, participants were told they would have 6 minutes to prepare a 5-minute speech about why they possess the qualities for their “dream job.” They were also told that they would have to give their 5-minute speech in a job-interview format to a “speech expert” while being videotaped and behaviorally analyzed (the “speech expert” was actually a research assistant from the lab). While the participant gave his or her speech, the confederate responded in a cold and unsympathetic manner. If participants did not take the entire 5 minutes to complete the speech, the speech expert alerted them of the time remaining, and asked them to continue. After 5 minutes, the speech expert asked the participant to count backwards from 2063 by 13. If the participant made a mistake, he or she was asked to start over from 2063. After 5 minutes, the speech expert asked the participant to stop.

Participants assigned to the control task were probed about their career goals, and then were asked to complete an innocuous personality survey tapping the five OCEAN personality traits for 16 minutes while alone in a testing room.

Sustained Attention to Response Task (SART)

Immediately following the conclusion of the psychosocial stress manipulation or control task, all participants completed a sustained attention to response task (SART; DiMenichi & Richmond, 2015; McVay & Kane, 2009). In this simple “go/no-go” task, participants were told to press the space bar as soon as a letter appeared on the screen, unless that letter was a vowel. Participants were given 2 sec to respond to each trial, and the entire SART lasted about 30 minutes in order to require persistent attention to complete. There were 600 trials, and 20% of trials were vowels (all letters were included except Y).

Survey Battery

After completing the SART, participants provided information about demographics and daily habits, including smoking habits, contraceptive use, and information about menstrual cycles, since these factors may affect cortisol levels. Furthermore, we distributed a survey battery so that we could explore whether individual differences in cortisol response or SART performance were related to personality traits. The battery included the General Causality Orientations Scale, which assesses intrinsic vs. extrinsic motivations, as well as how much an individual believes circumstances are mostly a matter of luck (Deci & Ryan, 1985); the Connor-Davidson Resilience Scale, which measures individual differences in trait resiliency (Connor & Davidson, 2003); and the Achievement Goal Questionnaire, which examines preference for wanting to achieve goals in order to master a new skill, perform well, or avoid failure (Elliot & Church, 1997). Surveys that examined emotional tendencies included the Beck Depression Inventory-II (Beck, Steer, & Carbin, 1988), and the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983), which assesses the extent to which stressors have felt uncontrollable in the last month. The Marlow-Crown Social Desirability Scale was also included to measure any bias in responding on the survey battery (Crowne & Marlowe, 1960). Surveys were completed on a computer via the website Qualtrics (Provo, Utah) and presentation order was randomized by the computer to prevent order effects.

Analyses

Cortisol

Preprocessing

Before conducting cortisol analyses, in order to fulfill the requirement for homoscedasticity required for most statistical tests, we examined the skewness of the cortisol measure at each of our 6 timepoints. Across all subjects, every timepoint had a positive skew, averaging 2.01 across all 6 timepoints. Therefore, we performed a power transformation to normalize our cortisol data. Based on a review by Miller and Plessow (2013) that examined the most effective transformations for cortisol time course data, we selected the power transformation $x' = (x^{0.26} - 1)/0.26$. After transformation, the skew of all timepoints averaged 0.04. Since there are individual differences in baseline cortisol values, we subtracted each transformed T0 value from the remaining 5 transformed cortisol timepoints (Mehta & Josephs, 2006). All following analyses use these transformed and baseline-adjusted values.

Preliminary Manipulation Checks

We conducted several preliminary analyses to ensure that our findings were not a result of extraneous variables. First, we conducted a two-way ANOVA examining main effects and an interaction effect of stress group and writing group on the T0 cortisol measurements to ensure that there were no significant differences in baseline cortisol between groups.

We conducted a one-way ANOVA that examined the effect of writing group on cortisol levels at time point T2 (i.e., peak cortisol response since the writing exercise) to examine whether individuals who wrote about a failure showed an increase in cortisol in comparison to individuals who wrote about a control topic. In other words, we sought to ensure that the failure writing exercise did not itself act as an acute stressor.

Since previous studies have shown that gender can influence cortisol levels (Kirschbaum et al., 1995), we also conducted a three-way ANOVA that examined the effect of gender, stress, and writing group on cortisol levels using an area under the curve with respect to increase (AUCi) analysis (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). We utilized the trapezoidal method, with T0 as our baseline value and points T1 – T5 as points in the analysis. Furthermore, since oral contraceptive use has been shown to affect cortisol responsivity (Kirschbaum et al., 1995), among our female participants, we conducted a one-way ANOVA that examined the effect of oral contraceptives on AUCi for female participants. We also tested if smoking habits affected peak cortisol levels by examining whether the number of cigarettes smoked per week significantly correlated with AUCi levels.

Main analysis

We conducted a two-way ANOVA examining the effect of writing group and stress group on the AUCi of participants' cortisol responses. Since we hypothesized that writing about a past failure would attenuate the release of cortisol, we expected to find a significant interaction of stress group and writing group on AUCi levels.

Behavior

To examine whether reflecting on failures improved performance on the SART after a stressor, we conducted a two-way MANOVA examining the effects of stress group and writing group on errors of commission on the SART (i.e., pressing when the correct answer should be to omit a response), errors of omission on the SART (i.e., failing to press when the correct answer should be to respond), and reaction time on the

SART. To examine whether individual differences in cortisol response predicted performance effects, we added AUCi cortisol values as a continuous predictor.

Writing sample content and survey battery

To explore how individual differences related to cortisol response or SART performance, we conducted correlations examining the relationships between 1) baseline cortisol, 2) AUCi of participants' cortisol levels, 3) SART errors 4) SART reaction time, 5) scores from all questionnaires in the survey battery, and 6) writing sample ratings.

Results: Study 1

Cortisol results

Results of Manipulation Check Analyses

We conducted several analyses to ensure that our main results were not caused by extraneous variables. To ensure that groups did not differ with respect to cortisol at baseline, we conducted a two-way ANOVA examining the effects of stress group and writing group on baseline cortisol. This analysis did not yield significant main effects (stress: $F(1, 95) < 0.01$, $p = 0.962$, $\eta_p^2 < 0.01$; writing: $F(1, 95) = 0.38$, $p = 0.540$, $\eta_p^2 < 0.01$) or an interaction effect, $F(1, 95) = 1.95$, $p = 0.166$; $\eta_p^2 = 0.02$. Moreover, the ANOVA that tested whether the two writing groups differed in cortisol level after the writing manipulation did not yield significance, $F(1, 95) = 0.16$, $p = 0.686$, $\eta_p^2 < 0.01$, suggesting that writing about past failures itself did not cause a differential increase in cortisol.

Groups also did not differ significantly from each other in gender, $\chi^2 = 0.83$, $p = 0.843$, $W = 0.18$, or age, $F(1, 95) = 1.68$, $p = 0.199$, $\eta_p^2 = 0.02$. See Appendix for a table illustrating the number of female and male participants in each group. Although we found a significant effect of gender on AUCi values of cortisol, $F(1, 95) = 6.32$, $p = 0.014$, $\eta_p^2 = 0.07$, we did not find a significant interaction of stress group and gender on AUCi values, $F(1, 95) = 0.04$, $p = 0.843$, $\eta_p^2 < 0.01$, nor did we find a significant interaction of writing x gender, $F(1, 95) = 0.20$, $p = 0.656$, $\eta_p^2 < 0.01$. Our results suggest that although males in our sample tended to have higher cortisol levels than the females in our sample, these results were not a result of our stress and/or writing manipulations.

When examining changes in cortisol within our female participants, we did not find a significant effect of oral contraceptives on AUCi values of cortisol, $t(53) = -0.73$, $p = 0.467$, $d = 0.46$. However, only 4 of the 55 women in our sample reported taking oral contraceptives, and all 4 of these women were in the non-stress condition (3 failure writing and 1 control writing). Removing these women from our data analysis led to qualitatively similar results. Moreover, the number of participants in each week of menstrual cycle did not differ across condition, $\chi^2 = 9.54$, $p = 0.656$, $W = 0.02$, nor did day in menstrual cycle significantly correlate with AUCi values across all female participants, $R = 0.05$, $p = 0.745$, or within female stress subjects, $R = 0.15$, $p = 0.462$. See Appendix for table detailing number of participants in each week of menstrual cycle across conditions.

Groups did not differ from each other in terms of proportion of smokers (failure writing and TSST, n = 2; control writing and TSST, n = 1; failure writing and filler task, n = 1; control writing and filler task, n = 1) and nonsmokers (failure writing and TSST, n = 22; control writing and TSST, n = 24; failure writing and filler task, n = 23; control writing and filler task, n = 24), $\chi^2 = 0.17$, $p = 0.876$, $W = 0.08$. Furthermore, we did not find a significant correlation between number of cigarettes smoked per week and AUCi levels of cortisol, within the stress participants, $r = -0.231$, $p = 0.113$. We found a marginally significant negative correlation between number of cigarettes smoked per week and AUCi levels across all participants, $r = -0.18$, $p = 0.083$.

Writing about failures buffers physiological stress responses to the TSST

When examining the effect of stress group and writing group on AUCi values of cortisol, we did not find a significant main effect of stress on AUCi, $F(1, 95) = 2.16$, $p = 0.145$, $\eta_p^2 = 0.02$. Moreover, we did not find a significant effect of writing on AUCi values, ($F(1, 95) = 0.01$, $p = 0.923$, $\eta_p^2 < 0.01$. In line with our hypothesis, we found a significant interaction effect of stress group x writing group, $F(1, 95) = 4.61$, $p = 0.034$, $\eta_p^2 = 0.05$. These results suggest that those who wrote about a past failure before undergoing the TSST exhibited significantly reduced cortisol levels.

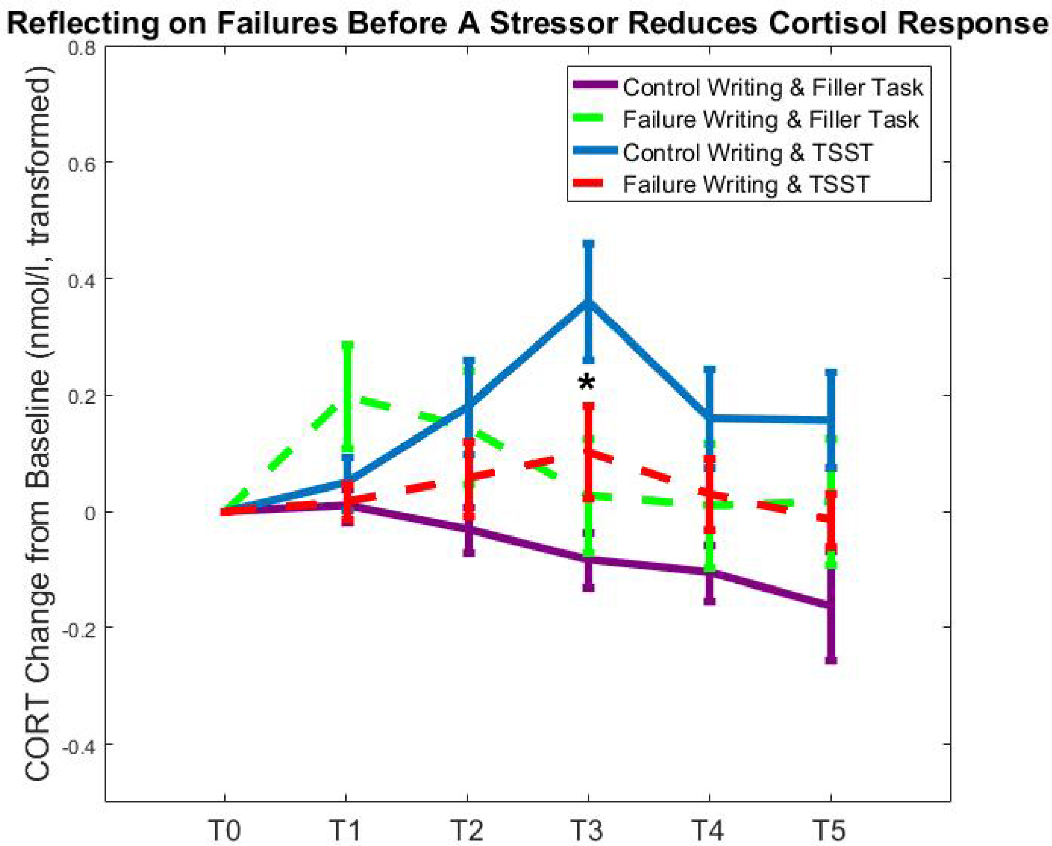

Figure 2. Study 1 Results. T0 = baseline; T1 = finish writing, 15 minutes since baseline; T2 = 10 minutes since stressor onset, 35 minutes since baseline, expected peak cortisol after writing; T3 = 30 minutes since stressor onset, 55 minutes since baseline, expected peak cortisol after stressor; T4 = 45 minutes since stressor onset, 70 minutes since baseline; T5 = 60 minutes since stressor onset, 85 minutes since baseline. Participants who were subjected to the psychosocial stressor exhibited cortisol increases from baseline (blue line), especially at peak cortisol since stressor conclusion (T3); however, participants who reflected on failures before experiencing the psychosocial stressor exhibited a reduced cortisol response (red line). Participants did not exhibit significant differences at peak cortisol since completing our writing manipulation (T2). Cortisol values represent transformed and baseline-adjusted values (see Method for details).

We also conducted several least-squared differences post-hoc analyses that examined group differences in AUCi values of cortisol. Specifically, in the control writing groups, the stress manipulation significantly increased cortisol (mean AUCi difference = 19.01, p = 0.011). However, this was not the case among participants who wrote about a past failure (mean AUCi difference = 3.56, p = 0.636). Thus, our findings suggest that writing about a past failure before undergoing acute stress significantly attenuated the cortisol response to a psychosocial stressor (Figure 2). See Appendix for complete results of the two-way ANOVA.

Behavioral results

Writing about a failure before stress buffers against stress's effect on performance

We examined the effect of writing group and stress group on errors of commission, errors of omission, and reaction time in the SART task. We found a significant main effect of writing group on reaction time, $F(1, 96) = 4.89$, $p = 0.029$, $\eta_p^2 = 0.05$, whereby writing about failures (regardless of whether the participant experienced a stressor) resulted in significantly slower reaction times on the SART (M = 637.83 ms, SD = 104.69 ms) compared to those who did not write about a past failure (M = 591.03 ms, SD = 104.79 ms). We also found a significant interaction of stress group and writing group on errors of commission on the task, $F(1, 96) = 4.55$, $p = 0.036$, $\eta_p^2 = 0.05$; participants who wrote about past failures before experiencing a stressor made significantly fewer errors of commission (M = 7.75, SD = 7.99) than those who did not write about a past failure before experiencing a stressor (M = 13.58, SD = 7.99). Our results suggest that writing about a past failure resulted in slower reaction times on the SART. Furthermore, writing about a past failure before stress resulted in improved performance. This is consistent with a previously documented speed-accuracy tradeoff in this task (DiMenichi & Richmond, 2015); indeed, here we also found a significant negative correlation between RT and error rates on the SART, $r = -0.215$, $p = 0.034$. See Appendix for full MANOVA results.

We also conducted the same MANOVA described above, and added AUCi as a continuous variable. While previously significant predictors remain unchanged, AUCi did not significantly predict any aspect of SART performance.

Individual differences in writing sample content and survey battery

We did not find any significant relationships across conditions regarding our individual differences measures (both survey and writing content ratings) and our physiological and behavioral results. See Appendix for a correlation table of our survey battery results.

Study 2: Examining When Expressive Writing is Valuable in Relation to Psychosocial Stress

In Study 1, we found that writing about a past failure significantly improved performance in the presence of a psychosocial stressor. However, it remains unknown whether writing about negative experiences only buffers against future stressors, or if it can also be used as an emotion regulation technique to decrease stress levels after an acute stressor. Although self-affirmations about personal values after experiencing chronic stress have led to performance improvements (Creswell, Dutcher, Klein, Harris, & Levine, 2013), there is no clear evidence whether self-affirmation is an effective emotional after an individual experiences acute stress. Empirical evidence about *when* writing about a past failure in relation to experiencing a psychosocial stressor results in performance improvements would be helpful to clinicians, educators, and even sports psychologists helping to improve performance after a stressor has already occurred.

In this study, we implemented methods similar to those utilized in Study 1: participants were randomly assigned to write about a past failure or trivial topic, complete a psychosocial stressor, and then complete a sustained attention task while under the effects of psychosocial stress. However, in this study, we varied when participants completed expressive writing in relation to experiencing a psychosocial stressor: while some participants were assigned to write about a past failure before experiencing a psychosocial stressor, some participants completed expressive writing after the psychosocial stressor. We examined whether writing about a past failure after a psychosocial stressor still led to performance improvements, and how heart rate—a common measure of physiological stress levels (Bakker, Pechenizkiy, & Sidorova, 2011)—related to performance differences. Alternatively, writing about a past failure after being exposed to a stressor could potentially *increase* stress levels by compounding two relatively stressful experiences, leading to decrements in performance.

Method: Study 2

Participants

One hundred, twenty-one participants were recruited from Rutgers University, Newark. Total study duration was approximately 1.5 hours, and participants received 1.5 course credit hours for participating in the study. Twelve participants were removed from analyses because of missed recordings on our heart rate device. Furthermore, five participants were removed from our analyses for declining to complete the Trier, leaving us with a final sample size of 104 subjects (71 female, mean age = 20.40, SD = 6.03). After giving informed written consent, participants were pseudo-randomly assigned a writing topic, and a task order. Participants were either randomly assigned to write about a difficult time in which they did not succeed, or a control topic (i.e., the plot of a recently viewed movie), and were also randomly assigned to either complete the writing task before (order 1) or after (order 2) the Trier Social Stress Task (see Chapter 2 for task description). All participants then completed the SART described in Chapter 2, and finally, demographic information and a survey battery. Our survey battery contained the CD-RISC, AGI, PSS and SDS discussed in Chapter 1. We also included the as well as the Need For Cognition Scale (NFC), which measures the tendency for an individual to prefer to engage in thinking (Olson, Camp, & Fuller, 1984), and the Cognitive Inference Questionnaire (CIQ), which asks participants to indicate how often they had thoughts that could have interfered with performance—e.g., worries about task performance, thoughts about things other than the task, etc. (Sarason, Sarason, Keefe, Hayes, & Shearin, 1986). Surveys were randomized to prevent order effects.

Lastly, we probed participants about general mood throughout the task. Specifically, we asked participants to rate how much they enjoyed and cared about doing well on the word learning task, if they preferred negative to no feedback on the task, and to rate their level of stress upon arrival, during the writing task, while completing the writing task, and while completing the survey. We also asked participants how stressful they felt when the original event they wrote about occurred (either their past failure or movie). After debriefing, all participants were probed to ensure that they believed the TSST. None of the participants reported not believing the manipulation.

Order 1 of the task allowed us to replicate our previous finding that writing about a past failure before a stressor significantly improves performance on an attention task (i.e., the results of Study 1), as well as examine how heart rate measures while under stress relate to our cortisol findings from Study 1. Furthermore, adding order 2 of the task allowed us to examine whether writing about a past failure immediately *after* a stressor also leads to the same performance benefits as writing about a failure before a stressor. There was the same number of participants across all four separate conditions (n = 26). See Figure 3 for an illustration of condition assignments.

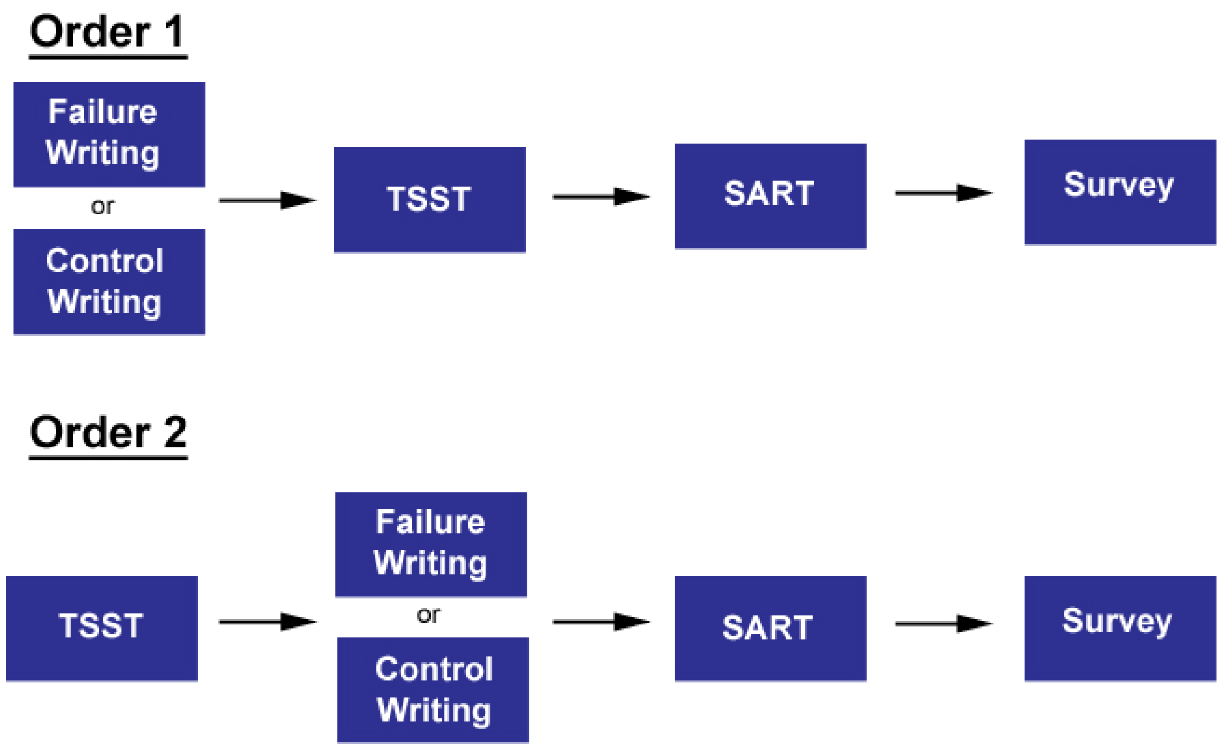

Figure 3. Study 2 Condition assignments. In order 1 of the experiment (top), participants were randomly assigned to write about a past failure or trivial topic, then complete a psychosocial stressor (TSST), followed by the sustained attention to response task (SART). In order 2 of the experiment, participants completed the TSST first, and then completed their assigned writing prompt after the TSST.

Heart Rate

Because stress tends to increase heart rate (Niizeki & Saitoh, 2012), we measured changes in heart rate throughout the task. After informed written consent, we placed a Fitbit (*Charge* model) on each participant's wrist. Heart rate was measured in 5-minute average increments from after written consent until completion of debriefing. By including heart rate in our study, we were able to examine if writing about a past failure affected responses of the autonomic nervous system (Niizeki & Saitoh, 2012), in addition to the HPA/endocrine responses already observed in Study 1. We also included heart rate in our study as a manipulation check—i.e., to ensure that the TSST actually stressed participants—and to see whether there were any condition differences in heart rate due to our writing intervention.

Analyses

Behavioral

To examine whether writing about failures before a stressor improved performance on a subsequent sustained attention task, we conducted an independent samples t-test that examined significant differences on errors of commission on the SART on order 1 participants. Furthermore, to examine whether writing about failures after a stressor improved performance, we conducted the same t-test on order 2 participants. We did not conduct a one-way ANOVA examining the effect of condition on errors of commission across all participants because our heart rate data suggests that participants who completed the SART directly after the stressor may have had higher stress levels during the SART than those who were assigned to write in between the stressor and the SART, making it difficult to parse apart the effects of the timing of the stressor and our writing manipulation on performance.

Heart Rate

We conducted independent samples t-tests that examined significant differences in heart rate at every 5-minute averaged time bin across writing conditions for order 1 participants. We also conducted these same analyses for order 2 participants. Furthermore, we conducted these same analyses again after subtracting heart rate measurements from a baseline heart rate taken 10 minutes after arrival at the lab. We subtracted this value because it represented heartrate baseline but accounted for any increases in heart rate that could have occurred from activity prior to the experiment (Luft, Takase, & Darby, 2009). Lastly, we examined whether heart rate changes were significantly correlated with errors on the task and/or any of our survey measures.

Results and Discussion: Study 3

We found that participants who wrote about a past failure before experiencing a psychosocial stressor exhibited significantly fewer errors of commission on the SART (M = 11.12, SD = 8.39) than participants who wrote about a trivial topic before being exposed to a psychosocial stressor (M = 19.54, SD = 17.13; $t(50) = -2.25$, $p = 0.029$), replicating our findings from Study 1. Importantly, similar to order 1, among order 2 participants, individuals who wrote about a past failure after the TSST exhibited significantly fewer errors on the SART (M = 10.73, SD =8.73) than participants who wrote about a trivial topic before the TSST (M = 16.96, SD = 13.07; $t(50) = -2.02$, $p = 0.049$). Moreover, there was no significant difference in errors between participants who wrote about a past failure before the TSST and participants who wrote about a past failure after the TSST ($t(50)$, = 0.16, $p = 0.872$). See Figure 4 for behavioral results. Our findings further support the assertion that writing about a past failure leads to performance improvements in the presence of psychosocial stressor, and suggest that the effect of writing on performance in the presence of stress may occur regardless if the writing occurs before or after the stressor.

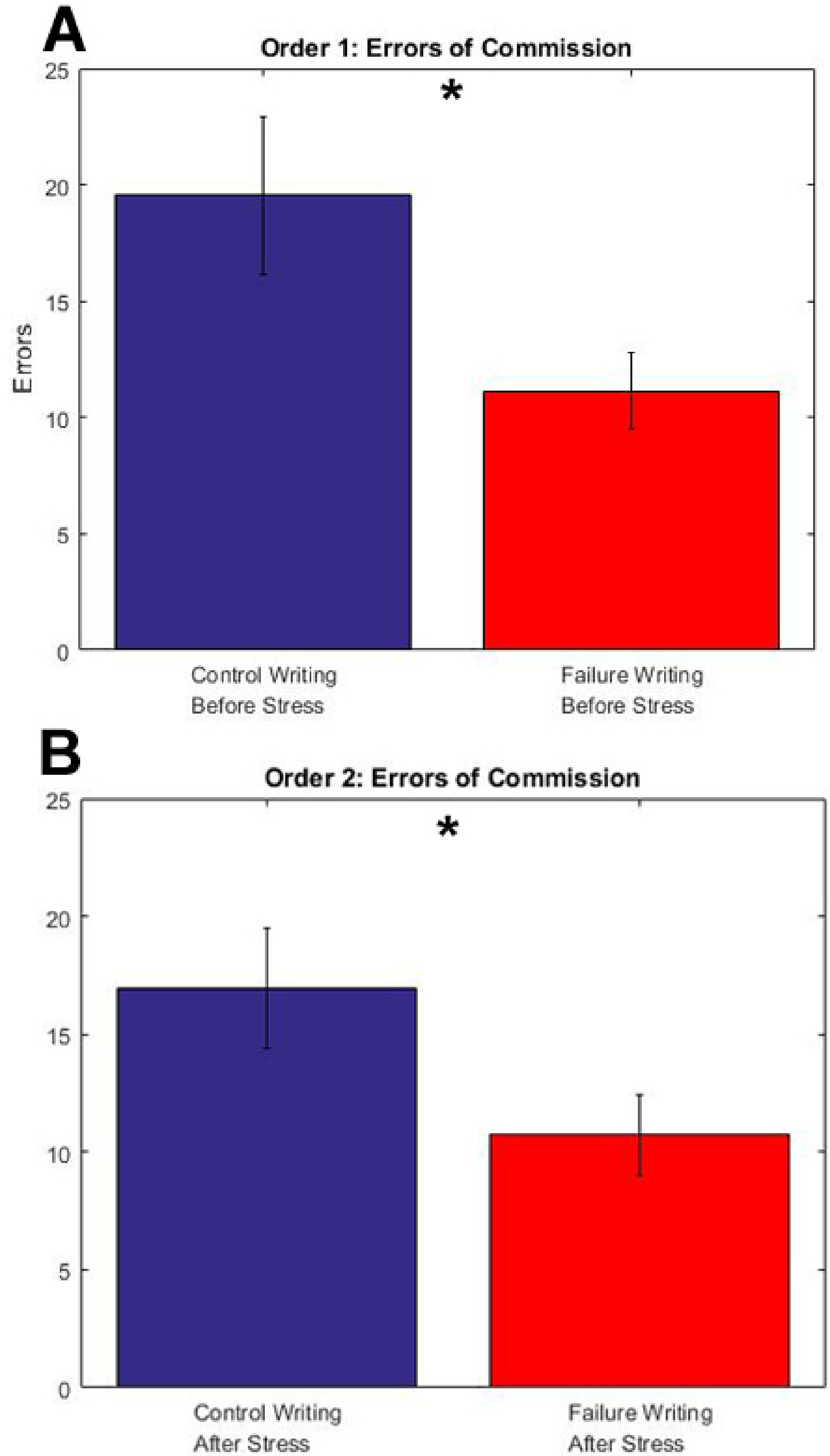

Figure 4. Study 2 Behavioral results. Writing about a past failure led to decreased errors on the SART while under psychosocial stress, regardless if participants wrote before (a) or after (b) initially being exposed to the psychosocial stressor.

*$p < 0.05$

Although exposure to psychosocial stress increased heart rate from baseline in all of our participants (order 1: $t(51) = 4.24$, $p < 0.001$; order 2: $t(50) = 5.29$, $p < 0.001$), we did not find a significant effect of writing group on any of our heart rate measures in order 1 nor in order 2 participants. Although writing about a past failure increased heartrate from baseline slightly less than writing about a trivial topic, we did not find a significant effect of writing group on increases in heart rate from baseline at any timepoint across writing group in either order, except in order 1 at the timepoint of the conclusion of the study: participants who wrote about a past failure exhibited significantly lower heart rate changes at the conclusion of the study than participants in the control condition ($t(50) = -2.30$, $p = 0.026$). Figure 5 illustrates changes in heartrate from baseline over the course of the experiment.

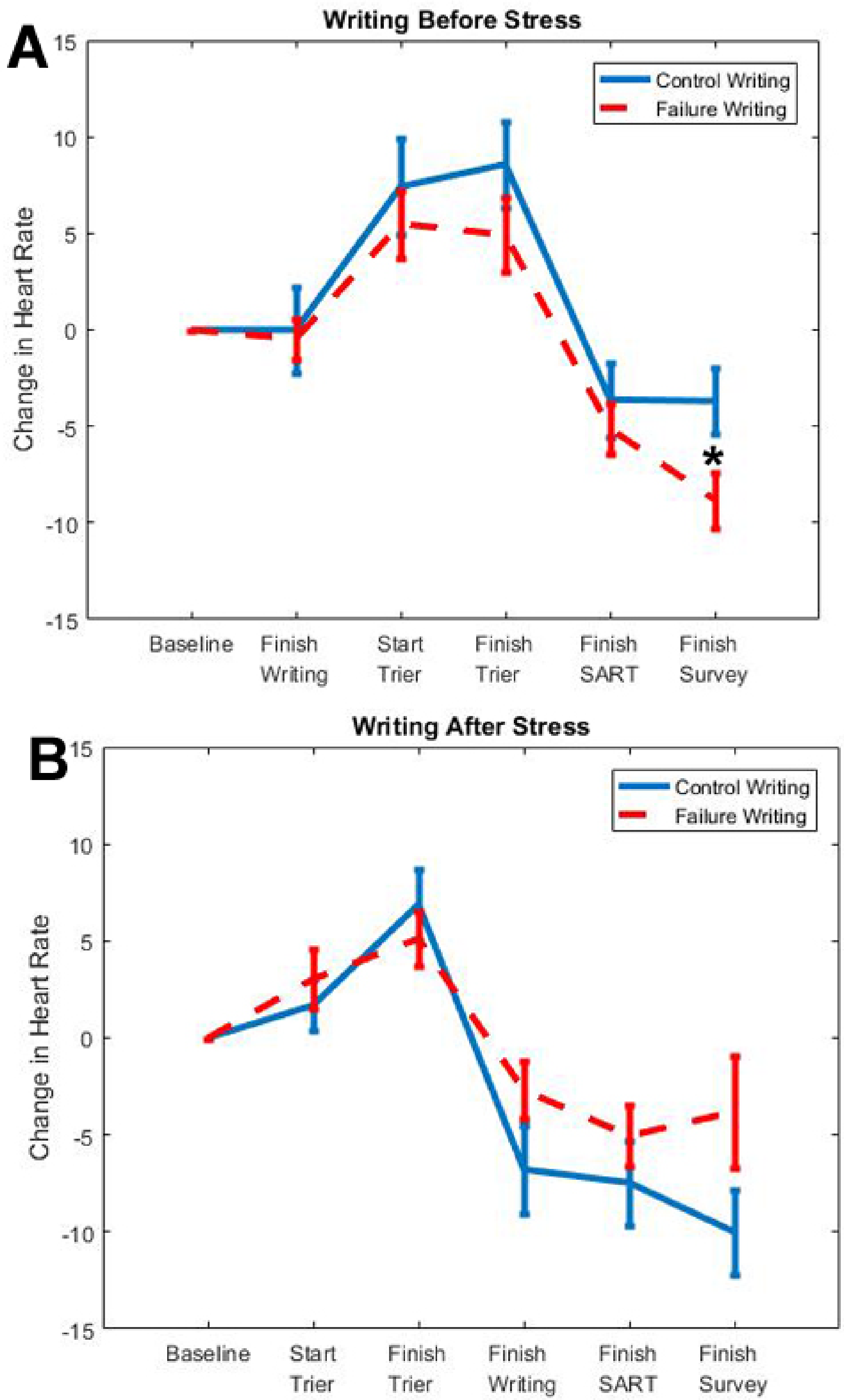

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Figure 5. Study 2 Changes in Heart Rate from Baseline. As expected, the TSST significantly increased heartrate from baseline. However, we did not see any significant differences across writing group in heart rate changes in order 1 (a) or order (2) of the task, with the exception being heart rate increases at the conclusion of the study for order 1 participants.

$p < 0.05$

This lack of significant finding of heart rate differences *during* the SART seemed surprising given that writing group had a significant effect on cortisol changes in Chapter 2. However, although the TSST has been shown to reliability increase both cortisol and heart rate (Kirschbaum et al., 1993), some stress studies have observed statistically significant differences in cortisol but not heart rate (MacMillan et al., 2009). Moreover, no heart rate measure was significantly correlated with errors of commission on the SART. Given that heart rate demonstrates changes in the autonomic nervous system (Luft et al., 2009), while changes in cortisol represent changes to the hypothalamic-pituitary-adrenal axis (Hennessy & Levine, 1979), perhaps writing about a past failure reduces the body's more cascaded responses to stress (as opposed to immediate), and this reduction results in performance improvements on a task that requires enduring sustained attention.

In an exploratory analysis examining behavior and scores on our survey battery, we found that, for order 1 participants, scores on the Cognitive Interference Questionnaire (CIQ) significantly correlated with increases in heart rate at the conclusion of the Trier ($r = 0.52$, $p = 0.007$) and conclusion of the SART ($r = 0.39$, $p = 0.048$). We did not find this significant relationship for order 2 participants ($r < 0.01$, $p = 0.992$; $r = 0.24$, $p = 0.249$). However, there was no significant relationship between scores on the CIQ and errors of commission for order 1 participants ($r = -0.20$, $p = 0.155$).

Broadly speaking, our results from Study 2 suggest that writing about a past failure may improve performance in the presence of a psychosocial stress. Moreover, one may be able to reflect on a failure before or after a stressor to exhibit these attentional performance improvements. Although we did not see a significant effect of writing on heart rate during the SART on either of our task orders, future research should be conducted that includes measures of cortisol (similar to those implemented in Chapter 2) to examine how writing about a past failure after psychosocial stress affects the body's endocrine responses, and how these changes relate to attentional performance.

Discussion: Chapter 2

Acute stress is harmful to sustained attentional performance (e.g., Qian et al., 2015). However, previous research has also suggested that reflecting about past traumas or current anxieties can improve wellbeing (Niles, Haltom, Mulvenna, Lieberman, & Stanton, 2014; Pennebaker, 1997) and immediate performance (Ramirez & Beilock, 2011). We examined the effect of writing about past failures on cortisol responses to a new psychosocial stressor and sustained attentional performance after stress. We found that when individuals were subjected to the Trier Social Stress Test, they exhibited increased cortisol levels, a typical response to a stressful event (Dickerson & Kemeny, 2004; Kirschbaum et al., 1995). However, when individuals wrote about a past failure before experiencing the psychosocial stressor, their cortisol response was attenuated, suggesting that writing about a past failure before experiencing a new stressor may lead to some reduction in one's physiological experience of stress. Moreover, higher stress responses were associated with poorer performance on a sustained attention task, but writing about failures before a stressor protected against the typical detrimental effect of acute stress on performance. Specifically, while stressed individuals who wrote about a control topic made the most errors of commission, stressed participants who had reflected on failures made the fewest errors of commission.

We did not find evidence that writing about failures alone leads to a significant increase or decrease of cortisol levels, counter to some literature that suggests that writing about past traumas itself affects stress (Pennebaker, 1997). Instead, we propose that writing about failures may make a new stressor seem subjectively less stressful by comparison. Longitudinal data provides support for this claim, as past stressful experiences have been shown to allow an individual to adapt better to a new stressor (Homberg, 2012). Specifically, Stress Inoculation Theory suggests that individuals who have experienced some level of lifetime adversity are more likely to exhibit resilience to a new stressor (Lyons, Parker, Katz, & Schatzberg, 2009). Furthermore, early life adversity can lead to more adaptive cognition (Frankenhuis & de Weerth, 2013). In the same way that past stressful experiences may allow an individual to adapt to new stressors, writing about a past failure may allow an individual to adapt to a new immediate stressor.

Writing about a failure before experiencing psychosocial stress resulted in reduced cortisol reactivity, as well as better performance on the SART. Moreover, in Study 2, we found that writing about a past failure improved performance while under psychosocial stress, regardless of whether participants wrote before or after experiencing the psychosocial stressor. Our results from Experiment 2 suggest that the timing of writing about a past failure in relation to enduring stress may not matter, at least in terms of improvements to attentional performance. Although some research has suggested that stress may affect performance in a U-shaped manner (Lupien, McEwen, Gunnar, & Heim, 2009; Yerkes & Dodson, 1908), others have found that increases in stress result in linear decreases in performance (Domes, Heinrichs, Rimmele, Reichwald, & Hautzinger, 2004; Van den Bos, Harteveld, & Stoop, 2009). Future work could further examine if there is a linear relationship between stress levels and performance in a sustained attention task.

We also found that writing about a failure resulted in increased reaction time on the SART. All participants in our experiment exhibited a speed-accuracy tradeoff: participants who had the slowest reaction times on the SART also exhibited the best performance. Taken together, these findings support previous claims that writing about a past failure may cause an individual to make slower, more deliberate choices in order to avoid another future failure, resulting in better performance (DiMenichi & Richmond, 2015).

One limitation of the Study 1 is that we did not assess self-reported stress levels throughout the experimental session. A behavioral pilot study we conducted suggested that repeatedly asking individuals about their stress levels after writing about a past failure eliminated the behavioral effects of the writing manipulation. Post-event processing literature suggests that asking participants to repeatedly reflect on stressful feelings about an event can increase negative feelings about that event (Mellings & Alden, 2000), and introspecting on an emotional response may actually change the response (Hutcherson et al., 2005; Silvia, 2002). However, we did not find any significant differences in stress ratings in Study 2.

Although we found a significant interaction of stress and writing prompt on errors of commission, in Study 1, we did not find a significant main effect of writing group on errors of commission, unlike DiMenichi and Richmond (2015), Study 2, and our follow-up study described in the Appendix. This could have occurred because the task structure of our task varies from the task structure described in the two other studies: in this study, participants took a 2-minute break halfway through the SART to provide a cortisol sample. This break could have improved attention on the SART, resulting in improved performance for all groups, and smaller performance differences between writing groups. Furthermore, in the three other studies, participants wrote about a past failure or control topic and immediately completed a sustained attention task. However, in the non-stress condition in this study, participants completed a filler task before completing the sustained attention task. Perhaps adding this filler task somehow affected performance on the sustained attention task, either because of the task itself or because of experimental timing.

While previous research has suggested that journaling may be beneficial to mental health (Barak & Grohol, 2011), the current studies suggests that writing about one's past failures might not only improve mental health and wellbeing, but also change the way an individual reacts to future and recently experienced stressors. Perhaps writing about a past failure increases perceived controllability over challenges. It has been shown that increasing perceived control alters the effect of stress on persistence (Bhanji, Kim, & Delgado, 2016). Future studies might investigate this possibility by assessing or manipulating perceived controllability during stress. Also, although we assessed various traits and tendencies that could contribute to our observed effects, it is unknown whether there are other individual differences (e.g., a tendency to disclose, or previous experience with life stressors) that could moderate how strongly writing about a past failure affects stress and performance.

In conclusion, we found that writing about past failures reduced one's cortisol responses to a new psychosocial stressor. Most importantly, we found that writing about a past failure before a stressor buffers against decreases in performance that are associated with high levels of stress. We also found that writing about a past failure both before or after being exposed to stress resulted in improved performance while under stress. In a real-world setting, this information may be valuable to clinicians, as well as educators hoping to improve attentional performance. Since writing about test anxieties has already been shown to protect against the negative effects of stress on performance on a high-stakes exam in a classroom setting (Ramirez & Beilock, 2011), this writing manipulation may be especially valuable to populations who exhibit high levels of performance anxiety.

Chapter 3: Examining How Failure Intensity Alters Neural Processing and Subsequent Memory

Although previous studies have shown that writing about negative experiences can improve performance (Klein & Boals, 2001; Ramirez & Beilock, 2011), it remains unknown what neural mechanisms are responsible for these performance gains. Information about neural mechanism would be vital for gaining insight as to *why* writing about past failures leads to cognitive enhancements, which could aid both educational and clinical approaches using expressive writing in their interventions. Moreover, although writing about past negative experiences or current worries has been shown to improve performance on a task that requires attention (DiMenichi et al., 2018; DiMenichi & Richmond, 2015; Klein & Boals, 2001; Ramirez & Beilock, 2011), little is known about how writing about past failures would affect performance on a task that requires attention, such as a learning task (Berryhill, Chein, & Olson, 2011).

Reward Processing in the Striatum

For example, if writing about failures before completing a learning task alters how one processes reward, we might expect to see differential processing of positive versus negative feedback in the striatum in participants randomly assigned to write about a past failure versus a trivial topic. While individuals tend to show greater activation in the dorsal striatum for positive feedback compared to negative feedback (Delgado et al., 2000; Tricomi & Fiez, 2012), this relationship may be altered after one reflects on a past failure. For example, writing about a past negative event like a failure may cause an individual to be more sensitive to negative feedback, which may be reflected in changes in activation in the striatum after being exposed to negative feedback.

Emotional Processing in the Amygdala and Cingulate Cortex

Another possibility is that asking an individual to reflect on a particularly emotional time in his or her life may elicit increases in brain processing in regions typically implicated in processing negative emotion, such as the amygdala (Davis & Whalen, 2001; Hamann et al., 2002; Roozendaal, McEwen, & Chattarji, 2009), and/or the cingulate cortex (Maddock et al., 2003; Shackman et al., 2011). While the amygdala is heavily involved in processing negative emotions pertaining to vigilance, such as fear (Davis & Whalen, 2001), the cingulate cortex tends to be in more involved in processing negative emotions that relate to the self, such as during one's own experience of negative affect (Shackman et al., 2011). Moreover, the anterior region of the cingulate cortex (ACC) tends to deal with processing error detection, while the mid-cingulate cortex

(MCC) tends to play a vital part of processing information regarding negative emotion (Maddock et al., 2003). This region also tends to be more active while an individual experiences physical pain (Shackman et al., 2011). Furthermore, the MCC tends to be deactivated while an individual is focused on a task requiring one's immediate attention (Harrison et al., 2011). Thus, if writing about a past failure induces acute negative thought processing, we may expect to see increased activation in the MCC, even throughout a learning task. However, if writing about a past failure results in better emotional and/or attention processing, we might expect to see decreases in MCC activity.

Individual Differences in Brain Processing

While differences in brain processing between writing groups may help us gain insight as to the benefits of expressive writing about past failures, individual differences in the quality, intensity, or other aspect of their expressive writing sample may help us understand what specifically about writing about past failure guides performance improvements. Considering that writing about more intense failures has previously led to greater health benefits (Harber et al., 1992; Pennebaker, 1997), one would expect that writing about a more intense failure may also result in greater immediate benefits to cognitive performance. Furthermore, information about individual differences in brain processing, and how these differences in brain processing relate to performance, may help us gain further information about the mechanism behind the benefits of expressive writings about past failures.

Current Study

In this experiment, we examined how writing about a past failure affected both performance and neural processing on a paired-association word learning task. We expected that writing about a difficult time in which one did not succeed would result in better memory both during the word learning task, as well as at a later surprise recall task, with changes in brain activation predicting these group performance differences. Alternatively, we predicted that individual differences in the quality of writing samples about past failures could predict individual differences in neural processing, which could in turn predict subsequent memory differences on our task.

Method: Study 2

Participants

Forty right-handed adults (24 female) aged 18-35 were recruited from the surrounding area of Rutgers University-Newark. Participants (mean age = 22.23, SD = 3.81) reported to the Rutgers University Brain Imaging Center (RUBIC; Newark, NJ). Upon arrival, participants provided written informed consent and completed a writing task outside the scanner. At the conclusion of the writing task, participants were given instructions about how to complete a word association learning task, which they then completed inside the fMRI scanner. After the scan, participants completed a surprise recall task, survey battery, and demographic information. The duration of the study was about 2 hours, and participants were paid $50 for their participation.

Writing Task

Before the start of the scan, participants were pseudo-randomly assigned to complete either the failure writing task or the control writing task, as described above (see Chapter 2).

Paired-Association Word Learning Task

After completing the writing task, all participants completed a paired-association learning task with and without feedback inside the MRI scanner (Lempert & Tricomi, 2016; Tricomi & Fiez, 2012). In the "learning phase" of the experiment, participants viewed a "target" word with two arbitrary word choices below each target, and participants were told to select the word that matched the target word. Before each set of trials, participants were shown a label indicating if the block contained "definite feedback" or "no feedback". In the definite feedback block, participants were given accurate feedback about their response—a green check mark if they were correct, or a red "X" if they were incorrect. In the no feedback condition, participants saw a pound sign after their response. See Figure 6 for task description.

Participants completed two rounds during the learning phase of the experiment. In the first round of the learning phase, word matches were new (and therefore arbitrary), but participants received feedback for all trials and were told to use this feedback for future rounds. After completing both rounds of the learning phase with the same set of words, participants completed the "test phase" on the words from the task outside the scanner, which asked participants to select the word that matched the target (without receiving any feedback) and rate their confidence in their response. See Figure 7 for experimental design.

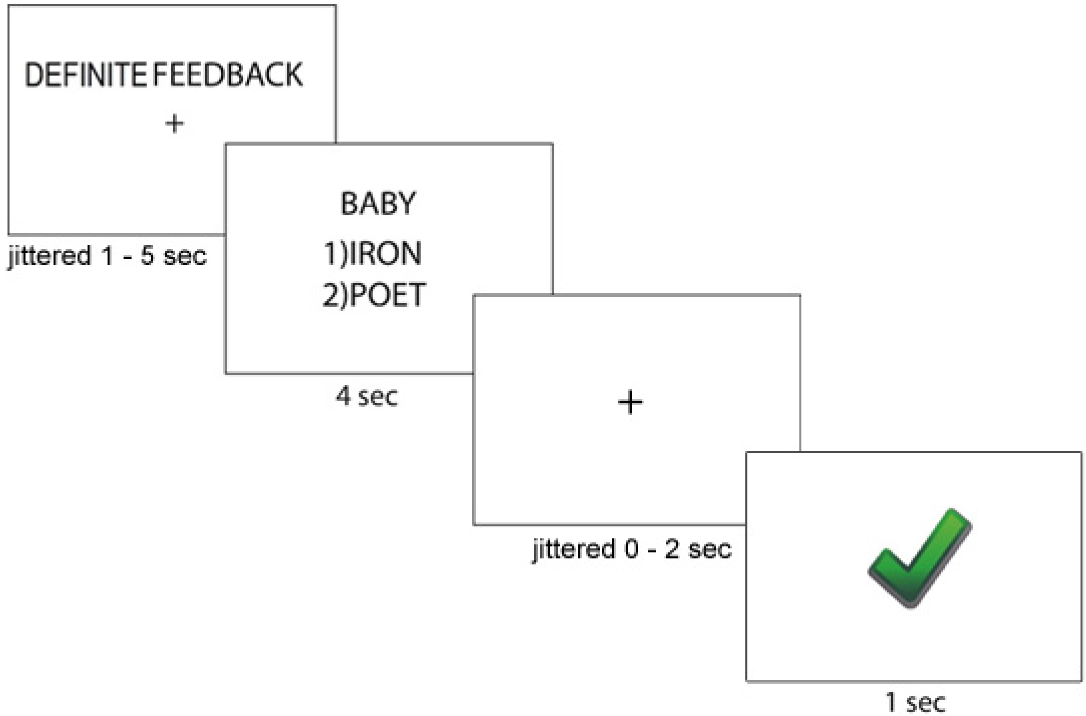


Figure 6. Paired-Association Word Learning Task Description. Participants were told whether they would receive feedback for the current block. Then, participants viewed a target word with two word choices, and pressed the key responding to their word choice. Participants then saw immediate accurate feedback regarding their word choice.

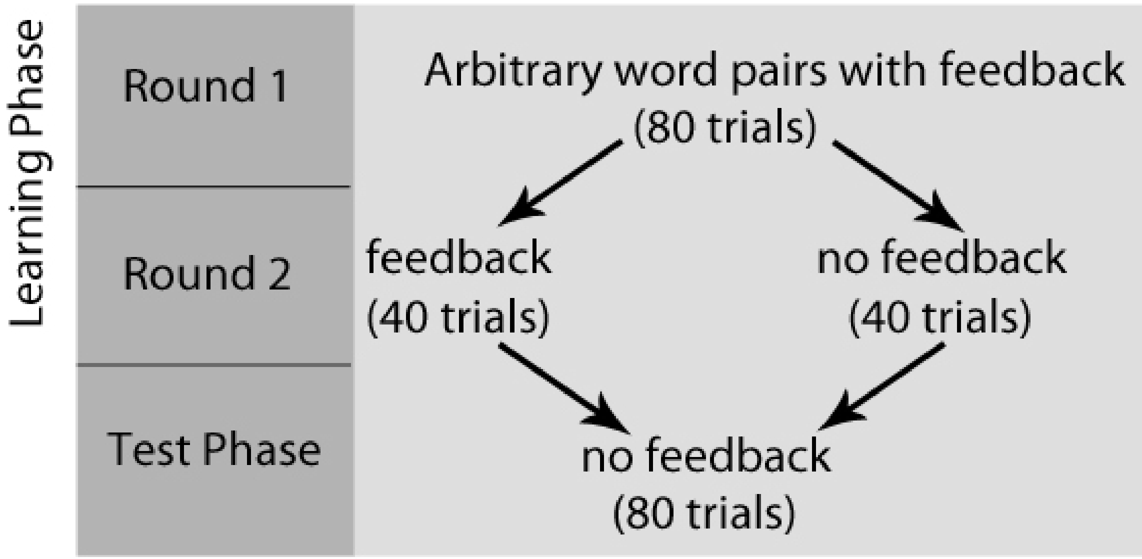


Figure 7. Paired-Association Word Learning Task Experimental Design. Participants completed two rounds of the learning phase inside the MRI scanner, followed by the test phase outside the scanner. In the first round of the learning phase, word matches were arbitrary, but participants received feedback for all trials and were told to use this feedback for future rounds. After completing both rounds of the learning phase, participants completed the "test phase," which asked participants to select the word that matched the target (without receiving any feedback) and rate their confidence in their response.

Survey Battery

After the conclusion of the surprise recall task, participants provided demographic information, as well as several surveys corresponding to traits that could possibly affect our writing manipulation. We included the Connor-Davidson Resilience Scale (CD-RISC), Achievement Goal Inventory (AGI), Need for Cognition Scale (NFC), Cognitive Inference Questionnaire (CIQ), and Social Desirability Scale (SDS)—see Chapter 2 for descriptions. Surveys were randomized to prevent order effects. We also included the mood questions described in Chapter 2.

fMRI Data Collection and Analyses

We utilized the 3 Tesla Siemens TRIO scanner and 12-channel head coil. Stimulus presentation was implemented with E-Prime Experimental Software (Psychology Software Tools, Pittsburgh, PA), and fMRI data was preprocessed and analyzed using BrainVoyager QX 2.3.1 Software (Brain Innovation, Maastricht, The Netherlands). Anatomical slices were collected using a T1-weighted protocol of 176 1-mm voxel sagittal slices, while functional slices were collected using a single-shot EPI pulse sequence with a TR of 2500 ms and TE of 25 ms. Forty-one contiguous oblique-axial 3 mm × 3 mm × 3 mm voxel slices were acquired in an oblique orientation of 30° to the anterior commissure-posterior commissure (AC-PC) axis. This orientation has been found to reduce signal dropout in the ventral prefrontal cortex (Deichmann, Gottfried, Hutton, & Turner, 2003).

During analysis, fMRI data was normalized to the Talairach stereotaxic space (Talaraich & Tournoux, 1988) before preprocessing. Preprocessing included slice-time correction, motion correction, 4 mm spatial smoothing, and high-pass temporal filtering (high pass GLM-Fourier, 3 sines/cosines, 3 seconds). Preprocessed data was then analyzed using a random-effects general linear model (GLM).

For each participant, we modeled the 4-second word presentation screen (Slide 2 in Figure 4) and the 1-second feedback presentation screen (Slide 4) as regressors in our model. The regressors were convolved with a canonical hemodynamic response function. A predictor for missed trials (i.e., when subjects failed to respond on Slide 2 within the 4 second response window) was included in the model as a predictor of no interest. Additionally, the six motion parameters were also included in the model as predictors of no interest. For all analyses, we utilized the continuity-based cluster-level threshold estimator in BrainVoyager, with an initial significance threshold of $p < 0.001$. We then selected to run 1000 Monte Carlo simulations, and corrected each contrast to a contiguity threshold cluster-level false positive alpha rate of 0.05.

Analysis of Feedback Across All Participants

We conducted a whole-brain analysis that examined activation at time of feedback presentation during round 2 of the learning phase (i.e., when word matches are no longer arbitrary, therefore making feedback meaningful to choice). A contrast of interest included Positive Feedback > Negative Feedback to replicate previous results showing that this task elicits positive vs. negative feedback differences in brain areas typically associated with feedback processing (Lempert & Tricomi, 2016; Swanson & Tricomi, 2014).

Analysis Across Writing Groups

We also conducted a whole-brain analysis that examined group differences in activation between both writing groups (failure writing topic vs. control writing topic). Contrasts of interests included a contrast that examined activation differences in the failure writing vs. control writing groups at time of word presentation during the learning phase of the task, as well as contrasts that examined group differences (failure vs. control) in feedback processing (i.e., positive feedback overall, negative feedback overall, and positive vs. negative feedback).

Behavioral Analyses

We conducted t-tests that examined group level differences in performance on the word association learning task. We looked at overall performance differences during round 2 of the learning phase (i.e., when choice is no longer arbitrary), as well as performance differences within each feedback context (feedback condition vs. no feedback condition). We also repeated these tests for test phase performance. We also examined if there were any significant correlations between our survey measures, performance, and brain activation in areas associated with writing group differences.

Results: Study 2

Behavioral Results

We examined differences in performance between writing groups. All analyses were performed after discarding missed trials (i.e., trials where participants did not respond within the 4 second response window). Contrary to our hypothesis, we did not find a significant difference in performance scores on round 2 of learning phase between writing groups (failure writing = 56.37%, SD = 9.64%, control writing = 55.78%, SD = 11.07%; $t(38) = 0.18$, $p = 0.856$), nor did we see differences when examining only words from the feedback (failure writing = 60.24%, SD = 8.64% control writing = 58.14%, SD = 11.61%; $t(38) = 0.65$, $p = 0.520$) or no feedback rounds (failure writing = 56.32%, SD = 09.22% control writing = 56.87%, 10.11%; $t(38) = -0.18$, $p = 0.856$). Furthermore, we did not see a significant difference between writing groups' scores at test (failure writing = 61.90% = 8.87%, control writing = 64.65%, SD = 9.55%; $t(38) = -0.94$, $p = 0.351$), nor did we see significant differences between groups' later memory for words learned in a feedback (failure writing = 65.90%, SD = 11.93%, control writing = 67.15, SD = 13,08%; $t(38) = -0.32$, $p = 0.754$) or no feedback context (failure writing = 57.90, SD = 8.59%, control writing = 62.50, SD = 9.92%; $t(38) = -1.45$, $p = 0.156$).

Since many of our participants exhibited scores close to or at chance, contrary to previous studies that utilized the same task in an fMRI scanner (DePasque & Tricomi, 2015; Lempert & Tricomi, 2016; Tricomi & Fiez, 2012), we also examined whether removing participants with test scores close to chance changed our results. We removed participants if all three test scores (overall, feedback words, or no feedback words) had greater than a 5% probability of being less than chance (Lee & Wagenmakers, 2005), in our case, test scores at 70 percent or below. However, removing these participants left us with a sample size of 17 (control group n = 10, failure group n = 7), causing the same t-tests described above to be underpowered (and not significant). Therefore, the remaining analyses described here are with our complete dataset (n = 40), but tend to focus on individual differences.

We found that confidence ratings at test significantly correlated with scores during round 2 of the learning phase (R = 0.43, $p = 0.006$), as well as greater later memory for words learned in a feedback context (R = 0.31, $p = 0.05$), but not the no feedback context (R = 0.05, $p = 0.77$). Moreover, when examining correlations between behavioral results and survey measures, we found that self-reported scores on the Need for Cognition (NFC) scale significantly positively correlated with overall performance scores in round 2 (R = 0.32, $p = 0.046$), as well as for later memory of words learned in a no feedback context (R = 0.34, $p = 0.035$). We also found that self-reported desire to do well on the task, as well as task enjoyment, significantly correlated with performance during round 2 of the learning phase (care ratings, R = 0.33, p = 0.039; enjoy ratings, R = 0.32, p = 0.045). Lastly, age was significantly positively correlated with overall performance during round 2 of the learning phase (R = 0.52, $p = 0.001$), as well as test phase memory (R = 0.50, $p = 0.001$), task enjoyment (R = 0.33, $p = 0.036$), and scores on the NFC scale (R = 0.38, $p = 0.016$). Therefore, perhaps the relatively young age of our sample (mean = 22.23, SD = 3.81) could explain why most of our subjects—regardless of writing group—did poorly on the learning task.

fMRI Results

Across All Participants

Replicating previous findings (Lempert & Tricomi, 2016; Swanson & Tricomi, 2014), participants exhibited significantly more activation in the striatum (caudate and nucleus accumbens) for positive vs. negative feedback during feedback blocks in round 2 of the learning phase. See Figure 8a for whole-brain differences, and Appendix, Table 7 for full brain results.

To examine whether individual differences in brain activation correlated with performance measures, we examined if individual differences in peak activation in this striatal region correlated with performance across all participants. We found a significant correlation between peak activation in the right dorsal striatum when viewing positive feedback compared to negative feedback on the task, and later memory for words learned in a feedback setting ($R = -0.35$, $p = 0.027$). Thus, more differentiated activation in the striatum in response to feedback significantly predicted better later memory for words originally learned in a feedback setting.

Across Writing Groups

While we did not see significant differences in feedback processing across groups, at the time of word presentation, failure writing participants exhibited significantly greater activation in the MCC than participants who wrote about a trivial topic, at a p-value of $p = 0.005$ corrected to $p < 0.05$. To determine the direction of this relationship—for example, if failure participants exhibited greater activation vs. less deactivation than control participants, we examined the beta weights of the GLM of this contrast. After examining these parameter values, it became evident that while control participants exhibited decreases in activation in the MCC, the mean activation in the MCC for failure participants hovered around 0. See Figure 5c for whole brain differences, and Appendix, Table 7 for full brain results.

Because the MCC is typically deactivated during task engagement (Harrison et al., 2011), while increases in activation is typically associated with processing of negative emotion (Maddock et al., 2003; Shackman et al., 2011), we examined how individual differences in MCC activation correlated with aspects of participants' writing task. Specifically, we found that within the group of participants randomly assigned to write about a past failure, writing about more severe failures (self-reported by the participant) predicted greater deactivation in the MCC ($r = -0.47$, $p = 0.038$). We did not see this same relationship for control participants ($r = 0.10$, $p = 0.680$). See Figure 8d for illustration of these correlations.

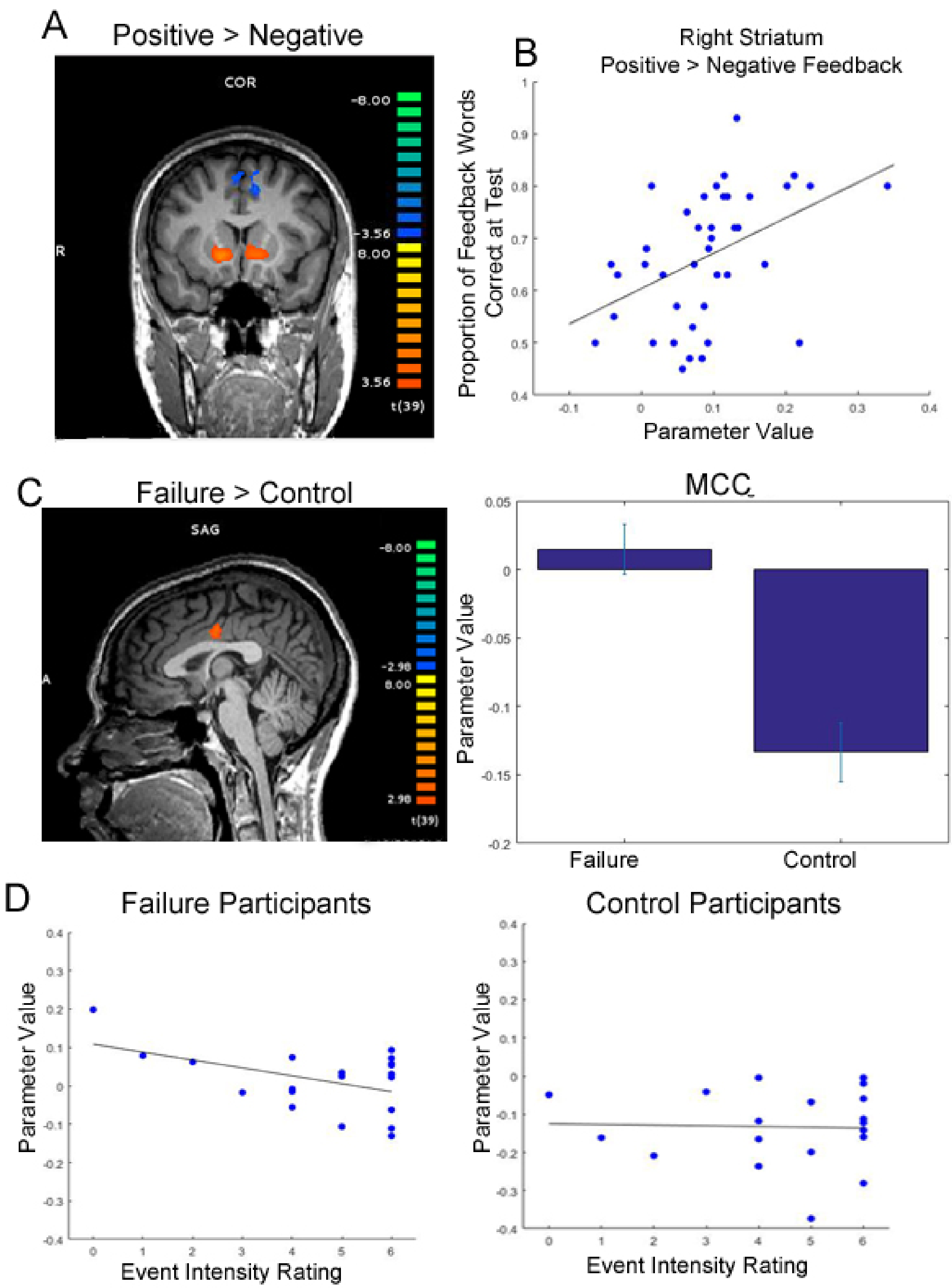


Figure 8. fMRI Results. (a) Participants showed greater activation in the striatum when viewing positive feedback compared to negative feedback during round 2 of the learning phase (when feedback was meaningful for performance). (b) Decreased activation in the right dorsal striatum when viewing negative feedback was significantly correlated with later memory for feedback words (c) Participants who were randomly

assigned to write about past failures showed greater activation in the mid cingulate cortex (MCC) while viewing target words throughout the learning phase than participants who wrote about a trivial topic. While control subjects showed typical decreases in activation in the MCC during the task, failure subjects averaged around 0 (right). (d) Individual differences in self-reported failure intensity significantly predicted MCC deactivation for failure participants (left). We did not see this same relationship for control subjects (right).

Finally, we conducted a Hayes mediation analysis (Hayes, 2012) that examined the relationship between the self-reported intensity of the failure that participants wrote about and test performance, with MCC activation as a mediator. For failure participants, the direct relationship between failure intensity and later memory for words learned in a no feedback setting approached significance (r = 0.40, *p* = 0.094). Importantly, we found that failure intensity significantly predicted MCC deactivation during the learning phase of the task (r = - 0.56, *p* = 0.011), and this MCC deactivation significantly predicted later memory for words learned in a no feedback setting (r = 0.48, *p* = 0.038). We have illustrated this mediation model in Figure 9.

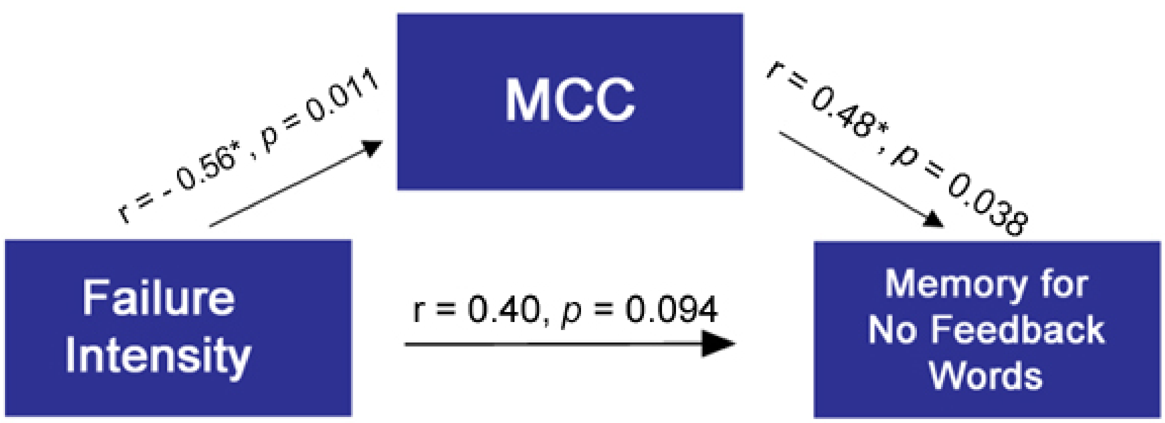


Figure 9. Mediation Model of Individual Differences for Failure Participants. For individuals assigned to write about a past failure, writing about more intense failures led to significantly greater deactivation in the mid-cingulate cortex (MCC) during the learning phase of the task. Furthermore, this MCC deactivation during the task predicted later greater memory for words learned in a no feedback context.

We did not find this significant relationship for participants who wrote about a trivial topic. We also found that MCC deactivation only mediated the relationship between failure intensity and memory for words learned in a no feedback setting, and not for words learned in a feedback setting. In deciphering why this disparity in results for words learned in different types of feedback contexts may have occurred, it may be important to note that participants overwhelmingly reported preferring negative feedback, something that tends to elicit negative emotions (Weidinger, Spinath, & Steinmayr, 2016), over no feedback (participants who preferred negative feedback = 21, preferred no feedback = 10, had no preference = 9; $\chi^2 = 6.65$, $p = 0.036$). This replicates a finding that has been previously found in our lab which utilize the same paired-association word learning task (Lempert & Tricomi, 2016). Thus, writing about a particularly intense failure may buffer negative emotions associated with a lack of feedback, as exhibited by decreased activation in the MCC. There was also no significant correlation between failure intensity ratings and self-reported desire to perform well on the task (R = -0.11, *p* – 0.500), suggesting that this result may not be simply a result of the motivated participants being better at following task instructions and writing about more intense failures. Overall, these results suggest that writing about a particularly intense failure decreases activation in the MCC, resulting in better memory for words learned in a less preferred (and maybe even more difficult) context.

Discussion: Study 2

When examining brain activation in all participants in our task, we found greater activation in the dorsal striatum when participants viewed positive feedback on the task as compared to negative feedback. This finding replicates previous work that suggests the dorsal striatum plays an important role in feedback processing (Lempert & Tricomi, 2016; Swanson & Tricomi, 2014; Tricomi & Fiez, 2012). Moreover, greater differential activation in the dorsal striatum when comparing responses to positive feedback versus negative feedback resulted in better later memory for words originally learned in a feedback setting. Our findings support previous research that suggests that individuals who exhibit greater striatal sensitivity tend to exhibit better error correction (Klein et al., 2007; Krugel, Biele, Mohr, Li, and Heekeren, 2009; Ullsperger, Danielmeier, & Jocham, 2014). Perhaps surprisingly, when individuals are less affected by feedback (as evidenced by a diminished response in the striatum) they may not learn as much from this type of feedback.

Furthermore, when examining differences across our two writing groups, we found that participants who were assigned to write about a difficult time in which they did not succeed exhibited greater activation in the mid-cingulate cortex (MCC) as compared to control subjects, who on average displayed decreases in activation from baseline. Our finding within control subjects may represent typical deactivation of the MCC that is found when an individual is processing a task and therefore not processing information with an emotional context (Harrison et al., 2011). The MCC is an area also typically activated while processing both negative information (Maddock et al., 2003), as well as physical pain (Shackman et al., 2011). Therefore, participants who wrote about past failures may have shown greater activation in the MCC because they were recently asked to process highly emotional (and likely negative) information about their past failings. Future research is necessary to confirm that writing about failures truly induces negative emotion (e.g., by asking participants to rate their emotion after writing), and examine how these ratings relate to MCC processing.

Paradoxically, when examining individual differences in failure writing and activation in the MCC, we found that self-reported failure intensity actually predicted greater *de*activation of the MCC. Moreover, this deactivation significantly predicted greater memory for words originally learned in a no feedback setting. Disclosure literature suggests that writing expressively about more intense negatives from one's past may actually result in the greatest health, physical, and cognitive benefits (Harber et al., 1992; Pennebaker, 1997). Furthermore, in longitudinal mindfulness interventions, individuals are trained to draw awareness to one's thoughts and feelings in the present moment, and then slowly let go of negative or nagging feelings to focus on the current moment (Kabat-Zinn, 2009). Neuroimaging studies suggest that mindfulness training can result in reduced activation in the mid-cingulate cortex during emotional stimuli (Farb et al., 2010). In the same way that drawing one's awareness to negative emotions may result in greater deactivation of the MCC, writing about a past failure may also utilize similar neural processing in order to result in improved cognitive processes. Moreover, while writing about failures superficially may result in increased emotional processing, reflecting on a particularly intense failure may result in neural processing (and subsequent learning) that more closely resembles not being exposed to emotional stimuli—i.e., the MCC deactivation exhibited by control writing participants. Taken together, our findings suggest that writing about more intense failures may allow an individual to better process negative thoughts before moving on to a new task, resulting in better learning during the task at hand.

Unfortunately, we did not see any significant performance differences across writing groups on our task. Behavioral results were also highly correlated with age in our sample, perhaps suggesting that younger participants had greater difficulty focusing on our learning task. Furthermore, although we did not find a significant relationship between age and self-reported failure intensity, perhaps younger participants had not yet experienced the *type* of failures that result in learning benefits after writing about them, especially considering that persistence improves as one as one ages, likely as a result of experience (Duckworth, Peterson, Matthews, & Kelly, 2007). Future studies might consider implementing our task on a sample with a slightly older mean age.

Broadly speaking, our findings suggest that writing about a past failure, especially a failure that one found to be particularly intense, may allow an individual to emotionally persevere in a new, perhaps particularly difficult task. Reflecting on more intense failures may facilitate better learning. Our results are particularly valuable to clinicians hoping to implement expressive writing into therapy, as well as educators hoping to improve learning, especially after students experience academic failure.

Chapter 4: Exploring How Writing About Past Failures Affects Motivation

Although writing about a past failure can increase attentional performance on a task requiring intrinsic motivation (DiMenichi & Richmond, 2015), it remains unknown if writing about a past failure has a direct effect on motivation, or which type of motivation (i.e., extrinsic vs. intrinsic) is most affected by writing about a past failure. While extrinsic motivation is affected by extrinsic rewards like money and positive feedback (Deci et al., 2001), intrinsic motivation is related to the desire to continue a task because one enjoys it, and/or a desire for task mastery. Thus, writing and thinking deeply about a past failure may increase performance by increasing an individual's own desire to master a new task. Specific information about the mechanism by which writing about past failures affects motivation is vital to educators hoping to utilize our writing manipulation in a classroom setting.

Two experiments examined various mechanisms behind how writing about past failures could lead to performance improvements. In Study 4, we examined whether adding extrinsic motivators also improved attentional performance, and how writing about a past failure altered performance on tasks requiring both extrinsic and intrinsic motivation. Finally, in Study 5, we examined whether writing about a past failure had a direct effect on intrinsic motivation.

Study 4: Examining How Varying Levels of Feedback Alters Expressive Writing's Effectiveness

Writing about negative experiences has been shown to improve performance on tasks requiring sustained attention (DiMenichi et al., 2018; DiMenichi & Richmond, 2015; Klein & Boals, 2001; Ramirez & Beilock, 2011), but little is known about how intrinsic motivation has played a role. After all, extrinsic rewards in general have been shown to improve performance (Murayama & Kitagami, 2014), and receiving positive feedback specifically—i.e., an extrinsic reward (Deci et al., 2001)—has also been shown to lead to performance improvements (Kluger & DeNisi, 1996). Thus, it is unknown if adding feedback to a sustained attention task would increase an individual's attention like writing about a past failure does. Furthermore, if writing about a past failure improves performance on a task in the absence of feedback but not its presence, this could mean that writing about failures could have an effect on intrinsic motivation but not extrinsic motivation, given that feedback is often considered an extrinsic reward (Deci et al., 2001). These findings would provide empirical evidence behind the mechanism of why expressive writing about negative experiences lead to performance improvements.

In this study, we randomly assigned participants to write about a past failure or trivial topic, and then randomly assigned these participants to complete a sustained attention to response task (SART) either with or without feedback on each trial. We predicted that we would replicate previous findings that writing about a past failure leads to performance improvements on the SART when feedback is not provided. Additionally, since positive feedback can be considered an extrinsic reward (Deci et al., 2001), an extrinsic rewards can result in increased attention and performance (Murayama & Kitagami, 2014), adding feedback to the SART may also lead to performance improvements.

Study 4 Method

Participants

Eight-two participants were recruited from Rutgers University-Newark. The study's duration was approximately 1 hour, and participants received 1 course credit hour for their participation. Two participant quit the experiment half way through the SART, leaving us with a final sample size of 80 participants (64 female; mean age = 20.49, SD = 4.73).

Our study followed a similar format to DiMenichi and Richmond (2015): upon arrival at the laboratory, participants were pseudo-randomly assigned to write about a past failure, or a trivial topic. All participants completed the SART, but in our study, were randomly assigned to complete the SART with or without feedback after each trial.

See Figure 10 for task assignments and SART illustration. All four conditions had an equal number of participants (n = 20).

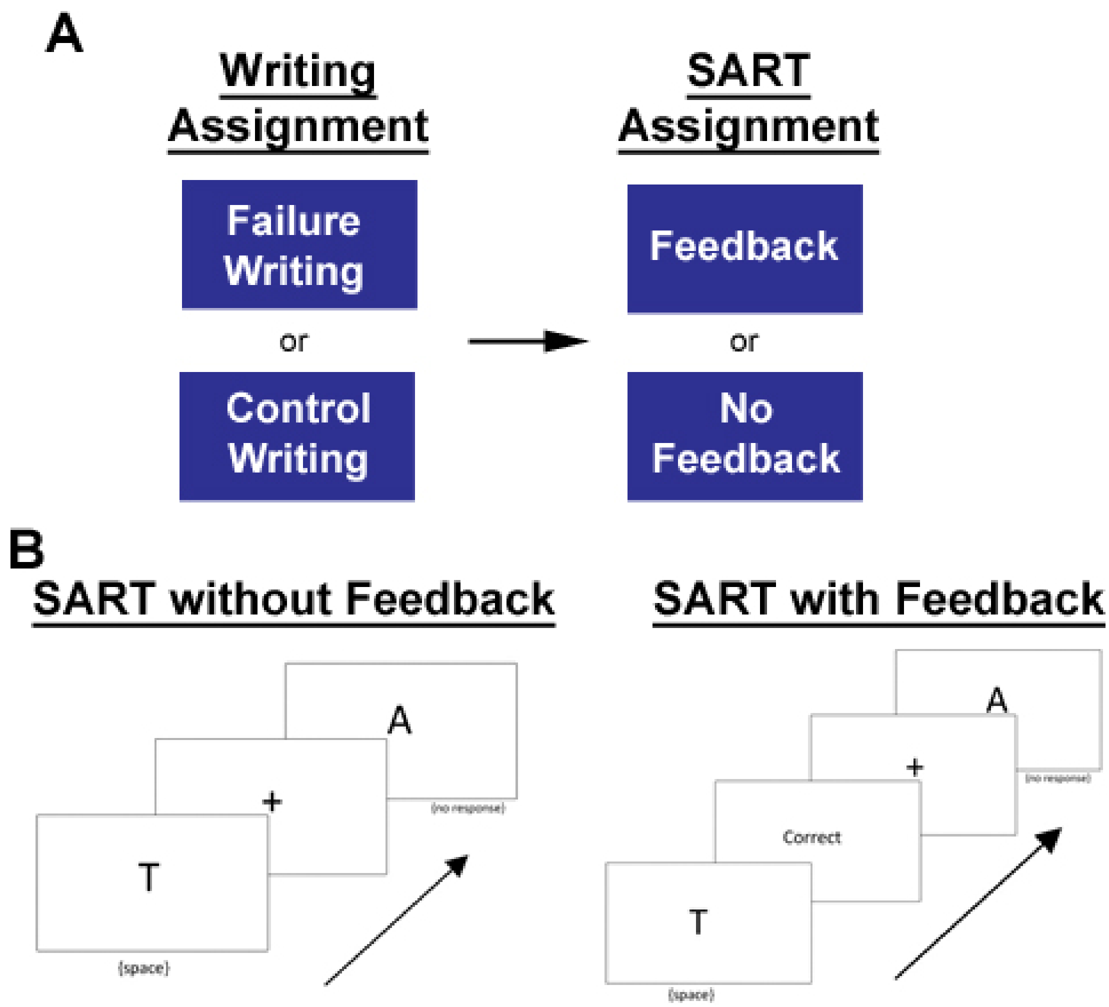


Figure 10. Study 4 Task Assignments. (a) Participants were randomly assigned to write about a past failure or trivial topic, and then were randomly assigned to complete the SART with or without feedback. (b) Participants were either randomly assigned to receive feedback on each trial of the SART (right), or to complete the SART without feedback (left), which was the version of the SART originally featured in DiMenichi and Richmond (2015).

We conducted a between-subjects 2 x 2 ANOVA that examined the main effect of writing group and main effect of presence of feedback on the SART, as well as the interaction of writing group x presence of feedback, on SART errors of commission. Because writing group can have an effect on reaction time (RT) on the SART, and all participants tend to exhibit a speed-accuracy tradeoff regardless of writing group (DiMenichi et al., 2018; DiMenichi & Richmond, 2015), we also conducted a correlation that examined the relationship between errors of commission and reaction time on the SART across all subjects Moreover, we also conducted a between-subjects 2 x 2 ANOVA that examined the main effect of writing group, main effect of presence of feedback, and interaction of writing group x feedback on RT on the SART.

Study 4 Results and Discussion

We found a significant main effect of feedback on SART performance ($F(1, 76) = 22.12$, $p < 0.001$): participants who received feedback on the task exhibited fewer errors of commission. Moreover, we found an effect of writing on errors of commission that approached significance ($F(1, 75) = 3.30$, $p = 0.073$), suggesting that writing about past failures may have offered marginal improvements to performance. Importantly, we found a significant interaction of writing group x presence of feedback on errors of commission ($F(1, 76) = 5.07$, $p=.027$), suggesting that while feedback may improve performance on the task, writing about a past failure when feedback is unavailable may still offer performance improvements. See Figure 11 for an illustration of results.

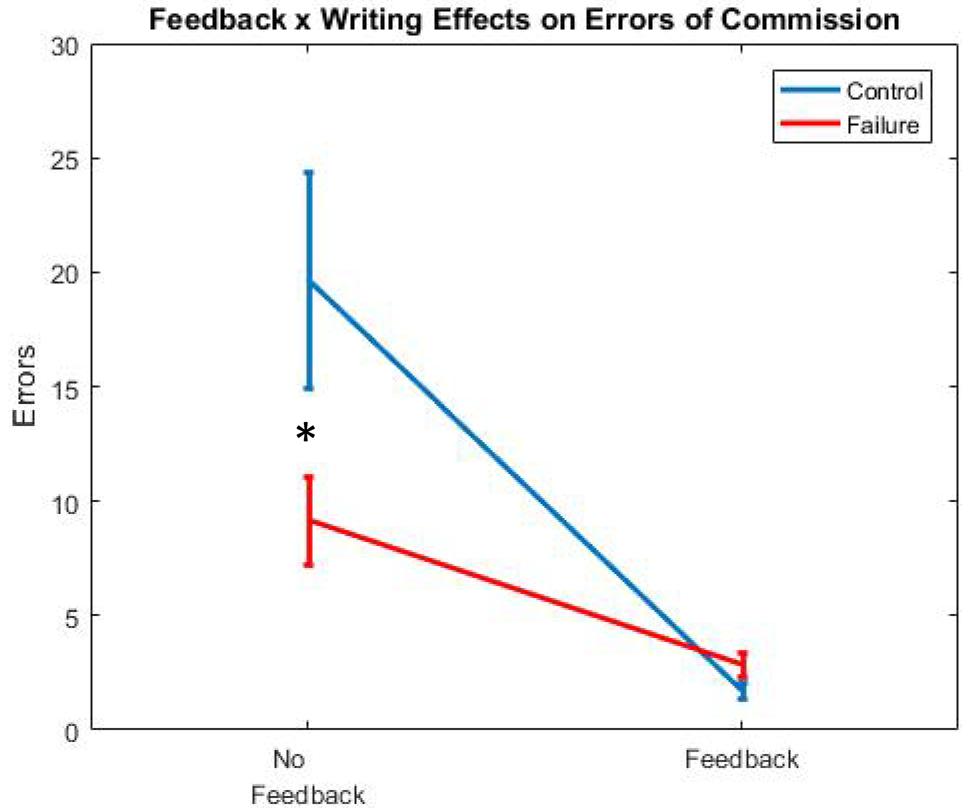


Figure 11. Study 4 Results. While being given feedback on the SART resulted in significantly better performance, being asked to write about a past failure in the absence of feedback significantly improved performance.

We also found a significant main effect of feedback on reaction times (RTs) on the SART: participants who received feedback on the SART exhibited slower RTs on the SART (F(1, 76) = 42.83. p < 0.001). Furthermore, although we did not find a significant main effect of writing on RTs (F(1, 76) = 0.72, p = 0.400), we did find a significant interaction effect of feedback x writing (F(1, 76) = 7.13, p = 0.009). We also replicated the typical speed-accuracy tradeoff associated with SART performance (r = - 0.49, p < 0.001). Thus, while adding an extrinsic reward (such as feedback) may improve performance by guiding a participant to make slower, more deliberate choices in order to increase the chances of receiving a reward, writing about a past failure in the absence of extrinsic rewards may improve performance by forcing a participant make slower, more deliberate choices, perhaps in order to avoid another future failure.

Broadly speaking, our results suggest that adding an extrinsic reward like feedback is likely to improve attentional performance on a long and enduring task. Moreover, writing about a past failure might improve sustained attention on a task in the absence of extrinsic motivation. However, least-squared differences post-hoc tests revealed that writing about a past failure in the presence of extrinsic rewards like feedback might not offer any additional improvements to performance (mean difference between failure writing and control writing participants in the feedback version of the SART = 1.13, $p = 0.759$). Thus, writing about a past failure may improve performance by offering a boost to intrinsic motivation on a task that requires intrinsic motivation to succeed.

Study 5: Examining How Writing About Past Failures Directly Affects Intrinsic Motivation

Although writing about a past failure has been found to influence performance, it is unknown how motivation plays a part in this relatively novel finding. Moreover, although we know that writing about a past failure improves performance on a task in the absence of immediate feedback, i.e., something that requires intrinsic motivation (Deci & Ryan, 1975), little is known about the direct, causal relationship of writing expressively about failures on motivation. Examining how writing about past failures affects one's motivation to complete a task may shed light on the mechanism behind *how* writing about past failures influences performance.

Specifically, one may be extrinsically motivated to do well on a task because of extrinsic rewards like money, food, and even positive feedback (Deci et al., 2001). On the other hand, individuals that are intrinsically motivated to achieve a goal often do so because of intrinsic rewards, like pure enjoyment or a desire to master a task or skill. Our results from Study 4 suggest that writing about a past failure may increase performance on a task that does not offer immediate extrinsic rewards (in this case, in the form of feedback), and that adding an extrinsic reward like feedback (Deci et al., 2001) may actually eliminate the effect of expressive writing on performance.

If writing about a past failure directly influences one's intrinsic motivation to complete a task, we might expect that writing about past failures would significantly increase the likelihood of individuals' decisions to continue to pursue a task in the absence of extrinsic rewards (such as positive feedback). Alternatively, if writing about past failures influences extrinsic motivation, we might expect to see performance group differences on a task offering extrinsic rewards like positive feedback. It also remains unknown whether writing about a past failure influences generally influences goal pursuit, as opposed to intrinsic motivation to continue a task.

In this study, we pseudo-randomly assigned participants to write about a past failure or trivial topic, and complete a task that offers extrinsic motivation in the form of a score. Moreover, we allowed participants to choose to continue to complete the task when extrinsic motivations (i.e., score on the task) was removed. We also manipulated whether participants were given the opportunity to continue the task, or to choose to complete the task directly after writing, in order to isolate if writing about a past failure generally influences one's decision to pursue goals, or if writing about past failures specifically influences one's intrinsic motivation to continue the task at hand. We predicted that being assigned to write about a past failure would significantly increase the likelihood of participants' intrinsic motivation to continue a task.

Study 5 Method

Participants

One hundred twelve participants were recruited from Rutgers University, Newark to participate in the study. The total study duration was approximately 1 hour, and participants were given 1 course credit hour for their participation. One participant's data was removed from our analyses because the program crashed. Two subjects were also removed from analyses because their average reaction time on the stopwatch task was faster than 1 second, suggesting they did not understand task directions. One subject was also removed for failing to complete our survey, leaving us with a final sample size of 108 subjects (85 females; mean age = 20.80 years, SD = 4.52).

After giving informed written consent, participants were pseudo-randomly assigned a writing topic, and a task order. Participants were either randomly assigned to write about a difficult time in which they did not succeed, or a control topic (i.e., the plot of a recently viewed movie), and were also randomly assigned to either complete the writing task before (order 1) or after the stopwatch task (order 2). Order 1 of the task allowed us to see if writing about a part failure increased participants' likelihood of being motivated to continue a task, while order 2 allowed us to examine if writing about a past failure generally caused participants to want to perform the stopwatch task. There were the same number of participants across all four separate conditions (n = 27). Lastly, all participants provided demographic information and completed a survey battery. See Figure 12 for an illustration of condition assignments.

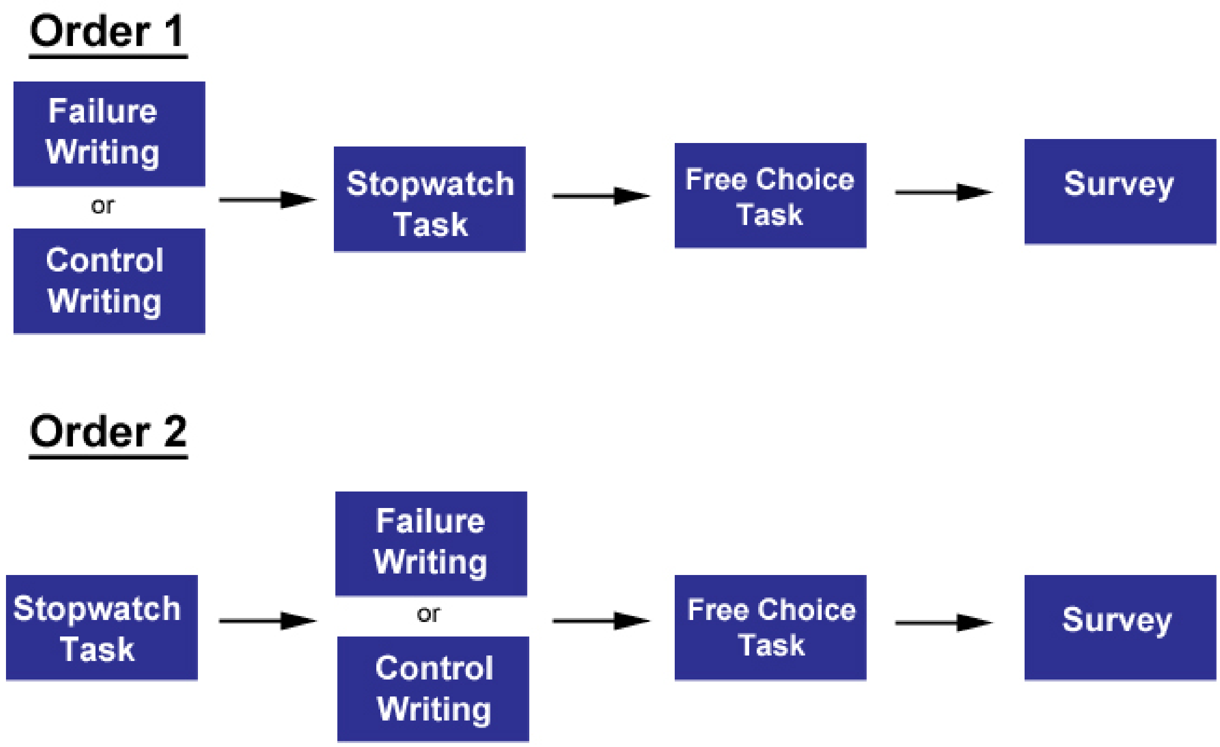


Figure 12. Study 5 Condition Assignments. In order 1 of the experiment (top), participants were randomly assigned to write about a past failure or trivial topic, then completed the stopwatch task. After completing the stopwatch task, participants were given a choice to continue the task, or rest. In order 2 of the experiment, all participants completed the stopwatch task first, then were randomly assigned to completing the failure writing or control writing portion of the task, and then were given the choice to go back to playing the stopwatch task or rest.

Stopwatch task

We utilized a classic choice motivation task adopted from Murayama, Matsumoto, Izuma, and Matsumoto (2010). In this task, participants view a dark blue timer on a computer screen that starts automatically. Participants are told to press the spacebar on their keyboard when the timer gets close to the target timepoint (5 seconds). If participants were able to press within 50 milliseconds of the target, the timer turned from blue to green, and 1 point was added to their score, shown to them throughout the task at the top of their screen. If participants pressed in less than or more than 50 milliseconds of the target, the timer turned red and their score did not change. The 50 millisecond response requirement makes this task particularly challenging (Murayama et al., 2010).

Free Choice Task

Before participants completed the survey battery, they ostensibly were told that there was an issue with the survey that would be fixed in "only a few minutes." They were told that while they were waiting, they could either choose to rest and sit quietly, or they could play an earlier version of the stopwatch task that was not done being programmed and therefore did not keep score. Participants were also told that if they changed their mind after their choice, they could alert the experimenter to complete the other task. Participants completed their chosen option for an additional five minutes.

As a manipulation check, at the completion of the study, the researcher informed participants of this deception. None of our participants reported not believing this aspect of the experiment. Moreover, no participant changed their initial task choice during the free choice period.

Survey battery

To examine if individual differences in trait measures affected performance and/or free choice decisions on our task, we implemented the CD-RISC, AGI, NFC, CIQ, SDS, and mood questions discussed in detail in Chapter 3, as well as the BDI-II utilized in Chapter 2. We also added the Regulatory Focus Questionnaire (RFQ) to our survey battery, which probes participants' tendency to seek out new opportunities and achievements—promotion focus—vs. avoid failure—prevention focus (Higgins et al., 2001).

Analyses

To examine if writing about failures increased the likelihood of participants choosing to continue playing the stopwatch task, we conducted a chi-squared test that examined significant differences in choice among both writing groups in order 1. We utilized a chi-squared test because all participants in our experiment chose only one task option during the free choice period—i.e., participants that chose to continue the task did so for the full 5 minutes, while participants that chose to rest did so for the full 5 minutes. To examine whether performance on the stopwatch task significantly affected the decision to keep playing the stopwatch task, we also conducted a logistic regression for the subjects in order 1 that tested whether score on the stopwatch task significantly predicted free choice decision.

To examine the likelihood of participants generally choosing to complete the stopwatch task, we conducted a chi-squared test that examined significant differences in choice among both writing groups in order 2. We also conducted a one-way ANOVA that looked at if condition (failure writing order 1, control writing order 1, failure writing order 2, and control writing order 2) had a significant effect on the scores on the stopwatch task. We also conducted one-way ANOVAs to examine if condition had an effect on reaction time, as well as standard deviation in reaction time—a common measure of sustained attention (McVay & Kane, 2012)—on the stopwatch task.

Study 5 Results and Discussion

We found that participants randomly assigned to write about a past failure before completing the stopwatch task were significantly more likely to choose to keep doing the stopwatch task than participants who wrote about a trivial topic before the task (χ^2 = 4.80, p = 0.028). Moreover, score on the stopwatch task did not significantly predict task choice (χ^2 = 1.70 p = 0.192, R^2 = 0.03), suggesting that how well participants did on the stopwatch task did not have a significant influence on participants' decisions to continue completing the task. Therefore, our results suggest that writing about a past failure may influence one's intrinsic motivation to continue a challenging task. See Figure 13a for task choice results for order 1 participants.

Although writing about a past failure influenced participants' decisions to continue the stopwatch task, writing about a past failure after completing the stopwatch task did not significantly affect participants' decisions to return to the task: within order 2 subjects, there was no significant difference in task choice across writing group (χ^2 = 0.68, p = 0.409). This lack of a significant result may suggest that writing about a past failure may not always influence the decision to pursue a task in general, but merely influences one's motivation to continue (based on our results from order 1 participants). See Figure 13b for task choice results for order 2 participants.

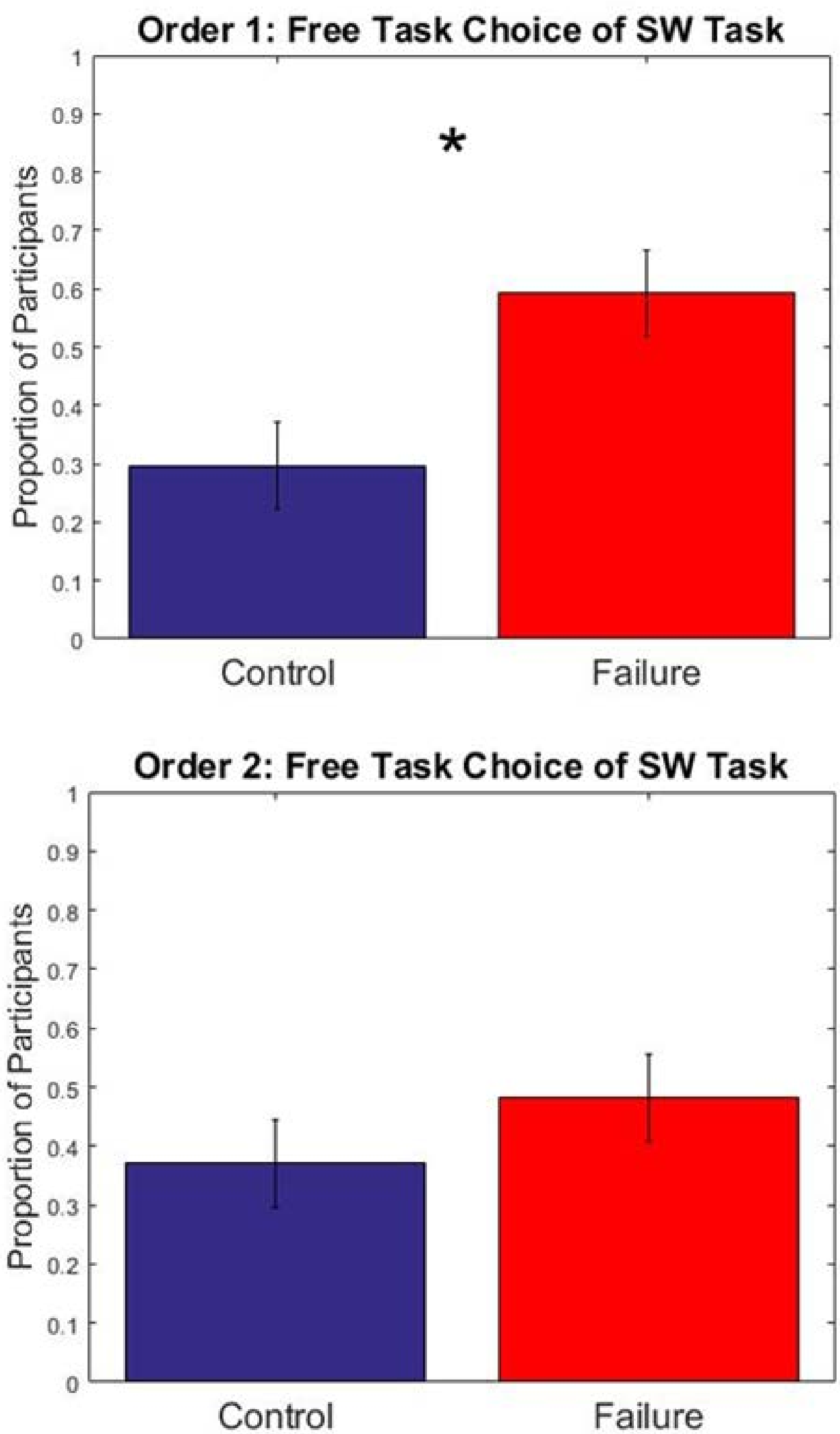


Figure 13. Stopwatch Task Free Choice Results. (a) When participants wrote about a past failure before completing the stopwatch task, they were significantly more likely to choose to continue the stopwatch task. (b) There was no significant effect of writing group on task choice when participants were given the opportunity to go back to completing the stopwatch task after writing.

*$p < 0.05$

Furthermore, there was no significant difference across all four conditions regarding scores on the stopwatch task ($F(1, 104) = 0.99$, $p = 0.400$), nor was there a significant effect of condition on reaction time ($F(1, 104) = 0.88$, $p = 0.452$) or standard deviation of reaction time ($F(1, 104) = 0.67$, $p = 0.570$). Moreover, post-hoc least-squared differences tests on these ANOVAs did not reveal any significant differences between individual groups. Our results suggest that intrinsic motivation to persist at a task after writing about a past failure may happen regardless of how well one does at the task at hand. Moreover, since Study 3 and 4 (as well as Chapter 2) utilized tasks where performance improves when an individual makes more careful, deliberate choices, it could be that writing about failures only improves performance on tasks that offer a speed-accuracy tradeoff.

Alternatively, because participants received feedback on the task—i.e., an additional point added to their score—participants may have been extrinsically motivated to do well on the stopwatch task. Thus, our results may support our assertion from Study 3 that writing about failures may positively influence one's intrinsic motivation to do well (e.g., continuing to do a task in the absence of a score or positive feedback), while it may not influence one's extrinsic motivation to do well (e.g., succeed at a task that instantly offers positive and negative feedback).

We also found a significant correlation between standard deviation of reaction time and self-reported mind-wandering scores ($r = 0.29$, $p = 0.003$). This result coincides with findings from attention literature that suggests that participants become more variable in their responses as mind-wandering increases (McVay & Kane, 2012). There were no other significant correlations between survey responses and our performance measures, either across all subjects or within specific groups.

Our findings from this experiment suggest that writing about a past failure before completing a challenging task may increase intrinsic motivation to persist. Furthermore, our results suggest that while expressive writing may influence one's intrinsic motivation, writing about past failures does not significantly alter performance on tasks that offer extrinsic motivation. Moreover, our results support the assertion that writing about past failures improves intrinsic motivation to persist specifically (instead of general goal pursuit).

Discussion: Chapter 4

Two studies examined the effects of writing about a past failure on motivation. In Study 4, we examined if extrinsic motivators like feedback altered expressive writing's effectiveness. While adding feedback to a sustained attention task resulted in performance improvements, writing about past failures in the presence of feedback did not offer any additional performance improvements. However, writing about a past failure did offer performance boosts in the absence of feedback. Our results from Study 4 suggest that writing about a past failure may be specifically beneficial to performance on tasks that do not offer extrinsic rewards.

To examine the effect of writing about failures on intrinsic motivation directly, we examined how writing about past failures improved the likelihood of individuals' choices to continue a task when given the opportunity to stop (Study 5). We found that writing about a past failure increased participant's intrinsic motivation to continue at a task (i.e., order 1 of the task), and this choice was separate from general increases in goal pursuit (i.e., order 2 of the task).

Although writing about a past failure improved performance on a sustained attention task in the absence of feedback (Study 4, order 1), reflecting on a past failure did not significantly improve performance on tasks that offered immediate feedback (Study 4, order 2 and Study 5). Since positive feedback can act as an extrinsic motivator, while the absence of feedback requires intrinsic motivation (Deci et al., 2001), perhaps writing about past failures improves performance by way of increasing intrinsic motivation. Moreover, our results from Study 5—that writing about a past failure increased the likelihood of participants' choosing to continue a task during free time—coincide with this proposed relationship between writing expressively about failures and intrinsic motivation.

Moreover, when writing about failures does lead to performance improvements, it may do so because reflecting on a past failure may increase individuals' desire to avoid future failures, especially in the absence of extrinsic rewards. We found that participants who wrote about past failures and then completed a sustained attention task without feedback in Study 4 made slower, more deliberate choices, and these more deliberate choices led to greater accuracy. Taken together from our findings from Study 5, perhaps writing about a past failure increases an individual's personal motivation to succeed, and individuals do this by making more careful choices.

Although writing about a past failure has improved performance on several studies in a laboratory setting, it is unknown how well our results translate to a real world setting, such as performing a sport after a major setback. Likewise, although we found in

Chapter 3 that varying *when* an individual writes about a failure in relation to a stressor or challenge can still lead to performance improvements, but it remains unknown *how long* writing about a past failure offers performance benefits, or if writing about failures longitudinally—e.g. in the form of therapy (Pennebaker et al., 1988)—would have cumulative effects. Future research should be conducted in order to examine how long each session of expressive writing lasts.

Broadly speaking, our findings suggest that reflecting on a past failure offers performance benefits by way of improving intrinsic motivation to do well. Moreover, when making more careful choices results in better performance, writing about a past failure will strengthen the probability of individuals utilizing this type of decision making. Our results are the first of their kind to suggest that expressive writing may improve performance by offering a boost to intrinsic motivation on a task that requires intrinsic motivation to succeed.

Chapter 5: General Discussion: Past Failures Help Us Prepare for Success

For decades, popular psychology has suggested that "just focusing on the positive" can lead to psychological, physical, and cognitive benefits (Creswell et al., 2013; James, 1884; Seligman & Csikszentmihalyi, 2000; Steele, 1988; Vaillant, 2000). Recently, however, more and more research has suggested that thinking and writing about *negative* experiences—be they past traumas (Harber et al., 1992; Hemenover, 2003; Pennebaker, 1997; Pennebaker et al., 1988) or current anxieties (Klein & Boals, 2001; Ramirez & Beilock, 2011)—can lead to strong psychological and cognitive improvements. Moreover, writing about a past negative has been shown to increase sustained attentional performance, while writing about a past success did not offer any significant improvements to attention (DiMenichi & Richmond, 2015).

Across three chapters and five separate research studies, we confirmed that writing about a past failure before a task significantly influenced behavior, and neural and physiological processing. In Chapter 1, we found that writing about a past failure itself did not result in a physiological stress reduction, contrary to what some have suggested (Pennebaker, 1997). However, we found that writing about a past failure before experiencing a new psychosocial stressor significantly attenuated the body's stress responses in relation to that stressor. Moreover, writing about a past failure improved sustained attention after exposure to stress. In Study 2, we found that regardless of when a person wrote about a past failure in relation to experiencing a psychosocial stressor, they still exhibited performance benefits. Our results suggest that the benefits of expressive writing may still occur if a stressor has already passed. Our findings from

Chapter 2 suggest that writing about a past failure before a new challenge may lead to better physiological and attentional preparedness.

In Chapter 3, we discovered that the type of failure one writes about could be vital to brain processing and subsequent memory. We found that overall, participants randomly assigned to write about past failures exhibited greater activation in an area of the brain implicated in processing negative emotion—the mid-cingulate cortex (MCC) (Maddock et al., 2003; Shackman et al., 2011)—while participants who wrote about trivial topics exhibited typical decreases in this brain region while completing a learning task (Harrison et al., 2011). Surprisingly though, we found that participants who wrote about more intense failures exhibited decreases in the MCC, more closely mimicking the MCC deactivation observed in our control subjects. Furthermore, for failure subjects, decreases in activation in the MCC predicted better later memory for words learned in a no feedback setting, likely our most difficult trials based on participant self-report. Our results from Study 3 suggest that reflecting on more intense failures may lead to greater cognitive benefits.

Moreover, although writing about a past failure improved performance on a task lacking extrinsic rewards and motivators, the addition of extrinsic rewards in Study 4 also led to performance benefits that subsequently eliminated the effect of our writing manipulation. Thus, to examine the direct effect of writing about a past failure on intrinsic motivation, we tested in Study 5 whether writing about a past failure increased the chances of a participant choosing to continue a task during their free time. We found that writing about a past failure significantly increased participants' intrinsic motivation to continue to pursue a task when not required to, and this choice was independent of general increases in goal pursuit. Our findings from Chapter 4 suggest that writing about a past failure may lead to improvements in intrinsic motivation.

Taken together, our results from these studies suggest that the mechanism by which writing about a past failure leads to cognitive benefits thinking deeply about a salient past failure (in our case, in the form of preparing and executing a writing sample) may better prepare an individual for new cognitive and psychological challenges.

The Stress Hypothesis, Revisited

Some researchers have suggested that writing about past negative experiences leads to improvements by reducing stress (Pennebaker, 1997; Pennebaker et al., 1988). However, our results from Chapter 2 suggest that being randomly assigned to write about a past failure does not lead to reductions in stress as a direct result of writing, counter to this hypothesis. However, we did find that writing about a past failure led to reductions in physiological stress in response to a psychosocial stressor. Moreover, writing about a past failure also improved sustained attention while under stress. Our findings suggest that writing about a past failure may lead to reductions in physiological stress responses to a new stressor or challenge, which may be responsible for the health benefits typically associated with expressive writing interventions (Pennebaker et al., 1988). However, *why* writing about a past failure leads to reductions in physiological responses to stressors still remains unclear with this proposed explanation of mechanism.

Working Memory Load Hypothesis, Revisited

Since writing about negative experiences can lead to improvements in performance on working memory tasks (Klein & Boals, 2001) and tasks that require working memory to succeed (Ramirez & Beilock, 2011), some have suggested that writing expressively about traumas or worries “frees up” cognitive load on attention, leading to more cognitive capacity to complete new tasks, therefore resulting in improved performance. However, although neural data could potentially provide empirical evidence for this assertion, this possible explanation has yet to be tested.

If expressive writing “freed up” the amount of information on attentional load, we would expect to see significant changes in brain areas typically associated with working memory processing, such as the prefrontal cortex (Barbey, Koenigs, & Grafman, 2010; Chein & Fiez, 2010) and/or posterior parietal lobe (Berryhill et al., 2011). Yet, in Study 2, we found that writing about a past failure resulted in neural changes in an area of the brain typically associated with emotional processing, the mid-cingulate cortex (MCC) (Maddock et al., 2003; Shackman et al., 2011), during a subsequent learning task. Paradoxically though, participants who chose to write about failures they personally labeled as more stressful exhibited *de*creased activation in the MCC, and these decreases predicted later memory for words learned in the most difficult context of a learning task. While our results do not offer support for the “working memory hypothesis” of expressive writing’s effectiveness, our findings from Chapter 3 support a common assertion from past studies on disclosure: writing about more intense failures can lead to the greatest cognitive benefits because it allows an individual to emotionally “work through” the negative event (Harber et al., 1992). However, *why* thinking and writing about negative experiences would lead to these later reductions in emotional processing during a new learning task cannot be explained by changes in working memory load.

Conclusions Drawn from Our Results: A “Preparatory Hypothesis”

While the stress and working memory explanations for expressive writing's effect on cognition and emotions explain *some* aspects of the mechanism behind expressive writing's success rates, these hypotheses do not fully explain many of the results in the five studies presented. However, a large body of literature on early life stressors suggests that experiencing negative events like traumas or stressors can result in more adaptive cognitive processes (see Frankenhuis and de Weerth (2013) for a review). In terms of real-life measures of performance, athletes may be more likely to win major events and break records after a close loss for a gold medal (Lewis, 2015) or even a recent major loss (Keflezighi, 2015). Furthermore, when examining how past adversities have affected coping mechanisms, experiencing past stressful adversities has been shown to allow an individual to adapt better to a new stressor (Homberg, 2012). Moreover, Stress Inoculation Theory suggests that individuals who have experienced more adversities are more likely to exhibit resilience to a new stressor (Lyons et al., 2009).

In the same way that past stressful experiences may allow an individual to adapt to new stressors, writing about a past failure may allow an individual to adapt to a new task or challenge. Thus, expressive writing may lead to performance benefits because reflecting on a negative such as a past failure may cause an individual to reflect on what steps they need to take in order to succeed at a new task. In fact, thinking about the steps needed to take to achieve a goal are more likely to result in goal attainment than simply fantasizing about the desired outcome (Oettingen & Mayer, 2002). Furthermore, in a clinical setting, cognitive behavioral therapy (CBT) asks individuals to think critically about their maladaptive tendencies and discuss the steps needed to improve them (Hollon & Beck, 1994). Importantly, CBT overwhelming has the higher psychological success rates compared to other treatment plans (Butler, Chapman, Forman, & Beck, 2006; Hofmann, Asnaani, Vonk, Sawyer, & Fang, 2012). In the same way an Olympic athlete who narrowly misses a gold medal decides to rethink her training plan to prepare for her next competition, reflecting deeply on a past failure may cause an individual to think more closely about the steps needed to achieve a new goal.

In Chapter 2, we found that after participants wrote about past failures, they made slower, more deliberate choices on our sustained attention task. This decision to be more careful resulted in more success on the new task at hand. Moreover, participants who wrote about past failures before and after experiencing a new stressor exhibited attenuated stress responses. In fact, their levels of cortisol, a hormone that typically peaks after stress, more closely and statistically resembled participants who were not exposed to a stressor. Similar to how those who experience moderate life adversities exhibit more adaptive cortisol responses (Lyons et al., 2009; MacMillan et al., 2009), perhaps after thinking deeply about a past failure, one is more emotionally prepared to handle a new stressor or challenge, resulting in better cognitive outcomes.

In Chapter 3, we found that participants who wrote about stressors they personally found more stressful exhibited greater decreases in brain activation during a subsequent task in the mid-cingulate cortex (MCC), an area of the brain typically associated with processing negative emotion (Maddock et al., 2003). Additionally, this reduction in activation resulted in better memory for words learned in the task’s least preferred context. This result suggests that being willing to think about more difficult failures can result in the best performance benefits by making one more emotionally prepared to succeed at a new difficult task. This result aligns with the idea that disclosing about more intense past negative experiences can lead to the greatest psychological benefits (Harber et al., 1992), as well as the assertion that those who experience more life adversities may be more cognitively and emotionally adaptive (Frankenhuis & de Weerth, 2013; Homberg, 2012; Lyons et al., 2009). Moreover, mindfulness training, where individuals are trained to focus on negative emotions while also letting go of nagging feelings (Kabat-Zinn, Lipworth, & Burney, 1985), results in both cognitive improvements (Jha, Krompinger, & Baime, 2007; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013), as well as deactivation of the MCC (Farb et al., 2010). Mindfulness training may help train an individual how to better process negative emotion, and our results suggest that thinking deeply about a difficult past failure may utilize similar neural mechanisms. Alternatively, individuals who have experienced more stressful failures and adversities may benefit the most from reflecting on them, similar to how those who have experienced moderate life adversity can exhibit greater emotional coping (Homberg, 2012; Lyons et al., 2009). Nevertheless, comparing this result with our results from Chapter 2, when one reflects a particularly intense failure, one may be more emotionally prepared for a new challenging task, resulting in improved learning.

We also found that age was a strong predictor of performance in Chapter 3. As individuals age, they tend to experience more adversities, making them develop greater persistence (Duckworth et al., 2007). Thus, perhaps our older participants performed better and learned more on our task because they were more likely to have greater adversities to reflect on.

Finally, writing about a past failure may prepare an individual to perform better on a new task, independent of whether the activity results in extrinsic benefits. In

Chapter 4, we found that participants randomly assigned to write about past failures did better on tasks lacking extrinsic motivation. Additionally, writing about past failures had a direct effect on intrinsic motivation: participants who wrote about difficult times in which they did not succeed were more likely to choose to continue a task when given the choice to stop. Thus, writing about a past failure may result in performance benefits because the individual then has a general desire to master a task, not because writing expressively increases one's desire for positive feedback or other extrinsic reward. After thinking about a past failure, individuals may be more emotionally and cognitively prepared to complete a new task or challenge, and reflect on the steps needed to succeed because they wish to do so personally, not because they have a desire to receive more extrinsic rewards.

Alternative Interpretations from "Disclosure" Literature

Alternatively, many have suggested that writing itself is the crucial mechanism behind why writing about negative experiences leads to psychological and cognitive benefits: that forming a narrative about negative events allows one to have closure about that event, resulting in cognitive and psychological benefits (Klein & Boals, 2001; Pennebaker, 1997). If writing about negative experiences leads to this immediate improvement in performance by this mechanism, this assertion would also suggest that individuals spend a large portion of their waking time thinking about past traumas or failures. In Study 1, we analyzed in depth if any aspect of writing correlated with physiological stress responses, but found no significant relationship.

Moreover, new pilot data from our lab suggests that telling an individual he or she will have to eventually write about a past failure in the near future, but not actually executing the writing task itself, still results in performance benefits. Moreover, performance of these participants is non-significant from participants given the opportunity to complete a full expressive writing task about past failures. See Appendix Figure 2 for results from this pilot study. These results suggest that simply thinking in depth about a past failure—something that is necessary in expressive writing paradigms—results in performance benefits, regardless if the person is actually given the opportunity to write a full narrative account of the event.

Limitations

Although reflecting on a past failure improved performance on sustained attention tasks, we did not see group differences in performance on tasks that offered forms of extrinsic motivation—i.e., feedback. This lack of a significant effect of expressive writing in these settings may suggest that writing about a past failure may only offer performance boosts to tasks that lack extrinsic rewards, while adding extrinsic rewards may offer such performance benefits that they eliminate the effectiveness of reflecting on a past failure. Furthermore, we might not see an effect of expressive writing on tasks that are already easier to complete (e.g., the sustained attention task with a break utilized in Study 1).

Moreover, our results from Chapter 3 suggest that the type of failure participants are willing to write about may matter when trying to utilize expressive writing for difficult tasks: participants who wrote about more intense failures exhibited the greatest decreases in emotional processing regions of the brain, resulting in better later memory. This result suggests that not all expressive writing about past failures offers the same amount of benefits. Alternatively, participants who have not yet experienced an intense failure may not exhibit as significant benefits from expressive writing.

Although we showed that one can still benefit from expressive writing both before and after a stressor occurs, it still remains unknown how long the effect of reflecting on past failures on performance lasts. Although expressive writing longitudinally can lead to both cognitive and psychological benefits (Klein & Boals, 2001; Lepore & Smyth, 2002; Pennebaker, 1997; Smyth et al., 2008), no one knows how long the effect of a single expressive writing session lasts. Researchers may wish to conduct follow-up tests in the weeks following a single expressive writing session to examine how long the effects last. Information about the length of the effect of expressive writing may be vital to those hoping to utilize expressive writing to improve performance, but that do not have the means to implement a longitudinal-style intervention.

Although many have shown that life adversities can lead to cognitive (Frankenhuis & de Weerth, 2013), psychological (Homberg, 2012), and physical benefits (Lewis, 2015; Lyons et al., 2009), it is sometimes difficult to draw comparisons between our performance measures in the laboratory and performance results in the classroom, or those that occur on the Olympic track. Although our findings from the laboratory may provide more information about mechanism, if we want to truly test the effectiveness of expressive writing on performance, we must do so with more externally valid dependent variables, such as actual exam scores (Ramirez & Beilock, 2011).

Implications

Five studies suggested that writing about a past failure could paradoxically lead to performance improvements, as well as reductions in physiological stress and the neural processing of negative emotion. Our results provide empirical support for the assertion that thinking deeply about a past failure leads to performance improvements by causing an individual to better implement the steps needed to achieve a new goal. Our findings are valuable to scientists interested in the mechanisms underlying the effects of expressive writing manipulations, as well as sports psychologists hoping to help an athlete bounce back after a major failure, and educators helping to improve both an intrinsic desire for learning as well as test scores, especially in those with test anxiety.

Appendix

Chapter 2

Follow-up Study Examining the Effect of Mood

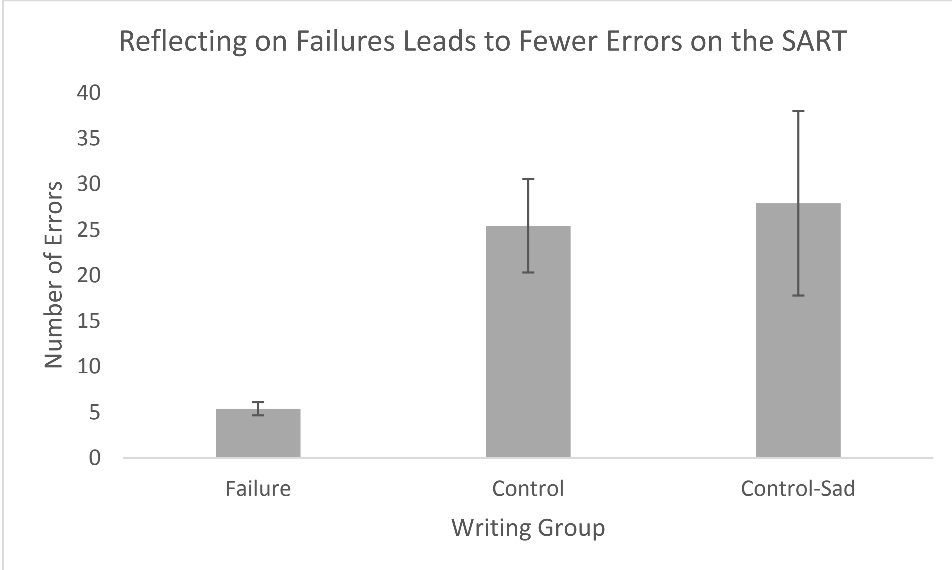
Method

Fifty-one participants were randomly assigned to write about a difficult time in their life in which they did not succeed (failure condition; n=17), the plot of a recently watched movie (control condition; n=17), or the plot of a recently watched sad movie (control-sad condition; n=17). Participants read their randomly assigned prompt on a computer screen, and were asked to write about the topic for 10 minutes. They typed their responses on a computer.

After 10 minutes, participants completed the Sustained Attention to Response Task (SART), a go/no-go task where participants were asked to press the space bar when they saw a letter, unless the letter was a vowel. Participants were given 2 sec to respond to each trial, and the entire SART lasted about 30 minutes, in order to require sustained attention to complete. There were 600 trials, and 20% of trials were vowels (all letters were included except Y). See Figure 2 in the main text for SART illustration.

Results and Discussion

A one-way ANOVA examining differences in SART scores between conditions revealed significance ($F(2,48) = 3.57$, $p = .036$). A least-squared differences post-hoc test revealed that participants who reflected on failures exhibited significantly fewer errors of commission on the SART (M = 5.29, SD = 2.89) than participants who wrote about the plot of a recently viewed movie (M = 25.41, SD = 21.08; mean difference = 20.12, p = 0.035) and participants who wrote about the plot of a recently viewed sad movie (M = 27.88, SD = 41.70; mean difference = 22.59, p = 0.019). There were no significant differences between SART commission error rates for participants who reflected on the plot of a recently viewed movie compared to those who reflected on the plot of a recently viewed sad movie (mean difference = 2.47, p =0.791).



Appendix Figure 1. Mood Pilot Results

Our findings suggest that reflecting on failures does not influence sustained attentional performance through changes in mood alone, since reflecting on a sad movie would also induce sad mood. Instead, our results suggest that something specific about reflecting on failures leads to improvements in sustained attention.

Table 1. Number of Male and Female Participants Across Groups

	Female	Male
Failure Writing x TSST	15	9
Control Writing x TSST	12	12
Failure Writing x Filler Task	13	11
Control Writing x Filler Task	15	11
Totals	55	43

Table 2. Menstrual Cycle Across Group for Female Participants

	Week 1	Week 2	Week 3	Week 4	Postmenopausal
Failure Writing x TSST	8	1	3	2	0
Control Writing x TSST	4	3	4	0	1
Failure Writing x Filler Task	4	2	3	3	0
Control Writing x Filler Task	5	5	3	2	0

Table 3. Effects of stress and writing manipulations on AUCi cortisol levels (Full two-way ANOVA results)

	AUCi
Corrected Model	F(1, 95) = 2.31 p = 0.081
Stress Group	F(1, 95) = 2.16 B = 0.3.56 p = 0.145
Writing Group	*F*(1, 95) = 0.01 *B* = -10.78 *p* = 0.923
Stress and Writing Interaction	***F(1, 95) = 4.61**** ***B = 22.57*** ***p = 0.034***

B = beta weight
***significant at p < 0.01*
**significant at p < 0.05*

Table 4. Effects of stress and writing manipulations on SART performance (Full two-way MANOVA results)

	Commission	Omission	Reaction Time
Stress Group	$F(1, 95) = 0.40$ $B = -2.42$ $p = 0.527$	$F(1, 95) = 3.09$ $B = 7.04$ $p = 0.082$	$F(1, 95) = 2.37$ $B = -39.40$ $p = 0.127$
Writing Group	$F(1, 95) = 2.20$ $B = -5.83$ $p = 0.142$	$F(1, 95) = 0.54$ $B = 4.08$ $p = 0.464$	***F(1, 95) = 4.89**** ***B = 39.95*** ***p = 0.029***
Stress and Writing Interaction	***F(1, 95) = 4.55**** ***B = 6.89*** ***p = 0.036***	$F(1, 95) = 0.46$ $B = -3.92$ $p = 0.500$	$F(1, 95) = 0.11$ $B = 13.68$ $p = 0.747$

**significant at* $p < 0.05$

Table 5. SART Performance Across Stress and Writing Group

The below table shows the total accuracy, error rates, and reaction time across groups.

SART Mean Number of Errors of Commission

	Failure Writing x TSST	Control Writing x TSST	Failure Writing x Filler Task	Control Writing x Filler Task
Errors of Commission	Mean = 7.75 SD = 6.46	Mean =13.58 SD = 9.12	Mean = 10.17 SD = 8.95	Mean = 9.12 SD =7.15
Errors of Omission	Mean =10.21 SD = 22.28	Mean = 6.13 SD =16.19	Mean =3.17 SD =6.00	Mean = 3.00 SD = 6.23
Reaction Time	Mean = 618.13 SD =112.50	Mean =578.18 SD =107.33	Mean =657.53 SD =118.93	Mean =603.89 SD = 77.12

Table 6. Survey Battery Results

We examined correlations between our survey measures, and baseline and peak cortisol. Below is a table illustrating these results. SDS = Social Desirability Scale; GCOS = General Causality Orientations Scale; RISC = Connor-Davidson Resilience Scale; AG = Achievement Goal Scale; BDII = Beck Depression Inventor-II; PSS = Perceived Stress Scale. Notably, we found strong relationships between social desirability bias (SDS) and many of our self-report measures.

****significant at p < 0.001*

	Cortisol: AUCi	SDS	GCOS: Auto	GCOS: Control	GCOS: Impersonal	RISC	AG: Performance	AG: Mastery	AG: Avoidance	BDII	PSS
Cortisol: baseline	r = -0.66*** p < 0.001	r = -0.12 p = 0.242	r = -0.029 p = 0.780	r = 0.13 p = 0.209	r = -0.01 p = 0.903	r = -0.16 p = 0.125	r = 0.18 p = 0.077	r = 0.01 p = 0.933	r = 0.18 p = 0.054	r = 0.22* p =0.031	r = 0.04 p = 0.699
Cortisol: AUCi		r = 0.10 p = 0.314	r = 0.02 p = 0.823	r = -0.11 p = 0.296	r = 0.02 p = 0.822	r = 0.20 p = 0.054	r = -0.16 p = 0.108	r = 0.05 p = 0.631	r = -0.20* p = 0.047	r = -0.24* p =0.020	r = -0.10 p = 0.379
SDS			r = 0.03 p = 0.810	r = -0.28** p = 0.005	r = -0.39*** p < 0.001	r = 0.43*** p < 0.001	r = -0.12 p = 0.248	r = 0.27** p = 0.007	r = -0.27** p = 0.006	r = -0.25* p = 0.012	r = -0.26* p = 0.019
GCOS: Auto				r = 0.28** p = 0.006	r = 0.10 p = 0.322	r = 0.20* p = 0.044	r = 0.03 p = 0.767	r = 0.37*** p < 0.001	r = -0.11 p = 0.268	r = 0.03 p = 0.795	r = 0.15 p = 0.179
GCOS: Control					r = 0.48*** p < 0.001	r = 0.11 p = 0.288	r = 0.385*** p < 0.001	r = -0.092 p = 0.367	r = 0.41*** r < 0.001	r = 0.05 p = 0.619	r = 0.07 p = 0.517
RISC						r = -0.23* p = 0.025	r = 0.06 p = 0.580	r = 0.40*** p < .001	r = -0.12 p = 0.250	r = -0.37*** p < 0.001	r = 0.04 p = 0.711
GCOS: Impersonal							r = 0.19 p = 0.058	r = -0.09 p = 0.387	r = .52*** p < 0.001	r = 0.29** p = 0.004	r = 0.14 p = 0.228
AG: Performance								r = 0.12 p = 0.238	r = 0.25* p = 0.012	r = -0.14 p = 0.157	r = 0.11 p = 0.350
AG: Mastery									r = -0.06 r = 0.559	r = -0.03 p = 0.799	r = 0.12 p = 0.269
AG: Avoidance										r = 0.30** p = 0.003	r = 0.21 p = 0.063
BDII											r = 0.26* p = 0.017

***significant at p < 0.01*

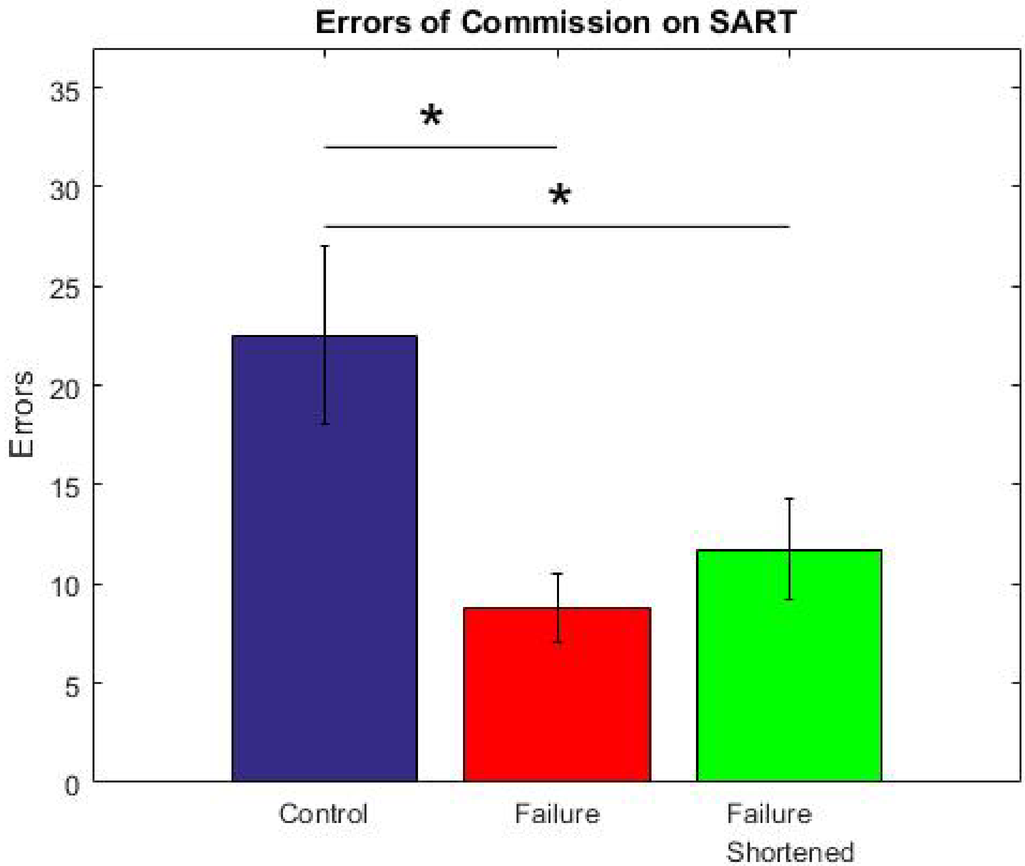
**significant at p < 0.05*

Chapter 3

Table 7. Study 2 Neural Activation Table

Region	BA	Number of voxels (3 x 3 x 3 mm^3)	Peak (Talaraich: x, y, z)	*t*
Feedback Presentation During Round 2 of Learning Phase (all subjects)				
Positive > Negative				
Right occipital gyrus	19	4494	38, -65, 0	4.51
Right putamen		1251	14, 10, -6	4.77
Left caudate head		1325	-7, 10, -3	4.73
Left occipital lobe	17	720	-13, -92, 6	4.25
Negative > Positive				
		891	-10, 1, 57	5.45
		627	-13, -17, 6	4.39
Word Presentation During Learning Phase (across subjects)				
Failure > Control				
Right occipital lobe	18	441	23, -80, 21	4.27
Mid-cingulate cortex	23	819	-4, -11, 33	4.07
Left cerebellum		880	-22, -77, -21	4.11
Left middle temporal gyrus	20	352	-55, -38, -12	4.06
Control > Failure				
Left occipital gyrus		386	-34, -86, 18	4.06

Chapter 5



Appendix Figure 2. Results from Writing Pilot Experiment. Participants (n = 69) were randomly assigned to write about a difficult time in which they did not succeed, or a trivial topic for 10 minutes (see Chapter 2 Method Section for details). Out of the failure participants, half were randomly assigned to have the task "crash" 3 minutes after initially opening the writing prompt (n = 23 per condition). The experimenter alerted participants that she would try to quickly fix the prompt from her computer outside of the testing room, and to still think about what they were going to write while they were left alone in the testing room (though she never provided the opportunity for these participants write). After 10 minutes into the writing task for all participants, they were instructed to stop the task, and complete a sustained attention to response task (see Chapter 2 Method). We found that our writing manipulation had a significant effect on errors on the SART ($F(1, 66) = 5.34$, $p = 0.007$). Replicating previous studies, participants who wrote about a past failure exhibited significantly fewer errors on the SART than control participants (mean difference = -13.74, $p = 0.003$). Critically, participants who just thought about their past failure and were not given the opportunity to write expressively also exhibited significantly fewer errors than control subjects (mean difference = -10.78, $p = 0.017$). Moreover, participants allowed to write about a past failure for 10 minutes did not exhibit significant performance differences from those who simply thought about a failure (mean difference = -2.96, $p = 0.506$).

*$p < 0.05$

Acknowledgement of Previous Publications

- Study 1 described in Chapter 2 is published as a manuscript titled "Writing about past failures attenuates cortisol responses and sustained attention deficits following psychosocial stress" in *Frontiers in Behavioral Neuroscience.*
- Chapter 3 is currently in preparation for publication.
- Study 2 (Chapter 2) and Studies 4 and 5 (Chapter 3) are currently being prepared as one manuscript for publication.

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