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Pain, Affect, and Rumination: An Experimental Test of the Emotional Cascade Theory in Two Undergraduate Samples

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Abstract

In spite of the fact that pain is an unpleasant experience that is generally avoided, recent research suggests that there may be some positive conquences of experiencing pain, including a reduction in negative affect. Better understanding of the mechanisms that allow pain to reduce negative emotions is important for the study of emotional functioning across populations. The current studies tested whether pain disrupts the link between rumination and negative affect, as suggested by the emotional cascade theory. In two undergraduate samples, we used a novel task measuring startle magnitude and self-reported unpleasantness during rumination and distraction and before and after the experience of a painful and non-painful stimulation. Results across the two studies and a quantitative review were mixed. The main prediction that pain relative to no-pain would decrease negative affect during rumination received some support only for the startle measure. A secondary prediction that the pain-related decrease in negative affect would be larger in rumination than distraction was not supported for either measure. The results highlight the importance of understanding the effects of pain of different modalities of emotional responding.

Keywords: Self-injury, Rumination, Startle, Pain, Emotional Cascade

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Introduction

The idea that humans and other organisms have a propensity to approach and/or maximize pleasure and avoid and/or minimize pain has a long history in psychology (Freud, 1929; Miller, 1944; Thorndike, 1935). In spite of this principle, people often engage in behaviors that have the potential for pain (e.g., contact sports), behaviors that cause pain in the short term (e.g. exercise), and behaviors that have harmful effects in the long term (e.g., smoking tobacco). Additionally, there are a number of clinically relevant behaviors that go against the idea of avoiding pain (e.g., purging). Perhaps the most extreme example of such a behavior is nonsuicidal self-injury (NSSI), which involves individuals self-inflicting pain, without suicidal intent (Nock, 2009). Given the broad spectrum of behaviors that involve some form of approaching pain, it seems important to elucidate the functionality of acute physical pain in order to understand emotional and behavioral functioning in various populations. To this end, the current suite of studies examined the effect of pain on the link between rumination and negative emotion among a non-clinical sample of young adults.

In spite of the fact that pain is an unpleasant experience that is generally avoided, recent research suggests that there may be some positive conquences of pain (e.g., it promotes affiliation and increases subsequent pleasure; see Bastian, Jetten, Hornsey, & Leknes, 2014 for a review). One of the most counterintuitive findings from this line of research is that the experience of pain leads to a reduction in negative affect (NA; Bresin, Gordon, Bender, Gordon, & Joiner, 2010; Bresin & Gordon, 2013; Franklin et al., 2010; Franklin, Lee, Hanna, & Prinstein, 2013) and an increase in positive affect (Franklin et al., 2013, 2014). These findings are particularly interesting given that theories of NSSI have suggested that the behavior is used as an emotion regulation strategy (Chapman, Gratz, & Brown, 2006; Linehan, 1993; Nock, 2009; Selby & Joiner, 2009). Interestingly, the decrease in NA following the experience of pain does not differ for individuals with a history of NSSI compared to individuals without a history of NSSI (Bresin & Gordon, 2013; Franklin et al. 2010). Therefore, it may be possible to gain insights into the clinical behavior of NSSI by using pain as a proxy in non-clinical samples. Regardless of sample type, the mechanisms that explain how pain reduces NA are largely unknown.

Given the absence of theories about how pain affects emotion in nonclinical samples and our interest in drawing some conclusions about clinical behaviors, we drew from the emotional cascade theory (Selby & Joiner, 2009), a well delineated model of how NSSI (and other dysregulated behaviors) influence emotional functioning in individuals with borderline personality disorder. The emotional cascade theory suggests that individuals who engage in NSSI experience frequent, intense NA because of a recursive feedback loop between state rumination and state NA. Specifically, when an emotional even happens, these individuals have a tendency to ruminate, or focus on the causes, consequences, and experience of their negative feelings (cf. Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This leads to increased negative affect, which in turn leads to more rumination; ultimately leading to an intense, almost unbearable, emotion. These individuals then engage in painful dysregulated behaviors (e.g., NSSI) in order to disrupt ruminative thinking, which leads to a subsequent reduction in negative emotions. Research supports the link between rumination and NA (e.g., Mor & Winquist, 2002; Nolen-Hoeksema, & Morrow, 1993; Selby, Anestis, Bender, & Joiner, 2009) and a causal link between the experience of pain and a reduction in NA (e.g., Bresin & Gordon, 2013; Franklin et al., 2010). However, no study to our knowledge has examined whether pain disrupts the link between rumination and NA. The current study tested this prediction using a novel experimental paradigm and distinct measures of NA in two samples of undergraduate students.

Although the emotional cascade theory is intended for clinical samples, it has broad relevance to understanding behavioral and emotional functioning in various populations. First, multiple studies using taxometric methods, have found that borderline personality disorder is not a distinct taxon, but lies on a continuum (Edens, Marcus, Ruiz, 2008; Rothschild, Cleland, Haslam, & Zimmerman, 2003). Indeed, non-clinical samples have been shown to exhibit varying levels of dysregulated traits and behaviors (e.g., Sprague & Verona, 2010) and have been studied in relation to putative etiological factors in borderline personality disorder (Trull, 2001). Thus, results from nonclinical samples have a high likelihood to generalize to clinical samples. Second, young adulthood is a high risk period for NSSI. For instance, a meta-analysis of studies using nonclinical samples showed that the unadjusted prevalence of NSSI was 21% between the ages of 18 and 24 (Swannell, Marting, Page, Hasking, & St John, 2014). Alcohol and eating disorders research literatures also study young adult samples given the high prevalence of these behaviors in young persons (e.g., Gordon, Holm-Denoma, Troop-Gordon, & Sand, 2012; Moberg & Curtin, 2009). Third, research has found that ruminative thinking can be experimentally induced in nonclinical samples (for a meta-analysis see Mor & Winquist, 2002), suggesting that state rumination (a key component of the emotional cascade model) can be studied in people who do not necessarily tend to ruminate. Finally, as mentioned above, previous studies have found that the effect of pain on emotion appears to be of similar magnitude in clinical and nonclinical samples (Bresin & Gordon, 2013; Franklin et al. 2010). Thus, it is probable that pain disrupts the consequences of rumination similarly in clinical and nonclinical samples, as problems with emotion regulation and NSSI are likely present along a continuum of severity in many populations.

Pain, Startle, and Negative Affect

Previous studies examining the effect of pain on NA have operationalized NA in terms of physiological reactivity (Franklin et al., 2013) and self-report ratings (Bresin & Gordon, 2013). The use of the startle reflex as a measure of defensive reactivity (a component of NA) in this literature has received attention recently. Startle is an advantageous measure of state defensive reactivity. The startle reflex is reliably modulated by defensiveness, with the largest blinks being elicited by highly arousing threatening foreground stimuli (e.g., human attack) and the smallest blinks elicited in the presence of highly arousing pleasant foreground stimuli (e.g., erotic couples; Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, 1995; Vaidyanathan, Patrick, & Cuthbert, 2009). However, when imagery scripts are the eliciting stimuli, both pleasant and unpleasant scenes involve increases in startle relative to neutral imagery (Miller, Patrick, & Levenston, 2002). Although studies show that immediate anticipation of shock pain increases startle magnitude (Grillon et al., 2006; Moberg & Curtin, 2009), the actual experience of a painful stimulus relative to a no-pain condition relates to subsequent *decreases* in startle magnitude (Franklin et al., 2010; Franklin et al., 2013), suggesting a reduction in defensive mobilization aspects of negative emotionality.

One methodological limitation to existing studies using startle as an index of emotional response to pain is that startle blinks have been elicited with no foreground stimulus present (e.g., anticipation of a speech), making it difficult to identify the actual elicitor of their responses. In addition, few studies have examined affective responding in more than one domain (for an exception see Franklin et al, 2010). Though some theories of emotion have predicted high coherence between the experiential, physiological, and behavioral aspects of emotional responding (e.g., Ekman, 1992, Levenson, 1994; Lazarus, 1991), empirical results show limited coherence at least across subjective and physiological indices (e.g., Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Mauss, Wilhelm, & Gross, 2004). This dissociation has been evident in studies using self-report and startle indices of NA (see Kindt, Soeter, & Vervliet, 2009; Soeter & Kindt, 2010), with this dissociation varying as a function of psychopathology diagnostic group (Cuthbert et al., 2003; Patrick, Bradley, & Lang 1993).

One explanation for the lack of coherence among domains of emotion responding is that emotional responding may be a function of two independent systems, one that is relatively automatic and effortless (e.g., psychophysiological responses), and one that is reflective and effortful (e.g., subjective experience; Evers et al., 2014). According to this theory, it is predicted that coherence should exist within a system but not necessarily across systems. In the area of pain and NA, there appears to be coherence across studies; however, the question of whether that convergence exists within participants in the same study has yet to be adequately addressed.

Current Study

The goal of this paper was to test the prediction that physical pain disrupts the relation between rumination and NA. We tested this prediction in two studies using a novel controlled laboratory paradigm that measured NA (as startle magnitude and self-reported unpleasant feelings) before and after the experience of pain during ruminative and non-ruminative thought. In order to gain a more accurate estimate of the effect size, we also conducted a meta-analysis across the two studies (cf. Braver, Thoemmes & Rosenthal, 2014). Based on the emotional cascade theory (Selby & Joiner, 2009), the first prediction was that NA during rumination would decrease following the experience of pain but not following the experience of a non-painful stimulus. The second prediction was that the decrease in NA following pain would be more prominent during rumination compared to non-ruminative thought.

The secondary goal of this paper was to explore the convergence of emotional responding in the context of rumination before and after physical pain across operationalizations of NA, specifically the experiential (i.e., self-reported unpleasantness) and defensive mobilization (i.e., startle magnitude) components. We predicted there would be coherence of changes in NA across startle magnitude and self-report, given cross-study coherence (e.g., Bresin & Gordon, 2013; Franklin et al., 2010).

Study 1

In Study 1, we used stimuli from previous studies on rumination (e.g., Nolen-Hoeksema & Morrow, 1993) as foreground stimuli to elicit ruminative and non-ruminative (i.e., distractive) thinking. In conjunction with the ruminative and distractive stimuli, we measured emotion-modulated startle and self-reported affect before and after the experience of a painful or a non-painful stimulation in a within-subject design (see Figure 1 for a schematic of the procedures). This study is the first to incorporate rumination versus distraction inductions into study of the effects of pain on changes in NA.

Method

Participants

The choice for sample size was based upon an a priori power analysis using Gpower3 (Faul, Erdfelder, Buchner, & Lang, 2007), which indicated that 110 participants would give adequate power (>.80) to detect medium effects (f = .25; Cohen, 1992) for a between-subjects by within-subjects interaction. We thought a medium effect size would be a size meaningful to detect. The power analysis represents a conservative estimate of power because our design entailed a within-subjects by within-subjects interaction, which cannot be calculated in Gpower3.

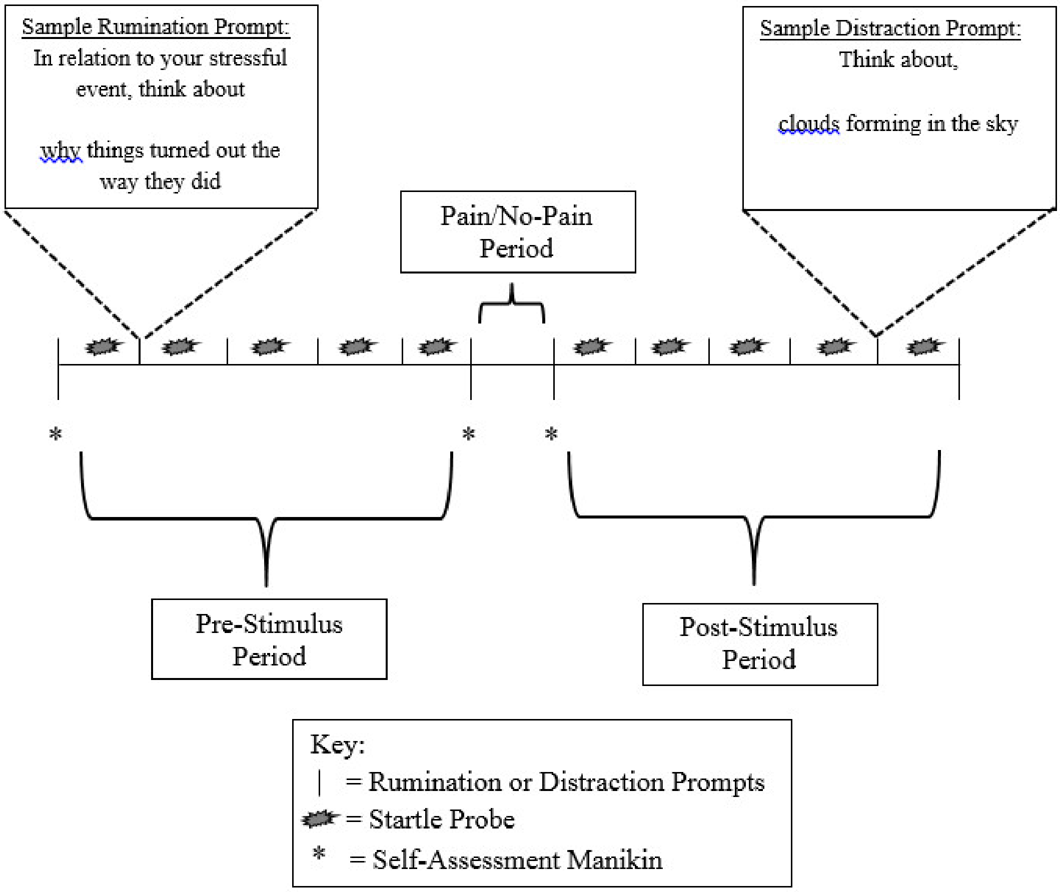

Figure 1: Diagram of Rumination Task Procedures

Participants were 114 (62 women) undergraduate students who completed the study for course credit. The mean age was 19.65 (*SD* = 1.44) years old. The racial/ethnic breakdown was relatively diverse for a college sample: 48% Caucasian, 29% Asian/Asian-American, 13% Hispanic/Hispanic-American, 5% other, 4% African-American, and almost 1% Pacific Islander or Hawaiian. Ninety-one participants had usable startle data. Five participants were discarded because of equipment problems (e.g., headphone malfunction), one participant became ill (unrelated to the study) and had to end prematurely, and the remaining participants (n = 17, 14%) had no discernible startle response (based on visual and computer inspection) on 30% or more of trials and were considered non-responders to the probe (Blumenthal, Cuthbert, Filion, Hackley, & Lipp, 2005). This rate of non-responders is similar to other research in undergraduate samples (Blumenthal et al., 2005; Vaidyanathan, Patrick, & Bernat, 2009). Participants were not excluded for any other reasons. Participants not included in the startle analysis did not differ from those who were included on age, gender, or self-reported unpleasantness (all p's > .05).

Procedure

The study session consisted of three different phases: baseline pain assessment, stressful life event task, and rumination testing procedure. Following the rumination task, participants were debriefed and thanked for their time. Participants were informed that they could stop the procedure at any time if they felt too much discomfort. None of the participants withdrew from the study for this reason. All procedures were approved by the Institutional Review Board at the University.

Phase 1: Pain stimuli and calibration.

To control for individual differences in pain sensitivity, participants completed a baseline pain assessment that was used to select the stimulus intensity that was deemed painful by each participant to be used in a later phase.

Consistent with some previous research (Bresin et al., 2010; Gratz et al., 2011), pain was produced by a pressure algometer (Wegner instruments FPIX 50, Greenwich, CT). The pressure algometer consists of a force gage (calibrated in Newtons with a range to 20 kg x 200g) fitted with a 1 cm in diameter rubber tip, which was applied to the participant. Pressures were applied to the palm of participant's left hand (Gratz et al., 2011). During the baseline pain assessment, participants were exposed to a series of different pressures (1kg, 2kg, 3kg, 4kg, 5kg) in a fixed order, after which they made verbal rating of stimulus intensity on a scale ranging from 0 (*no sensation*) to 100 (*intolerable pain*) with 50 (*pain threshold*) as a midpoint (Tran, Wang, Tandon, Hernandez-Garcia, & Casey, 2010).

These verbal ratings were used to determine the intensity of the pain administered to each participant during the rumination task. Specifically, during the rumination task in blocks designated as pain blocks, participants were exposed to the pressure they rated *closest* to 60 at the baseline assessment (M = 56.54, SD = 8.27). A similar cutoff for painful stimuli has been used in previous research (Bresin & Gordon, 2013; Niedtfeld et al., 2010). During blocks designated as no-pain blocks, a pressure of .02 kg, considered non-painful by all participants, was applied for 30 seconds (see Bresin & Gordon, 2013 for more details on this procedure).

Phase 2: Stressful event selection.

To provide a focal stimulus for the rumination blocks, participants were asked to write about a stressful event from their lives. Specifically, participants were asked to pick a particular situation that made them feel angry, embarrassed, ashamed, guilty, or upset where they felt they were not living up to their expectations for themselves. Participants were asked to pick an event that they rated 8 or greater on a 1 (*not stressful at all*) to 10 (*the most stress I have experienced*) scale (M = 8.46, SD = .61). Common themes of events were: academic failure, problems in romantic relationships, and embarrassing social situations. After choosing an event, participants were given five minutes to describe in writing the details of the event (e.g., what happened, the bodily and emotional sensations they felt). The goal of this phase was to give participants a clear incident to recall during the rumination task. Imagery scripts based on this procedure have been shown to increase reactivity as measured by a number of psychophysiological measures of emotion (see Sinha, 2008 for a review) including modulation of the startle reflex (Vrana & Lang, 1990).

Phase 3: Rumination task.

The procedures of the rumination task were adapted from Nolen-Hoeksema (Morrow & Nolen-Hoeksema, 1990; Nolen-Hoeksema & Morrow, 1993). Participants were told that they were completing a visualization and concentration task, which required them to focus their attention on a series of thoughts and ideas. The thoughts and ideas were, in fact, prompts that focused attention on the stressful event in rumination blocks (e.g., "In relation to your stressful event, think about why you reacted the way you did"), or neutral things in the distraction blocks (e.g., "Think about a truckload of watermelons"). The former prompts were meant to manipulate the process of rumination. Previous research has shown that these prompts increase NA in college undergraduate students relative to distraction prompts (Morrow & Nolen-Hoeksema, 1990; see Mor & Winquist, 2002 for a meta-analysis). Prompts were presented in discrete blocks with one minute "rest" periods between blocks. There were three block types in the rumination task. Two block types used the rumination prompts, with one administering the pain stimulus half-way through the block (Rumination-pain) and the other administering the non-painful stimulus (Rumination-no pain). The third block, to control for attentional focus, used the distraction prompts and involved the experience of pain (Distraction-pain). We did not include a distraction-no pain block, because it was not integral to our hypotheses. Each of the Rumination-pain, Rumination-no pain, and Distraction-pain blocks were repeated once for a total of 6 blocks. The three block types were presented in one of six orders, counterbalanced order across participants.[1]

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[1] To rule out the possibility of block order effects, we examined differences in startle magnitude in terms of a between-subject design, by looking only at the first block for each participant. In this case, the Time by Block Type interaction did not reach significance, F(2, 143) = 1.81, p = .167, pseudo-r2 = .004. There was a marginal interaction between the rumination contrast and Time, γ = 1.17, t = 1.83, p = .069, d = .21. The decrease in startle from Pre-stimulus to Post-stimulus period significantly differed from zero in the Rumination-pain block (d = -.37, p = .007) , but not the Rumination-no pain block (d = -.15, p = .248,). The pain contrast did not significantly interact with time, γ = -1.07, t = -1.69, p = .093, d = -.14; however, consistent with the main results, there was a significant decrease in startle magnitude for the Rumination-pain block and the Distraction-pain block (d = -.52, p = .002). Thus, the results of the first block are

Each block began with participants rating their current level of unpleasantness. Within each block, there were three different periods (see Figure 1). During the Pre-stimulus period, participants were presented a series of 5 prompts one at a time for 30 seconds each (separated by 500 milliseconds of a blank screen). Depending on the block, the prompts were all either rumination or distraction prompts. For each prompt, there was a startle probe presented 10, 15, or 20 seconds after the prompt appeared, for a total of 5 startle responses across the pre-stimulus period. The timing of the probes was based on previous imagery studies using startle methodology (Robinson & Vrana, 2000). The Pre-stimulus period ended with participants rating their current level of unpleasantness. During the Pain/no-pain period, the experimenter entered the room and administered either a painful or non-painful stimulus for 30 seconds. During these 30 seconds, one prompt and startle probe were presented. Reponses to these probes were not used in the analyses. After the 30 seconds, the experimenter left and participants again rated their current unpleasantness. The procedures for the final period, the Post-stimulus period, were identical to the Pre-stimulus period, with 5 prompts and 5 startle probes presented.

Each prompt was displayed on the center of the screen in white font on a black background (via DMDX software; Forster & Forster, 2003). Prompts were displayed in a random order within block, but repeated between blocks (within each block type). Thus, in this paradigm, participants were focused on processing the prompts, not anticipating the possibility of upcoming pain, as in other paradigms (e.g., Grillon et al., 2006).

Dependent Measures

Manipulation check.

After each set of three blocks, participants made ratings on their ability to concentrate, visualize, and focus during the previous three blocks (α = .74 for the first 3 blocks; α = .89 for the second 3 block) on a 5-point scale (1 = *not at all,* 5 = *extremely*). This scale was created, based on previous imagery research (e.g., Miller et al., 2002).

Startle.

The eyeblink component of the startle reflex was recorded using two 4-mm Ag-AgCl electrodes placed on the obicularis oculi muscle underneath the left eye. The signal was amplified using a Neuroscan Synamps 2 and digitized online at 2000 Hz using a 24-bit A/D converter. The startle reflex was elicited by a 50 millisecond 105 dB burst of white noise presented over earphones. Prior to the rumination task, seven habituation probes were presented to reduce the effect of abnormally large blinks. In addition to the probes presented within each block, two probes were also presented during each rest period.

Startle data were reduced using the Physbox add-on toolbox to EEGlab in Matlab (Curtin, 2011; Delorme & Makeig, 2004). Following standard protocols (e.g., Blumenthal et al., 2005), the data were first high-pass filtered (28 Hz butterworth filter), then rectified and low-pass filtered (30 Hz butterworth filter). An automated procedure calculated the startle magnitude, defined as the peak response between 20-100 ms post-probe relative to the mean of the 50 ms baseline. Negative values were set to zero. Non-responses were defined as trials where the peak did not exceed the maximum value of the baseline period and excluded (6.67% of trials). In addition, trials with peak baseline values that exceeded the absolute value of 10 μV were discarded (1.62% of trials). Probes were T-scored across all trials (aside from habituation trials) within-subjects prior to analysis.

Self-report affect.

Participants indicated self-reported affect using an adaptation of the Self-Assessment Manikin (SAM; Lang, 1985). The SAM is a self-report measure of current emotional state. Participants indicated their current feelings using two items: unpleasantness (pleasant to unpleasant) and arousal (low to high). Items are rated using a 9 point scale, where points are indicated by pictures, with higher scores meaning higher unpleasantness and arousal. Participants

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similar to the results collapsed across order; the minimal differences are likely due to decreased statistical power of the between-subjects design.

were asked to rate how they felt at the moment they responded. Ratings were made 1) at the beginning of each block (before the Pre-stimulus period), 2) before the Pain/no-pain period, and 3) right after the Pain/no pain period but before they began the Post-stimulus period prompts. In this report, we focus on the unpleasantness scale, as it most directly tests our hypotheses about NA.[2]

Data Analysis

Because our data were collected as time points nested within-participants, we used multi-level modeling (MLM; Singer & Willett, 2003) for our analyses. MLM was chosen because it is robust to violations of ANOVA assumptions common in psychophysiological data (e.g., sphericity of the variance/co-variance matrix; Judd, Westfall, & Kenny, 2012; Quené, & van den Berg, 2004). Analyses were conducted using the PROC MIXED procedure in SAS 9.3 (SAS Institute, 2012). We used full maximum likelihood estimation for model parameters and the Kenward and Roger (1997) approximation for denominator degrees of freedom in conjunction with recommendations from the literature (Singer 1998; Judd et al., 2012). We report effect sizes in two different ways. For omnibus tests, we report *pseudo-*r^2, which was calculated by dividing the difference between the within-subject variance component of the reduced model (i.e., the model without relevant parameters) and full model (i.e., the model with all parameters) by the variance component of the reduced model (Singer & Willett, 2003). For key follow-up tests, we report Cohen's *d* standardized on the square root of the model based within-subject variance estimate.

We analyzed the startle data with an MLM model that contained Time (Pre-stimulus period, Post-stimulus period), Block Type (Rumination-pain, Rumination-no pain, Distraction-pain), and their interaction as the within-subject model. Trial number was also added as a within-subject covariate to adjust for habituation to the startle probe during the task. The intercept and trial number were random effects and there were no between-subject predictors. We decomposed the predicted Time and Block Type interaction in a number of ways. First, to establish that the rumination prompts were successful in increasing NA relative to distraction prompts, we created a contrast score (cf. Rosnow & Rosenthal, 1996) that compared the average startle magnitude in the Pre-stimulus period for the two rumination blocks to that of the Pre-stimulus period for the distraction block. Second, to test our primary prediction, we compared the change from the Pre-stimulus period to the Post-stimulus period across Block Type by creating two contrast terms. The *pain contrast* tested the effect of pain holding rumination constant (Rumination-pain versus Rumination-no pain). The *rumination contrast* tested the effect of rumination holding pain constant (Rumination-pain versus Distraction-pain). Given that the Time effect reflected differences between the Pre-stimulus and Post-stimulus period, a significant Time by contrast interaction indicated that the change in startle magnitude differed across blocks. Finally, we looked at the simple effect of Time within each Block Type.

The analyses considering our second measure of NA, self-reported unpleasantness, were similar. In this case, the within-subject model contained Time (3 levels: beginning of the block, before the Pain/no pain period, after the Pain/no pain period), Block Type, and their interaction. The intercept was the only random effect, and there were no between-subject predictors. As with startle, we decomposed the expected interaction in multiple ways. First, to establish that the rumination prompts were successful in increasing self-report NA relative to distraction prompts, we created a contrast score that compared the average NA change from the beginning of the block to just before the Pain/no pain period for the two rumination blocks compared to the distraction block. Second, to test our primary hypothesis about the effects of pain on NA, we again calculated the pain and rumination contrasts and examined their interaction with Time; in this case, before the Pain/no pain period and after the Pain/no pain period.

[2] We also completed the same analyses with arousal as a dependent measure. There was a significant interaction between Block Type and Time, F(2, 912) = 3.21, p = .012, pseudo-r2 = .01. There was no significant change either in the Rumination-pain (d = -.01, p = .915) or the Rumination-no pain blocks, (d = 0, p = 1), from the beginning of the block until before the Pain/no-pain period. However, there was a significant decrease in arousal in the Distraction-pain block (d = -.42, p = .001). When comparing the change from Before the pain/no pain period to after the pain/no pain period, there was no significant change in the Rumination-No Pain block, d = -.15, p = .227. There was a marginal increase in arousal in the Rumination-Pain block (d = .22, p = .095) and a significant increase in arousal in the Distraction-Pain block (d = .37, p = .004), suggesting that the experience of pain lead to an increase in arousal regardless of the Block Type.

Results

Manipulation Check: Concentration

Participants reported moderate concentration during the first three blocks of the rumination task (M = 3.22, SD = .86) that significantly decreased during the second three blocks (M = 2.50, SD = .88), $t(113) = -7.24$, $p < .001$, d = -.67. Adjusting for self-reported concentration did not affect the results reported below.

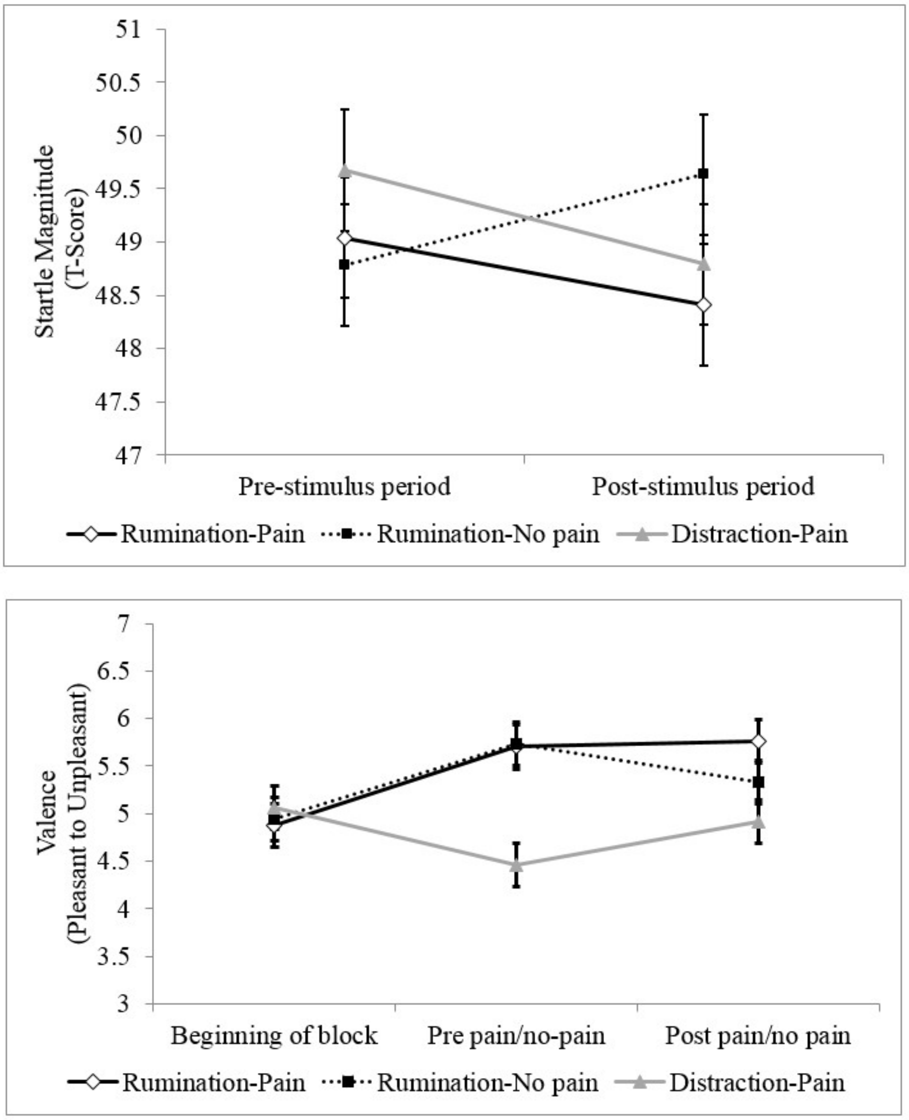

Figure 2: Top Panel: Startle Magnitude (and 95% Confidence Intervals) as a Function of Time and Block Type for Study 1. Bottom Panel: Valence (Pleasant to Unpleasant) as a Function of Time and Block Type Study 1.

Main Analyses

Startle Magnitude.

The results for startle magnitude showed that neither the main effect of Time (Pre-stimulus period, Post-stimulus period), $F(1, 5180) = .37$, $p = .544$, $pseudo\text{-}r^2 = .00$, nor Block Type (Rumination-pain, Rumination-no pain, Distraction-pain), $F(2, 4566) = 1.16$, $p = .313$, $pseudo\text{-}r^2 = .06$, were significant. The Time by Block Type interaction was significant, $F(2, 5181) = 4.95$, $p = .007$, $pseudo\text{-}r^2 = .19$. Figure 2 displays the means for the interaction. The first follow-up test comparing rumination versus distraction prompts on startle magnitude during the Pre-stimulus period was not significant, *F*(1, 2130) = 2.15, $p = .142$, *pseudo*-$r^2 = .001$. That is, rumination did not initiate heightened defensive activation in participants (distraction block: *M* = 50.53; rumination blocks: *M* = 49.97, *d* = .06).

In line with our prediction, the pain contrast (Rumination-pain versus Rumination-no pain) significantly interacted with Time, γ = -.53, *t* = -3.12, *p* = .001, *d* = -.16, suggesting that the change from the Pre-stimulus period to the Post-stimulus period differed as a function of pain. There was a reduction in startle magnitude from the Pre-stimulus to the Post-stimulus period in the Rumination-pain block, although this change was not significantly different from zero, *t*(5179) = -1.32, *p* = .188, *d* = -.06. Conversely, there was a significant increase in startle magnitude during the same time period in the Rumination-no pain block, *t*(5179) = 2.19, *p* = .028, *d* = .10. Thus, these results partially support our first prediction, in that pain produced a marginally significant decrease in rumination-related startle, whereas no-pain resulted in rumination-related significant increase in startle.

In terms of our second prediction, there was a marginally significant interaction between the rumination contrast (Rumination-pain versus Distraction-pain) and Time, γ = .33, *t* = 1.92, *p* = .054, *d* = .03, in the opposite direction as predictions. Startle decreased from Pre-stimulus to Post-stimulus period more so in the Distraction-pain block, *t*(5189) = -1.92, *p* = .055, *d* = -.09, than the Rumination-pain block, *t*(5179) = -1.32, *p* = .188, *d* = -.06. Thus, pain did not produce larger startle reductions in rumination than distraction conditions.[3]

Self-reported unpleasantness.

First, it is worth noting that the three Block Types did not significantly differ on self-reported valence at the beginning of the block (*p* = .208), indicating that carry-over effects were minimized. In terms of our main analysis, there was a significant main effect of Block Type, *F*(2, 912) = 57.56, $p < .001$, *pseudo*-$r^2 = .11$, and Time, *F*(2, 912) = 21.00, $p < .001$, *pseudo*-$r^2 = .04$. More importantly, there was a significant Block Type by Time interaction, *F*(4, 912) = 31.26, $p < .001$, *pseudo*-$r^2 = .12$. The first set of follow-up tests showed that the change from the beginning of the block to before the Pain/no pain period was significantly different when comparing the two rumination blocks to the distraction block, *F*(1, 570) = 114.77, $p < .001$, *pseudo*-$r^2 = .08$. Thus, unlike with startle, the rumination prompts increased self-reported NA, *t*(912) = 10.75, *p* < .001, *d* = .98, and distraction prompts reduced it, *t*(912) = -5.56, *p* < .001, *d* = -.74. The means are displayed in the top panel of Figure 3.

Comparing self-reported NA before and after the pain/no-pain stimulus, the pain contrast significantly interacted with Time, γ = .22, *t* = 5.05, *p* < .001, *d* = .37. Unlike with the startle data, there was not a significant change from before the pain to after the pain in the Rumination-pain block, *t*(912) = -.52, *p* = .602, *d* = -.07, and instead there was a significant decrease in unpleasantness in the Rumination-no pain block, *t*(912) = -3.69, *p* < .001, *d* = -.49. Thus, pain relative to no-pain did not lead to decreases in unpleasantness as a function of rumination. The rumination contrast also significantly interacted with Time, γ = .20, *t* = 4.38, *p* < .001, *d* = .23. As already noted, pain did not produce a change in self-reported unpleasantness in the rumination-pain block, whereas there was a significant increase in unpleasantness following the experience of pain in the distraction-pain block, *t*(912) = 4.17, *p* < . 001, *d* = .14. Hence,

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[3] Given that previous studies show that women tend to ruminate more than men (Nolen-Hoeksema et al., 2008), we examined whether gender moderated the normative effects. For Study 1, the omnibus three-way interaction was not significant, *F*(2, 5125) = 1.82, *p* = .165, *pseudo*-$r^2 = .001$ with startle magnitude as the dependent measure. For completeness, we examined simple effects within gender. For women, there was not a significant reduction of startle magnitude in response to pain in the Rumination-pain block (*d* = .03, *p* = .559) nor a significant increase during the Rumination-No Pain block (*d* = .10, *p* = .110). However, there was a significant decrease during the Distraction-pain block (*d* -.16, *p* = .006). For men, none of the effects reached statistical significance. The pattern of results, nevertheless, was similar to the normative effects (Rumination-pain: *d* = -.11, *p* = .120; Rumination-no pain: *d* = .13, *p* = .063; Distraction-Pain: *d* = .01, *p* = .850). The three-way interaction for unpleasantness did not approach significance, *F*(1,113) = .08, *p* = .989.

For Study 2, the omnibus three-way interaction was significant, *F*(2, 3001) = 3.34, *p* = .035, *pseudo*-$r^2 = .002$ for startle magnitude. For women, there was a significant reduction in startle magnitude during the Rumination-pain block (*d* = -.33, *p* < .001), no change during the Rumination-no pain block (*d* = .06, *p* = .351), and a nonsignificant decrease in the Distraction-pain block (*d* = -.10, *p* = .256). For men, none of the effects were significant, with effect sizes close to zero (Rumination-Pain: *d* = .02, *p* = .863; Rumination-No Pain: *d* = -.01, *p* = .774; Distraction-Pain: *d* = .01, *p* = .965). Again, the three-way interaction for unpleasantness was not significant, *F*(1,1133) = .47, *p* = .757. Together these results suggest that at least in terms of startle magnitude, the effects may be stronger for women compared to men the results for unpleasantness did not support either hypothesis that pain versus no-pain would decrease NA, especially during rumination.

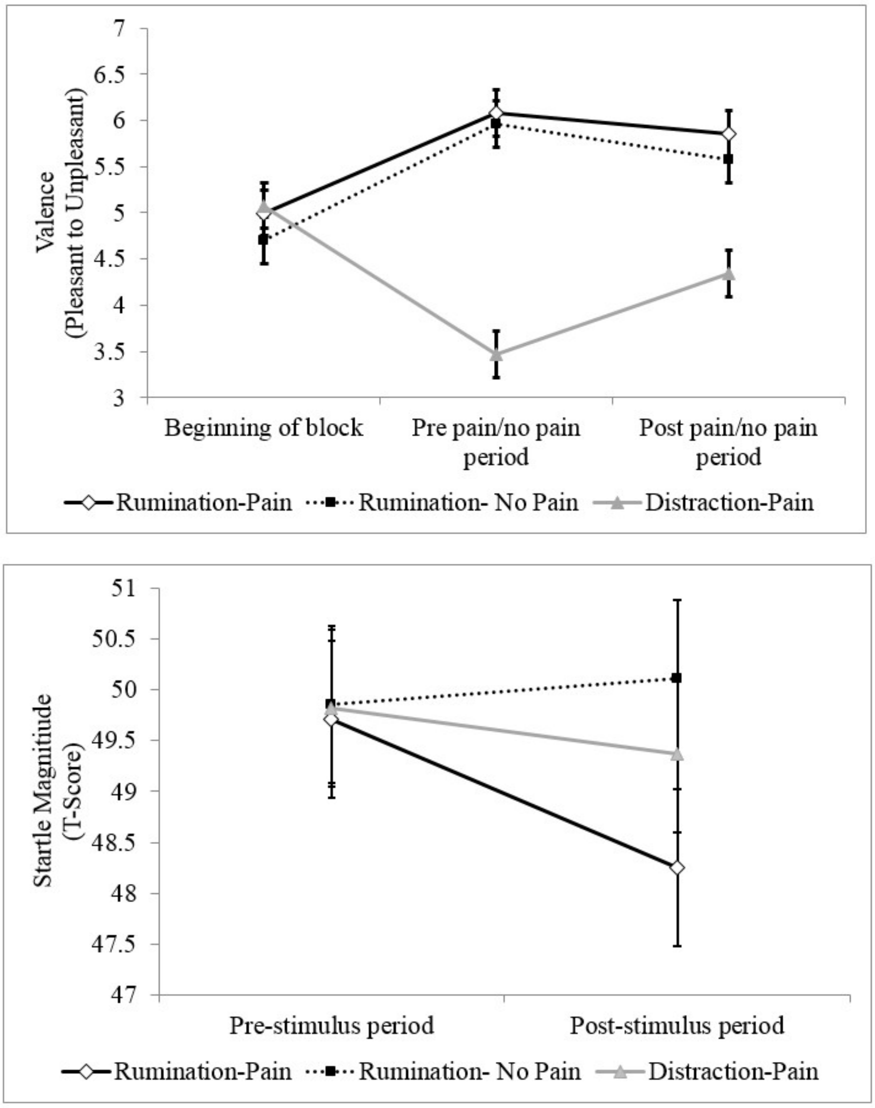

Figure 3: Top Panel: Startle Magnitude (and 95% Confidence Intervals) as a Function of Time and Block Type for Study 2. Bottom Panel: Valence (Pleasant to Unpleasant) as a Function of Time and Block Type Study 2.

Discussion and Study 2

We had two predictions for Study 1. Our main prediction was that during rumination, a painful stimulation would lead to a decrease in NA, whereas a non-painful stimulation would not. This was supported when startle magnitude, but not self-reported unpleasantness, was the measure of NA. During the Rumination-pain block there was a non-significant decrease in startle magnitude following the experience of pain, whereas in the Rumination-no pain block there was a significant increase, suggesting that the experience of pain attenuated the general tendency for defensive mobilization aspects of NA (as indexed by startle magnitude) to increase during rumination. Our secondary prediction was that the decrease in NA following the experience of pain would be larger during ruminative relative to distraction imagery. This was not supported for either dependent measure. Counter to previous studies in the area (e.g., Franklin et al., 2010), we did not find coherence in emotional responding across measures.

Given the novelty of our paradigm and the inconsistent findings across measures, we thought it important to conduct a close replication (cf. Brandt et al., 2014), with some minor enhancements in the methods. First, we shortened the task because of the significant decrease in participant's ability to concentrate during the second set of blocks, which may have reduced the overall effects. Second, we made changes to the past event recall instructions, in the hopes that recalling a more stressful and agitating event would increase the ability for the rumination prompts to increase startle magnitude. Finally, we were concerned that the distraction prompts diverged from the relaxing prompts used in psychophysiological research (e.g., Cuthbert et al., 2003; Vrana, Cuthbert & Lang, 1989). Therefore, in Study 2 the distraction prompts involved relaxation themes.

Method

Participants

The target sample size for Study 2 was the same as Study 1 and based on the same power analysis. However, we collected data until the end of the semester giving us 142 (72 women) undergraduate students who participated for course credit or $16 compensation. This sample had very similar characteristics to the sample from Study 1, with a mean age of 19.28 (*SD* = 2.56) and a racial/ethnic distribution of 44% Caucasian, 27% Asian, 12% Latino or Latina, 10% African American, and 4% other.

From the full sample, 108 participants had useable startle data. 32 participants (22%) were either non-responders (i.e., > 30% of trials without a blink) or had data with excessive noise. Another 8 participants had technical problems (e.g., computer freezing) and were missing physiological data. Thus, we lost slightly more participant data in Study 2 compared to Study 1. Participants not included in the startle analysis did not differ on any study variables from those included in startle analysis (all *p*'s > .05).

Procedure

The procedures for Study 2 were similar to Study 1. Participants completed the pain calibration procedure, recalled a stressful event and completed the rumination task composed of 3 within-subject block types (Rumination-pain, Rumination-no pain, Distraction-pain). Startle and self-reported unpleasantness were collected in the same manner. We did make three key changes to the procedure worth noting. First, we dropped the second set of blocks; thus, each participant completed each of three block types (Rumination-pain, Rumination-no pain, and Distraction-pain) only one time. Order was counterbalanced across participants. Concentration ratings in Study 2 (*M* = 3.41, *SD* = .80) were comparable to those reported by participants during the first set of blocks in Study 1, but somewhat higher (*d* = .22). It is worth noting that this change reduced the number of startle trials available to be averaged for each condition from a maximum of 10 to 5. This also made it so that each block type only had one set of self-reported ratings per participant.

Second, in order to enhance the ability for the rumination prompts to elicit NA, we made changes to the instructions to the recall task. Instead of being told to select a general stressful event, participants were asked to choose an important situation in which they failed to live up to their expectations (e.g., a serious mistake) and caused them serious regret. The goal of this was to help participants pick events that were likely to elicit rumination (e.g., failures, mistakes). Participants were also given 8 rather than 5 minutes to write about the event, in order to help them recall more details. Participants in Study 2 rated their event as more stressful (*M* = 8.77, *SD* = .78) than those in Study 1 with a medium sized effect (*d* = .39), suggesting that the changes to the task enhanced the ability of participants to recall a highly stressful event.

Finally, we used a different set of prompts for the distraction block. This was done to be more in line with other startle imagery studies (e.g., Cuthbert et al., 2003). Specifically, we used low arousal, relaxing prompts (Cuthbert et al., 2003; Vrana et al., 1989; sample prompt "Think about lying on the sand at the beach on a warm day listening to the sound of the waves.").

Results

Startle Response

We followed the same data analytic plan as in Study 1. The omnibus effects for startle were less robust, with none reaching statistical significance: Time, $F(1, 2995) = 2.76$, $p = .096$, *pseudo*-$r^2 = .001$, Block Type, $F(2, 947) = 2.59$, *p*

= .075, *pseudo*-r^2 = .001, Time by Block Type interaction, *F*(2, 3001) = 2.43, *p* = .087, *pseudo*-r^2 = .001. The means for the interaction are displayed in the top panel of Figure 3. Because this was a replication, we still conducted follow-up analyses, even though the omnibus interaction was marginally significant. Similar to Study 1, the startle magnitude during the Pre-stimulus period of the two rumination blocks was not significantly larger than that of the distraction block, *F*(1, 502) = .14, *p* = .704, *pseudo*-r^2 = .000. That is, as in Study 1, rumination versus distraction did not initiate heightened defensive activation in participants.

The pain contrast of Block Type (Rumination-pain versus Rumination-no pain) had a marginally significantly interaction with Time, γ = -.40, *t* = -1.79, *p* = .072, *d* = -.19. Further follow-ups tests showed that consistent with our prediction, and with Study 1, the pattern of results differed for the two rumination blocks. Specifically, there was a significant reduction in startle magnitude from the Pre-stimulus period to the Post-stimulus period in the Rumination-pain block, *t*(3012) = -2.60, *p* = .009, *d* = -.16, whereas there was no significant change in the Rumination-no pain block, *t*(2990) = .46, *p* = .643, *d* = .02. Unlike Study 1, the rumination contrast (Rumination-pain versus Distraction-pain) did not interact with Time, γ = -.04, *t* = -.22, *p* = .825, *d* = -.11, indicating equivalent decreases in startle across the Rumination-pain and Distraction-pain blocks, *t*(2994) = -.80, *p* = .421, *d* = -.04. In summary, although the exact pattern of results involving startle is different from Study 1, and the results were overall weaker, the conclusion is similar. That is, during rumination, the experience of pain decreased startle magnitude in relation to rumination without the experience of pain.

Self-Reported Unpleasantness

For self-reported unpleasantness, the main effects were significant for Block Type, *F*(2, 282) = 132.53, *p* < .001, *pseudo*-r^2 = .18, and Time, *F*(2, 282) = 7.62, *p* < .001, *pseudo*-r^2 = .01, as was the Block Type by Time interaction, *F*(4, 526) = 55.37, *p* < .001, *pseudo*-r^2 = .16. The means are displayed in the bottom panel of Figure 3. As in Study 1, follow-up tests showed that the rumination prompts increased self-reported unpleasantness (*d* = .90) compared to the distraction prompts (*d* = -1.23) from the beginning of the block to before the Pain/no pain period, *F*(1, 708) = 215.41, *p* < .001, *pseudo*-r^2 = .23. Thus, the rumination manipulation increased the subjective experience of unpleasantness across both studies, even though it did not increase startle magnitude.

The Pain contrast by Time (pre Pain/no pain period, post Pain/no pain period) interaction was significant, γ = .23, *t* = 3.08, *p* < .001, *d* = .13. Unlike Study 1, there was a decrease in self-reported unpleasantness in both the Rumination-pain and the Rumination-no pain blocks, *t*’s(709) = -1.42 and -2.53, *p*’s = .154 and .011, *d*’s = -.16 and -.29, although the reduction was significantly larger in the latter. Thus, again the first hypothesis was not supported using self-reported unpleasantness.

The rumination contrast also significantly interacted with Time, γ = .38, *t* = 6.25, *p* < .001, *d* = .88. Unlike Study 1, but more consistent with our second hypothesis, there was a decrease in unpleasantness following pain in the Rumination-pain block (as reported above), whereas there was a significant increase in unpleasantness in the Distraction-pain block, *t*(709.3) = 5.64, *p* < . 001, *d* = .67.

Discussion and Meta-analysis

The goal of Study 2 was to replicate the results of Study 1. Some of the results were the same across the studies. Rumination increased self-reported unpleasantness but not startle magnitude in both studies, showing that ruminative thinking initiated subjective experiences of distress but not defensive mobilization. However, there were some differences in the significance of specific effects across the two studies (e.g., non-significant decrease in startle during the Rumination-pain block in Study 1 and a significant decrease in Study 2). Recently, scholars have questioned whether our expectations for replications are attainable. For example, using simulations, Stanley and Spence (2014) showed that measurement error has a large influence on how likely an effect is to replicate in any given set of studies, even when the effect is true in the population. One way to deal with issues of measurement and sampling error is to use meta-analytic techniques to combine multiple studies (Braver et al., 2014). Simulation work shows that even combining the results from two studies using meta-analysis gives a more accurate estimate of the true effect size than either study alone (Braver et al., 2014). Thus, to enhance our ability to draw conclusions from our data, we conducted a meta-analysis across the two studies.

Results

These analyses were conducted using the difference between means standardized by the square root of the model-based within-subject variance component (cf. Bresin, Finy, Sparague, & Verona, 2014). The variance for the effect size included the correlation between conditions, as is recommended by Dunlap, Cortina, Vaslow, and Burke (1996) for within-subject designs. These analyses were conducted in R (R development Core Team, 2010) using the metafor package (Viechtbauer, 2010). We computed the point estimates and 95% confidence intervals based on random effects models with restricted maximum likelihood estimation, as is recommended in the literature (Braver et al., 2014). We also examined the test for heterogeneity of effect sizes, which tests the null hypothesis that the effects sizes come from the same distribution versus the alternative that the effect sizes come from more than one distribution (Braver et al., 2014). This test helped us determine whether the differences in the effect sizes between our studies were more than expected by chance.

Startle.

We examined our first hypothesis by comparing the effect size and 95% confidence intervals for the change from the Pre-stimulus period to the Post-stimulus period in the Rumination-pain and the Rumination-no pain blocks (pain contrast). Across the two studies, the decrease in startle magnitude within the Rumination-pain block was small and negative, though not significantly different from zero (d = -.10, 95% CI [-.26, .05]). The effect size for the Rumination-no pain block was positive and not significantly different from zero (d = .06, 95% CI [-.07, .20]). The two effects were marginally different from each other (p = .095). Given that the point estimates are opposite in sign, our primary hypothesis that pain would disrupt the link between rumination and startle has some support across the two studies. This support is modest, however, because the effects are not significantly different from each other.

We examined our second hypothesis by comparing the intervals for the change in startle from the Pre-stimulus to the Post-stimulus period in the Rumination-pain and the Distraction-pain blocks (rumination contrast). Across the two studies, there was a small non-significant decrease in startle magnitude in the Distraction-pain block (d = -.06, 95% CI [-.22, .08]). The large overlap between the confidence intervals between both pain blocks indicates that they are not significantly different from each other. It is also worth noting that, in all cases, the tests for heterogeneity were not significant (p's range from .551 to .793), suggesting that despite the differences between the studies, each pair of effect sizes (e.g., Rumination-pain Study 1 and Rumination-pain Study 2) came from the same population of effect sizes.

Self-reported unpleasantness.

We repeated the same steps above with self-reported unpleasantness as the dependent variable and time as before the Pain/no pain period and after the Pain/no pain period. Inconsistent with previous studies (Bresin et al., 2010; Bresin & Gordon, 2013), there was no significant decrease in rumination-related unpleasantness following painful stimulation (d = -.04, 95% CI [-.28, .18]), but there was a decrease following non-painful stimulation (d = -.40, 95% CI [-.58, -.22]). Despite the overlapping intervals, these effects were significantly different from each other (p = .039). Thus, there was little evidence to support our first hypothesis when NA was measured with self-report across the studies.

For our second hypothesis, we again compared the change in the Rumination-pain block (see above) and the Distraction-pain block. Counter to the absence of change in the Rumination-pain block, there was a significant increase in unpleasantness in the Distraction-pain block (d = .60, 95% CI [.47, .72]). Given that the confidence intervals did not overlap, this suggests that although rumination-related unpleasantness did not decrease following pain, unpleasantness in the distraction condition increased following pain. For self-reported unpleasantness, the heterogeneity test was not significant for the Rumination-no pain and the Distraction-pain blocks (p's .122 and .358). It was significant for the Rumination-pain block, $Q(1) = 5.74$, p = .016, suggesting that the effect sizes significantly differ between the two studies.

Discussion

The goal of this meta-analysis was to quantitatively combine the seemingly discrepant results from the two studies. In terms of our first hypothesis that during rumination, pain leads to a reduction in NA compared to non-painful stimulation, we found modest support for startle magnitude and no support for self-reported unpleasantness. In terms of our second hypothesis, there was no evidence of the reduction in NA following pain being larger during rumination compared to distraction, although there was evidence that self-reported unpleasantness may increase following pain in distraction. Finally, it is worth noting that in all cases but one (i.e., Rumination-pain for self-reported unpleasantness) the test for heterogeneity of the effect size was not significant, suggesting that despite the numerical differences in the effect sizes across studies, each effect (e.g., Rumination-pain for startle) from the two studies likely came from the same population of effects. In sum, the meta-analysis allowed us to provide a more reliable estimate of effects and pattern of findings, from which we base our overall conclusions in the General Discussion.

General Discussion

In hopes of enhancing the understanding of the mechanisms of how pain affects NA, the goal of this set of studies was to test whether pain disrupts the impact of ruminative thinking on NA (cf. Selby & Joiner, 2009). These studies made use of a novel experimental paradigm based on methods used in previous research (e.g., Bresin & Gordon, 2013; Franklin et al., 2010; Nolen-Hokesema & Morrow, 1993) and took advantage of having large samples, multi-method assessment of emotion, and meta-analytic techniques to consolidate the results of our two studies.

We had two predictions, which received mixed support. We partially supported our first prediction that during rumination, a painful but not non-painful stimulation would lead to a decrease in NA, but only for startle magnitude (and only a small effect size) and not self-reported unpleasantness. Our second prediction that the decrease in NA following pain would be larger during ruminative relative to distraction imagery was not supported for either dependent measure. Though the results did not cleanly support the predictions, these studies contribute to our understanding of the effect of pain on emotion and possibly have some implications for understanding harmful dysregulated behaviors, like NSSI.

Startle Results

The meta-analyzed effects indicated a small decrease in the Rumination-pain block and little to no change in the Rumination-no pain block, supporting the predicted distinction between the two blocks, although these effects were only marginally different from each other. These results may add to the literature in a number of ways. First, these results provide modest experimental support for a previously untested tenet of the emotional cascade theory (Selby & Joiner, 2009), indicating that further research, possibly in clinical samples, would be meaningful and clarify whether these findings generalize to understanding extreme behaviors like NSSI. Second, our methodology is an advancement on previous pain-affect studies using psychophysiological measures, in that we used clear focal stimuli (i.e., prompts versus preparing for a speech). The standardized way in which we induced rumination and NA makes the results more interpretable, although it may have also resulted in smaller effect sizes.

Based on our meta-analytic results, we found little support for our second hypothesis, in that startle magnitude following the experience of pain decreased in both the rumination and distraction conditions. One plausible explanation is that the experience of pain reduces the amount of resources available for cognitive processes (Selby & Joiner, 2009; also see Eccleston & Crombez, 1999). If that is the case, it is possible that the experience of pain reduced attentional focus to the startle probe itself during the Post-stimulus period, which in turn reduced startle magnitude due to attentional but not emotional reasons. Future research could use event-related potentials (e.g., P300 to the startle probe) to test this explanation. Another possibility is that participants were ruminating during the distraction blocks, which could have obscured differences between the two blocks. Measurement of state rumination would be necessary to rule out this possibility.

Reconciling Startle Magnitude and Self-reported Unpleasantness Results

The results for NA as indexed by startle magnitude and self-reported unpleasantness diverged in a number of ways across our studies. First, in both of our studies, the rumination induction did not increase startle magnitude compared to distraction, but did increase self-reported unpleasantness. Second, there was divergence in the change in NA following the experience of pain across modalities in both studies. For example, the Distraction-pain block resulted in a decrease in startle, indicating a reduction in NA, but an increase in self-reported unpleasantness, indicating an increase in NA. Although counter-intuitive, these differential findings across startle and subjective reports are consistent with a broader literature showing the lack of coherence in the emotional response across components of emotion (e.g., Evers et al., 2014; Mauss et al., 2004).

Using the framework provided by Evers et al. (2014), one interpretation of the lack of convergence is that affective manipulations and pain manipulations influence different aspects of the two emotional systems (reflective and automatic). More specifically, it is possible that the rumination (versus distraction) manipulation in our studies had a larger effect on increasing self-reported unpleasantness (relative to startle magnitude) because rumination requires the reflective aspects of cognition (Nolen-Hoeksema et al., 2008), of which experiential aspects of emotion are outputs. In contrast, the experience of pain may have had a larger (or more unique) effect on startle magnitude (relative to self-reported unpleasantness) because emotional reactions to pain utilize the automatic aspects of emotion (Eccleston & Crombez, 1999), of which the startle reflex, involving defensive mobilization, is one of the outputs. This explanation could be tested in future studies by examining whether the results for self-reported unpleasantness replicate for other aspects of the reflective emotional system (e.g., behavior) and the startle results replicate for automatic aspects of emotion (e.g., skin conductance).

Another possibility is that coherence across components of emotion may be attenuated under low arousal conditions (Mauss et al., 2004). The rumination manipulation we used likely did not induce emotional intensity high enough for convergence across psychophysiological and experiential aspects to occur. This could be tested in future studies by comparing multiple inductions eliciting varying levels of emotional intensity, as has been done in previous work (Lang & Bradley, 2010) and can be applied to the study of NA reductions following pain.

A final possibility is that our measure of self-reported unpleasantness may not have been precise enough to capture experiential changes in affect. Previous studies that have found effects of pain on experiential aspects of emotion have used scales like the Positive and Negative Affective Schedule, which mostly measure valence at high levels of arousal (Watson, Clark, & Tellegen, 1998; Watson, Wiese, Vaidy, & Tellegen, 1999), whereas our scale only measured valence. Other scales also have more coverage of different emotional experiences (e.g., shame, hostility). If pain affects some negative emotions more than others, our general measure of unpleasantness may not have captured this. This may explain why our self-report results differ from studies using other self-report measures, a possibility that could be tested in future research.

Limitations and Conclusions

In interpreting our results, there are a number of limitations that should be considered. First, this was not a clinical sample; therefore, generalizations about how these results may apply to clinical samples are as of yet tenuous. There are reasons to assume that these results would generalize to clinical samples. First, given that previous research has not found a difference in the effect of pain on emotion between clinical and non-clinical samples (Bresin & Gordon, 2013), it is likely that these results would generalize to individuals with high levels of borderline traits. In fact, it is possible that the effects could be stronger in clinical samples, because a meta-analysis found the rumination inductions increase NA more for clinical than non-clinical samples (Mor & Windquist, 2002). Although there are reasons to assume that the results would generalize, these assumptions need to be explicitly tested. Second, some of our statistical tests did not reach statistical significance, which possibly indicates insufficient statistical power. Though we chose our sample size based on a priori power, the size of the effects was smaller than the predicted medium effect size based on previous studies. Also, in trying to remedy problems with decreased concentration across repetitions of blocks in Study 1, we reduced the number of trials in Study 2, which inadvertently decreased the precision of our estimates of effect size. We did combine our results across the two studies to enhance our ability to draw conclusions. Still, our results were not particularly strong and more replications are necessary. Finally, as mentioned previously, there was dramatic divergence across our psychophysiological and self-report results, making the results difficult to interpret. However, we feel that this also provides an opportunity for understanding nuances in the psychological processes involved in the affect regulation properties of pain. Overall, we feel that this paradigm from our study could be used to study the effects of pain in clinical and nonclinical samples alike with more precision and allowing for use with various measures of emotion.

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