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The effects of self-injury on acute negative arousal: A laboratory simulation

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Abstract Research suggests that performance of non-suicidal self-injury (NSSI) is associated with the reduction of high-arousal negative affect. The present study examined this phenomenon in a laboratory setting. Individuals with a history of NSSI ($n = 39$) and non-NSSI controls ($n = 33$) underwent an anger induction, and were randomized to self-administer either a high level of electric shock, or a mild shock (control condition) to their upper arm. Consistent with previous research, injurers displayed greater pain analgesia than controls. Contrary to expectations, high shock did not result in enhanced arousal reduction for injurers. However, the high shock led to greater arousal reduction for injurers than controls. Notably, in the high shock condition, higher levels of electrical stimulation (i.e., voltage administered) predicted greater reductions in negative arousal, whereas higher subjective ratings of pain predicted smaller reductions in negative arousal. This pattern suggests that more intense self-inflicted pain facilitates reduction of negative arousal provided the subjective experience of pain is not too aversive. Findings help clarify emotion-regulation models of NSSI.

Keywords Non-suicidal self-injury · Emotion regulation · Pain analgesia · Shock

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Introduction

Non-Suicidal Self-Injury (NSSI) is defined as the deliberate and direct destruction of/injury to one's body without suicidal intentions and not for socially-sanctioned purposes (e.g., Herpertz 1995; Klonsky 2007; Muehlenkamp 2005). Self-injury is a growing public health concern due to its typically young age of onset—between 13 and 16 years of age (Muehlenkamp and Gutierrez 2004; Rodham et al. 2004)—and increasing frequency in the population (Jacobson and Gould 2007; Ross and Heath 2002; Whitlock et al. 2006). Between 1 and 4% of adults and 13–23% of adolescents report a lifetime history of NSSI (Jacobson and Gould 2007). NSSI is also associated with many adverse psychiatric outcomes, including anxiety, depression, borderline personality disorder (BPD), and suicidality (Andover et al. 2005). Yet despite its prevalence and significant public health impact, there is still much about the behavior's nature and functions that remains poorly understood, making its occurrence difficult to predict, even in populations identified as at-risk.

The affective context in which NSSI is most likely to occur appears to be an important avenue for investigation. Recent research suggests that emotional experience plays a critical role in determining who self-injures and why. Self-injurers appear to experience more frequent, intense, and dysregulated negative emotions in their daily lives than individuals who do not self-injure (Andover et al. 2005; Gratz and Roemer 2008; Klonsky et al. 2003; Najmi et al. 2007; Nock et al. 2008). There is also increasing evidence for psychophysiological abnormalities suggestive of disordered emotional experience in individuals who self-injure (e.g., Crowell et al. 2005; Nock and Mendes 2008; Sachsse et al. 2002). For instance, hyperactivity of the hypothalamic-pituitary (HPA) axis in self-injurers has been proposed (Sachsse et al. 2002), as well as increased

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sympathetic nervous system (SNS) activity in self-injurers compared to controls (Nock and Mendes 2008). Additionally, there is evidence for decreased parasympathetic nervous system (PNS) activity at rest in self-injurers as compared to controls (Crowell et al. 2005), suggesting deficits in systems related to recovery of homeostasis following arousal. Taken together, these studies suggest that self-injurers are physiologically hyperreactive to stressors, corresponding to self-report of emotional hyperreactivity, and that they may have subsequent difficulty regulating this physiological response.

It appears that this emotional hyperreactivity and subsequent difficulty regulating emotional experience may in fact be a primary reason for self-injury, as self-injury has been shown to quickly alleviate emotional distress, at least in the short term (e.g., Chapman et al. 2006; Klonsky 2007, 2009; Nock et al. 2009). While studies examining the functions of self-injury indicate that the behavior can serve a number of different purposes–including self-punishment, exerting control over others, preventing or halting dissociative episodes, resisting the urge to attempt suicide, and sensation-seeking—regulating negative affect is the function most frequently reported by those who self-injure (Briere and Gil 1998; Brown et al. 2002; Herpertz 1995; Kemperman et al. 1997; Shearer 1994 for a review see Klonsky 2007).

The affect-regulation function of self-injury is further clarified by research demonstrating that high-arousal negative affective states, such as anxiety, frustration, anger, tension, and agitation tend to decrease following self-injury, while specific low-arousal positive affective states, including relief and calm, increase (Klonsky 2007, 2009). Further, the magnitude of change in these negative arousal states after self-injury strongly predicts lifetime frequency of self-injury, suggesting the behavior is negatively reinforced (Klonsky 2009). This pattern of increased negative arousal preceding self-injury followed by decreased negative arousal subsequent to self-injury has been reported in other studies as well (e.g., Claes et al. 2010; Muehlenkamp et al. 2009; Nock et al. 2009). Taken together, these findings suggest a causal link between self-injury and a reduction in negative emotional experience.

However, a considerable limitation of many studies that have attempted to examine change in emotional states pre- and post-self-injurious behaviors is the reliance on retrospective self-report, in that it may be difficult for people to report accurately on emotions or complex mental processes experienced in the past (Nisbett and Wilson 1977). In addition, retrospective self-report cannot establish a causal link between self-injury and the reductions in negative arousal reported by self-injurers. For example, it is possible that self-injurers engage in self-injury at the peak of an intense emotional experience—an experience whose intensity must necessarily decrease—and that the self-injury is merely concurrent with the decrease, not causal.

An experimental model would allow for causal inferences as well as examination of changes in emotional state in real time. A few studies have examined self-injury under controlled, laboratory conditions. Some have utilized self-injury imagery as a proxy for self-injury (Brain et al. 1998, 2002; Haines et al. 1998; Welch et al. 2008) and found that heightened negative arousal was reported prior to self-injury imagery, followed by reductions in arousal and negative affect subsequent to self-injury imagery. This was not observed in response to control imagery (e.g., accidental injury, an angry interaction, or a low-arousal neutral event).These studies represent the best causal evidence to date for the effects of self-injury on negative affect. At the same time, important methodological limitations should be noted. First, imagining a past episode of self-injury may not be an effective proxy for a behavior which depends largely on physical experience, and the accuracy of recall for the complicated chain of mental events preceding and accompanying self-injury may be limited (Nisbett and Wilson 1977). Second, simply recalling the chain of events preceding and following an incident of self-injury does not eliminate the possibility of the confound described previously, that if self-injury (or its proxy) occurs at the peak of an overwhelming emotional experience, subsequent decrease in emotional intensity may or may not be due to the self-injury. Further, in many of the studies cited above, the control imagery did not match the self-injury imagery on subjective ratings of emotional response; including imagery of an equally arousing and negative emotional experience that was *not* followed by self-injury might have better allowed for stronger causal inferences. Finally, in some studies, self-injury imagery was not presented to controls, making it difficult to determine whether the experience of self-inflicted pain might confer benefits that are specific to individuals with a history of self-injury and not to non-injuring controls (e.g., Bresin et al. 2010; Hollin and Derbyshire 2009). Indeed, there has been very little research on the effect of self-injury proxies on controls.

One other laboratory study provides evidence suggestive of a causal link between self-injury and reduced negative arousal. Russ et al. (1992) utilized a cold pressor task (immersing hands in chilled water) as a proxy for self-injury, and showed that BPD patients with a history of self-injury exhibited significant reductions in self-reported negative affective states (e.g., depression, anxiety, anger) following the cold pressor task. While this is consistent with affect-regulation models of self-injury, and avoids the problems associated with retrospective imagery, in this study the cold-pressor task was administered to all participants. The lack of a control condition again makes it difficult to evaluate causality.

Additionally, this study included a group of non-injuring controls, who exhibited a similar pattern (though non-significant) of reduction in negative arousal in response to the self-injury proxy as self-injurers. It is possible that the same mechanism that reduces negative arousal in self-injurers may be present in controls (Russ et al. 1992), but it is also possible that controls may differ in systematic ways from injurers (e.g., higher pain sensitivity) such that the aversive nature of pain may outweigh or mask the emotional benefits.

The present study was conceived to address the gaps in the literature described above, and to establish a causal link between self-injury and subsequent reductions in negative arousal. Therefore, in the present study, an anger mood manipulation was used in order to simulate the high-arousal, high negative-affective emotional states known to precede and diminish following self-injury (Klonsky 2009). Following this mood manipulation, participants (both self-injurers and non-injuring control participants) self-administered a shock to their upper arm. Half the participants were randomly selected to shock themselves at a level of shock they had previously determined to be "painful but still tolerable" (self-injury condition) and half received a low level of shock that was only slightly perceptible (control condition). Shock was selected as a suitable proxy for self-injury because it is both a sharp and relatively localized sensation. Based on the previous work described above (Klonsky 2009), we hypothesized that the self-injury proxy (i.e., strong self-administered shock to the upper arm) would cause a greater reduction in negative arousal in self-injurers than the low shock in the control condition. We also included participants without a history of self-injury as a control group, but our hypotheses here are necessarily speculative. As noted above, one possibility is that non-injuring controls would *also* experience a reduction in negative arousal in the high shock condition. An alternate possibility is that this group would experience no change following the self-injury proxy, and that only the controls in the low-shock condition would report reduced negative arousal. Finally, for both groups of participants in the high shock condition we examined the relationships of (a) shock magnitude and (b) subjective pain to reductions in negative arousal. We expected higher shock magnitude to facilitate greater arousal reduction, but subjective experience of pain to block or dampen arousal reduction.

Method

Participants

Forty-one participants with a history of self-injury were recruited over the course of two semesters from a screening of 875 college students in lower-level psychology classes participating in research for course credit. The screening consisted of items from the Inventory of Statements about Self-Injury (ISAS; Klonsky and Glenn 2009; Klonsky and Olino 2008), in which participants were asked about the frequency with which they had engaged in self-injurious behaviors "intentionally (i.e., on purpose) and without suicidal intent." Participants were emailed and invited to participate in the study if they (a) endorsed any history of cutting and/or endorsed engaging in any other self-injurious behavior five times or more, and (b) endorsed at least one function of self-injury on the ISAS (Klonsky and Glenn 2009). This operational definition of clinically relevant self-injury is consistent with the proposed DSM-V definition which stipulates a minimum of five episodes performed "with a purpose," and with an intention to inflict bodily harm or cause pain, but without the intent to die (http://www.dsm5.org/ProposedRevisions/Pages/proposedrevision.aspx?rid=443). In addition, thirty-eight undergraduate participants who endorsed no history of any self-injury on the same screen were recruited to comprise the control sample.

Six participants (two self-injurers) reported on a manipulation check experiencing no effect of the mood manipulation and so were excluded from analyses. The final sample was therefore seventy-two participants (46 female), consisting of 39 self-injurers (29 female), and 33 controls (17 female). Mean age of the final sample was 20.24 (SD = 2.22). Regarding ethnicity, 52.8% of participants were Caucasian, 26.4% were Asian/Asian-American, 11.1% were African-American, 8.3% were Latino/Hispanic, and 1.4% were "Other."

Procedure

Questionnaires assessing demographic characteristics were administered prior to the experimental protocol. The protocol consisted of several stages, described below (see Fig. 1 for an illustration of the protocol).

Shock selection. Participants were first asked to choose a level of shock that was "painful but still tolerable" for them. Two electrodes were affixed parallel to the outside upper portion of the participant's non-dominant arm, and participants were asked to use their dominant hand to hold the manual control which would deliver the shock. Shock was delivered to the participants' upper arms, as arms are the most frequent parts of the body targeted by self-injury (Whitlock et al. 2006). An experimenter who was blind to the participants' NSSI history explained that the sensation would begin at a very low level of shock and would increase until the participant decided the sensation was appropriate, and that participants would maintain manual control over the shock at all times. Participants were asked

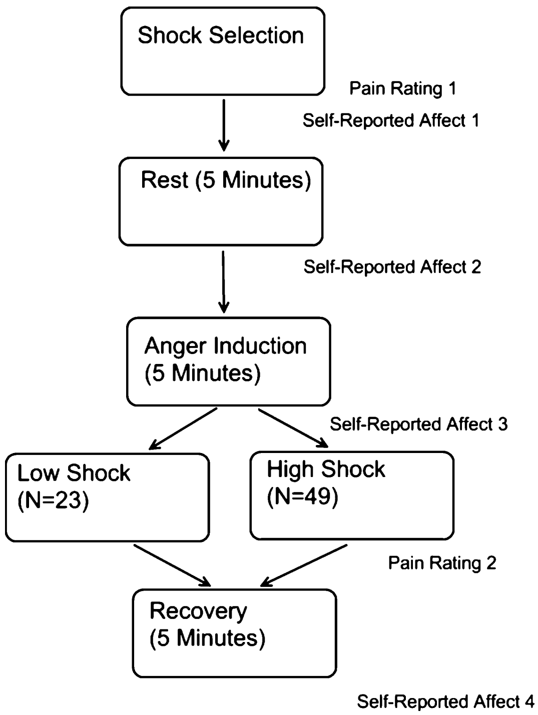

Fig. 1 A sample trial from the task. All participants participated in the shock selection, rest, anger induction, and recovery periods. Self-injurers and non-injurers were randomized to either the low shock or high shock conditions. Self-reported ratings of pain and affect were collected between some tasks in the protocol

to self-administer each shock for 5 s, which was counted out by the experimenter. The shock selection procedure began with no voltage delivered. After each shock the participant was asked if the intensity could be increased. Provided the participant consented to go higher, the level was raised by increments of .7 V. When the participant selected a level of shock that was painful but still tolerable, and expressed a preference to no longer increase the intensity of the shock, the experimenter recorded the level of shock selected. Next, the participant rated how painful the highest level of shock was for them on a scale of one to ten, with one being not at all painful and ten being the most pain they had ever experienced. They were then asked to rate how they were feeling on the Self-Assessment Manikin (SAM; Lang 1980; self-reported affect time one). After the ratings, the next stage involving the mood manipulation and self-administered shock began.

First, participants were asked to sit quietly for 5 min in order to decrease any impact on their affective state that setting the shock levels may have had. Participants were instructed to simply sit still and relax, while keeping their eyes open and focused on a blank computer screen in front of them. At the end of 5 min, they were again asked to rate how they were feeling (self-reported affect time two). Following this, participants were instructed in the mood induction. For the mood induction, participants were asked to write for 5 min about an incident in which they had become "extremely angry." Participants were instructed to type their responses into a text box displayed on a computer. Specifically, participants were instructed to "try to re-experience the emotions you experienced as the event unfolded. Focus on the feelings and the visceral responses the event triggered, as if you were an actor trying to communicate the emotional drama of your experience. Really delve into your deepest feelings and the sensations you experienced during the event. How did your heart beat? How did your face feel? What sensations did you feel? Let yourself feel the event as if you were right there, reliving it and re-experiencing it." At the conclusion of the writing task, participants were again asked to rate how they were feeling (self-reported affect time three). A manipulation check demonstrated that the writing task was effective at changing self-reported mood. The mean increase in arousal from time two to post-anger-manipulation was ($M = 2.02$, SD $= 1.94$; $t(69) = 11.31$, $p < .001$; Cohen's $d = 1.30$). The mean increase in negative valence from time two to post-anger-manipulation was ($M = 1.08$, SD $= 1.91$; $t(69) = 11.03$, $p < .001$; Cohen's $d = 1.18$).

Next, participants were asked to self-administer the shock four times for 5 s each time, with 3 s separating each shock. Again, the experimenter counted out the 5 s. Half of the participants in each group (self-injurers and controls) received the shock at the level they had previously selected (high shock condition). The other half received a *lower* level of shock than the one they had previously selected (2 V; low shock condition). After the shock, participants were again asked to rate how painful the shock had been on a scale of one to ten (pain rating two). Six participants initially randomized to the Low Shock condition chose not to go above the 2 V level of shock during the initial shock selection phase. Because these participants effectively received their highest selected level of shock during the experimental shock phase, these participants were included in the High Shock condition for analytic purposes.

Finally, the participants were given a 5-min "recovery" period; as in the resting stage, they were asked to simply sit still and relax, while keeping their eyes open and focused on a blank computer screen in front of them. At the conclusion of 5 min, participants were again asked to rate how they were feeling (self-reported affect time four). Finally, participants were debriefed and exited the study.

Measures

Inventory of statements about self-injury (ISAS; Klonsky and Glenn 2009; Klonsky and Olino 2008). The ISAS assesses lifetime frequency of 12 NSSI behaviors performed "intentionally (i.e., on purpose) and without suicidal intent." Participants are asked to estimate the number of times they have performed the following behaviors: cutting, burning, severe scratching, banging/hitting self, biting, carving, wound picking, needle-sticking, pinching, hair pulling, rubbing skin against rough surfaces, and swallowing chemicals. Additional questions assess descriptive and contextual factors, including age of onset, most recent incident of self-injury and whether the individual wants to stop self-injuring. The behavioral scales have demonstrated good reliability and validity (Klonsky and Olino 2008).

In the present study, participants endorsing one or more of the behaviors listed above were instructed to complete the second section of the ISAS, which assesses 13 potential functions of NSSI: anti-suicide, autonomy, affect-regulation, anti-dissociation, interpersonal boundaries, interpersonal influence, marking distress, peer-bonding, self-care, self-punishment, revenge, sensation seeking, and toughness. Three items corresponded to each function. For example, a sample affect-regulation item is, "When I self-harm I am releasing emotional pressure that has built up inside of me." Participants rated each item on the following scale: 0 "not relevant," 1 "somewhat relevant," and 2 "very relevant" to the individual's "experience of self-harm"; thus, scores for each of the 13 ISAS functions can range from 0 to 6.

Depression anxiety stress scales (DASS-21; Henry and Crawford 2005). The DASS-21, a shortened version of the original 42-item measure (Henry and Crawford 2005), includes three 7-item scales measuring depression, anxiety, and stress. Participants indicate how much each statement applied to them over the *past week* on a 4-point likert scale from 0 = *Did not apply to me at all* to 4 = *Applied to me very much, or most of the time*. The DASS-21 has demonstrated excellent internal consistency (*Mean* $\alpha = .90$) and has been shown to better distinguish features of depression and anxiety than other existing measures (e.g., Beck Depression and Anxiety Inventories; Lovibond and Lovibond 1995).

Borderline symptom list (BSL-23). The BSL-23 (Bohus et al. 2009) is composed of 23 items that asks participants to rate how much they have suffered from 23 problems in the *last week* on a scale from 0 = *not at all* to 4 = *very much*. Sample items from the BSL are: "I wanted to punish myself," "My mood rapidly cycled in terms of anxiety, anger, and depression," "The idea of death had a certain fascination for me," and "I felt disgusted by myself." The BSL was translated by its authors from German to English (Bohus et al. 2007). The short-form of the English version of the BSL has shown robust correlations with BPD assessed by semi-structured interview (Glenn et al. 2009).

McLean screening instrument for borderline personality disorder (MSI-BPD; Zanarini et al. 2003). The MSI-BPD is a self-report measure of the DSM-IV BPD criteria. When compared to a validated structured interview, sensitivity and specificity of the MSI-BPD were both above .90 in a sample of young adults (Zanarini et al. 2003).

The difficulties in emotion regulation scale (DERS; Gratz and Roemer 2004), a 36-item, six-scale self-report measure designed to assess clinically relevant difficulties in emotion regulation, was utilized to evaluate emotion dysregulation. The subscales include nonacceptance (e.g., "When I'm upset, I become angry with myself for feeling that way."), goals (e.g., "When I'm upset, I have difficulty focusing on other things."), impulse (e.g., "When I'm upset, I become out of control."), awareness (e.g., "I pay attention to how I feel."), strategies (e.g., "When I'm upset, I know that I can find a way to eventually feel better."), and clarity (e.g., "I have difficulty making sense out of my feelings."). Participants indicate on a likert scale how often each item applies to themselves, with responses ranging from 1 (almost never) to 5 (almost always). The DERS has demonstrated good internal consistency, test–retest reliability, and construct validity (Gratz and Roemer 2004; Tull and Roemer 2007), and has been validated for use in both adults (Gratz and Roemer) and adolescents (Weinberg and Klonsky 2009).

The self-assessment manikin (SAM; Lang 1980) is a visual analog scale, consisting of an "arousal" and a "valence" scale. The SAM arousal scale consists of five characters depicting a range of visceral responses from calm to excited; the numbers 1 through 9 are presented below the characters, with 1 corresponding to a strong bodily response (e.g., stimulated, jittery, wide-awake) and 9 corresponding to no bodily response (e.g., relaxed, calm, dull, sleepy). Participants were asked to rate only their level of arousal on this scale, rather than the affective quality of their response. The valence scale also consists of five characters depicting a range from happy to unhappy, with the numbers '1' through '9' again presented below the characters. The number '1' corresponds to the happiest figure, and '9' corresponds to the most unhappy figure. Participants were instructed to use this scale to rate the extent to which they felt pleasant or unpleasant emotions. On both of the scales, '5' represented the midpoint, and participants were encouraged to use any point on the scale. For presentation purposes here, the arousal ratings have been reverse-coded so that a score of 9 represents highly unpleasant valence and high arousal. Because we make specific predictions regarding reductions in negative arousal, difference scores were computed for post-anger induction and post-self-administered shock for both valence and arousal. These difference scores were then summed.

Results

Descriptive characteristics of self-injury

Among the self-injurer group, 20 individuals (54.1%) had injured within the past year of their participation in the experiment. The mean age of onset was 13. The median frequency of any form of self-injury was 23 times. The most common behaviors endorsed were cutting (66.7% endorsed at least once), severe scratching (53.1% endorsed at least once), banging/hitting self (59.9% endorsed at least once), and interfering with wound healing (45.2% endorsed at least once). Thirty-one individuals (79.5%) endorsed utilizing more than one method in their lifetime, and 13 (33.3%) endorsed utilizing more than five methods in their lifetime.

The most frequently endorsed function in the present sample of self-injurers was affect regulation (95%), followed by self-punishment (82%),followed by marking distress (74%). The frequency of the remaining functions is as follows: Anti-dissociation (64%), anti-suicide (41%), autonomy (34%), interpersonal boundaries (41%), interpersonal influence (32%), peer-bonding (0%), self-care (36%), revenge (15%), sensation seeking (18%), and toughness (51%).

Differences between self-injurers and controls on clinical measures

Independent *t* tests were conducted to determine whether there were any differences between injurers and non-injurers on clinical variables. As expected, injurers endorsed significantly higher levels of depression, anxiety, stress, and BPD symptoms as well as greater overall difficulties with emotion regulation (see Table 1 for means and significance testing). Notably, injurers and non-injurers did *not* significantly differ on two subscales of the DERS; Awareness and Clarity.

Levels of shock and self-reported pain

Additional independent *t* tests were used to examine whether injurers and non-injurers differed in the level of shock selected as "painful but still tolerable." Indeed, injurers selected significantly higher levels of shock ($t(70) = 1.99$, $p < .05$; $M = 4.18$, SD = 1.94) than non-injurers ($M = 3.40$, SD = 1.14). Notably, however, though they selected and received higher levels of shock, injurers did *not* report significantly greater subjective levels of pain ($t(70) = .59$, $p = .56$; $M = 4.86$, SD = 1.94) than non-injurers ($M = 5.12$, SD = 1.80) after receiving the shock at time one. Because the balance of males and females in each group was not identical, differences between genders were also examined: Males ($M = 3.72$, SD = 1.37) and females ($M = 3.90$, SD = 1.81) did not differ in the level of shock selected ($t(70) = .44$, $p = .66$), nor in their subjective levels of pain at time one ($t(70) = .01$, $p = .99$; males: $M = 4.98$, SD = 2.02; females: $M = 4.98$, SD = 1.80). All subsequent analyses were then conducted with and without gender as a covariate.

Table 1 Clinical characteristics of self-injurers as compared to controls

Measure	Self-injurers Mean (SD)	Controls Mean (SD)
BSL-23	54.68 (25.09)***	32.33 (10.37)
MSI-BPD	15.28 (2.94)***	12.97 (2.62)
DASS-depression	15.67 (6.44)***	9.88 (2.95)
DASS-anxiety	12.10 (4.67)*	9.78 (3.36)
DASS-stress	15.72 (5.47)***	10.91 (3.56)
DERS SUM	97.11 (31.26)**	76.50 (21.08)
DERS nonacceptance	15.79 (8.43)**	10.88 (5.40)
DERS goals	17.15 (5.23)**	13.81 (5.01)
DERS impulse	13.87 (7.57)*	10.85 (4.64)
DERS awareness	15.20 (5.85)	15.55 (4.82)
DERS strategies	21.21 (9.12)***	14.39 (5.98)
DERS clarity	12.54 (4.32)	11.55 (3.68)

* Indicates differences significant at $p < .05$, ** indicates differences significant at $p < .01$, and *** indicates differences significant at $p < .001$

We also wanted to examine how group (self-injurer vs. controls) and condition (high vs. low shock) influenced subjective ratings of pain from the second shock, experienced following the mood induction. Thus, a 2 (group) × 2 (condition) ANOVA was conducted. Self-report of pain varied by group, ($F(1, 68) = 7.56$, $p < .01$; $\eta_p^2 = .10$), such that self-injurers reported less pain overall ($M = 3.15$, $s_M = .34$) than controls ($M = 4.51$, $s_M = .36$). Self-report of pain also varied by condition ($F(1, 68) = 20.68$, $p < .001$; $\eta_p^2 = .23$), such that individuals in the low shock condition reported less pain overall ($M = 2.71$, $s_M = .41$) than individuals in the high shock condition ($M = 4.96$, $s_M = .28$). However, the effect of shock condition varied by group ($F(1, 66) = 6.14$, $p < .05$; $\eta_p^2 = .08$; See Fig. 2), such that, though there was no significant difference between self-injurers in the high shock condition ($M = 4.89$, $s_M = .38$) and controls in the high shock condition ($M = 5.02$, $s_M = .42$), self-injurers in the low shock condition rated the shock to be less painful ($M = 1.42$, $s_M = .56$) than controls in the same condition ($M = 4.00$, $s_M = .59$; See Fig. 1). When gender was included as a covariate, the results were nearly identical. There was no effect of gender, ($F(1, 67) = .29$, $p = .59$; $\eta_p^2 = .004$), but self-report of pain continued to vary by group, ($F(1, 67) = 7.77$, $p < .01$; $\eta_p^2 = .10$), and by condition ($F(1, 67) = 20.58$, $p < .001$; $\eta_p^2 = .24$).

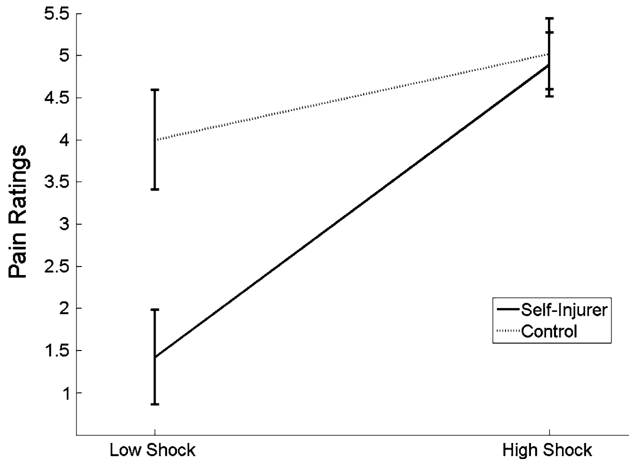

Fig. 2 Self-report of pain experienced during self-administered shock

Furthermore, the effect of shock condition varied by group ($F(1, 67) = 6.03$, $p < .05$; $\eta_p^2 = .08$).

Emotional valence and arousal before shock

Before examining effects of the shock on affective valence and arousal, we wanted to determine whether there were any group differences at any of the first three time points prior to shock and recovery (see Table 2 for means and standard deviations of SAM ratings). Two 2 (group) × 3 (time point; baseline, following rest, following writing task) repeated-measures ANOVAs were used to examine arousal and valence. Though self-reported arousal varied significantly by time ($F(2, 134) = 75.01$, $p < .001$; $\eta_p^2 = .53$), such that participants reported significantly greater arousal following the writing task ($M = 5.99$ SD = 1.88) than following shock selection ($M = 4.13$ SD = 1.85; $t(68) = 7.41$, $p < .001$) or than following the rest period ($M = 3.09$ SD = 1.96; $t(68) = 11.31$, $p < .001$), arousal did not vary as a function of group ($F(1,67) = .04$, $p = .84$; $\eta_p^2 = .001$), nor did the effect of time on levels of arousal vary as a function of group ($F(2, 134) = .62$, $p = .54$; $\eta_p^2 = .01$). Comparing self-injurers to controls at time 3 suggests no group differences in reported arousal immediately following the writing task ($t(68) = .67$, $p = .51$). Including gender as a covariate did not significantly impact these results; specifically, there was no effect of gender ($F(1, 66) = 1.78$, $p = .19$; $\eta_p^2 = .03$), nor did gender interact with time to predict arousal ($F(2,132) = .08$, $p = .92$; $\eta_p^2 = .001$). However, the main effect of time persisted ($F(2, 132) = 44.71$, $p < .001$; $\eta_p^2 = .40$). With gender included as a covariate, arousal still did not vary as a function of group ($F(1,66) = .01$, $p = .92$; $\eta_p^2 = .00$), nor did the effect of time on levels of arousal vary as a function of group ($F(2, 132) = .62$, $p = .54$; $\eta_p^2 = .01$).

Valence also varied as a function of time ($F(2, 134) = 77.19$, $p < .001$; $\eta_p^2 = .55$), such that participants reported significantly greater negative affect following the writing task ($M = 5.80$ SD = 1.64) than following shock selection ($M = 3.77$ SD = 1.60; $t(68) = 10.03$, $p < .001$) or following the rest period ($M = 3.88$ SD = 1.56; $t(68) = 11.03$, $p < .001$). Like arousal, valence did not vary as a function of group ($F(1,67) = 3.33$, $p = .07$; $\eta_p^2 = .05$), nor did the effect of time on valence vary as a function of group ($F(2, 134) = .95$, $p = .39$; $\eta_p^2 = .01$). However, immediately following the writing task, self-injurers reported significantly higher levels of negative valence ($t(68) = 2.29$, $p < .05$) than controls. As above, the inclusion of gender as a covariate did not significantly impact these results; there was no effect of gender ($F(1, 66) = .29$, $p = .59$; $\eta_p^2 = .00$), nor did gender interact with time to predict arousal ($F(2,132) = .53$, $p = .59$; $\eta_p^2 = .01$). However, the main effect of time persisted ($F(2, 132) = 53.43$, $p < .001$; $\eta_p^2 = .45$). With gender included as a covariate, arousal still did not vary as a function of group ($F(1,66) = 3.57$, $p = .06$; $\eta_p^2 = .05$), nor did the effect of time on levels of arousal vary as a function of group ($F(2, 132) = .63$, $p = .54$; $\eta_p^2 = .01$).

Table 2 Group/Condition means for self-report of arousal and valence following shock selection (1), following the rest period, (2), following the writing task (3) and following recovery (4)

	Arousal 1 (SD)	Arousal 2 (SD)	Arousal 3 (SD)	Arousal 4 (SD)	Valence 1 (SD)	Valence 2 (SD)	Valence 3 (SD)	Valence 4 (SD)
Self-injurers, low shock condition ($n = 12$)	3.91 (2.11)	2.73 (2.37)	5.55 (2.02)	3.55 (1.97)	4.36 (1.86)	4.00 (2.05)	6.27 (1.56)	4.82 (1.78)
Self-injurers, high shock condition ($n = 27$)	4.26 (1.75)	3.15 (1.59)	5.81 (1.59)	3.33 (1.59)	3.85 (1.32)	4.07 (1.17)	6.15 (1.54)	4.56 (1.50)
Controls, low-shock condition ($n = 11$)	3.56 (1.74)	2.30 (1.64)	5.90 (1.29)	2.82 (1.89)	3.78 (1.99)	3.70 (1.42)	5.40 (1.51)	4.00 (1.26)
Controls, high shock condition ($n = 22$)	4.32 (1.94)	3.64 (2.24)	5.23 (2.33)	4.00 (2.25)	3.36 (1.62)	3.73 (1.80)	5.27 (1.75)	4.18 (1.59)

Emotional change after shock

In order to determine whether the administration of shock effectively reduced negative arousal for self-injurers, change scores were computed, subtracting SAM ratings at time four (after recovery) from SAM ratings at time three (after anger induction). Consistent with Klonsky (2009) we make specific predictions about self-injury reducing negative arousal. Therefore, the difference score for arousal was summed with the difference score for valence to create a negative arousal variable. A two-way ANOVA was then used to determine whether there was an interaction between group (injurers vs. non-injurers) and condition (low shock vs. high shock) in the reduction of negative arousal. There was no significant effect of group ($F(1, 66) = .21, p = .65$; $\eta^2_p = .00$) or condition ($F(1,\ 66) = 1.58,\ p = .21;\ \eta^2_p =$ .02). However, as predicted, the effect of condition varied significantly as a function of group ($F(1,\ 66) = 4.82,$ $p < .05$; $\eta^2_p = .07$; see Fig. 3). Specifically, self-injurers exhibited larger reductions in negative arousal if they were in the high-shock condition ($M = 4.07$, $s_M = .49$) than low shock condition ($M = 3.46$, $s_M = .76$), whereas non-injurers exhibited smaller reductions in negative arousal if they were in the high-shock condition ($M = 2.32$, $s_M = .54$) than the low shock condition ($M = 4.60$, $s_M = .8$). When gender was included as a covariate, the results were the same. There was no effect of gender ($F(1, 65) = .34, p = .56; \eta^2_p = .01$), nor was there any significant effect of group ($F(1, 65) = .12$, $p = .73$; $\eta^2_p = .02$) or condition ($F(1, 65) = 1.50, p = .23$; $\eta^2_p = .02$), though the effect of condition continued to vary significantly as a function of group ($F(1,\ 65) = 4.62$, $p < .05$; $\eta^2_p = .07$).

In order to examine the specificity of these results, the two-way ANOVA was again conducted with all of the clinical variables reported above included as covariates (i.e., each of the subscales of the DASS, the DERS, as well as the summed scores from the BSL-23 and the MSI-BPD). The effects were the same: there was no significant effect of group ($F(1, 66) = .14$, $p = .71$; $\eta^2_p = .00$) or condition ($F(1,\ 66) = .63$, $p = .43$; $\eta^2_p = .01$). However, the interaction between condition and group remained significant ($F(1, 66) = 4.17$, $p < .05$; $\eta^2_p = .08$).

Planned contrasts demonstrated that there was a significant difference in the magnitude of the reduction between self-injurers and controls in the high shock condition ($t(47) = 2.65$, $p < .01$), and a significant difference between controls in the high and low shock conditions ($t(30) = 2.70$, $p < .01$). However, there was no significant difference between self-injurers in the high and low shock conditions ($t(36) = .63$, $p = .54$).

In order to disambiguate these effects, the same analyses were then conducted with arousal change scores and valence change scores separately. For valence, there was no significant effect of group ($F(1,\ 66) = .77$, $p = .38$; $\eta^2_p = .01$), no significant effect of condition ($F(1,\ 66) =$ .01, $p = .92$; $\eta^2_p = .00$), and no significant interaction between group and condition ($F(1,\ 66) = .22$, $p = .64$; $\eta^2_p = .00$). With gender included as a covariate, the effects were the same; there was no main effect of gender ($F(1,$ $65) = .17$, $p = .69$; $\eta^2_p = .00$), no significant effect of group ($F(1,\ 65) = .86$, $p = .35$; $\eta^2_p = .01$) no significant effect of condition ($F(1,\ 65) = .01$, $p = .91$; $\eta^2_p = .01$), and no significant interaction between group and condition ($F(1, 65) = .23$, $p = .63$; $\eta^2_p = .00$).

For arousal, however, there was a significant interaction between group and condition ($F(1,\ 66) = 7.69$, $p < .01$; $\eta^2_p = .10$; See Fig. 3), such that self-injurers in the high shock condition had larger reductions in arousal ($M = 2.48$, $s_M = .34$) than self-injurers in the low shock condition ($M = 2.00$, $s_M = .53$), and non-injurers in the high shock condition had smaller reductions in arousal ($M = 1.28$, $s_M = .38$) than non-injurers in the low shock condition ($M = 3.30$, $s_M = .58$), who showed the greatest reduction of all. There was no significant effect of group ($F(1,\ 66) = .002$, $p = .96$; $\eta^2_p = .00$) or condition ($F(1,$ $66) = 2.99$, $p = .09$; $\eta^2_p = .04$). As above, the inclusion of gender as a covariate did not change the results: there was no main effect of gender ($F(1,\ 65) = 1.38$, $p = .24$; $\eta^2_p = .02$), no significant effect of group ($F(1, 65) = .07$, $p = .79$; $\eta^2_p = .001$) and no significant effect of condition ($F(1,\ 65) = 2.83$, $p = .10$; $\eta^2_p = .04$). The interaction between group and condition, however, remained significant ($F(1, 65) = 7.36$, $p < .01$; $\eta^2_p = .10$).

Planned contrasts demonstrated that there was a significant difference in reduction of arousal between self-injurers and controls in the high shock condition ($t(47) = 2.90$, $p < .01$), and a significant difference between controls in the high and low shock conditions

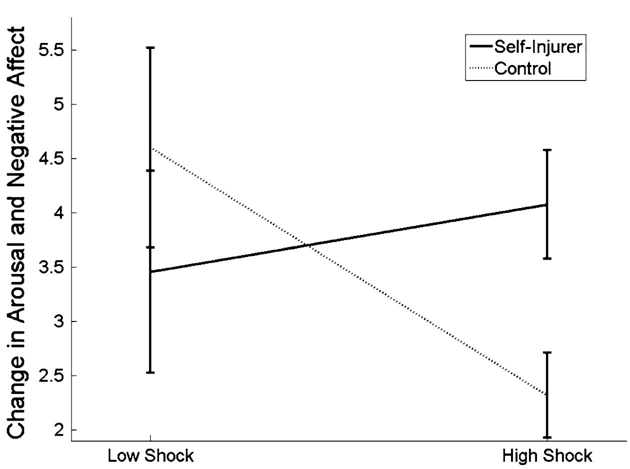

Fig. 3 Interaction between group (self-injurers vs. controls) and condition (low shock vs. high shock) on reduction of negative arousal

($t(30) = 3.25$, $p < .01$). However, there was no significant difference between self-injurers in the high and low shock conditions ($t(36) = .74$, $p = .47$).

Relationship between subjective pain, voltage, and reduction in negative arousal

In the high-shock group, the relationships among reductions in negative arousal, shock magnitude (voltage), and subjective levels of pain resulting from the shock were examined. Both self-injurers and controls were included in this analysis in order to examine the full range of response. Because we had directional hypotheses, one-tailed Pearson's correlations were conducted (see Fig. 4). Reduction in negative arousal was positively associated with level of shock self-administered at time 2 ($r(49) = .26$, $p < .05$), such that a higher level of shock predicted a greater reduction in negative arousal. As hypothesized, negative arousal was also negatively associated with subjectively-reported levels of pain at time 2 ($r(49) = -.26$, $p < .05$), such that greater experience of pain predicted smaller decreases in negative arousal. Notably, subjective levels of pain were not significantly related to magnitude of self-administered shock at time 2 $r(49) = -.13$, $p > .05$). A multiple regression was then conducted, with change in negative arousal as the dependent variable, and subjective pain and voltage as simultaneously-entered independent variables. The overall model was significant ($R^2 = .12$; $F(2, 48) = 3.12$, $p < .05$), though neither pain ($\beta = -.23$, $t(48) = 1.66$, $p = .10$) nor voltage ($\beta = .23$, $t(48) = 1.63$, $p > .11$) retained a significant unique association with reduction in negative arousal following shock. The regression was then run again, controlling for gender; in this iteration, the overall model was no longer significant ($R^2 = .15$; $F(3, 48) = 2.61$, $p = .06$). Furthermore, neither gender ($\beta = -.17$, $t(48) = 1.23$, $p = .22$) nor pain ($\beta = -.25$, $t(48) = 1.76$, $p = .08$) nor voltage ($\beta = .22$, $t(48) = 1.58$, $p = .12$) retained a significant unique association with reduction in negative arousal following shock.

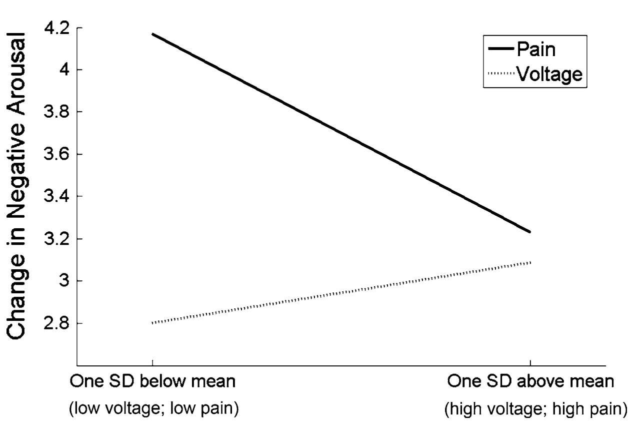

Fig. 4 Relationship of reduction of negative arousal to subjectively-reported pain and objectively-measured level of shock

We then examined these effects on valence and arousal separately, again in the high-shock group only. Reduction in negative valence was positively associated with level of shock self-administered at time 2 ($r(49) = .27$, $p < .05$), such that a higher level of shock predicted a greater reduction in negative valence, though this reduction was not significantly associated with subjectively-reported levels of pain at time 2 ($r(49) = -.13$, $p = .18$). As above, this was followed by a multiple regression, with change in negative valence as the dependent variable, and subjective pain and voltage as simultaneously-entered independent variables. The overall model was not significant ($R^2 = .08$; $F(2, 48) = 2.08$, $p = .14$), and neither pain ($\beta = -.10$, $t(48) = .70$, $p = .49$) nor voltage ($\beta = .26$, $t(48) = 1.81$, $p = .08$) retained a significant unique association with reduction in negative valence following shock. When controlling for gender, the results were the same. The overall model remained not significant ($R^2 = .09$; $F(3, 48) = 1.39$, $p = .26$), and neither gender ($\beta = -.04$, $t(48) = .30$, $p = .77$) nor pain ($\beta = -.10$, $t(48) = .67$, $p = .51$) nor voltage ($\beta = .26$, $t(48) = 1.80$, $p = .08$) retained a significant unique association with reduction in negative arousal following shock.

Reduction in arousal was positively—but not significantly—associated with level of shock self-administered at time 2 ($r(49) = .15$, $p = .16$), such that a higher level of shock predicted a greater reduction in arousal. Reduction in arousal was, however, significantly associated with subjectively-reported levels of pain at time 2 ($r(49) = -.28$, $p < .05$). The multiple regression described above was then repeated, with change in arousal as the dependent variable. Here, the overall model was not significant ($R^2 = .09$; $F(2, 48) = 2.24$, $p = .12$), and neither pain ($\beta = -.26$, $t(48) = 1.84$, $p = .07$) nor voltage ($\beta = .11$, $t(48) = .80$, $p = .43$) was significantly associated with reduction in self-reported arousal following shock. When controlling for gender, however, the overall model was significant ($R^2 = .18$; $F(2, 48) = 3.20$, $p < .05$). Though voltage was not significantly related to reduction in arousal ($\beta = .10$, $t(48) = .73$, $p = .47$), both gender ($\beta = -.30$, $t(48) = 2.18$, $p < .05$) and pain ($\beta = -.29$, $t(48) = 2.08$, $p < .05$) showed significant unique associations with reduction in arousal following shock.

Relationship between clinical variables and reduction in negative arousal following shock

In the whole sample, none of the clinical variables were significantly related to reduction in negative arousal, nor to change in arousal or valence separately (all ps $> .20$). When these analyses were repeated in the high-shock-only condition, there were again no significant associations (all $ps > .20$).

Discussion

The present study examined emotional response of self-injurers and controls during an anger induction and after self-administering shock, utilizing both self-report and objective indices of autonomic activity. Findings regarding change in self-reported arousal and valence were largely consistent with previous research and theory (e.g., Klonsky 2007, 2009; Russ et al. 1992) on emotional response to self-injury. That is, self-injurers reported greater decreases in negative arousal following self-administration of a strong shock compared to non-injuring controls. In addition, self-injurers self-administering a strong shock exhibited a trend towards greater decreases in negative arousal compared to self-injurers administering a low level of shock in a control condition. Taken together, the overall pattern of results suggests that, consistent with our hypotheses and previous research (e.g., Brain et al. 1998; Haines et al. 1998; Nock et al. 2009), there is a causal link between self-injury and reduction in negative arousal. Subsequent analyses intended to disambiguate the effects of arousal and valence suggest that change in levels of arousal may play a particularly important role. This is consistent with previous research emphasizing the importance of focusing on arousal when understanding the effects of self-injury on affect (Klonsky 2009), and suggests that research and interventions targeting the level of arousal experienced by self-injurers during episodes of emotional distress may be important.

Consistent with previous research (see e.g., Nock and Prinstein 2005), self-injurers compared to controls also appeared to demonstrate pain analgesia during the initial setting of shock levels, in that they selected significantly higher levels of shock to be subjectively "painful but still tolerable," yet reported similar levels of pain to the controls. Likewise, after receiving the shock a second time (i.e., during the experimental protocol) self-injurers in the low shock condition reported significantly lower levels of pain than controls in the low shock condition, though the two groups experienced the same objective level of shock. This was not so of the high shock condition, however; self-injurers in the high shock condition reported similar levels of subjectively experienced pain as controls in the high shock condition. In addition, self-injurers in this condition reported significantly larger reductions in arousal. Thus, at the same level of subjectively-experienced pain, self-injurers experience greater reductions in arousal than controls. Furthermore, the negative correlation with subjective pain and reduction in negative arousal in the high-shock condition suggests that, even among self-injurers, the novelty of the shock may have made it more aversive than their typical methods. However, for those who were able to tolerate the shock better, the reduction in negative arousal was enhanced. Specifically, it appears that those individuals who are able to inflict the highest objective level of pain (as measured by voltage administered) with the least subjective cost (as measured by self-reported pain) are those individuals who experience the greatest benefits in terms of reduction of negative arousal (e.g., Brain et al. 2002). This finding may highlight an important feature that distinguishes those who become habitual self-injurers. Our results suggest that subjective pain is a cost that interferes with the arousal-reduction properties of NSSI. Thus, greater pain threshold and reduced pain sensitivity may enable a subset of individuals to maximally benefit from the arousal-reduction consequences of NSSI. Indeed, several studies have documented both higher pain threshold and reduced pain sensitivity in NSSI (Hooley et al. 2010; Russ et al. 1992, 1999).

Self-injurers in the present study reported higher levels of depression, stress, anxiety, symptoms of BPD, and emotion dysregulation than controls. In particular, self-injurers reported greater difficulty accessing strategies to regulate their emotional experience, as well as difficulty accepting their emotional experiences. Though self-injurers and controls did not report greater levels of state arousal or negative affect at baseline, after the angry mood induction, self-injurers reported higher levels of negative affect. This is consistent with previous research suggesting that self-injurers are both more reactive to emotional stimuli and less able to access effective strategies to regulate their emotional experience. The immediate decrease in levels of negative affect and arousal provided by an act of self-injury appears to negatively reinforce the behavior (Klonsky 2007, 2009). In the absence of adaptive regulatory strategies, therefore, NSSI may provide enormous short-term gains, despite its adverse long-term consequences.

Limitations of the present study suggest directions for future research. For example, while the level for the low-shock condition was initially set at a level experimenters agreed was only slightly perceptible, several participants found the low-shock condition somewhat painful, and this may have minimized the differences observed. Indeed, it is possible that the low-shock condition provided enough painful sensation to itself serve as a proxy for self-injury for some individuals. This, too, may explain the relatively small difference between self-injurers in the high- and low-shock conditions. Future studies could also include a third, no-shock condition. Additionally, standardizing the shock level in the low-shock condition controlled for variability in voltage delivered, but not for subjective experience of pain, which likely accounts for the differences in self-reported pain between self-injurers and controls in the low-shock condition at time two. Future studies might also examine the impact of allowing subjects to select a level of shock which is perceptible but not painful.

While the present findings support an affect-regulation model by which self-injurers engage in self-injury in order to reduce emotional arousal, the mechanisms underlying this change in arousal remain unclear. Some have proposed that decreases in negative affect may be caused by distraction from/avoidance of emotional experience caused by the shock (e.g., Chapman et al. 2006; Nock 2009). While this is possible, it is not clear from the results of the present study why the shock should have been more distracting for self-injurers than for controls. Release of endorphins as a result of self-injury has also been proposed as a mechanism underlying this change (e.g., Nock 2009)—future studies combining physiological indices with self-report should be better able to elucidate the mechanisms by which NSSI might drive changes in affective states.

While shock appears to have been an adequate proxy for self-injury in the present study, the wide variety of methods of self-injury reported suggest that shock may not be equally effective for all individuals with a history of self-injury. Specifically, the sensation elicited by a shock to the arm may be very different from the sensation elicited by hitting or banging oneself. The critical role seeing blood may play in affect reduction for self-injurers (Glenn and Klonsky 2010), may also make shock a less effective proxy. Furthermore, the relatively strenuous test imposed by the experimental conditions of the present study may have partially concealed the effects of the shock. For example, participants in the low-shock conditions may have been relieved upon not receiving the painful shock they selected, thus leading to reductions in negative arousal in this group. In naturalistic settings, self-injurers choose when and whether to self-injure, whereas in the present study participants were randomized to shock conditions. This may have created heightened negative arousal—particularly in the control participants—which was subsequently reduced upon receipt of a less-painful level of shock. Naturalistic research examining self-injurious behaviors as they occur in real life—utilizing methods such as ambulatory monitoring and ecological momentary assessment—avoid the need for self-injury proxies and artificial constraints on the behavior and could provide valuable information in the future as to processes preceding and underlying these behaviors (e.g., Nock et al. 2009).

Additional limitations of the present study include a relatively small sample size ($n = 39$ self-injurers), reliance on a self-report measure to assess history of self-injury, and use of a college sample. Though between 14–17% of college students (Favazza et al. 1989; Whitlock et al. 2006) report a history of self-injury, the participants in the present study were most likely less severe than a clinical population. Indeed, in the present sample, only 54% of the self-injury participants had engaged in NSSI within the 12 months prior to the study. Likewise, while control participants were screened to ensure no history of self-injury, and while the self-injury group scored higher on clinical variables than the control group, the presence or absence of other psychological disorders in controls was not assessed. Future studies should examine emotional reactivity in larger samples of self-injurers and controls, as well as psychiatric controls with no history of self-injury, from community and clinical populations, and utilize structured interviews to diagnose self-injury as well as other disorders. Furthermore, the use of larger and more diverse samples should permit examination of the relationship between specific psychiatric constructs and reduction in negative affect following self-injury.

The present study adds valuable information to the growing body of research literature on self-injury, and begins to elucidate emotional processes underlying the performance of self-injurious behaviors. Future studies that aim to identify self-injury proxies best suited to laboratory research, as well as research utilizing methods with maximum external validity (e.g., ambulatory monitoring, diary methodologies), will be necessary to further clarify how and why self-injury reduces negative affective arousal.

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