The Effect of Resilience on Task Performance and Persistence during Repeated Exposure to Heat

Pain

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# This thesis titled

# The Effect of Resilience on Task Persistence and Performance during Repeated Exposure to Heat

Pain

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### ABSTRACT

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The Pain Resilience Scale was recently developed to assess dimensions of resilience critical to pain-related adaptation and was found to predict experimental pain sensitivity in a pain-free population. Pain resilience has also been theoretically linked to behavioral persistence despite pain. To date, however, this hypothesis has not been experimentally tested. To address this gap in the literature, in the current study 105 healthy young adults underwent a baseline series of five heat pain threshold assessments, followed by a baseline administration of the Paced Auditory Serial Addition Test (PASAT) delivered with somatosensory distraction (i.e. detection of warm and cool thresholds), and finally simultaneous administration of the PASAT and a series of five heat pain threshold assessments. Results of hierarchical multiple linear regressions indicate that, after controlling for scores on a baseline PASAT and pain sensitivity, pain resilience was positively related to task persistence, B=0.12 p=0.03, and task performance, B=0.14 p=0.03, on the PASAT. These findings provide novel support for the relationship between pain resilience and behavioral perseverance as well as additional experimental validation of the PASAT.

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### INTRODUCTION

Pain adaptation can take numerous forms and plays an important role in the experience of both acute and chronic pain. The term adaptation can be defined as sensory adaptation, which is evidenced by lower pain ratings or habituation to pain stimulation when the protective information provided by initial nociception is no longer relevant (Woolf & Ma, 2007). Positive adaptation can also be observed in the reduced interference of pain in behavior and mood, i.e behavioral and emotional adaptation to pain (Sturgeon & Zautra, 2013). Psychological influences on pain adaptation have received a great deal of research attention over the past thirty years. This has primarily taken the form of research on psychological constructs that confer vulnerability to maladaptive responses to pain, including anxiety, depression, pain-related fear, and pain catastrophizing (Gatchel, Peng, Peters, Fuchs, & Turk, 2007; Quartana, Campbell, & Edwards, 2009; Sturgeon & Zautra, 2010, 2013).

More recently, researchers have begun to acknowledge that psychological vulnerability alone fails to account for a significant proportion of the variance in pain adaptation (Wideman et al., 2013). Focus on resilience as an individual difference variable, defined as the propensity to maintain positive physical and emotional functioning despite significant challenge, has provided an additional approach to the study of pain adaptation (Sturgeon & Zautra, 2010, 2013). Resilience, along with other measures of positive psychology, have been proposed to exist largely independently from vulnerability constructs (Sturgeon & Zautra, 2013). Dispositional resilience has been related to positive adaptation to chronic pain, including increased positive emotional experiences, higher quality of life, as well as reduced symptoms of depression and anxiety (Bodde, Schrier, Krans, Geertzen, & Dijkstra, 2013; Kilic, Dorstyn, & Guiver, 2013; Min et al., 2013; Ong, Zautra, & Reid, 2010; Viggers & Caltabiano, 2012). There is also a small, but growing, body of research asserting that psychosocial resilience plays a role not only in adaptation to chronic pain, but also in the experience of experimentally-induced acute pain. The first study conducted in this line of research examined the relationships among pain sensitivity, stress, and resilience (Friborg et al., 2006). Pain-free individuals were randomized into either a high or low stress condition. Participants then underwent a 45-minute submaximal tourniquet ischemic pain task during which a blood pressure cuff affixed to the bicep was inflated to 200 mmHg, occluding blood flow. A moderation effect was identified, whereby individuals scoring above the median on the Resilience Scale for Adults reported less pain, but only in the high stress condition (Friborg et al., 2006). In a more recent study, scores on the Brief Resilience Scale, a six-item measure of an individual's perceived ability to bounce back from challenge, were positively related to the degree of habituation over five consecutive heat pain threshold assessments (Smith et al., 2009). Together, these experimental studies have identified a role for resilience in both sensory and emotional adaptation to acute pain.

It may be the case, however, that measures of general resilience, such as those described above, fail to capture dimensions of resilience critical to pain experience. Recently, we developed a measure of pain-specific resilience, the Pain Resilience Scale, informed by developments in research on resilience in chronic pain. This measure was designed to capture intrapersonal aspects of resilience critical to pain experience, including cognitive-affective positivity, as well as continued behavioral engagement and goal pursuit when individuals are faced with pain (Slepian, Ankawi, Himawan, & France, In Revision). As part of the initial validation of this instrument, healthy young adults were exposed to a submaximal tourniquet ischemic pain stimulus. Results of this study indicated that individuals with higher scores on the Pain Resilience Scale reported less pain across the five minute task (Slepian et al., In Revision). Furthermore, evidence from this study supported hypothesized relationships between pain resilience and measures of vulnerability, particularly pain catastrophizing. These initial findings supports a role for pain resilience in sensory adaptation to pain, but leaves the other two aspects of adaptation, emotional and behavioral, yet to be examined.

The maintenance of goal-directed activity despite pain, experimentally indexed by task performance or persistence while in pain, remains an under-examined aspect of behavioral adaptation to pain (Sturgeon & Zautra, 2013). It has been demonstrated that pain has an interrupting effect on task-related behavior, interfering with both attention required for task performance as well as the motivation necessary for persistence (Buhle & Wager, 2010; Moore, Keogh, & Eccleston, 2012). Importantly, these prior studies have been limited to an examination allocation of attentional resources rather than behavioral persistence. Although theoretical reviews have implicated pain resilience in behavioral persistence despite pain (Sturgeon & Zautra, 2010, 2013), this hypothesis has yet to be examined experimentally. Importantly, the Pain Resilience Scale was developed, in part, with an eye toward capturing this critical dimension of resilience. As such, it should be expected that pain resilience would be related to behavioral adaptation to pain.

Accordingly, the current study attempted to replicate findings of Smith and colleagues (Smith et al., 2009) regarding the positive relationship between resilience and habituation of heat pain thresholds, while extending the design to examine persistence and performance on a concomitant Paced Auditory Serial Addition Test (PASAT), a mental arithmetic task that serves both to induce stress as well as index task persistence and performance. In a within-subjects design, participants completed a baseline series of five heat pain thresholds, the PASAT with non-noxious somatosensory distraction (warm and cool detection thresholds), and finally the PASAT with a second series of five heat pain thresholds. We hypothesized that pain resilience would be positively related to habituation of heat pain thresholds, moderate the impact of the PASAT on habituation, and predict increased task persistence and improved performance when individuals are faced with pain.

### METHODS

## Participants

Undergraduate students (N=108) were recruited through the psychology department participant pool at a large Midwestern university. The final sample (N=105) was primarily female (58.1%), had a mean age of 19.3 years (SD = 1.3), and the majority self-identified as White (80%). Three participants consented to participate but were subsequently excluded on the basis of self-reported chronic pain (n=1) or insufficient English fluency (n=2).

### Measures

### Pain Resilience

The newly developed Pain Resilience Scale (PRS) was used to examine individual resilience to pain. The PRS consists of 14 items addressing individuals' propensity to maintain positive affect and behavioral perseverance when faced with pain. Respondents rated the degree to which the items applied to them, on a scale from 0 (*not at all*) to 4 (*to a great degree*). A full-scale Pain Resilience score was then computed by summing the items. Initial psychometric assessment of the PRS indicates that the scale demonstrates good reliability (Cronbach's alpha = 0.93; test-retest ICC = 0.8) and predictive validity in an experimental examination of ischemic pain (Slepian et al., In Revision).

## Pain Catastrophizing Scale

Catastrophizing was measured using the Pain Catastrophizing Scale (PCS), a measure of an exaggerated negative orientation toward pain (Sullivan et al., 2001; Sullivan, Bishop, & Pivik, 1995). The PCS includes thirteen statements wherein individuals are asked to rate the degree to which each applies to them on a scale from 0 (*not at all*) to 4 (*all the time*), and a full scale score is computed by summing the items. The PCS is a reliable (Cronbach's alpha = .87; test-retest ICC

- .93) and valid measure of pain catastrophizing, being consistently related to increased pain sensitivity and greater pain-related distress in experimental pain studies (George, Valencia, & Beneciuk, 2010; Sullivan et al., 2001; Sullivan et al., 1995). Additionally, pain catastrophizing has been described as the most central of the vulnerability constructs (Hood, Pulvers, Carrillo, Merchant, & Thomas, 2012; Sturgeon & Zautra, 2013).

### Paced Auditory Serial Addition Test

The Paced Auditory Serial Addition Test (PASAT) is a serial-addition task that taps working memory, divided attention and information processing speed and was originally developed to test information processing speed in individuals with head injury (Gronwall, 1977). A random series of numbers ranging from 1-9 is presented and participants are instructed to add each number to the one immediately preceding it. Participants are required to switch between two main tasks, calculating sums and encoding newly presented digits (working memory and attention), while maintaining the pace of the task (information processing speed). Validation studies have found moderate correlations between the PASAT and other tests of attention (Tombaugh, 2006). In healthy individuals, the PASAT loads on attention-concentration as well as sustained attention factors (Bate, Mathias, & Crawford, 2001; Crawford, Obonsawin, & Allan, 1998). Importantly, the PASAT is also recognized as an aversive task that can induce negative mood in individuals previously in neutral or positive moods (Holdwick & Wingenfeld, 1999).

## Apparatus

#### Medoc

A computer-controlled Medoc TSA-II Neuro Sensory Analyzer (TSA-2001, Ramat Yishai, Israel) was used to deliver heat threshold stimuli. A thermode was affixed to the volar forearm of the nondominant arm using a Velcro strap. The thermode is a Peltier-element-based stimulator with upper and lower surfaces through which semiconductor junctions pass an electrical current to create a temperature gradient. The thermode can be heated or cooled between 0 and 50°C at a pre-determined rate (e.g., 1°C/s) from a pre-determined baseline temperature (e.g. 32°C). If the participant clicks a mouse, or the temperature reaches the preset maximum, the thermode automatically and rapidly returns to the baseline temperature at a rate of 10°C/s.

## Procedure

Participants were recruited via an online Psychology Experiment Management system and invited to participate in a one-hour study titled "An Examination of the Relationship between Responses to Thermal Stimulation and Cognitive Processes". Participants were greeted and seated in a comfortable chair in a temperature and light-controlled room. Prior to initiation of the study, written informed consent was obtained. After consenting, participants were asked to complete a demographic questionnaire as well as the Pain Resilience Scale and Pain Catastrophizing Scale.

### Practice Heat Pain Threshold

After completion of questionnaires, participants were introduced to the pain threshold testing procedure and instructed how to rate each stimulus. A 3cm x 3cm thermode was affixed to the volar forearm of the participant's nondominant arm. They were then given a computer mouse and instructed that the thermode would heat up, and as soon as they felt it to be painful they should press a mouse button. Stimulations were then delivered using the Medoc TSA Thermode, starting from a baseline temperature of 32 °C and increasing at 1°C/s until the participant indicated that the sensation was painful by clicking the mouse. The temperature was then automatically reduced back to 32°C at a rate of 10°C/s.

# Habituation

Following this brief practice, participants completed a series of five heat pain thresholds with a 30 second rest between the mouse click and the subsequent threshold assessment.

#### PASAT

First, participants received recorded instructions explaining the task. They were then given a short practice session to ensure they understood task instructions. Prior to initiation of the task, participants had the thermode once again affixed to the volar surface of the non-dominant forearm. Participants were informed that during the PASAT the thermode would either cool down or warm up. They were instructed to indicate, by mouse click, as soon as they recognized a change in temperature (i.e. as soon as they recognized the thermode to be either warm or cool). For this task, the thermode again began at a baseline temperature of 32 °C and ramped either up or down at 1°C/s. This task was repeated at 30-second intervals, beginning with a cool detection threshold and subsequently alternating between warm and cool detection threshold sfor a total of five trials. This served as a control for the active element of heat pain threshold testing in the subsequent "habituation + PASAT" task. A series of 60 numbers were presented at 2.4 second intervals for a total task length of 144 seconds. Participants were asked to state aloud the sum of each number and the one immediately prior. Answers were recorded by the experimenter.

# Habituation + PASAT

Next, participants completed a simultaneous habituation task and PASAT. The thermode was again affixed to the volar forearm of the nondominant arm and the previous thermal pain

threshold procedure was repeated. To avoid habituation from the previous trial, the thermode was moved approximately two inches proximally on the arm. As soon as the PASAT digit string administration began, the first heat stimulus began to increase in temperature. Participants were instructed to respond to the PASAT aloud. Meanwhile, they clicked the mouse button when heat stimulation became painful. Participants completed a total of five heat pain threshold assessments at 30-second intervals. The total duration of the PASAT trial was extended to 288 seconds to ensure that the task lasted the entire duration of heat pain threshold testing. However, only the first sixty PASAT items were scored for analysis.

## Debriefing

Following completion of the procedure, participants were debriefed and given the opportunity to ask questions regarding the protocol or purpose of the study. The full procedure lasted approximately 50 minutes for each participant. This study was approved by Ohio University's Institutional Review Board.

### Data Analysis

## Habituation of heat pain thresholds

Two separate conditional growth curve models were constructed to examine habituation of heat pain thresholds at baseline and when individuals were under PASAT-related stress. Habituation was defined in the model as a positive growth curve coefficient. The initial heat pain threshold, and all of the two and three-way interactions between initial heat pain threshold and within-subject variables (habituation growth curve and PASAT condition) were entered into each model to control for ceiling effects in habituation for individuals who demonstrated above average heat pain thresholds, as they had less room for habituation. All person-level variables were centered prior to being entered into the models. The first of these models examined habituation across five heat pain threshold assessments under baseline conditions (i.e. no simultaneous requirements on the participant). First, unconditional growth curves (linear, logarithmic, and quadratic) were entered into the model and fit indices were examined to determine which curve provided the best fit. Next, person-level variables, including initial heat pain threshold, pain resilience, and pain catastrophizing, were entered into the model to determine if growth curves varied as a function of these variables.

The second growth curve model examined changes in habituation resulting from the simultaneous completion of the stressful PASAT. First, unconditional growth curves were entered into the model (linear, logarithmic, and quadratic) and fit indices were examined to determine if habituation was observed under both baseline and PASAT. Next, the PASAT condition (dichotomous variable; 0 for baseline, 1 for PASAT) and the interaction between PASAT condition and the growth curve were entered into the model as fixed effects. This allowed examination of simple main effects of the PASAT on average heat pain threshold as well as the impact of the PASAT on habituation of heat pain thresholds. In the final step, person level variables (pain resilience, pain catastrophizing, and initial heat pain threshold) were entered into the model. All two- and three-way interactions between person-level variables and within-subject variables were also entered into the model as fixed effects.

## PASAT persistence and performance.

Two separate hierarchical linear regressions were used to assess the relationship between 1) Pain Resilience and task performance and 2) Pain Resilience and task persistence. Task performance was defined as the number of correct responses on the PASAT. Task persistence was defined as the number of responses on the PASAT. For each regression analysis scores from the first PASAT administration and average heat pain threshold during testing were entered on the first block to control for baseline skill on the task as well as pain sensitivity. Pain resilience and pain catastrophizing scores were added in the second, and final, block of the model using a stepwise entry procedure.

### RESULTS

# Habituation of heat pain thresholds

On average, individual heat pain thresholds increased by 1.9° across the five heat pain threshold assessments, demonstrating habituation of heat pain thresholds. As described above, growth curve analyses were conducted to examine the influence of pain resilience on habituation to heat pain thresholds. First, a random intercept only model indicated that 88.1% of the variance in thresholds occurred at the level of the participant. Following this, three unconditional growth curves, linear, logarithmic, and quadratic were fitted to the data. Examination of fit statistics indicated that the logarithmic growth curve (AIC = 1877.87, BIC = 1894.96) provided a better fit to the data than either the linear trend (AIC = 1881.99, BIC = 1898.67) or the quadratic (AIC = 2805.83, BIC = 2818.65). This growth curve is depicted in Figure 1. Following this, initial heat pain threshold, pain resilience, pain catastrophizing, and their interactions were entered into the model, which significantly improved the fit of the model,  $\Delta X^2_{LR}(7, N=105) = 342.57, p < 0.001$ . The fixed effects in the final model are presented in Table 1. After controlling for initial pain sensitivity, pain resilience and pain catastrophizing were unrelated to habituation of heat pain thresholds or average heat pain threshold.<sup>1</sup> In sum, these results indicate that heat pain thresholds increase in a logarithmic fashion over five assessments, i.e. increasing more rapidly over the first several assessments then leveling off over the remainder of the assessments. Furthermore, this logarithmic growth curve did not vary as a function of pain resilience or pain catastrophizing.

<sup>&</sup>lt;sup>1</sup> These effects are unchanged when pain resilience and pain catastrophizing are entered into the model independently



Figure 1. Habituation of heat pain threshold across five trials.

Table 1.

Conditional logarithmic growth curve model predicting habituation of heat pain thresholds.

Fixed Effects	Estimate	95% CI	t
Intercept	43.77	43.54, 43.99	383.35***
Growth Curve <sup>a</sup>	1.15	1.01, 1.28	16.39***
Initial Threshold <sup>b</sup>	1.01	0.95, 1.07	33.69***
Pain Resilience <sup>b</sup>	-0.01	-0.04, 0.02	-0.67
Pain Catastrophizing <sup>b</sup>	-0.003	-0.03, 0.02	-0.28
Pain Resilience * Pain Catastrophizing	-0.6E-3	-0.004, 0.002	-0.34
Growth Curve * Pain Resilience	0.01	-0.01, 0.03	0.77
Growth Curve * Pain Catastrophizing	0.01	-0.01, 0.02	0.81
Growth Curve * Initial Threshold	-0.15	-0.18, -0.12	-8.37***
Growth Curve * Pain Resilience * Pain	-0.06E-3	-0.002, 0.002	-0.55
Catastrophizing			

<sup>a</sup>A logarithmic growth curve provided the best fit to the data. That is, the original series of assessments (1-5) were transformed via natural log to 0, 0.69, 1.10, 1.39, 1.61. <sup>b</sup>Estimates for person-level variables (initial threshold, pain resilience, and pain catastrophizing) reflect mean-centered values. \*\*\* p<0.001 \*\* p<0.01 \*p<0.05

Effects of PASAT administration on habituation of heat pain thresholds

A second series of growth curve models was constructed to examine whether stress

affected habituation to repeated heat pain threshold assessments and the influence of pain

resilience on that relationship. A model containing random intercept indicated that 65.3% of the

variance in thresholds occurred at the level of the subject. Examination of unconditional growth

curves indicated that the logarithmic growth curve (AIC = 5118.72, BIC = 5138.63) provided a

better fit to the data than either a linear (AIC = 5124.51, BIC = 5144.38) or quadratic (AIC =

5139.19, BIC = 5159.05). PASAT condition and its interaction with the growth curve were then

entered into the model, significantly improving the fit of the model,  $\Delta X^2_{LR}(2, N=105) = 250.78$ , p<.001. Person-level variables (pain resilience, pain catastrophizing, and initial heat pain threshold) and all two- and three-way interactions between person-level and within-subject variables were then entered into the model to examine if the growth curve was conditional upon these variables. Altogether, addition of these fixed effects significantly improved the fit of the model,  $\Delta X^2_{LR}(12, N=105) = 190.81$ , p<0.001. All fixed effects included in the final model are reported in Table 2.<sup>2</sup> Controlling for person-level variables, there was a significant interaction between PASAT condition and the growth curve, B=0.60, p=0.004, and a simple effect of PASAT condition, B=-2.62, p<0.001. That is, while completing the PASAT individuals evidenced both lower average heat pain thresholds and greater rate of increase in heat pain thresholds. This is illustrated in Figure 2. There was a significant two-way interaction between pain resilience and PASAT condition, B=-0.08, p<0.05. Follow up analyses indicated that during the PASAT administration, there was a simple effect of pain resilience, B=-0.09, p=0.007. After controlling for PASAT condition and initial pain sensitivity, neither pain resilience nor pain catastrophizing were related to habituation of heat pain thresholds. To summarize, habituation during the PASAT was best described by a logarithmic growth curve, similar to baseline. However, individuals showed a greater rate of increase in heat pain thresholds during the PASAT. This effect did not vary as a function of either pain resilience or pain catastrophizing. There was also a simple effect of PASAT, whereby average heat pain threshold was lower during the PASAT administration. Pain resilience moderated this effect in that pain resilience was negatively associated with average heat pain threshold during the PASAT.

<sup>&</sup>lt;sup>2</sup> These effects were unchanged when pain resilience and pain catastrophizing were entered into the model independently.

Table 2.

Conditional logarithmic growth curve model predicting effects of the PASAT on habituation of

**Fixed Effects** Estimate 95% CI t 189.17\*\*\* 43.78 43.32, 44.23 Intercept Growth Curve<sup>a</sup> 7.81\*\*\* 1.15 0.87, 1.45 PASAT -2.62 -3.08, -2.16 -11.23\*\*\* Initial Threshold 15.80\*\*\* 1.01 0.88, 1.13 Pain Resilience<sup>b</sup> -0.01 -0.07, 0.05 0.78 Pain Catastrophizing<sup>b</sup> -0.003 -0.06, 0.05 0.90 Growth Curve \* PASAT 0.60 0.19, 1.01 2.88\*\* Growth Curve \* Initial Threshold -0.15 -0.23, -0.07 -3.74\*\*\* Growth Curve \* Pain Resilience 0.01 -0.03, 0.05 0.44 Growth Curve \* Pain Catastrophizing 0.01 -0.03, 0.04 0.37 PASAT \* initial threshold -3.95\*\*\* -0.25 -0.38, -0.13 **PASAT \* Pain Resilience** -0.14, -0.01 -2.41\* -0.08 PASAT \* Pain Catastrophizing 0.02 -0.04, 0.07 0.58 PASAT \* Growth Curve \* Initial Threshold 0.04, 0.26 2.58\* 0.15 PASAT \* Growth Curve \* Pain Resilience 0.002 -0.06, 0.06 -1.25 PASAT \* Growth Curve \* Pain Catastrophzing -0.03 -0.08, 0.02 0.92

heat pain thresholds.

<sup>a</sup>A logarithmic growth curve provided the best fit to the data. That is, the original series of assessments (1-5) were transformed via natural log to 0, 0.69, 1.10, 1.39, 1.61. <sup>b</sup>Estimates for person-level variables (initial threshold, pain resilience, and pain catastrophizing) reflect mean-centered values.

\*\*\* p<0.001 \*\* p<0.01 \*p<0.05



Figure 2. Effects of PASAT on habituation of heat pain thresholds over five trials.

Task Persistence during heat pain threshold testing

On average, individuals demonstrated greater task persistence, defined by number of responses given during the PASAT, on the second administration (M= 43.5, SD = 8.5) than on the first (M=41.0, SD = 8.7),  $t_{pared-sample}(103) = 5.5$ , p < 0.001. A hierarchical linear regression was conducted to examine the influence of pain resilience on this increase. First, task performance

from the first PASAT and average heat pain threshold were entered into the model. Task persistence on the first administration was positively related to task persistence when individuals were faced with concomitant heat pain threshold testing, B = 0.83, *p*<0.001, accounting for 72.2% of the variance. Pain resilience and pain catastrophizing were entered into the second block of the using a stepwise entry procedure. Of these, only pain resilience was retained in the final model, significantly improving the fit of the model, *F<sub>change</sub>* (1,100)= 4.47, *p* = 0.04. Estimates for the final model are listed in Table 3. Controlling for first administration task persistence and pain sensitivity, pain resilience was positively related to task persistence when individuals were undergoing pain testing, B = 0.12 *p*=0.04. That is, every 1-point increase in pain resilience was associated with an additional 0.12 attempted responses on the PASAT when individuals were undergoing pain testing, accounting for 1.2% of the variance in task persistence. Pain Catastrophizing was unrelated to task persistence on the PASAT, Beta-in = .054 *p*=0.32.

Table 3.

Predictor	В	SE	Т
Baseline Persistence	0.84	0.05	16.72, <i>p</i> < 0.001
Pain Sensitivity	0.06	0.11	0.58
Pain Resilience	0.12	0.06	2.11, <i>p</i> < 0.05
Pain Catastrophizing <sup>a</sup>	0.05	0.05	0.99

Final regression model predicting PASAT persistence during heat pain threshold assessments.

<sup>a</sup>Estimates for pain catastrophizing reflect scores if the PCS were forced into the final model.

### Task Performance during heat pain threshold testing

Similarly to the results described above, task performance increased, on average, from the first administration of the PASAT (M=36.6, SD = 9.5) to the second (M=39.7, SD = 9.1),  $t_{paired}$  $_{sample}(103) = 6.26$ , p < 0.001. A hierarchical linear regression was conducted to examine the influence of pain resilience on this increase. First, task performance from the first PASAT and average heat pain threshold were entered into the model. Task performance on the first administration accounted for 71.4% of the variance in, and was positively related to, task performance when individuals were faced with concomitant heat pain threshold testing, B= 0.82, p<0.001. Pain resilience and pain catastrophizing were entered into the second block of the model using the stepwise entry method. Only pain resilience was retained in the final model, which significantly improved the model fit,  $F_{change}(1,100)=4.53$ , p = 0.04. The final model is described in Table 4. Controlling for first administration task performance and pain sensitivity, pain resilience was positively related to task performance when individuals were undergoing pain testing, B = 0.14, p=0.04. On average, each one point increase on the Pain Resilience Scale was associated with an additional 0.14 correct responses on the second administration of the PASAT, accounting for 1.2% of the variance in performance. Pain catastrophizing was unrelated to performance on the PASAT, Beta-in = 0.06 p = 0.32.

Table 4.

*Final regression model predicting PASAT performance during heat pain threshold assessments.* 

Predictor	В	SE	t
Baseline Performance	0.81	0.05	16.23, <i>p</i> < 0.001
Pain Sensitivity	0.05	0.12	0.46
Pain Resilience <sup>a</sup>	0.14	0.05	2.34, <i>p</i> < 0.05
Pain Catastrophizing <sup>a</sup>	0.06	0.06	1.00

<sup>a</sup>Estimates for pain catastrophizing reflect scores if the PCS were forced into the final model.

### DISCUSSION

The findings of this study provide the first experimental evidence relating pain resilience, as measured by the Pain Resilience Scale, to task performance and persistence during experimental pain testing. It has been theorized that behavioral adaptation to pain, or the ability to maintain goal-directed activity despite pain, is a critical aspect of pain resilience. As such, the current study provides additional support for the construct validity of the Pain Resilience Scale. Results of the current study did not, however, support our hypotheses that pain resilience would be related to habituation of heat pain thresholds and moderate the effects of mental stress on habituation.

On average, participants did show evidence of habituation (i.e. an increase of heat pain thresholds across five assessments delivered at 30-second intervals). Furthermore, heat pain thresholds habituated to a greater degree under conditions of additional stress. The effects of non-noxious acute stress applied concomitantly with experimental pain induction have been extensively studied, but not firmly established. Reports include both stress-induced analgesia as well as stress-induced hyperalgesia (Friborg et al., 2006; Terkelsen, Andersen, Molgaard, Hansen, & Jensen, 2004). These effects may be dependent on duration and intensity of both noxious and non-noxious stressors. In the current study, participants evidenced lower average thresholds during stress as well as a greater degree of habituation. These effects were maintained after controlling for the initial heat pain threshold when under stress. As such, it does not appear that the degree of habituation observed was simply resulting from correction after a lower initial threshold. It may be the case that multiple endogenous pain modulation processes are activated by acute stress, including both endogenous inhibition (e.g. habituation) and facilitation (e.g. hyperalgesia). These effects need to be further examined with additional controls, such as a non-stressful cognitive load, and counter-balanced order of administration of pain testing with and without a concomitant stressor.

The Pain Resilience Scale, however, was unrelated to habituation under either baseline or stress conditions. As such, it appears that the current study was unable to replicate the findings of Smith and colleagues (Smith et al., 2009). Additionally, pain resilience did not moderate the effect of habituation. It is possible that lack of replication is due, in part, to differences between the sample used by Smith and colleagues and the sample of the current study. All participants in the Smith et al (Smith et al., 2009) study were women between the ages of 35 and 60 (M=49). It may be that older participants have greater experience with a variety of painful experiences and therefore greater opportunity for positive pain-related learning. We have previously argued that resilience becomes particularly salient when individuals are faced with suprathreshold, or otherwise challenging, pain stimulation (Slepian et al., In Revision). With this in mind, it is also possible that pain resilience is not brought to bear on threshold-level pain. Developmental theories of resilience posit that resilience develops as a result of prior experience of successful coping with moderate pain or stress (Brockhurst, Cheleuitte-Nieves, Buckmaster, Schatzberg, & Lyons, 2015; Lee, Buckmaster, Yi, Schatzberg, & Lyons, 2014; Lyons, Buckmaster, et al., 2010; Lyons & Macri, 2011; Lyons, Parker, & Schatzberg, 2010). It may be the case that pain resilience becomes particularly relevant when pain-related memories are triggered by the stimulus. If so, then limited ecological validity of heat pain threshold testing may limit engagement of these prior learning experiences (i.e. previously learned adaptive response to pain are not generalized to the current context). Furthermore, volunteers in the current study had little incentive to endure significant increases in heat pain, which may be reflected in reduced habituation for the sample as a whole.

The critical finding of the current study was that, after controlling for scores on the first administration of the PASAT and pain sensitivity, pain resilience predicted greater task persistence and performance despite pain. Our study represents the first experimental evidence linking pain resilience to behavioral perseverance while individuals are undergoing painful stimulation. While the effect sizes were modest, it is important to note that scores on the PASAT are largely determined by individual differences in intelligence and math skills (Tombaugh, 2006), and this is reflected in the high proportion of variance attributable to baseline PASAT administration. It is possible, and perhaps likely, that pain resilience would bear a stronger relationship to persistence and performance on behavioral tasks not as reliant on math skills.

By controlling for pain sensitivity, it appears that although resilient individuals reported lower heat pain thresholds during the PASAT, this was not the reason why they were able to maintain focus on the PASAT. Indeed, it is possible that this relationship, taken with the relationship between pain resilience and task persistence/performance is evidence for a behavioral strategy wherein individuals were indicating lower thresholds in order to prevent attentional interference caused by pain. In a series of prior studies, researchers have identified two behavioral patterns in individuals concomitantly undergoing attention and pain testing (Erpelding & Davis, 2013; Seminowicz, Mikulis, & Davis, 2004). One of these tended to direct their attention toward the task, rather than the pain, showing enhanced performance despite pain. The other tended to focus attention on pain rather than the task, and evidenced greater attentional interference due to pain. These patterns were unrelated to either pain sensitivity or pain catastrophizing (Erpelding & Davis, 2013; Seminowicz et al., 2004), which is consistent with the current findings. However, measures of positive psychology, such as pain resilience, were not examined in these prior investigations. It may be the case that the behavioral strategy associated with pain resilience in the current study is indicative of propensity to maintain focus on the task reported in these studies.

These behavioral differences that have been identified and predicted by pain resilience are also consistent with extant literature on the relationship between self-regulation, executive function, and pain. Self-regulation theory posits that individuals have to prioritize attentional resources (Solberg Nes, Carlson, Crofford, de Leeuw, & Segerstrom, 2010; Solberg Nes, Roach, & Segerstrom, 2009). Pain requires a great deal of these limited resources, causing interference in behavior, particularly executive functioning (Solberg Nes et al., 2010; Solberg Nes et al., 2009). It has been hypothesized that positive psychological states, in particular, can help bolster these self-regulatory faculties (Boselie, Vancleef, Smeets, & Peters, 2014; Karsdorp, Ranson, Schrooten, & Vlaeyen, 2012). Pain resilience may act in a similar fashion. The current study, however, provides only observational evidence of the relationship between pain resilience and task persistence and performance. Future studies should examine methods of inducing state resilience and the impact of state resilience on task-related behavior.

As with all research, the current study was not without limitations. One of the primary limitations of the study was reliance on a pain-free undergraduate sample that was limited in both demographic diversity and experience with endogenous pain due to their relative youth. This may limit translation of these findings to an older, general adult population. A second limitation regards the order of tasks completed by participants. Due to our interest in habituation of heat pain thresholds under baseline conditions, we did not counterbalance the order of our procedures. As such, it is possible that pain resilience was related to improved stress habituation in general rather than coping with concomitant pain and stress. Future studies should control for potential habituation and order effects. Finally, experimental pain induction in the current study was limited to assessment of heat pain thresholds. As described above, it has been reported that the role of pain resilience in sensory and emotional adaptation to acute pain becomes more evident with increasing stimulation strength and duration. As such, the current study needs to be extended through the use of supra-threshold, extended duration pain induction, as greater sensory and emotional adaptation to pain may be evident in situations where pain stimulation is more intense and difficult to escape.

In sum, the current study represents the first experimental investigation of the relationship between resilience and task-related behavior during concomitant pain testing. Pain resilience was found to predict improved task persistence (number of attempted responses) and performance (number of correct responses) on the Paced Auditory Serial Addition Task when individuals were simultaneously completing a series of heat pain threshold assessments. These findings provide initial support for our hypotheses regarding the relationship between pain resilience and behavioral adaptation to pain as well as additional support for the predictive validity of the Pain Resilience Scale.

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# APPENDIX A: QUESTIONNAIRES, MEASURES, AND ADDITIONAL PSYCHOMETRICS

Demographic and Health Information

Session Date:	Session Time:		
Sex: Male / Female			
Age (years):			
Race: Please choose a category (or categories) t	hat best describes your racial bac	kgroun	nd:
American Indian/Alaskan native         Asian         Native Hawaiian/Other Pacific Islander	Black or African America White Other (	an	_)
Ethnicity: Please choose a category that best des	cribes your ethnicity:		
Hispanic or Latino 1	Not Hispanic or Latino		
Questions about your health:			
Do you have <i>any</i> significant health problem(s)? (If yes, please describe		YES	NO )
Have you ever been told by your doctor that you	have <u>any</u> of these health problem	IS:	
• a heart condition NO			YES
• a neurological disorder (i.e., disease of the ne	ervous system)	YES	NO
• a muscular disorder (i.e., disease related to y	our muscles, or muscle control)	YES	NO
• chronic back pain (i.e., almost daily back pai	n for 3 or more months)	YES	NO
Did you take <i>any</i> pain medicine in the past 24 ho	urs?	YES	NO
(If yes, please list the medicine(s) and whether the medicine (s) and whet	nen:		)

# Pain Resilience Scale

<u>Directions</u>: We are interested in the different ways that people respond to intense or prolonged pain (toothache, muscle strain, headache). Using a 0 ("Not at all") to 4 ("All the time") scale, please rate how much each of the following items describe how you respond when faced with intense or prolonged pain.

	When faced with intense or prolonged pain	Not at all	To a slight degree	To a moderate degree	To a great degree	All the time
1.	I get back out there	0	1	2	3	4
2.	I still work to accomplish my goals	0	1	2	3	4
3.	I push through it	0	1	2	3	4
4.	I try to continue working	0	1	2	3	4
5.	I like to stay active	0	1	2	3	4
6.	I focus on positive thoughts	0	1	2	3	4
7.	I keep a positive attitude	0	1	2	3	4
8.	It doesn't affect my happiness	0	1	2	3	4
9.	I still find joy in my life	0	1	2	3	4
10.	I keep a hopeful attitude	0	1	0	3	4
11.	I don't let it get me down	0	1	2	3	4
12.	I don't let it upset me	0	1	2	3	4
13.	I avoid negative thoughts	0	1	2	3	4
14.	I try to stay relaxed	0	1	2	3	4



Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feelings that you have when you are in pain. Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the following scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

0 - not at all 1 - to a slight degree 2 - to a moderate degree 3 - to a great degree 4 - all the time

When I'm in pain ...

	I worry	all	the	time	about	whether	the	pain	will	end.
--	---------	-----	-----	------	-------	---------	-----	------	------	------

- 2 I feel I can't go on.
- It's terrible and I think it's never going to get any better.
- It's awful and I feel that it overwhelms me.
- I feel I can't stand it anymore.
- I become afraid that the pain will get worse.
- I keep thinking of other painful events.
- I anxiously want the pain to go away.
- I can't seem to keep it out of my mind.
- I keep thinking about how much it hurts.
- I keep thinking about how badly I want the pain to stop.
- There's nothing I can do to reduce the intensity of the pain.
- I wonder whether something serious may happen.

# PANAS

**DIRECTIONS:** This scale consists of 20 words that describe feelings and emotions. Read each word, then circle a number indicating to what extent you feel this way RIGHT NOW.

1 very slightly or not at all	2 a little	3 moderately	4 quite a bit		e	5 xtrer	nely	
1. interested				1	2	3	4	5
2. distressed				1	2	3	4	5
3. excited				1	2	3	4	5
4. upset				1	2	3	4	5
5. strong				1	2	3	4	5
6. guilty				1	2	3	4	5
7. scared				1	2	3	4	5
8. hostile				1	2	3	4	5
9. enthusiastic				1	2	3	4	5
10. proud				1	2	3	4	5
11. irritable				1	2	3	4	5
12. alert				1	2	3	4	5
13. ashamed				1	2	3	4	5
14. inspired				1	2	3	4	5
15. nervous				1	2	3	4	5
16. determined				1	2	3	4	5
17. attentive				1	2	3	4	5
18. jittery				1	2	3	4	5
19. active				1	2	3	4	5
20. afraid				1	2	3	4	5

### APPENDIX B: ADDITIONAL ANALYSES

Role of affect in the relationship between pain resilience and task-related behavior.

A series of regression analyses were conducted to examine whether changes in affect mediate the relationship between pain resilience and task persistence and performance when individuals are in pain, following the procedure outlined by Baron and Kinney (1985). As shown above, when controlling for initial PASAT scores, pain resilience predicted both task persistence and task performance when individuals were faced with concomitant pain threshold testing. Regression analyses were then conducted to examine the relationship between changes in positive and negative affect and PASAT behavior. Change in positive affect was unrelated to either PASAT persistence or performance (both p's > 0.05). Change in negative affect was unrelated to PASAT performance (p > 0.05), but was negatively related to PASAT persistence, B=-0.31, p<0.05. That is, an increase of one point on the scale of negative affect was associated with 0.31 fewer responses attempted on the second administration of the PASAT. The final model is described in Supplementary Table 1. However, pain resilience was unrelated to changes in negative affect resulting from the simultaneous habituation and PASAT procedure, r=-0.04, p>.05. Due to this finding, the subsequent mediational analyses were not conducted.

## Supplementary Table 1.

*Regression model examining relationship between changes in negative affect and PASAT persistence* 

Predictor	В	SE	t
Baseline Performance	0.82	0.05	16.76***
Pain Sensitivity	0.03	0.11	0.32
Change in Negative Affect	-0.31	0.15	-2.02*
*** $n < 0.001 \cdot * n < 0.05$			

\*\*\* *p*<0.001; \**p*<0.05

# Effect of pain resilience on temporal summation of heat pain.

Temporal summation of heat pain was defined as the increase in heat pain intensity, as reported on a 10cm VAS, from the first to the last of ten 1-second heat stimuli. Results of a repeated measures ANOVA indicated that pain intensity ratings did not change across the ten stimulation,  $F_{Greenhouse-Geisser}(4.56, 473.92) = 0.27$ , p=0.92. This effect, or lack thereof, is depicted in Supplementary Figure 1. That is, on average, individuals did not show an increase in heat pain intensity over the ten stimuli (M = .04, SD = 2.02). Due to the absence of observed temporal summation, this hypothesis was not tested further.



Supplementary Figure 1. Temporal summation of heat pain.



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