The role of sustained attention toward threatening stimuli in fearlessness about death: An ERP study

by

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Abstract

Given that suicide is one of the leading causes of death in the United States, it is critical to identify those most at risk for suicide. Prominent theories of suicide and empirical evidence suggest that dysregulated threat reactivity is associated with capability for suicide. The present study examined the relationships between neural indices of sustained attention to threat (late positive potential [LPP]) and attentional control (P300) with suicide capability and risk factors for suicide. A sample (n = 61) drawn from two studies recruiting healthy participants and those at elevated risk for suicidal thoughts and behaviors completed self-report measures about suicide capability and suicide risk as well as a computerized task while electrocortical data were collected. Results did not support a relation between indices of attention to threat (i.e., Δthreat LPP) or reward (i.e., Δpositive LPP) with suicide capability, even among those with elevations in suicide ideation or other suicide risk factors. Overall, these findings suggest that further research is needed to unravel the complex relationships among sustained attention to emotional images and suicide risk variables.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

3ST	Three Step Theory
ACSS	Acquired Capability for Suicide Scale
AS	Anxiety Sensitivity
ASI-3	Anxiety Sensitivity Index- Third Edition
AU	Auburn University
CAPS-5	Clinician Administered PTSD Scale for DSM-5
CDC	Center for Disease Control
DASS-21	Depression Anxiety Stress Scales
DIAMOND	Diagnostic Interview for Anxiety, Mood, and Obsessive-Compulsive and Related Neuropsychiatric Disorders
DSI-SS	Depressive Symptom Inventory – Suicide Subscale
EEG	Electroencephalogram
EIT	Emotional Interrupt Task
EKG	Electrocardiogram
EMA	Ecological Momentary Assessment
EOG	Electrooculogram
ERP	Event Related Potential
FAD	Fearlessness about Death
IAPS	International Affective Picture System
INQ-R	Interpersonal Needs Questionnaire-Revised
IPT	Interpersonal Theory of Suicide

LEC-5	Life Events Checklist for DSM-5
LPP	Late Positive Potential
P3	P300
PB	Perceived Burdensomeness
PPE	Painful and Provocative Events
SA	Suicide Attempt
SCID-5	Structured Clinical Interview for DSM-5
SCID-5-RV	Structured Clinical Interview for DSM-5 Research Version
SCR	Skin Conductance Response
SI	Suicide Ideation
STBs	Suicidal Thoughts and Behaviors
TB	Thwarted Belongingness
U.S.	United States
Δpositive LPP	Positive LPP Difference Wave
Δpositive P3	Positive P3 Difference Wave
Δthreat LPP	Threat LPP Difference Wave
Δthreat P3	Threat P3 Difference Wave

Introduction

As of 2019, the Center for Disease Control (CDC) estimated that approximately 10.6 million American adults endorsed suicide ideation (SI) within the last year (Ivey-Stephenson et al., 2022). Of those, an estimated 1.4 million individuals attempt suicide (Ivey-Stephenson et al., 2022) resulting in more than 45,000 deaths (CDC, 2020). According to the CDC's National Center of Health Statistics, suicide rates increased over 35% between 2000 and 2018 (Garnett et al., 2022). While suicide rates in the United States (U.S.) appear be slightly decreasing at a rate of approximately 5% since 2018 (Garnett et al., 2022), in 2020, suicide remained the 2nd leading cause of death among individuals ages 10-14 and 25-34 years old, and 12th leading cause of death in the U.S. overall (CDC, 2020). Therefore, identifying vulnerabilities to suicidal thoughts and behaviors (STBs) is crucial to developing interventions to further promote downward trends in suicide deaths.

Theories of Suicide

The Interpersonal Theory of Suicide (IPT; Joiner, 2005; Van Orden et al., 2010, 2008) and Three Step Theory (3ST; Klonsky & May, 2015) are two of the most well studied and supported models for suicidality. According to the IPT and 3ST, suicidal thoughts arise from pain (e.g., psychological or emotion) and hopelessness that circumstances will improve (Joiner, 2005; Klonsky & May, 2015; Van Orden et al., 2010). While the both the IPT and 3ST classify SI into two categories: passive and active, the theories posit differential mechanisms for manifestation. The IPT specifies that passive SI (e.g., "I wish I was dead") emerges when an individual experiences interpersonal disconnectedness from others, otherwise known as thwarted belongingness (TB), or believes that others would be better off without them (i.e., perceived burdensomeness; PB). However, active SI, characterized as desire for suicide ("I want to kill

myself"), develops when TB and PB occur simultaneously in combination with hopelessness about these cognitive-affective states improving in the future (Joiner, 2005; Van Orden et al., 2010). Klonsky and May (2015) conjecture that active SI and suicidal desire manifest when pain surmounts an individual's sense of connectedness (Klonsky & May, 2015).

An abundance of literature supports the roles of TB and PB in SI. For example, in a sample of adolescents, Barzilay et al., (2015) found that while individuals endorsing either TB or PB were more likely to endorse SI, the interaction between TB and PB predicted even greater risk for SI. Likewise, Van Orden and colleagues (2008) found that while TB and PB separately predict SI, the interaction of TB and PB accounted for additional variance in current SI among a sample of undergraduates (Van Orden et al., 2008). Joiner et al., (2009) similarly found that TB and PB predicted current SI in an adult community sample, even when controlling for depressive symptoms. Consistent with the IPT, a meta-analysis conducted by Chu et al., (2017) found that TB and PB are significantly associated with SI and suicide risk, and the interaction between the constructs strongly predicted SI. In accordance with the 3ST, Dhingra and colleagues (2019) demonstrated that pain and hopelessness were associated with suicide desire, and the interaction between both constructs accounted for even greater variance in suicide desire. These results were additionally replicated in a sample of Chinese undergraduate students (Yang et al., 2019), community samples of adults (Klonsky & May, 2015; Pachkowski et al., 2021), and psychiatric inpatients (Tsai et al., 2021). Additionally, in a longitudinal investigation of suicidality among a sample of adult psychiatric inpatients, Tsai et al., (2021) found that pain and hopelessness prospectively predicted future suicidal desire.

Capability for Suicide

The IPT and 3ST additionally pose a framework that explains the transition from actively considering suicide to attempting, and potentially dying from suicide. Both theories suggest that capability for suicide, is necessary to carry out a suicide attempt (SA). Joiner (2005) originally conceptualized capability for suicide as the ability to overcome the inherent fear and pain associated with dying in order to engage in lethal or near lethal self-injury (Joiner, 2005). The IPT theorizes that capability for suicide is acquired through exposure to painful and provocative events (PPE), such as attempting suicide, engaging in self injury, or experiencing a traumatic event (Van Orden et al., 2010). Through opponent processes, individuals habituate to fear inducing and threatening stimuli (Joiner, 2005; Solomon & Corbit, 1974). Thus, diminished responding to threat, whether external or self-inflicted, increases risk for and facilitates greater tolerance of subsequent PPEs. Consequently, capability for suicide increases, thereby elevating risk for SA should SI and desire for suicide emerge (Joiner, 2005; Klonsky & May, 2015; Van Orden et al., 2008, 2010). The 3ST expanded on additional mechanisms contributing to capability for suicide to include genetic or biological factors (i.e., dispositional capability) and knowledge of or access to lethal means (i.e., practical capability; Klonsky & May, 2015).
The IPT posits that capability for suicide is a multidimensional latent construct composed of fearlessness about death (FAD) and pain tolerance (Van Orden et al., 2010). As engaging in suicidal behaviors requires confrontation with innately frightening and threatening stimuli, individuals must endorse reduced fear of death. Hence, non-zero levels of FAD are associated with elevated capability for suicide, and thus, provide for greater risk for SA (Van Orden et al., 2008, 2010). While capability for suicide is necessary to engage in a SA, increased FAD or capability for suicide are not inherently perilous. However, should an individual endorse

elevated FAD with co-occurring SI and desire for suicide, conditions are met for a SA to occur (Joiner, 2005; Klonsky & May, 2015; Van Orden et al., 2008, 2010).

Existing research supports the theoretical implication of FAD and capability for suicide in suicidal behaviors posed by the IPT and 3ST. For instance, capability for suicide was associated with SA history in a community sample of adolescents (Barzilay et al., 2015). Similarly, Ferm et al., (2020) found that in a sample of adolescents receiving intensive outpatient treatment for suicidality (i.e., endorsed current active SI or past-month SA), higher baseline FAD predicted history of SA and non-suicidal self-injury, and greater FAD prospectively predicted increased risk for SA. In a study examining suicidality among university students, capability for suicide distinguished between suicide ideators without history of SA and those with a history of attempt (Dhingra et al., 2019). Moreover, the results remained significant when differentiating groups by capability type including dispositional, acquired, and practical contributors (Dhingra et al., 2019). Additionally, evidence from a study conducted with adult inpatients, suicide capability at intake prospectively differentiated between individuals attempting suicide within three months of discharge from those who did not engage in SA (Tsai et al., 2021). In a test of the full IPT, Joiner and colleagues (2009) found that a three-way interaction between TB, PB, and lifetime number of SAs (cf. measure of capability for suicide) predicted recent SA among young suicidal adults. In a study investigating suicidality among outpatient adults, the interaction between capability for suicide and PB predicted clinician rated risk for suicide (Van Orden et al., 2008). Similarly, Bryan and colleagues (2010) demonstrated that history of SA was predicted by an interaction between PB and capability for suicide among activity duty military personnel. Additionally, capability for suicide predicted self-reported risk for suicide among a sample of deployed active-duty military service members reporting greater levels of PB (Bryan

et al., 2012). A meta-analysis from Chu and colleagues (2017) found that greater capability for suicide was significantly associated with lifetime history of SAs and SI but revealed a non-significant relationship between capability and suicide risk. Moreover, Christensen et al., (2014) found similar results in a large community sample, such that the interaction between SI and capability for suicide, but not capability alone, predicted lifetime history of SA. This evidence supports leading theories of suicide in that increased FAD facilitates capability to engage in future SA. Despite considerable theoretical and empirical support for the implication of FAD in suicide behaviors, little is known about nature of the mechanism underlying this construct, thereby hampering our understanding of how this construct develops and, importantly, how it might be mitigated.

Defensive Responding to Threatening Stimuli in Suicide Capability

One promising neurobehavioral mechanism associated with FAD is blunted defensive responding to threat. Intact threat responding systems are critical for an organism's survival. When imminent threat is detected, the autonomic nervous system activates defense responses including threat detection, allocation of resources necessary to fuel responses, and cessation of competing biological functions. Following autonomic arousal, organisms are then prepared to engage in various behaviors, such as fleeing or confronting threat, to mitigate harm and optimize chance for survival. Deficits or delays at any point in this defense cascade, from detection to action, could result in grave harm or fatality. Dysregulation of threat systems has been implicated in clinical or subclinical conditions (Cuthbert et al., 2003; D'Andrea et al., 2013; Gilbert, 2001; Haddad et al., 2012; Kim et al., 2019). Consistent with the prominent theories of suicide previously outlined, diminished responding to fear provoking and painful stimuli is associated with capability for suicide (Joiner, 2005; Klonsky & May, 2015; Van Orden et al., 2008, 2010).

Of course, enacting lethal or near lethal harm to the self is inherently challenging as it requires an individual to both mentally and physically overcome a natural, biological drive for preservation. Several self-report, behavioral, physiological and neuroimaging methods have been used to examine threat responses in humans, including among healthy controls and individuals with various psychopathologies. One neural marker of sustained attention toward threat, a theoretical component of threat responding, is the late positive potential (LPP).

The Late Positive Potential

The LPP is an event related potential (ERP) component that reflects sustained attention and processing occurring from approximately 400-1000ms following the presentation of emotionally salient information. In a laboratory setting, stimuli with emotional relevance, such as images depicting threat, mutilation, neutral, positive or erotic content are presented on a computer screen while electroencephalogram (EEG) data are collected. In response to viewing emotionally arousing pictures, individuals demonstrate LPPs with larger amplitudes compared to neutral pictures, reflecting greater emotional responding. Within the context of threat, a larger LPP elicited to threatening relative to neutral stimuli reflects greater threat reactivity, while a smaller LPP indicates a blunted neural response to threat (Dillon et al., 2006; Hajcak & Olvet, 2008; Weinberg & Hajcak, 2010). The LPP has demonstrated good to excellent reliability (Huffmeijer et al., 2014; Moran et al., 2013).

The utility of the LPP as a biological index of sustained attention has been demonstrated in healthy control and clinical samples. In a sample of healthy undergraduates, Wheaton and colleagues (Wheaton et al., 2013) found that individuals rated threatening images as more unpleasant, emotionally arousing, and threatening compared to neutral images. Moreover, the healthy sample demonstrated larger LPPs to threatening images relative to neutral. Similar

results were demonstrated in a study of healthy controls presented with words related to threat, pleasant, and neutral subjects, such that both threatening and pleasant words elicited greater LPPs compared to neutral images (Dillon et al., 2006).

The LPP has additionally been used to measure threat reactivity among several clinical conditions, including depression, anxiety, and suicide. Individuals with depression consistently demonstrate reduced LPP to threatening and positive images relative to controls, reflecting diminished emotional responding to stimuli associated with both negative and positive emotional valence (Foti et al., 2010; Kayser et al., 2000; Weinberg et al., 2016). Conversely, several studies suggest that anxiety is associated with an exaggerated Δthreat LPP (i.e., difference between threat and neutral LPP) compared to healthy subjects, suggesting greater emotional reactivity to threatening stimuli (MacNamara & Hajcak, 2009, 2010). While Weinberg et al., (2016) found decreased neural reactivity to threatening and rewarding stimuli among individuals with depression, the study did not find a significant association between anxiety and LPP magnitude elicited by threat nor reward. Moreover, the same study found that SI was associated with blunted threat and reward LPP, even when controlling for other depressive symptoms (Weinberg et al., 2016). Weinberg and colleagues (2017) examined the LPP in a sample of suicide ideators with and without a history of SA. The results of the study found that individuals with a history of SA, regardless of current SI status, demonstrated smaller LPPs in response to threatening images, compared to current ideators without a history of SA. Hence, lifetime history of SA, is associated with blunted threat reactivity (Weinberg et al., 2017). Nonetheless, Albanese et al., (2019) found no significant association between the Δthreat LPP and SA, nor with SI status during a passive picture viewing paradigm. However, in an emotional regulation paradigm in which participants either increased or decreased emotional responding to

threatening/mutilation images, greater SA was associated with better ability to volitionally decrease threat reactivity compared to SI (Albanese et al., 2019).

The P3

The P300, or P3, is another ERP component that has been associated with attention to emotionally salient information, including threatening stimuli. The P3 is parietally maximal at approximately 300ms following the presentation of a target stimulus (e.g., shape) during a task requiring some behavioral response (e.g., pressing a button). Moreover, the P3 is enhanced following presentation of emotionally salient information, such that it appears to be related to the motivational significance of a particular stimuli (Hajcak et al., 2010; Keil et al., 2002; Olofsson et al., 2008; Weinberg & Hajcak, 2010). The amplitude of the P3 represents the intensity of stimulus processing, such that a larger amplitude P3 response is associated with greater attention to the stimulus. In a laboratory setting, the extent to which emotionally salient information influences the P3 is measured by EEG and examined by presenting threatening, positive, and emotional stimuli during the completion of a goal-directed task. Blunted P3 responses evoked by target stimuli presented after threatening images (i.e., threat P3) reflects worse ability to ignore threatening images and reduced attention to target stimuli. The P3 demonstrates good to excellent reliability (Huffmeijer et al., 2014).

Present Study

The present study examined the relationship between a measure of self-reported capability for suicide and neural responses to threatening stimuli in a mixed sample consisting of healthy individual and those with elevated risk for STBs. To our knowledge, only one group has explored the relationship between FAD and the Δthreat LPP. Bauer and colleagues (2020) found no significant relationship between FAD and the Δthreat LPP in a clinical sample of treatment

seeking individuals. However, in a subsample of participants endorsing recent or current SI (i.e., non-zero DSI-SS total score), blunted Δthreat LPP predicted increased FAD. These results suggest that current/recent suicide ideators demonstrating blunted neural threat reactivity report elevated capability for suicide.

Given that a paucity of literature has explored biological mechanisms of capability for suicide, the present study investigated whether the relationship between neural indices of threat reactivity, including the Δthreat LPP and Δthreat P3, and FAD is moderated by SI and other suicide risk factors, including TB and PB. Moreover, the interactions between the ERP components and suicide constructs were examined to explore the effects of these relationships on another facet of suicide capability, pain tolerance. Based on the review of the literature, we hypothesized that the relationship between FAD and the Δthreat LPP would differ based on the interaction between the Δthreat LPP and clinical risks for suicide, including SI, TB, and PB. Exploratory analyses were conducted to examine relationships between the Δthreat P3, capability for suicide, and suicide risk constructs.

Methods

The current study was derived from two samples of participants recruited for a longitudinal study examining neurobehavioral mechanisms underlying suicidality among individuals with elevated risk for STBs, and another research project examining longitudinal threat reactivity and sensitivity to negative reinforcement in a healthy sample without current psychopathology or SI. Participants from both samples reported on constructs related to STBs and completed an EEG procedure during the baseline and follow-up laboratory sessions. The present study utilized data from the baseline periods only.

Study 1: Elevated Risk for STBs Sample Participants and Procedure

Participants recruited as part of the elevated risk for STBs sample consisted of Auburn University (AU) undergraduates and community members with elevated risk for STBs (n = 30). Participants were recruited primarily using the AU Department of Psychological Science's Research Participation SONA system. Community members were recruited through social media advertisements and local flyer postings. Eligibility criteria included being aged 18-65, English-speaking, and the endorsement of at least one of the following criteria: current SI, current elevated depression symptoms (confirmed past or current major depressive episode during clinical interview), current elevations in PB (sum of the three interpersonal needs questionnaire-revised [INQ-R] PB items ≥ 12), and/or current elevations in anxiety sensitivity (AS) cognitive concerns (sum of three anxiety sensitivity index- third edition [ASI-3; Taylor et al., 2007] items ≥ 3). Individuals who reported moderate-high intent to die by suicide (intent > 5 on a scale from 0-10; Chu et al., 2015), imminent suicide risk requiring immediate hospitalization, or uncontrolled bipolar or other psychotic disorder during the baseline interview were excluded. Two participants were excluded due to uncontrolled bipolar disorder and psychotic symptoms, while no participants were excluded from the present study due to moderate-high intent to die by suicide or imminent suicide risk.

Those interested in participating completed an informed consent form through Qualtrics. Immediately following informed consent, participants were automatically redirected to a brief, online, Qualtrics screener to determine pre-eligibility. The online screener assessed for age, presence of current mental health conditions, SI, PB, and AS cognitive concerns. Following completion of the screener survey, pre-eligible individuals were notified by email to schedule a clinical interview conducted by phone with trained graduate students. The clinical interview

took approximately one hour to complete and consisted of several mood disorder modules from the Structured Clinical Interview for DSM-5 Research Version (SCID-5-RV), Life Events Checklist for DSM-5 (LEC-5; Weathers, Blake, Schnurr, Kaloupek, Marx, et al., 2013), Clinician Administered PTSD Scale for DSM-5 (CAPS-5; (Weathers, Blake, Schnurr, Kaloupek, & Keane, 2013), SCID-5 psychosis screener, and a suicide risk assessment interview (Chu et al., 2015; Joiner et al., 1999). At the end of the clinical interview, interviewers completed a coping card with all participants consisting of a safety plan to follow during periods of SI and emergency resources. Additionally, interviewees were provided with contact information for the National Suicide Prevention Hotline and a list of local mental health resources.

Those deemed eligible based on responses to the pre-screener and clinical interview were contacted to schedule a baseline, in-person laboratory appointment in which they participated in a non-invasive EEG procedure while completing a picture viewing task and a battery of questionnaires. The lab visit took approximately 4 hours to complete. Following the lab visit, participants completed a brief ecological momentary assessment (EMA) period and concluded participation with an in-person laboratory appointment one month after the baseline appointment in which the initial laboratory procedures were repeated. Only the baseline data was used in the present study.

Study 2: Healthy Sample Participants and Procedure

The healthy sample utilized in the present study consisted of AU undergraduates and members of the Auburn-Opelika community (n = 35). AU psychology students were recruited through the university's Department of Psychological Sciences Research Participation SONA system while community members were recruited though social media advertisements and local

flyer postings. Eligible participants were aged 18-65, English speaking, did not meet criteria for a current mental health condition, and had no prior history of STBs.

Individuals interested in participating completed an informed consent form through Qualtrics, followed by a brief, online pre-screener. Then, those deemed pre-eligible for participation received an email to schedule a clinical interview with a trained graduate student to confirm eligibility. The clinical interview was conducted by phone and lasted approximately 15-30 minutes. Participants were administered the mood disorder modules from the Diagnostic Interview for Anxiety, Mood, and Obsessive-Compulsive and Related Neuropsychiatric Disorders (DIAMOND) and a suicide risk assessment interview (Chu et al., 2015; Joiner et al., 1999) to confirm eligibility. Individuals who endorsed STBs on the suicide risk assessment devised a coping card with the trained graduate clinician to follow during periods of SI. They were also provided with a list of local mental health and emergency resources available in the area, along with contact information for the National Suicide Prevention Hotline.

Eligible participants were scheduled for an in-person laboratory appointment in which they completed a series of questionnaires and computerized tasks while electrocortical data were collected. Following the baseline appointment, participants were scheduled for a follow-up appointment within one month of the initial session, in which they completed the questionnaires, tasks, and EEG procedure included in the baseline laboratory phase. Only the baseline data were be used in the present study.

Power Analysis

An a priori power analysis was conducted using the *InteractionPoweR* package (Baranger et al., 2022) in *R studio* version 4.1.1 (RStudio Team, 2020). Based on Bauer et al. (2020) and Albanese et al. (2019), the following parameters were submitted to the power analysis:

Correlations between SI and FAD (r = .0), Δthreat LPP and FAD (r = .3), SI and the Δthreat LPP (r = .0), and the SI* Δthreat LPP interaction (r = .37), α = .05. Results indicated that a sample of 59 individuals are needed to detect the proposed interactions with 80.19% power.

Participants

Participants (n = 65) were recruited for participation in the present study. Four participants were excluded from analyses due to missing data, yielding a total sample of 61 participants. Participants (M_{age} = 21.84, SD = 5.24) were 73.8% female. In terms of race, the sample was 77.0% White/Caucasian, 8.2% Black/African American, 13.1% Asian, 1.6% American Indian/Native American, 1.6% Native Hawaiian/Pacific Islander and 9.8% other. 13.1% self-identified as Hispanic. Most participants were enrolled as full-time students (91.8%), completed at least some college (49.2%), and were employed at least part-time (41.0%). With respect to suicidality, 26.2% of participants reported current SI and 13.1% self-reported a history of suicide attempt (see Table 1). All procedures were approved by the university's Institutional Review Board.

Self-report Measures

Acquired Capability for Suicide Scale (ACSS; Ribeiro et al., 2014; Van Orden, et al., 2008)

The ACSS is a 20-item self-report measure of suicide capability. Participants indicate levels of FAD and pain tolerance rated on a scale from 0 *not at all like me* to 4 *very much like me* on items such as "I am not at all afraid to die" and "The pain involved in dying frightens me." Total scores for the ACSS range from 0 to 80, with higher scores indicating increased capability for suicide. The ACSS demonstrates strong psychometric properties and construct validity (Van Orden et al., 2008; Ribeiro et al., 2014). In the present study, the ACSS FAD (α = .88) subscale

and pain tolerance items (α = .71) demonstrated good and acceptable internal consistency, respectively.

Interpersonal Needs Questionnaire - Revised (INQ-R; Van Orden et al., 2012)

The INQ-R is a 15-item self-report measure assessing TB and PB as described by the IPT. Participants indicate the extent to which they have recently felt disconnected from others and were a burden to others, on a 7-point Likert scale from 1 *not at all true for me to* 7 *very true for me.* Total scores for the INQ-R range from 15 to 105, with higher scores corresponding to greater TB and PB. The INQ-R has demonstrated good reliability and construct validity in past research (Van Orden et al., 2012). Consistent with previous research, the INQ-R TB (α = .91) and PB (α = .94) subscales demonstrated excellent internal consistency.

Depressive Symptom Inventory – Suicide Subscale (DSI-SS; Metalsky & Joiner, 1997)

The DSI-SS is a 4-item self-report measure assessing SI severity. Participants report on the frequency in which they experience SI, extent of planning for engaging in a SA, degree of control over SI, and impulse to kill themselves within the past two weeks. Individuals provide responses on a scale of 0 to 3, with non-zero responses suggesting presence of SI. Additionally, total scores range from 0 to 12, such that higher responses are associated with more severe SI. The DSI-SS demonstrates strong reliability and validity (Joiner et al., 2002; Metalsky & Joiner, 1997). Similarly, the DSI-SS evidenced excellent internal consistency (α = .90) in the present study.

Depression Anxiety Stress Scales (DASS-21; Lovibond & Lovibond, 1995)

The DASS-21 is a 21-item self-report measure of symptoms of depression, anxiety, and stress. Participants indicate the extent to which they experienced each symptom over the past week on a scale of 0 *did not apply to me* to 3 *applied to me very much*. Each of the three

symptom scales is composed of 7 items, with possible scores ranging from 0 to 21 per scale. The DASS-21 demonstrates sound psychometric properties (Anthony et al., 1998; Lovibond & Lovibond 1995). The DASS-21 demonstrated acceptable to good internal consistency across the depression (α = .86), anxiety (α = .74), stress (α = .78) subscale. Given that depression (Foti et al., 2010; Kayser et al., 2000; Weinberg et al., 2016) and anxiety (MacNamara & Hajcak, 2009, 2010) have been shown to effect the amplitude of the LPP, the DASS-21 depression and anxiety subscale scores were included as covariates in the present study.

Psychophysiological Measures

EEG Data Collection

Electrocortical data were collected with a 32-channel BrainVision actiCHAMP amplifer (1000 Hz sampling rate, online analog bypass filter: 0.05-100Hz). Participants were first fitted with a specialized cap, which holds 32 EEG sensors. Once the cap was placed on the participant's head, a conductive gel was applied using a specialized, plastic applicator. Once each of the sensors achieved a low impedance (<20 kOhms) connection, data collection began. The FCz and AFz were used as the online reference and ground, respectively. Offline, the data were re-referenced to the average mastoids (TP9 and TP10).

Ocular artifacts such as eye movements and blinks were collected with two sensors placed above and below the eye (i.e., vertical electrooculogram [EOG]) and two sensors placed on the outer edge of each eye (i.e., horizonal EOG). Moreover, two electrocardiogram (EKG) sensors were placed on inner forearms to collect heart rate data, and two skin conductance response (SCR) sensors were placed on the non-dominant hand to record physiological responses to baseline and picture viewing task.

Emotional Interrupt Task (EIT; Mitchell et al., 2006, 2008)

The emotional picture viewing paradigm included threat/mutilation, neutral and pleasant images (40 images each) selected from the International Affective Picture System (IAPS; Bradley & Lang, 2007). These pictures are well-validated and designed to elicit emotional responses that can be detected during EEG procedures. During the Emotional Interrupt Task (EIT), participants passively viewed the images for 1000ms. Following this presentation, a target (either a circle or square) appeared that the participant then responded to by pressing a corresponding button (either left or right). After the target was presented for 150 ms, the original IAPS image re-appeared for 1000 ms. Images were presented in blocks of image types to avoid carry over effects. The order of blocks, and order of images within each block, were randomized across participants to avoid order effects.

EEG Data Cleaning and Processing

EEG processing was performed using Brain Vision Analyzer – 2.1 (Brain Products, Gilching, Germany). Data was first visually inspected for bad (e.g., damaged electrode or poor signal) or noisy channels, and interpolated as needed. Data were then re-referenced to the average of both mastoid electrodes and bandpass-filtered from .01-30 Hz (Butterworth, 4^{th} order). Feedback-locked epochs were extracted from 200 ms prior to stimulus onset to 1000 ms after stimulus onset. Ocular correction was performed using the Gratton et al. (1983) algorithm. Segments containing voltage steps > 50 μV, a voltage difference of 175 μV within 400 ms, or low activity with a voltage difference < .05 μV within 100 ms were automatically rejected. Baseline rejection of 200 ms pre-stimulus was applied and the LPP was averaged separately for each image type from 400 ms to 1000 ms following stimulus onset and quantified as the average of a centro-parietal pool (Cz, Pz, CP1, CP2).

Data Analysis

Data were examined for normality and outliers were replaced by upper and lower fence values. First, unstandardized residualized difference scores were computed by regressing the neutral LPP onto the threat LPP (i.e., Δthreat LPP) and pleasant LPP (i.e., Δpleasant LPP), respectively. This process was repeated to compute the Δthreat P3 and Δpleasant P3. Next, correlations were calculated among study variables, including the residualized difference scores and their component LPPs. The main effects of the Δthreat LPP on FAD was examined when accounting for relevant covariates. Biological sex, age, depression, and anxiety were included as covariates to account for their respective relationships with suicide risk (Brent et al., 1999; Hawton, 2000; Henriksson et al., 1993; Krysinska & Lester, 2010; Panagioti et al., 2009; Stanley et al., 2016).

Then, the interactions between neural indices of threat (i.e., Δthreat LPP/P3) and SI predicting FAD and pain tolerance were examined using the PROCESS macro for SPSS with 10,000 bias-corrected bootstrap samples (Hayes, 2012). Significant interactions were probed, and additional moderation models were conducted to determine if the observed effects were driven by the Δthreat LPP/P3, threat LPP/P3, or neutral LPP/P3. Additional analyses regarding the interaction of Δthreat LPP/P3 and other suicide risk factors, including TB and PB, were also explored. Identical analyses were then conducted entering the Δpleasant LPP and Δpleasant P3 as independent variables and pain tolerance as a dependent variable. Benjamini-Hochberg corrections were applied to address the issue of multiple comparisons and reduce the probability of Type 1 error (Benjamini & Hochberg, 1995).

Hypothesis Testing

Hypothesis A

Hypothesis A posited that the relationship between the Δthreat LPP and FAD differs across levels of SI severity, such that blunted Δthreat LPP predicts increased FAD among those with greater SI. The interaction between Δthreat LPP and SI predicting FAD was examined to test the following hypotheses:

$H_{0:}$ There is no significant difference in the relationship between Δthreat and FAD across levels of SI severity.

$H_{1:}$ There is a significant difference in the relationship between Δthreat and FAD across levels of SI severity.

Hypothesis B

Hypothesis B posited that the relationship between the Δthreat and FAD differs by levels of TB, such that blunted Δthreat LPP predicts increased FAD among those with greater TB. The interaction between Δthreat LPP and TB predicting FAD was examined to test the following hypotheses:

$H_{0:}$ There is no significant difference in the relationship between Δthreat and FAD across levels of TB.

$H_{1:}$ There is a significant difference in the relationship between Δthreat and FAD across levels of TB.

Hypothesis C

Hypothesis C posited that the relationship between the Δthreat and FAD differs by levels of PB, such that blunted Δthreat LPP predicts increased FAD among those with greater PB. The

interaction between Δthreat LPP and PB predicting FAD was examined to test the following hypotheses:

$H_{0:}$ There is no significant difference in the relationship between Δthreat and FAD across levels of PB.

$H_{1:}$ There is a significant difference in the relationship between Δthreat and FAD across levels of PB.

Results

Descriptive Statistics and Correlations

Data were examined for normality and outliers were replaced by upper and lower fence values. Descriptive statistics and bivariate correlations are shown in Table 2. Notably, there were significant bivariate associations between INQ-R PB and INQ-R TB (r = .65, p < .001; $p_{adjusted}$= .006), INQ-R PB and FAD (r = .32, p = .01, $p_{adjusted}$= .06), INQ-R PB and DSI-SS (r = .63, p < .001, $p_{adjusted}$= .006), INQ-R TB and DSI-SS (r = .49, p < .001, $p_{adjusted}$= .006) FAD and pain tolerance (r = .46, p < .001, $p_{adjusted}$= .006), FAD and Δthreat LPP (r = .25, p = .05, $p_{adjusted}$= .16), pain tolerance and DSI-SS (r = .27, p = .03, $p_{adjusted}$= .12), Δthreat LPP and Δthreat P3 (r = -.45, p < .001, $p_{adjusted}$= .006), and Δthreat P3 and Δpositive P3 (r = .30, p = .02, $p_{adjusted}$= .09). However, after applying a Benjamini-Hochberg INQ-R PB and INQ-R TB, INQ-R PB and DSI-SS, INQ-R TB and DSI-SS, FAD and pain tolerance, Δthreat LPP and Δthreat P3 remained statistically significant.

EIT Trials

Descriptive statistics were calculated for the threat, positive, and neutral trials presented during the EIT. The mean number of threat/mutilation trials completed by participants during the task was 35.49 (SD = 3.85, Range = 16). More specifically, participants completed on average

18.05 (*SD* = 2.13, Range = 9) threat and 17.51 mutilation (*SD* = 1.96, Range = 7) trials. On average, participants completed 36.31 positive trials (SD = 3.06, Range = 14). Lastly, participants completed an average of 35.64 neutral trials (SD = 3.55, Range = 17). Split-half reliabilities between the threat, positive, and neutral trials for both the LPP and P3 were calculated by performing Spearman-Brown correlations between the odd and even IAPS images. Results indicated significant associations between the threat LPP odd and even trials (r =.55, p < .001), neutral LPP odd and even trials (r =.49, p < .001), and positive LPP odd and even trials (r =.70, p < .001). Moreover, there was a significant association between Δpositive LPP odd and even trials (r = .41, p < .001). However, the association between the Δthreat LPP odd and even trials (r = .16, p = .22) was not significant. Waveforms for the LPP elicited by threat, positive, and neutral IAPS images during the EIT are presented in Figure 1.

Similarly, there was a significant association between threat P3 odd and even trials (r = .68, p < .001), neutral P3 odd and even trials (r = .71, p < .001), and positive P3 odd and even trials (r = .67, p < .001). Lastly, a significant association emerged between the Δthreat P3 odd and even trials (r = .39, p = .004). However, the association between the Δpositive P3 odd and even trials was not significant (r = .22, p = .09).

ΔThreat LPP and FAD

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δthreat LPP and FAD when controlling for age, sex, anxiety, and depression. Results indicated that Δthreat LPP was not significantly related to FAD (B = 0.46, SE = 0.28, p = .10, $p_{adjusted}$= .52; see Table 3).

Interaction of ΔThreat LPP and SI Predicting FAD

The interaction between SI and Δthreat LPP predicting FAD was tested. The interactive effect of Δthreat LPP and SI did not significantly predict FAD (B = -0.37, SE = 0.24, p = .13, $p_{adjusted}$= .52; see Table 3).

Exploratory Analyses

Interactions between TB and PB with Δthreat LPP were examined to explore whether the constructs moderated the relationship between Δthreat LPP and FAD. Results indicated that the interactive effect of Δthreat LPP and TB did not significantly predict FAD (B = 0.02, SE = 0.02, p = .37, $p_{adjusted}$= .74). Similarly, the interactive effect of Δthreat LPP and PB did not significantly predict FAD (B = -0.001, SE = 0.04, p = .99, $p_{adjusted}$= .99).

ΔPositive LPP and FAD

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δpositive LPP and FAD when controlling for age, sex, anxiety, and depression. Results indicated that the Δpositive LPP did not significantly predict FAD (B = 0.02, SE = 0.34, p = .94, $p_{adjusted}$= .99; see Table 3).

Interaction of ΔPositive LPP and SI Predicting FAD

The interaction between SI and Δpositive LPP predicting FAD was tested. The interactive effect of Δpositive LPP and SI was not a significant predictor of FAD (B = 0.02, SE = 0.34, p = 0.71, $p_{adjusted}$= .99; see Table 3).

Exploratory Analyses

Interactions between TB and PB with Δpositive LPP were examined to explore whether the constructs moderated the relationship between Δpositive LPP and FAD. The interactive

effect of Δpositive LPP and TB was not a significant predictor of FAD (B = 0.03, SE = 0.02, p = .23, $p_{adjusted}$=.61). Similarly, the interactive effect of Δpositive LPP and PB was not a significant predictor of FAD (B = 0.03, SE = 0.05, p = 0.58, $p_{adjusted}$= .80).

ΔThreat LPP and Pain Tolerance

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δthreat LPP and pain tolerance when controlling for age, sex, anxiety, and depression. Results indicated that Δthreat LPP was not significantly related to pain tolerance (B = 0.35, SE = 0.27, p = .21, $p_{adjusted}$= .40; see Table 4).

Interaction of ΔThreat LPP and SI Predicting Pain Tolerance

The interaction between SI and Δthreat LPP predicting pain tolerance was tested**.** The interactive effect of Δthreat LPP and SI did not significantly predict pain tolerance (B = -0.15, SE = 0.24, p = .45, $p_{adjusted}$= .59; see Table 4).

Exploratory Analyses

Interactions between TB and PB with Δthreat LPP were examined to explore whether the constructs moderated the relationship between Δthreat LPP and pain tolerance. Results indicated that the interactive effect of Δthreat LPP and TB did not significantly predict pain tolerance (B = 0.002, SE = 0.02, p = 0.95, $p_{adjusted}$= .95). Similarly, the interactive effect of Δthreat LPP and PB did not significantly predict pain tolerance (B = -0.05, SE = 0.05, p = .24, $p_{adjusted}$=.41).

ΔPositive LPP and Pain Tolerance

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δpositive LPP and pain tolerance when controlling for age, sex, anxiety, and depression. Results

indicated that Δpositive LPP did not significantly predict pain tolerance (B = 0.18, SE = 0.33, p = .58, $p_{adjusted}$= .66; see Table 4).

Interaction of ΔPositive LPP and SI Predicting Pain Tolerance

The interaction between SI and Δpositive LPP predicting pain tolerance was tested. The interactive effect of Δpositive LPP and SI significantly predicted pain tolerance (B = -0.71, SE = 0.32, p = .03, $p_{adjusted}$= .17; see Table 4). However, probing the interaction revealed that the relationship between Δpositive LPP and pain tolerance was not significantly moderated by mean (B = 0.19, SE = 0.32, p = .56), low (B = 0.53, SE = 0.35, p = .14), or high (B = -0.44, SE = 0.43, p = .31) levels of SI. There are two possible explanations for this finding. First, the interaction was probed at high (1 SD above mean), low (1 SD below mean), and mean levels of SI. It is possible that the relationship between Δpositive LPP and pain tolerance is contingent on SI outside of these tested levels, however, lower levels of SI could not be tested as one standard deviation below the mean for of SI was below the minimum value observed within the data set. Another possible explanation for this result is that while SI is the theoretical moderator in the present study, the Δpositive LPP may moderate the relationship between SI and Pain Tolerance. This relationship was examined and a significant interaction emerged, such that Δpositive LPP moderated the relationship between SI and on pain tolerance (B = -0.71, SE = 0.32, p = .03, $p_{adjusted}$= .17). Probing the interaction revealed that low Δpositive LPP was a marginally significant moderator for the relationship between SI and on pain tolerance (B = 3.05, SE = 1.63, p = .07), but not mean (B = 0.83, SE = 1.38, p = .55) or high Δpositive LPP (B = -1.39, SE = 1.78, p = .44). Nevertheless, the interaction effect of Δpositive LPP and SI no longer significantly predicted pain tolerance after applying a Benjamini-Hochberg correction.

Exploratory Analyses

Interactions between TB and PB with Δpositive LPP were examined to explore whether the constructs moderated the relationship between Δpositive LPP and pain tolerance. Results indicated that the interactive effect of Δpositive LPP and TB did not significantly predict pain tolerance (B = -0.02, SE = 0.02, p = .52, $p_{adjusted}$= .63). Similarly, the interactive effect of Δpositive LPP and PB did not significantly predict pain tolerance (B = -0.05, SE = 0.05, p = .33, $p_{adjusted}$=.47).

ΔThreat P3 and FAD

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δthreat P3 and FAD when controlling for age, sex, anxiety, and depression. Results indicated that the Δthreat P3 did not significantly predict FAD (B = -0.38, SE = 0.32, p = .23, $p_{adjusted}$= .61; see Table 5).

Interaction of ΔThreat P3 and SI Predicting FAD

The interaction between SI and Δthreat P3 predicting FAD was tested. The interactive effect of Δthreat P3 and SI significantly predicted FAD (B = 0.75, SE = 0.37, p = .04, $p_{adjusted}$= .52; see Table 5 and Figure 2). Probing the interaction revealed that reduced Δthreat P3 predicted greater FAD among those with low SI (B = -0.71, SE = 0.35, p = .048), but not at mean (B = -0.35, SE = 0.31, p = .27) or high levels (B = 0.33, SE = 0.46, p = .48) of SI. To determine whether the interactive effect of Δthreat P3 and SI predicting FAD was driven by the threat P3 rather than the neutral P3, interactions between threat P3 and SI, and neutral P3 and SI predicting FAD were examined. Results indicated that the interactive effect of the threat P3 and SI did not significantly predict FAD (B = 0.35, SE = 0.25, p = .15). Moreover, the interactive effect of the

neutral P3 and SI did not significantly predict FAD (B = 0.06, SE = 0.27, p = .83). This pattern of results suggests that the significant interaction between Δthreat P3 and SI on FAD was driven by the difference between the threat P3 and neutral P3. However, after applying a Benjamini-Hochberg correction, the interaction between Δthreat P3 and SI no longer significantly predicted FAD.

Exploratory Analyses

Interactions between TB and PB with Δthreat P3 were examined to explore whether the constructs moderated the relationship between Δthreat P3 and FAD. Results indicated that the interactive effect of Δthreat P3 and TB did not significantly predict FAD (B = 0.03, SE = 0.03, p = .28, $p_{adjusted}$=.64). Similarly, the interactive effect of Δthreat P3 and PB did not significantly predict FAD (B = 0.05, SE = 0.07, p = .46, $p_{adjusted}$= .74).

ΔPositive P3 and FAD

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δpositive P3 and FAD when controlling for age, sex, anxiety, and depression. Results indicated that Δpositive P3 did not significantly predict FAD (B = -0.03, SE = 0.44, p = .95, $p_{adjusted}$= .99; see Table 5).

Interaction of ΔPositive P3 and SI Predicting FAD

The interaction between SI and Δpositive P3 predicting FAD was tested. The interactive effect of Δpositive P3 and SI did not significantly predict FAD (B = 0.82, SE = 0.52, p = .12, $p_{adjusted}$= .52; see Table 5).

Exploratory Analyses

Interactions between TB and PB with Δpositive P3 were examined to explore whether the constructs moderated the relationship between Δpositive P3 and FAD. Results indicated that the interactive effect of Δpositive P3 and TB did not significantly predict FAD (B = -0.02, SE = 0.04, p = .60, $p_{adjusted}$= 80). Similarly, the interactive effect of Δpositive P3 and PB did not significantly predict FAD (B = 0.05, SE = 0.07, p = .46, $p_{adjusted}$=.74).

ΔThreat P3 and Pain Tolerance

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δthreat P3 and pain tolerance when controlling for age, sex, anxiety, and depression. Results indicated that Δthreat P3 did not significantly predict pain tolerance (B = -0.33, SE = 0.31, p = .28, $p_{adjusted}$= .43; see Table 6).

Interaction of ΔThreat P3 and SI Predicting Pain Tolerance

The interaction between SI and Δthreat P3 predicting pain tolerance was tested. The interactive effect of Δthreat P3 and SI was a marginally significant predictor of pain tolerance (B = 0.70, SE = 0.36, p = .05, $p_{adjusted}$= .17; see Table 6 and Figure 3). Probing the interaction revealed that blunted Δthreat P3 predicted greater pain tolerance among those with low SI (B = -0.68, SE = 0.34, p = .05), but not at mean (B = -0.34, SE = 0.30, p = .27) or high levels (B = 0.28, SE = 0.45, p = .53) of SI. To determine whether the interactive effect of Δthreat P3 and SI on pain tolerance was driven by the threat P3 rather than the neutral P3, the interactions between threat P3 and SI, and neutral P3 and SI predicting pain tolerance were examined. Results indicated that the interactive effect of the threat P3 and SI did not significantly predict pain tolerance (B = 0.20, SE = 0.24, p = .43). Moreover, the interactive effects of the neutral P3 and

SI did not significantly predict pain tolerance (B = -0.17, SE = 0.26, p = .53). This pattern of results suggests that the significant interaction between Δthreat P3 and SI on pain tolerance was driven by the difference between the threat P3 and neutral P3. However, after applying a Benjamini-Hochberg correction, the interaction between Δthreat P3 and SI no longer significantly predicted pain tolerance.

Exploratory Analyses

Interactions between TB and PB with Δthreat P3 were examined to explore whether the constructs moderated the relationship between Δthreat P3 and pain tolerance. Results indicated that the interactive effect of Δthreat P3 and TB did not significantly predict pain tolerance (B = 0.04, SE = 0.03, p = .16, $p_{adjusted}$= .36). Similarly, the interactive effect of Δthreat P3 and PB did not significantly predict pain tolerance (B = 0.10, SE = 0.07, p = .17, $p_{adjusted}$= .36).

ΔPositive P3 and Pain Tolerance

Main Effects

Multiple linear regressions were performed to examine the relationship between the Δpositive P3 and pain tolerance when controlling for age, sex, anxiety, and depression. Results indicated that Δpositive P3 did not significantly predict pain tolerance (B = 0.18, SE = 0.43, p = .68, $p_{adjusted}$= .72; see Table 6).

Interaction of ΔPositive P3 and SI Predicting Pain Tolerance

The interaction between SI and Δpositive P3 predicting pain tolerance was tested. The interactive effect of Δpositive P3 and SI significantly predicted pain tolerance (B = 1.30, SE = 0.49, p = .01, $p_{adjusted}$= .17; see Table 6 and Figure 4). Probing the interaction revealed that greater Δpositive P3 predicted greater pain tolerance among those with greater SI (B = 1.22, SE = 0.56, p = .03), but not among those with mean (B = 0.07, SE =0.41, p = .87) or low levels (B = -

0.56, *SE* = 0.50, *p* = .27) of SI. To determine whether the interactive effect of Δpositive P3 and SI on pain tolerance was driven by the positive P3 rather than the neutral P3, the interactions between positive P3 and SI, and neutral P3 and SI predicting pain tolerance were examined. Results indicated that the interactive effect of the positive P3 and SI did not significantly predict pain tolerance (*B* = 0.31, *SE* = 0.31, *p* = .31). Moreover, the interactive effects of the neutral P3 and SI did not significantly predict pain tolerance (*B* = -0.17, *SE* = 0.26, *p* = .53). This pattern of results suggests that the significant interaction between Δpositive P3 and SI on pain tolerance was driven by the difference between the positive P3 and neutral P3. However, after applying a Benjamini-Hochberg correction, the interaction between Δpositive P3 and SI no longer significantly predicted pain tolerance.

Exploratory Analyses

To determine whether TB and PB moderate the relationship between Δpositive P3 and pain tolerance, an exploratory moderation analysis was performed. Results indicate that the interactive effect of Δpositive P3 and TB did not significantly predict pain tolerance (*B* = 0.08, *SE* = 0.04, *p* = .06, $p_{adjusted}$= .17).

However, the interactive effect of Δpositive P3 and PB significantly predicted pain tolerance (*B* = 0.24, *SE* = 0.12, *p* = .05, $p_{adjusted}$= .17; see Figure 5). Probing the interaction revealed that greater Δpositive P3 was associated with greater pain tolerance among those with high PB (*B* = 1.81, *SE* = 0.92, *p* = .05) but not at mean (*B* = 0.49, *SE* = 0.45, *p* = .28) or low (*B* = -0.42, *SE* = 0.50, *p* = .41) PB. Moreover, to determine whether the interactive effect of Δpositive P3 and PB on pain tolerance was driven by the positive P3 rather than the neutral P3, the interactive effects of the positive P3 and PB, and neutral P3 and PB on pain tolerance were examined. Results indicated that the interactive effect of the positive P3 and SI did not

significantly predict pain tolerance (B = 0.02, SE = 0.6, p = .73). Moreover, the interactive effects of the neutral P3 and SI did not significantly predict pain tolerance (B = -0.02, SE = 0.04, p = .58). This pattern of results suggests that the significant interaction between Δpositive P3 and PB on pain tolerance was driven by the difference between the positive P3 and neutral P3. However, after applying a Benjamini-Hochberg correction, the interaction between Δpositive P3 and PB no longer significantly predicted pain tolerance.

Discussion

The current study examined whether sustained attention toward task-irrelevant threatening images was related to several facets of capability for suicide, and whether this relationship was more pronounced among those with SI or other suicide risk factors. Results of the present study did not support the main hypothesis that Δthreat LPP would be related to FAD directly or among only those with high SI. Several significant findings emerged while examining relationships between the Δpositive LPP, Δthreat P3, and Δpositive P3, and suicide capability, though none of these associations remained significant when using a Benjamini-Hochberg correction for multiple comparisons. For instance, a significant interaction emerged between SI and the Δpositive LPP and predicting pain tolerance, such that SI was differentially related to pain tolerance at different levels of Δpositive LPP. Additionally, lower Δthreat P3 predicted greater FAD and pain tolerance among those with low SI, but not at high SI, suggesting that reduced attention to targets in the context of task-irrelevant threatening images was only related to suicide capability among those with low SI. The present study also found that greater Δpositive P3 predicted greater pain tolerance among those with high, but not low, SI, suggesting that the ability to devote greater attentional resources to targets in the context of socially-relevant positive images may contribute to more tolerance for pain. Taken together,

these findings suggest that sustained attention to task-irrelevant emotional images was not related to FAD and pain tolerance but point towards the potential utility of examining attentional control indices in the context of emotional images to understand the capability for suicide. However, given that these relationships did not surpass the threshold of significance after adjusting for multiple comparisons, replication is necessary to support these findings.

In contrast to Bauer and colleagues' (2020) findings, the present study did not support that SI moderates the relationship between the Δthreat LPP and FAD. There are several plausible reasons for the conflicting results between the two studies. First, the present study used an emotional interrupt task (EIT) in which the emotional images are task-irrelevant distractors and participants are instructed to respond to the targets that interrupt the images. This task differs in an important way from passive viewing tasks used in prior work (e.g., Bauer et al., 2020), most notably in that the goal of the task is for participants to devote attentional resources to responding to the targets (i.e., shapes on the screen) despite the presence of emotionally salient images on the screen. While this may change what the LPP reflects, it is important to note that a distinct advantage of the EIT is that it ensures participant engagement in the task relative to passive image viewing. The LPP presented in the Bauer et al. (2020) was based on only 6 trials and did not evince high reliability scores. While the raw LPP amplitudes in the present study demonstrated acceptable split-half reliability, the residualized difference score reliabilities fell below this threshold. Future research using both tasks should use additional trials to increase the reliability of the resulting LPP. Lastly, it is also possible that the present sample was not large and/or severe enough to capture the hypothesized effects. Therefore, it may be important to use more severe samples to examine the underlying neurobiological mechanisms of FAD.

The present study found some, albeit weak, support that blunted Δthreat P3 predicts greater FAD and greater pain tolerance among those with low SI, though these findings did not remain significant after correcting for multiple comparisons. The opposite pattern was observed for positive images; greater Δpositive P3 predicted greater pain tolerance among those with greater SI, but not low SI. However, these results also did not survive the corrections for multiple comparisons. If further research were to confirm these findings, it would suggest that having worse ability to attend to target stimuli in the presence of distracting threat/mutilation images and better ability to attend to target stimuli in the presence of distracting positive images were each associated with increased capability for suicide. Taken together, these findings suggest that attention to goal-directed targets in the context of emotional distractors may be a relevant future area of research towards understanding suicide capability.

The results of the present study should be considered in light of the following limitations. First, given that these findings were no longer statistically significant after adjusting the significance threshold, further research is needed to evaluate the robustness of the relationships among the P3, suicide capability, and SI. Additionally, split-half reliabilities could be improved in future studies. For instance, while the positive, neutral, and threat trials for both the LPP and P3 demonstrated good split-half reliabilities, the residualized difference scores showed predictably worse reliability. Moreover, given that poor internal consistency is associated with weakened effect sizes (Hajcak et al., 2017), the results of the present study likely underestimate the relationships between ERP components, SI, and capability for suicide. Future studies should seek to address these limitations by increasing the number of trials used and by utilizing a longitudinal design to examine relationships between the P3, SI, and capability for suicide. This would provide better understanding of the reliability of the P3 predicting FAD and pain

tolerance. Additionally, future work may examine the extent to which the P3 distinguishes between current SI with and without a history of SA reveal the utility of using the P3 to predict important suicide risk outcomes.

In summary, the present study failed to provide a conceptual replication of prior research linking blunted threat reactivity with increased FAD, even when considering active SI, TB, or PB as potential moderators. Some evidence emerged implying that attention to task-relevant targets in the context of emotional images may be related to capability for suicide, but these findings were non-significant when corrections for multiple comparisons were applied thereby mitigating the interpretability. Thus, the relationship between sustained processing of threat/mutilation stimuli, suicide capability, and SI may be more complex than previously understood. Future research should examine the longitudinal relationships between neural indices of attention to emotionally salient information and capability for suicide.

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Table 1

Descriptive statistics for participant characteristics

Participant Characteristics	Frequency (n)	Percentage (%)
Sex		
Male	16	26.2%
Female	45	73.8%
Race		
Caucasian/White	47	77.0%
African American/Black	5	8.2%
Asian	8	13.1%
American Indian/Native American	1	1.6%
Native Hawaiian/Pacific Islander	1	1.6%
Other	6	9.8%
Hispanic/Latino	8	13.1%
Education Level		
Highschool or equivalent	16	26.2%
Some college, no degree	30	49.2%
Associate's degree	1	1.6%
Bachelor's degree	7	11.5%
Master's degree	6	9.8%
Doctoral degree	1	1.6%
Employment		
Full-Time	10	16.4%
Part-Time	25	41.0%
Unemployed, not seeking employment	22	36.1%
Unemployed, seeking employment	4	6.6%
Student		
Part time	1	1.6%
Full time	56	91.8%
Not a student	4	6.6%
Suicidality		
Current SI	16	26.2%
Lifetime History of SA	8	13.1%

N= 61

Table 2

Descriptive statistics and bivariate correlations between age, sex, ACSS FAD, ACSS Pain Tolerance, DSI-SS, LPP, P3 and covariates

	M (SD)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Age	21.84 (5.24)	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Sex	1.74 (0.44)	-.18	-	-	-	-	-	-	-	-	-	-	-	-
3. INQ-R PB	9.74 (5.43)	-.12	-.14	-	-	-	-	-	-	-	-	-	-	-
4. INQ-R TB	24.33 (1.44)	.16	-.27*	.65***	-	-	-	-	-	-	-	-	-	-
5. ACSS FAD	13.33 (7.42)	-.11	-.32*	.32*	.03	-	-	-	-	-	-	-	-	-
6. ACSS Pain Tolerance	23.13 (7.67)	-.15	-.37**	.30*	.20	.46***	-	-	-	-	-	-	-	-
7. DASS-21 Depression	5.11 (4.48)	.002	-.05	.72***	.67***	.05	.23	-	-	-	-	-	-	-
8. DASS-21 Anxiety	4.23 (3.68)	-.11	.11	.55***	.46***	.02	.05	.58***	-	-	-	-	-	-
9. DSI-SS	0.48 (0.89)	-.14	-.18	.63***	.49***	.08	.27*	.61***	.55***	-	-	-	-	-
10. ΔThreat LPP	0.21 (3.42)	.07	-.20	-.08	-.05	.25*	.17	-.13	.003	-.02	-	-	-	-
11. ΔPositive LPP	-0.02 (3.14)	.21	-.44***	.05	-.04	.12	.16	-.11	-.11	-.07	.27*	-	-	-
12. ΔThreat P3	0.004 (3.10)	-.25	.07	-.11	-.17	-.13	-.13	-.21	-.21	-.03	-.45***	-.04	-	-
13. ΔPositive P3	0.05 (2.22)	-.26*	-.03	.06	.03	.05	.09	-.08	.09	-.01	.03	-.20	.30*	-

Note. $N = 61$. INQ-R PB = Interpersonal Needs Questionnaire – Revised Perceived Burdensomeness, INQ-R TB = Interpersonal Needs Questionnaire – Revised Thwarted Belongingness, ACSS FAD = Acquired Capability for Suicide Scale Fearlessness about Death, ACSS Pain Tolerance = Acquired Capability for Suicide Scale Pain Tolerance, DASS-21 Depression = Depression Anxiety and Stress Scale Depression subscale, DASS-21 Anxiety = Depression Anxiety and Stress Scale Anxiety subscale, DSI-SS = Depression Symptom Index Suicide Scale.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$

Table 3

Linear regressions examining main and interactive effects of SI and ΔThreat LPP and ΔPositive LPP on ACSS-FAD

Variables	*B*	*SE*	LL	UL	*p*
Main Effects					
ΔThreat LPP	0.46	0.28	-0.09	1.02	.10
Age	-0.25	0.18	-0.61	0.11	.17
Sex	-5.07	2.16	-9.40	-0.73	.02*
DASS-21 Depression	0.11	0.26	-0.41	0.63	.68
DASS-21 Anxiety	-0.01	0.31	-0.64	0.62	.97
Interactive Effects					
ΔThreat LPP x DSI-SS	-0.37	0.24	-0.86	0.12	.13
ΔThreat LPP	0.84	0.37	0.10	1.58	.03*
DSI-SS	-0.49	1.42	-3.33	2.35	.73
Age	-0.25	0.18	-0.62	0.11	.16
Sex	-5.17	2.24	-9.67	-0.67	.03*
DASS-21 Depression	0.17	0.28	-0.40	0.73	.56
DASS-21 Anxiety	-0.02	0.33	-0.69	0.65	.95
Main Effects					
ΔPositive LPP	0.02	0.34	-0.65	0.70	.94
Age	-0.24	0.18	-0.61	0.13	.20
Sex	-5.78	2.40	-10.58	-0.98	.02*
DASS-21 Depression	0.03	0.26	-0.50	0.55	.92
DASS-21 Anxiety	0.06	0.32	-0.58	0.70	.85
Interactive Effects					
ΔPositive LPP x SI	0.02	0.34	-0.67	0.71	.95
ΔPositive LPP	0.00	0.38	-0.76	0.76	.99
DSI-SS	-0.55	1.49	-3.54	2.45	.72
Age	-0.25	0.19	-0.63	0.13	.19
Sex	-6.04	2.56	-11.18	-0.91	.02*
DASS-21 Depression	0.07	0.29	-0.51	0.66	.80
DASS-21 Anxiety	0.10	0.35	-0.60	0.80	.78

Note. $N = 61$. LL = Lower limit of 95% confidence interval. UL = Upper limit of 95% confidence interval. ACSS FAD = Acquired Capability for Suicide Scale Fearlessness about Death, ACSS Pain Tolerance = Acquired Capability for Suicide Scale Pain Tolerance, DASS-21 Depression = Depression Anxiety and Stress Scale Depression subscale, DASS-21 Anxiety = Depression Anxiety and Stress Scale Anxiety subscale, DSI-SS = Depression Symptom Index Suicide Scale.

* = $p < .05$, ** = $p < .01$, *** = $p < .001$

Table 4

Linear regressions examining main and interactive effects of SI and ΔThreat LPP and ΔPositive LPP on ACSS-Pain Tolerance

Variables	*B*	*SE*	LL	UL	*p*
Main Effects					
ΔThreat LPP	0.35	0.27	-0.20	0.89	.21
Age	-0.34	0.18	-0.69	0.01	.06
Sex	-5.99	2.13	-10.25	-1.72	.01*
DASS-21 Depression	0.52	0.25	0.01	1.03	.04
DASS-21 Anxiety	-0.25	0.31	-0.87	0.37	.42
Interactive Effects					
ΔThreat LPP x DSI-SS	-0.15	0.24	-1.77	3.90	.45
ΔThreat LPP	0.50	0.37	-0.24	1.24	.18
DSI-SS	1.07	1.41	-1.77	3.90	.45
Age	-0.31	0.18	-0.67	0.05	.09
Sex	-5.47	2.24	-9.96	-0.98	.02*
DASS-21 Depression	0.44	0.28	-0.13	1.00	.13
DASS-21 Anxiety	-0.35	0.33	-1.02	0.32	.30
Main Effects					
ΔPositive LPP	0.18	0.33	-0.48	0.84	.58
Age	-0.34	0.18	-0.70	0.02	.06
Sex	-0.02	2.33	-10.68	-1.36	.01*
DASS-21 Depression	0.48	0.26	-0.04	0.99	.07
DASS-21 Anxiety	-0.20	0.31	-0.82	0.42	.52
Interactive Effects					
ΔPositive LPP x DSI-SS	-0.71	0.32	-1.34	-0.07	.03*
ΔPositive LPP	0.53	0.35	-0.18	1.23	.14
DSI-SS	0.82	1.38	-1.96	3.59	.56
Age	-0.30	0.18	-0.66	.05	.09
Sex	-5.95	2.27	-10.71	-1.20	.02*
DASS-21 Depression	0.35	0.27	-0.19	0.89	.20
DASS-21 Anxiety	-0.15	0.32	-0.80	0.50	.64

Note. $N = 61$. LL = Lower limit of 95% confidence interval. UL = Upper limit of 95% confidence interval. ACSS FAD = Acquired Capability for Suicide Scale Fearlessness about Death, ACSS Pain Tolerance = Acquired Capability for Suicide Scale Pain Tolerance, DASS-21 Depression = Depression Anxiety and Stress Scale Depression subscale, DASS-21 Anxiety = Depression Anxiety and Stress Scale Anxiety subscale, DSI-SS = Depression Symptom Index Suicide Scale.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$

Table 5

Linear regressions examining main and interactive effects of SI and ΔThreat P3 and ΔPositive P3 on ACSS-FAD

Variables	*B*	*SE*	LL	UL	*p*
Main Effects					
ΔThreat P3	-0.38	0.32	-1.01	0.25	.23
Age	-0.29	0.19	-0.67	0.08	.12
Sex	-5.79	2.14	-10.07	-1.51	.01*
DASS-21 Depression	-0.02	0.26	-0.53	0.50	.95
DASS-21 Anxiety	0.03	0.32	-0.60	0.66	.92
Interactive Effects					
ΔThreat P3 x DSI-SS	0.75	0.37	0.02	1.49	.04*
ΔThreat P3	-0.71	0.35	-1.41	-0.01	.05*
DSI-SS	-0.36	1.42	-3.21	2.48	.80
Age	-0.38	0.19	-0.76	-0.003	.05*
Sex	-6.69	2.21	-11.10	-2.23	.004**
DASS-21 Depression	0.03	0.28	-0.53	0.59	.91
DASS-21 Anxiety	-0.06	0.33	-0.73	0.61	.86
Main Effects					
ΔPositive P3	-0.03	0.44	-0.92	0.86	.95
Age	-0.24	0.19	-0.62	0.14	.21
Sex	-5.87	2.18	-10.23	-1.51	.01*
DASS-21 Depression	0.02	0.26	-0.50	0.55	.93
DASS-21 Anxiety	0.07	0.32	-0.58	0.71	.84
Interactive Effects					
ΔPositive P3 x DSI-SS	0.82	0.52	-0.23	1.87	.12
ΔPositive P3	-0.53	0.53	-1.61	0.55	.33
DSI-SS	-0.81	1.46	-3.74	2.12	.58
Age	-0.33	0.20	-0.73	0.07	.10
Sex	-6.98	2.33	-11.64	-2.31	.004**
DASS-21 Depression	0.07	0.29	-0.50	0.64	.81
DASS-21 Anxiety	0.10	0.34	-0.58	0.79	.77

Note. $N = 61$. LL = Lower limit of 95% confidence interval. UL = Upper limit of 95% confidence interval. ACSS FAD = Acquired Capability for Suicide Scale Fearlessness about Death, ACSS Pain Tolerance = Acquired Capability for Suicide Scale Pain Tolerance, DASS-21 Depression = Depression Anxiety and Stress Scale Depression subscale, DASS-21 Anxiety = Depression Anxiety and Stress Scale Anxiety subscale, DSI-SS = Depression Symptom Index Suicide Scale.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$

Table 6

Linear regressions examining main and interactive effects of SI and ΔThreat P3 and ΔPositive P3 on ACSS-Pain Tolerance

Variables	*B*	*SE*	LL	UL	*p*
Main Effects					
ΔThreat P3	-0.33	0.31	-0.95	0.28	.28
Age	-0.38	0.18	-0.74	-0.02	.04*
Sex	-6.52	2.09	-10.70	-2.34	.003**
DASS-21 Depression	0.42	0.25	-0.09	0.93	.10
DASS-21 Anxiety	-0.22	0.31	-0.84	0.40	.48
Interactive Effects					
ΔThreat P3 x DSI-SS	0.70	0.36	-0.01	1.41	.05
ΔThreat P3	-0.68	0.34	-1.37	0.01	.05
DSI-SS	1.23	1.38	-1.54	4.00	.38
Age	-0.43	0.18	-0.80	-0.06	.02*
Sex	-6.64	2.15	-10.96	-2.32	.003**
DASS-21 Depression	0.33	0.27	-0.21	0.88	.23
DASS-21 Anxiety	-0.43	0.33	-1.08	0.22	.19
Main Effects					
ΔPositive P3	0.18	0.43	-0.69	1.04	.68
Age	-0.31	0.18	-0.68	0.06	.10
Sex	-6.48	2.12	-10.72	-2.23	.003**
DASS-21 Depression	0.47	0.26	-0.04	0.98	.07
DASS-21 Anxiety	-0.22	0.31	-0.84	0.42	.50
Interactive Effects					
ΔPositive P3 x DSI-SS	1.30	0.49	0.32	2.27	.01*
ΔPositive P3	-0.56	0.50	-1.56	0.45	.27
DSI-SS	0.71	1.36	-2.02	3.44	.61
Age	-0.40	0.18	-0.77	-0.03	.03*
Sex	-7.33	2.17	-11.67	-2.99	.001**
DASS-21 Depression	0.39	0.37	-0.14	0.92	.15
DASS-21 Anxiety	-0.31	0.32	-0.95	0.32	.33

Note. $N = 61$. LL = Lower limit of 95% confidence interval. UL = Upper limit of 95% confidence interval. ACSS FAD = Acquired Capability for Suicide Scale Fearlessness about Death, ACSS Pain Tolerance = Acquired Capability for Suicide Scale Pain Tolerance, DASS-21 Depression = Depression Anxiety and Stress Scale Depression subscale, DASS-21 Anxiety = Depression Anxiety and Stress Scale Anxiety subscale, DSI-SS = Depression Symptom Index Suicide Scale.
* = $p < .05$, ** = $p < .01$, *** = $p < .001$

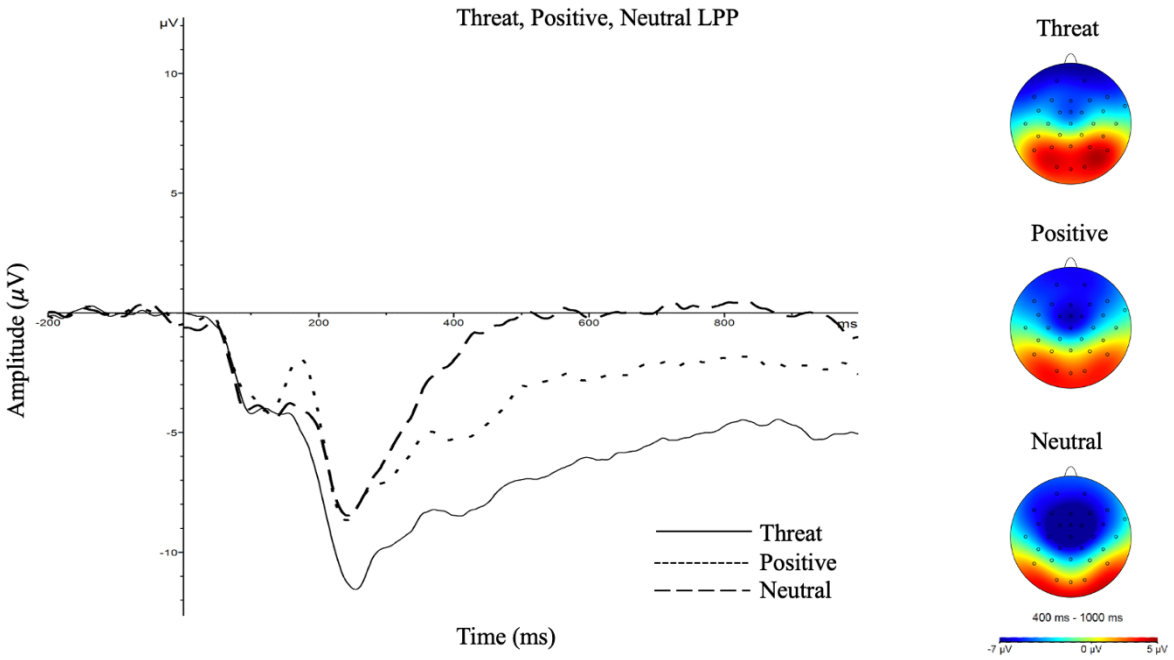

Figure 1. Waveforms for threat, positive, and neutral IAPS images presented during EIT. LPP = Late Positive Potential; EIT = Emotion Interrupt Task

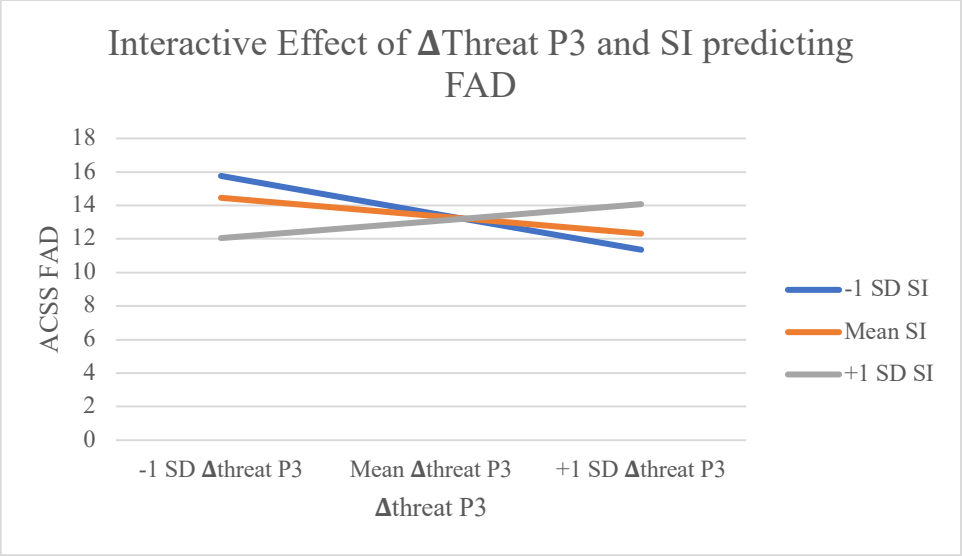

Figure 2. The interactive effects of the **Δ**threat P3 and SI predicting FAD. Results indicated that greater Δthreat P3 predicted lower FAD among those with low SI. *SD* = standard deviation; SI = Suicide ideation; ACSS = Acquired Capability for Suicide Scale; FAD = Fearlessness about death.

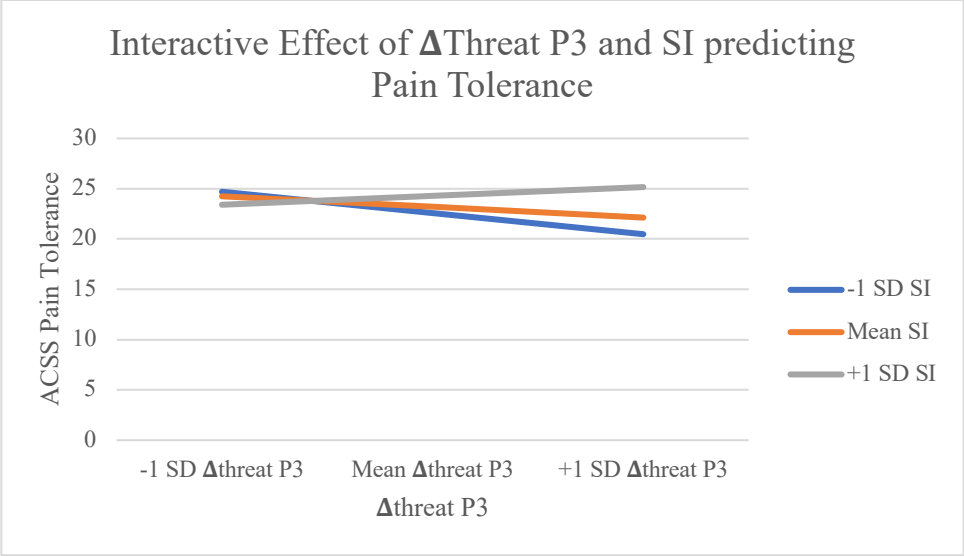

Figure 3. The interactive effects of the **Δ**threat P3 and SI predicting pain tolerance. Results indicated that greater Δthreat P3 predicted lower pain tolerance among those with low SI. *SD* = standard deviation. SI = Suicide ideation; ACSS = Acquired Capability for Suicide Scale.

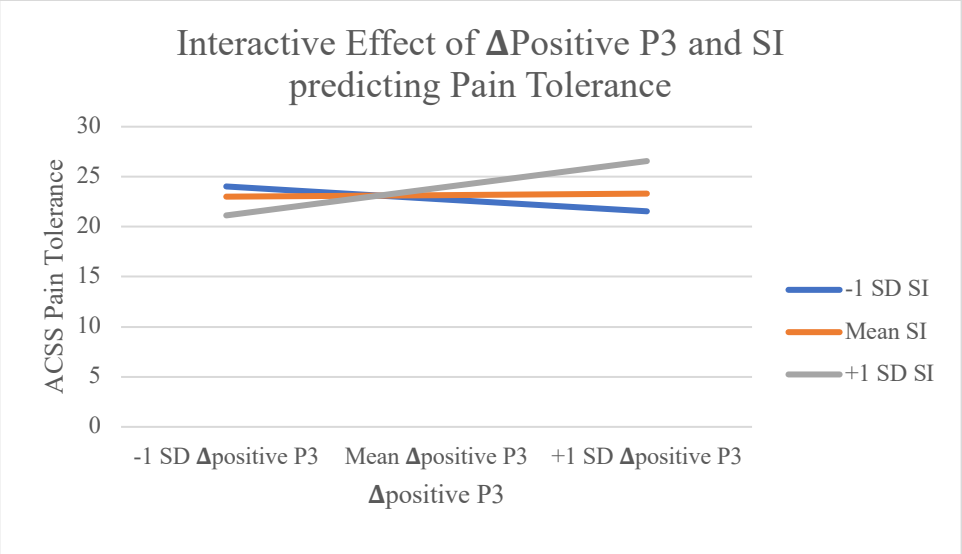

Figure 4. The interactive effects of the **Δ**positive P3 and SI predicting pain tolerance. Results indicated that greater **Δ**positive P3 predicted greater pain tolerance among those with greater SI. *SD* = standard deviation; SI = Suicide ideation; ACSS = Acquired Capability for Suicide Scale.

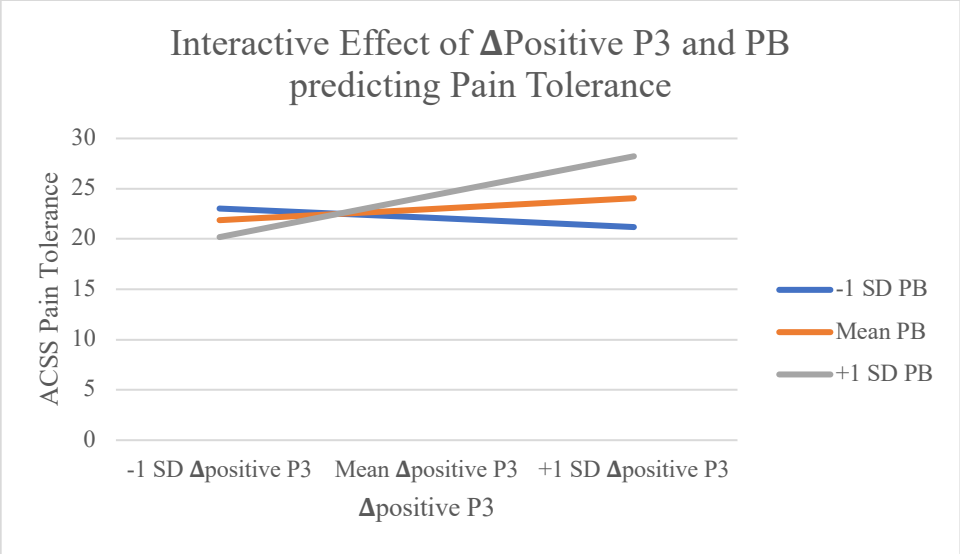

Figure 5. The interactive effects of the **Δ**positive P3 and PB predicting pain tolerance. Results indicated that greater Δpositive P3 was associated with greater pain tolerance among those with high PB. *SD* = standard deviation; PB = perceived burdensomeness; ACSS = Acquired Capability for Suicide Scale.