Published in final edited form as:

Cognit Ther Res. 2018 August ; 42(4): 510–523. doi:10.1007/s10608-017-9883-4.

Interactive effects of traumatic brain injury and anxiety sensitivity on PTSD symptoms: A replication and extension in two clinical samples

Brian J. Albanese^a, Richard J. Macatee^a, Joseph W. Boffa^a, Craig J. Bryan^{b,c}, Michael J. Zvolensky^d, and Norman B. Schmidt^a

^aDepartment of Psychology, Florida State University, Tallahassee, FL, USA

^bNational Center for Veterans Studies, Salt Lake City, UT, USA

^cDepartment of Psychology, University of Utah, UT, USA

^dDepartment of Psychology, University of Houston, TX, USA

1. Introduction

The clinical implications of Traumatic Brain Injury (TBI) has received growing interest resulting, in large part, from the high prevalence of TBI among military populations (Terrio et al., 2009 ; Vasterling et al., 2006) and associations with increased risk of posttraumatic stress symptoms (PTSS; Barnes, Walter, & Chard, 2012 ; Bryan & Clemans, 2013 ; Bryant et al., 2010 ; Hoge et al., 2008 ; Ruff, Riechers, Wang, Piero, & Ruff, 2012 ; Schneiderman, Braver, & Kang, 2008). However, TBI is not unique to soldiers deployed in current military conflicts. In 2012, nearly 3.5 million American civilians sustained a TBI (Coronado et al., 2012) and evidence from a seminal cohort study in New Zealand revealed that over 30% of civilians experienced at least one TBI by age 25 (McKinlay et al., 2008). Thus, it is important to also examine the mechanisms linking TBI with PTSS in non-active duty military populations.

TBI research has thus far largely focused on establishing a direct link between TBI and PTSS. For instance, a seminal article found that experiencing a TBI during deployment elevated the likelihood that United States (U.S.) Army Infantry soldiers ($n = 2,525$) met criteria for post-traumatic stress disorder (PTSD; Hoge et al., 2008). Notably, the link between TBI and PTSD was not explained by combat intensity and other relevant covariates (physical health, other physical injuries, depression symptoms), suggesting that TBI is not merely a proxy for other variables related to PTSD (Hoge et al., 2008). Similar associations have been found in civilians. Bryant et al. (2010) found that civilians reporting to a trauma

Address correspondence to Norman B. Schmidt, Ph.D., Distinguished Research Professor, Department of Psychology, Florida State University, 1107 W. Call Street, Tallahassee, FL.

Conflicts of interest: Brian J. Albanese declares that he has no conflicts of interest. Richard J. Macatee declares that he has no conflicts of interest. Joseph Boffa declares that he has no conflicts of interest. Craig Bryan declares that he has no conflicts of interest. Michael Zvolensky declares that he has no conflicts of interest. Norman B. Schmidt declares that he has no conflicts of interest.

Research involving human participants: All research was approved by the appropriate Institutional Review Boards prior to the beginning of data collection as well as renewed as necessary throughout the study duration, including the present data analyses.

center for a TBI were more likely to meet criteria for PTSD at 3 months and 12 months post-injury compared to those who incurred non-brain related physical injuries (Bryant et al., 2010). Similarly, female domestic abuse survivors with positive TBI histories reported greater PTSS than those without TBIs, even when accounting for other physical injuries (Valera & Berenbaum, 2003).

Despite the association between TBI and elevated PTSS, research evaluating this relationship in the context of well-established cognitive-affective risk factors for PTSS is lacking. Anxiety sensitivity (AS; Reiss & McNally, 1985a) is one of the most well-researched cognitive-affective risk factors for PTSS (see Taylor, 2003 for a review). AS reflects the extent to which an individual evaluates benign, anxiety-related sensations as having deleterious consequences in cognitive, physical, or social domains (Reiss & McNally, 1985a). For instance, an individual with elevated AS cognitive concerns may catastrophically misinterpret symptoms of cognitive dyscontrol (e.g., difficulty concentrating) as indicative that they are going crazy. An individual with elevated AS physical concerns may believe that a racing heart is a sign that they are having a heart attack. Lastly, an individual with elevated AS social concerns may think that others noticing their symptoms of anxiety will lead to social rejection.

AS total score and lower-order subfactors are believed to contribute to the genesis and maintenance of PTSS in two primary ways: 1) via the amplification of peri-traumatic emotionality and 2) by exacerbating post-traumatic affective responses to trauma reminders (see Taylor, 2003 for a review). AS functions by amplifying existing anxious arousal through a positive feedback loop in which an individual with high AS interprets initial symptoms of anxiety as indicative of impending danger, thereby generating greater anxiety which is further misinterpreted (Reiss & McNally, 1985b ; Taylor, 2003). Thus, high AS can lead to exaggerated peri-traumatic emotionality (i.e., greater affective responses during a traumatic event) as well as greater affective responses to trauma reminders because the individual fears not only the traumatic event itself but also the accompanying anxious arousal (Taylor, 2003). Importantly, greater affective responses both during the trauma and when confronted with reminders of the trauma are associated with elevated PTSS (Tucker, Pfefferbaum, Nixon, & Dickson, 2000).

Indeed, a breadth of literature supports the link between AS and PTSS across a variety of study designs (see Olatunji & Wolitzky-Taylor, 2009 for a review). For instance, greater AS has been cross-sectionally associated with greater PTSS among police officers (Asmundson & Stapleton, 2008), community outpatients (Albanese et al., in press), non-treatment seeking community adults (Vujanovic, Zvolensky, & Bernstein, 2008), treatment-seeking veterans (Raines et al., 2017), and adults with substance abuse (McDermott, Tull, Gratz, Daughters, & Lejuez, 2009). Moreover, AS has been shown to predict PTSS longitudinally when assessed after a trauma (Marshall, Miles, & Stewart, 2010) and prospectively when AS is measured prior to a trauma (Boffa et al., 2016), thereby fitting the definition of a true risk factor (Kraemer et al., 1997).

It is plausible that AS, in particular AS cognitive and physical concerns, may moderate the effect of TBI on PTSS. TBI is believed to influence PTSS via disruptions in cognitive

control (i.e., cognitive dyscontrol) and exaggerated emotional reactivity (Aupperle, Melrose, Stein, & Paulus, 2012 ; Bryant et al., 2010 ; Glenn et al., 2017). As described above, AS increases both PTSS-related (Asmundson & Stapleton, 2008 ; Boffa et al., 2016 ; Taylor, 2003 ; Vujanovic, Zvolensky, & Bernstein, 2008) and TBI-related (Albanese, Boffa, Macatee, & Schmidt, 2017) symptoms of cognitive dyscontrol and arousal via the misinterpretation of these sensations as harmful. Therefore, the effects of TBI on PTSS may be potentiated among those with high AS cognitive and AS physical concerns due to the amplification of TBI-related symptoms of cognitive dyscontrol and anxious arousal, respectively. Indeed, Albanese et al. (2017) found evidence that TBI was more strongly related to PTSS among those with elevated AS cognitive concerns. However, this study was unable to test if AS total score, physical concerns, or social concerns demonstrated similar interactive effects.

On the other hand, there is also reason to believe that TBI moderates the effect of AS on PTSS via TBI-disruptions in cognitive functioning. Tangential evidence for this comes from studies showing that poor cognitive functioning (e.g., attentional control) moderates the effects of AS on PTSS (Albanese et al., in press ; Bardeen & Fergus, 2015). One study has also directly tested this hypothesis. Among a sample of active duty soldiers, Albanese et al., (2017) demonstrated that TBI amplified the relations between AS cognitive concerns and PTSS. Yet, as mentioned above, this study was unable to test the interactive effects of TBI and AS total, AS physical concerns, and AS social concerns, representing a considerable limitation.

The present study was designed to replicate Albanese et al.'s (2017) prior finding that TBI and AS cognitive concerns interact to predict greater PTSS, and extend this finding by examining the interactive effects of TBI with AS total score, AS physical concerns, and AS social concerns, respectively. Further, Albanese et al. (2017) investigated this interaction among active duty military service members. Therefore, the present study will also extend these findings by examining the proposed interactive effects in two treatment-seeking civilian populations to examine if the interaction observed in Albanese et al. (2017) is generalizable to at-risk civilian populations: 1) trauma-exposed adults attempting to quit smoking and 2) trauma-exposed adults seeking treatment for suicide risk. These samples represent convenience samples of trauma exposed individual derived from larger clinical trials (see Sample and Setting sections for study 1 and study 2) to provide an initial investigate into the interactive effects of TBI and AS on PTSS among civilians.

First, we hypothesized that we would replicate prior findings (Albanese et al., 2017) demonstrating a two-way interaction between TBI and AS cognitive concerns, such that AS cognitive concerns had a stronger relationship with PTSS among individuals with a TBI history and that TBI has a stronger relationship with PTSS among those with elevated AS cognitive concerns. In addition, we hypothesized a significant two-way interaction of TBI and AS physical concerns predicting greater PTSS, given the association of TBI with physical arousal (Ryan & Warden, 2003) and the specificity of AS physical concerns to the amplification of physical arousal. Given research showing that the relationship between AS total score and PTSS is amplified among those with cognitive dysfunction like that observed among those with a TBI history (Albanese, Boffa, Macatee, & Schmidt, 2017), we also

hypothesized a significant two-way interaction of TBI and AS total score will emerge. Lastly, we refrained from hypotheses regarding the interaction of TBI and AS social concerns due to a dearth of theoretical or empirical support either supporting the existence or absence of this effect.

2. Study 1 – Method

2.1. Sample and setting

Participants ($N = 257$) were adult daily smokers recruited from communities in the Southeastern and Northeastern United States to participate in a larger study ($N = 453$) examining the effects of an anxiety-based treatment on smoking cessation (Schmidt, Raines, Allan, & Zvolensky, 2016). Inclusion criteria for the parent study required participants be at least 18 years of age, demonstrate elevated levels of AS (i.e., at least 1.5 SD above the community mean), and have smoked a minimum of eight cigarettes per day for at least the past year. Exclusion criteria included the presence of un-medicated psychotic disorders, serious medical conditions, and the use of extracurricular smoking cessation programs or tobacco products.

All participants selected for the present analyses indicated a history of trauma exposure based on Parts 1 and 2 of the Post-traumatic Stress Diagnostic Scale (Foa, Cashman, Jaycox, & Perry, 1997). Participants ranged in age from 18–68 ($M = 39.84$, $SD = 12.54$), and were fairly split among genders (51.36% male). Most participants identified their race/ethnicity as White/Caucasian (84.05%), with the rest of the sample made up of Black non-Hispanic (9.34%), Hispanic (2.33%), Asian (1.12%), Black Hispanic (0.78%), and 2.33% ‘Other’ (e.g., bi-racial).

2.2. Procedure

Eligible participants completed a structured clinical interview and self-report assessments of anxiety, substance use, and smoking behaviors prior to treatment randomization (see Schmidt, Raines, Allan, & Zvolensky, 2016 for additional details regarding the intervention). The study was approved by each university’s respective Institutional Review Board. Informed consent was obtained from all participants prior to data collection.

2.3. Measures

Anxiety Sensitivity Index – 3 (ASI-3)—The ASI-3 (Taylor et al., 2007) is an 18-item self-report measure developed to improve the psychometric properties of the original ASI (Reiss & McNally, 1985a) and used to index one’s tendency to interpret benign anxiety-related arousal symptoms as potentially dangerous. The ASI-3 is composed of a total score and three lower-order subscales: AS cognitive concerns, AS physical concerns, and AS social concerns. The ASI-3 has exhibited strong psychometric properties, including internal consistency, factor stability, and divergent validity (Chavarria et al., 2015 ; Farris et al., 2015 ; Taylor et al., 2007). In the current study, the ASI-3 total, cognitive, physical, and social scores demonstrated good internal reliability (α ’s = .93, .90, .89, and .83, respectively).

Medical History Form (MHF)—The present study used an adapted version of the MHF (Scheftner & Endicott, 1984) to record lifetime history of medical problems. The MHF is a structured instrument administered by trained interviewers and assesses a number of potential medical problems a person may have had (e.g., epilepsy, cardiac problems, hypertension, allergies, respiratory disease, asthma). Included in this is the presence/absence of a medically diagnosed head injury, in which participants are asked to indicate if they have ever had a head injury. This item was used in the present analyses to assess each individual's history of a probable TBI (i.e., no TBI history or probable TBI history). The MHF has excellent psychometric properties and has been extensively used in previous research to screen for medical problems and potential TBIs (Hays, Marshall, Wang, & Sherbourne, 1994 ; Leyro & Zvolensky, 2013).

Post-traumatic Stress Diagnostic Scale (PDS)—The PDS (Foa, Cashman, Jaycox, & Perry, 1997) is a standardized measure of DSM-IV PTSD diagnostic criteria, including trauma characteristics and past-month symptom severity. Participants were asked to indicate how much they have been bothered by PTSS during the past month. In the present study, responses to each item were sum-scored to calculate a total score index of PTSS severity; this method has demonstrated excellent internal consistency ($\alpha = .92$) in prior studies (Foa, Cashman, Jaycox, & Perry, 1997). In the present study, internal consistency of PDS total scores was excellent ($\alpha = .93$).

Penn State Worry Questionnaire (PSWQ)—The PSWQ is a 16-item measure of pathological worry and trait anxiety (Meyer, Miller, Metzger, & Borkovec, 1990). In the present study, PSWQ scores were used to covary potential effects of anxiety symptomology. In prior studies (Fresco, Heimberg, Mennin, & Turk, 2002), the PSWQ demonstrated good internal consistency ($\alpha = .90$). Internal consistency was excellent in the present sample ($\alpha = .94$).

Inventory of Depression and Anxiety Symptoms – General Depression subscale (IDAS-GD)—The IDAS (Watson et al., 2007) is a 64-item self-report measure from which 10 specific symptom dimension subscales can be calculated. In the present study, only the 20-item General Depression subscale was used to covary potential effects of depression symptoms. Previous evidence suggests the IDAS-GD subscale yields scores with good internal consistency (α 's = .88–.92) across multiple samples (Watson et al., 2007). Scores on this scale yielded excellent internal consistency ($\alpha = .94$) in the present sample.

2.4. Data analytic plan

Descriptive statistics and correlations between all variables were first computed and reported using the scale scores. All subsequent analyses included depression symptoms, anxiety symptoms, age, and biological sex as covariates due to their associations with TBI outcomes (Albanese, Boffa, Macatee, & Schmidt, 2017 ; McKee et al., 2009), AS (Stewart, Taylor, & Baker, 1997), and PTSS (Norr, Albanese, Boffa, Short, & Schmidt, 2016)¹. The PROCESS Macro for SPSS (Hayes, 2012) was used to test four separate models examining the interactive effects of TBI with AS total score, AS cognitive concerns, AS physical concerns, and AS social concerns. Following each respective interactive model, the conditional effects

of TBI on PTSS were probed at the 10th, 25th, 50th, 75th, and 90th percentiles of the respective AS total/subscale score. Lastly, conditional effects of the respective AS total/subscale score on PTSS were examined among individuals who endorsed no prior TBIs and individuals who reported a probable TBI history.

3. Study 1 - Results

3.1. Sample descriptive statistics and correlations

Sample descriptive statistics and correlations can be found in Table 1. Notably, high zero-order correlations were observed between the ASI-3 total score and ASI-3 subscale scores, as is consistent with extant literature (Norr, Albanese, Allan, & Schmidt, 2015 ; Zvolensky et al., 2016). Given that the ASI-3 total score is scored as a sum of all ASI-3 items that are used for each subscale, the high correlations between these factors is unsurprising.

3.2. Interactive effects of AS total and subscales and probable TBI on PTS

To test whether AS total score and AS subscales moderated the effect of probable TBI on PTSS we conducted four separate models examining the interaction of probable TBI and AS total score and each subscale. Gender, age, depression symptoms, and anxiety symptoms were included as covariates (see Table 2 for a full summary).

Results indicated that the interaction of probable TBI and AS total score was non-significant ($B = .25$, $SE = .14$, $t = 1.73$, $p = .08$, 95% CI $[-.03, .53]$). Among the subscales, probable TBI significantly interacted with AS cognitive concerns ($B = 1.03$, $SE = .45$, $t = 2.27$, $p = .02$, 95% CI $[.14, 1.92]$) but not AS physical concerns ($B = .13$, $SE = .30$, $t = .44$, $p = .66$, 95% CI $[-.46, .72]$) or AS social concerns ($B = .55$, $SE = .34$, $t = 1.64$, $p = .10$, 95% CI $[-.11, 1.21]$).

3.3. Probing the interactive effects of AS cognitive concerns and probable TBI on PTS

The significant interaction of AS cognitive concerns and probable TBI was probed to further understand the potential two-way interaction. First, the conditional effects of TBI on PTSS at levels of AS cognitive concerns was examined. Results indicated that TBI was a non-significant predictor of PTSS among individuals with low AS cognitive concerns (i.e., 25th percentile; $B = -.56$, $SE = 1.90$, $t = -.30$, $p = .77$, 95% CI $[-4.30, 3.18]$) and median AS cognitive concerns (i.e., 50th percentile; $B = .47$, $SE = 1.64$, $t = .28$, $p = .78$, 95% CI $[-2.77, 3.70]$). However, probable TBI was a significant predictor of PTSS among those with increasingly elevated levels of AS cognitive concerns (i.e., 75th percentile AS cognitive concerns, $B = 4.59$, $SE = 1.79$, $t = 2.56$, $p = .01$, 95% CI $[1.06, 8.11]$; 90th percentile AS cognitive concerns, $B = 9.74$, $SE = 3.62$, $t = 2.69$, $p = .008$, 95% CI $[2.61, 16.86]$).

Next, the conditional effects of AS cognitive concerns on PTSS among those with and without a probable TBI were probed. Results indicated that AS cognitive concerns

¹Analyses were also conducted using the presence/absence of any other medical illness (indexed by the MHF) as an additional covariate, and the same pattern of results emerged. In addition, the interaction of AS total and subscale scores with the history of other medical illness on PTSS was also examined, but non-significant (p 's $> .30$). To keep the analyses in studies 1 and 2 consistent, only results without medical illness history are presented.

significantly predicted PTSS among those with a probable TBI ($B = 1.08$, $SE = .44$, $t = 2.42$, $p = .016$, 95% CI [.20, 1.95]) but did not predict PTSS among those without a probable TBI ($B = .05$, $SE = .14$, $t = .33$, $p = .74$, 95% CI [-.23, .32]).

3.4. Study 1 discussion

The findings in study 1 are limited by the measure of probable TBI history available, which included only the presence or absence of a past TBI diagnosis. However, the severity of a probable TBI, such as the duration of loss of consciousness (LoC; Cantu, 1992 ; WHO, 1992), may also be relevant. Study 2 addressed this gap by utilizing a well-established self-report measure of TBI history that assesses the severity of probable TBI via the duration of LoC.

4. Study 2 – Method

4.1. Sample and setting

Participants ($N = 117$) were adult community outpatients recruited to participate in a larger study ($N = 304$) examining the effects of an anxiety-based treatment on suicide (ClinicalTrials.gov Identifier NCT00387049). This subset of participants were selected based on their indication of prior trauma exposure on the PDS and the availability of the TBI-Q data. All data were collected during the baseline appointment prior to treatment randomization.

Inclusion criteria for the parent study required participants be at least 18 years of age, demonstrate elevations of at least 1.5 SD above the community mean on one of several risk factors for suicidality (i.e., thwarted belongingness, perceived burdensomeness; Van Orden et al., 2010), including AS cognitive concerns (Taylor et al., 2007). Participants were also required to be proficient in English. Exclusion criteria included the presence of current or past psychotic spectrum disorders, un-medicated bipolar spectrum disorders, serious medical conditions that would preclude participation in the intervention (e.g., respiratory disorder, cardiovascular disease), or significant suicidal intent requiring immediate hospitalization. Participants ranged in age from 18–75 ($M = 38.83$, $SD = 16.07$), and were fairly evenly split among genders ($n = 62$ female; 52.99%). Approximately one-third (35.89%) of the sample reported a history of military service but no participants were active duty. Most participants identified their race/ethnicity as White/Caucasian (59.83%), with the rest of the sample made up of African American/Black (29.06%), Asian (2.56%), Pacific Islander (0.85%), American Indian/Native American (0.85%), and 6.84% ‘Other’ (e.g., bi-racial).

4.2. Procedure

Individuals who met initial eligibility criteria completed self-report questionnaires and a semi-structured diagnostic interview. All study procedures were approved by the university’s Institutional Review Board, and informed consent was obtained from all participants prior to data collection.

4.3. Measures

Anxiety Sensitivity Index – 3 (ASI-3)—As in the first study, the ASI-3 (Taylor et al., 2007) total, cognitive, physical, and social scales demonstrated good to excellent internal consistency among this sample (α 's = .93, .92, .86, and .84, respectively).

Traumatic Brain Injury Questionnaire (TBI-Q)—In study 2, TBI history was assessed via the TBI-Q (Diamond, Harzke, Magaletta, Cummins, & Frankowski, 2007), a 4-item questionnaire that was adapted for civilian use from a TBI measure initially intended for use with military populations (Brief Traumatic Brain Injury Screen; Schwab et al., 2006). The TBI-Q has shown good sensitivity and specificity for TBI history when verified against clinical TBI interview, and has successfully identified TBI history in prior studies (Diamond, Harzke, Magaletta, Cummins, & Frankowski, 2007 ; Matthews, Simmons, & Strigo, 2011 ; Matthews, Spadoni, Lohr, Strigo, & Simmons, 2012 ; Richardson, Cyr, Nelson, Elhai, & Sareen, 2014 ; Shu, Onton, O'Connell, Simmons, & Matthews, 2014). The present study used the TBI-Q to index TBI history severity. Item 2 of the TBI-Q asks participants to indicate if they have experienced any of a number of symptoms, including “Being dazed, confused, or seeing stars,” “Not remembering the injury,” “having any symptoms of a concussion afterward (such as headache dizziness, irritability, etc.),” losing consciousness (knocked out) for less than a minute,” “losing consciousness for 1–20 minutes,” and “losing consciousness for longer than 20 minutes.” In line with literature indicating that losing consciousness, and longer durations of loss of consciousness, are associated with greater TBI severity (Hoge et al., 2008; O'Neil et al., 2013), individuals were stratified into the following groups: No TBI, TBI with no LoC, TBI with up to 1 minute LoC, TBI with 1–20 minutes LoC, and TBI with greater than 20 minutes LoC.

Post-traumatic Stress Diagnostic Scale (PDS)—The PDS (Foa, Cashman, Jaycox, & Perry, 1997) was used in study 2 to index trauma exposure and verify lifetime presence of a Criterion A traumatic event. We included only Parts 1 and 2 of the PDS, for which participants were asked to identify from a list of twelve choices, events which they had experienced or witnessed (Part 1); followed by a question to clarify which event, if participants indicated more than 1, currently bothered them the most, and a space to briefly detail that event (Part 2).

PTSD Checklist for DSM-5 (PCL-5)—The PCL-5 (Weathers et al., 2013) is a 20-item self-report questionnaire that assesses the past month severity of each of the 20 *DSM-5* criteria for PTSD on a 5-point Likert scale from 0 (*not at all*) to 4 (*extremely*). In preliminary studies, scores from the full PCL-5 have demonstrated good internal consistency (α 's = .94–.96) among analog (Blevins, Weathers, Davis, Witte, & Domino, 2015) and veteran (Bovin et al., 2016) samples. In the present sample, PCL-5 score internal consistency was excellent (α = .95).

Spielberger State-Trait Anxiety Inventory – Trait Anxiety Subscale (STAI-T)—The STAI (Spielberger, 1983) is a 40-item self-report measure indexing individual differences in two domains: State anxiety (i.e., current anxiety; 20-items) and Trait anxiety (i.e., how the participant feels on average; 20-items). The current study utilized the Trait

anxiety subscale (STAI-T) as a covariate in all analyses. The STAI-T has shown good internal consistency in previous studies (Spielberger, 1983). In the current study, the STAI-T demonstrated excellent internal consistency ($\alpha = .90$).

IDAS General Depression subscale (IDAS-GD)—As in the first study, the IDAS-GD (Watson et al., 2007) subscale was used to covary for depression symptoms in all study 2 analyses. Baseline scores on the 20-item IDAS-GD subscale demonstrated good internal consistency in the present sample ($\alpha = .88$).

4.4. Data analytic plan

The progression of data analysis in study 2 was identical to the data analytic plan used in study 1. However, the measures for anxiety (i.e., the STAI-T), PTSS (i.e., the PCL-5), and TBI history (TBI-Q) differed. Notably, the TBI-Q indexes the severity of the probable TBI via the duration of LoC endorsed (Cantu, 1992 ; WHO, 1992). Thus, the conditional effects of AS total/subscale scores on PTSS were probed for each TBI group.

5. Study 2 – Results

5.1. Sample descriptive statistics and correlations

A full summary of sample descriptive statistics and correlations can be found in Table 3. Of note, 43 (36.75%) individuals reported no probable TBI history, 36 (30.77%) individuals reported a probable TBI without LoC, 15 (12.82%) reported a probable TBI with LoC < 1 minute, 15 (12.82%) reported a probable TBI with LoC between 1 and 20 minutes, and 8 (0.07%) participants endorsed a probable TBI with LoC > 20 minutes. As expected, the ASI-3 total score shared high correlations with each of the ASI-3 subscales.

5.2. Moderating effects of AS on the relationship between probable TBI status and PTS

To test if AS total score and AS subscales moderated the effect of TBI on PTSS we conducted four separate models examining the interaction of probable TBI and AS total score, AS cognitive concerns, AS physical concerns, and AS social concerns. Gender, age, depression symptoms, and anxiety symptoms were included as covariates (see Table 4 for a full summary).

Results indicated that the interaction of probable TBI and AS total score was not statistically significant ($B = .10$, $SE = .06$, $t = 1.69$, $p = .09$, 95% CI $[-.47, 3.70]$). Among the subscales, probable TBI interacted significantly with AS cognitive concerns ($B = .30$, $SE = .14$, $t = 2.10$, $p = .038$, 95% CI $[.02, .58]$), but not with AS physical concerns ($B = .26$, $SE = .16$, $t = 1.66$, $p = .10$, 95% CI $[-.05, .57]$) or AS social concerns ($B = .21$, $SE = .17$, $t = 1.23$, $p = .22$, 95% CI $[-.13, .54]$).

5.3. Probing the interactive effects of AS cognitive concerns and probable TBI on PTS

The conditional effects of the presence and severity of a probable TBI on PTSS at levels of AS cognitive concerns was then examined. Results indicated that TBI status was a non-significant predictor of PTSS among individuals with low AS cognitive concerns (i.e., 10th percentile AS cognitive concerns, $B = -1.43$, $SE = 1.62$, $t = -.88$, $p = .38$, 95% CI $[-4.64,$

1.78]; 25th percentile AS cognitive concerns; $B = -.24$, $SE = 1.24$, $t = -.19$, $p = .85$, 95% CI [-2.70, 2.22]) and median AS cognitive concerns (i.e., 50th percentile; $B = .66$, $SE = 1.07$, $t = .61$, $p = .54$, 95% CI [-1.47, 2.78]). However, probable TBI was a significant predictor of PTSS among those with increasingly elevated levels of AS cognitive concerns (i.e., 75th percentile AS cognitive concerns, $B = 2.74$, $SE = 1.28$, $t = 2.14$, $p = .03$, 95% CI [.20, 5.29]; 90th percentile AS cognitive concerns, $B = 4.83$, $SE = 2.03$, $t = 2.38$, $p = .019$, 95% CI [.80, 8.85]).

Next, the conditional effects of AS cognitive concerns on PTSS among those without a probable TBI and increasing levels of probable TBI severity were probed. Results indicated that AS cognitive concerns did not significantly predict PTSS among those with no probable TBI history ($B = .29$, $SE = .26$, $t = 1.12$, $p = .26$, 95% CI [-.22, .80]). Among individuals with any probable TBI, AS cognitive concerns had an increasingly robust relationship with PTSS among those with a probable TBI but no LoC ($B = .59$, $SE = .21$, $t = 2.78$, $p = .006$, 95% CI [.17, 1.01]), a probable TBI with LoC < 1 minute ($B = .89$, $SE = .25$, $t = 3.52$, $p < .001$, 95% CI [.39, 1.38]), a probable TBI with LoC between 1 and 20 minutes ($B = 1.18$, $SE = .35$, $t = 3.38$, $p = .001$, 95% CI [.49, 1.88]), and a probable TBI with LoC > 20 minutes ($B = 1.48$, $SE = .47$, $t = 3.15$, $p = .002$, 95% CI [.55, 2.42]).

6. General Discussion

The present study examined two independent samples in order to replicate and extend prior research revealing the interactive effects of probable TBI history and AS cognitive concerns on PTSS (Albanese et al., 2017) to include all AS subscales. Results across samples partially supported hypotheses; probable TBI status (regardless of the measurement approach) exhibited a significant interaction with AS cognitive concerns, but the interactions with AS total score and AS physical concerns were not significant. These results are consistent with prior research that only examined the AS cognitive concerns subscale (Albanese et al., 2017), and extended these findings in two important ways: 1) by revealing that this effect may be specific to AS cognitive concerns, and 2) by demonstrating that the interaction of TBI and AS cognitive concerns on PTSS is not specific to active duty military populations, and may be found among civilians seeking treatment for nicotine cessation (study 1) and suicide risk (study 2).

It is plausible that the potentiating effects of high AS cognitive concerns on the relationship between TBI and PTSS arises from the amplification of cognitive dyscontrol symptoms. Elevated AS cognitive concerns heighten cognitive dyscontrol via catastrophic misinterpretations of these symptoms as harmful or dangerous (Olatunji & Wolitzky-Taylor, 2009). Given that cognitive dyscontrol is theorized to be a mechanism linking TBI with PTSS (Aupperle, Melrose, Stein, & Paulus, 2012), a cognitive-affective factor that can modulate cognitive dyscontrol would be apt to moderate the effects of TBI on PTSS. An individual with a probable TBI history and high AS cognitive concerns may react fearfully to TBI-related symptoms of cognitive dyscontrol, thereby increasing their symptoms of cognitive dyscontrol through a positive feedback loop; ultimately, enhancing PTSS by promoting avoidance of anxiety-provoking trauma reminders that spark arousal-related cognitive dyscontrol.

The present study failed to replicate the previous finding that low AS cognitive concerns blunted the effects of TBI on PTSS (Albanese et al., 2017). Methodological differences, such as the measurement of the number of lifetime TBIs (Albanese et al., 2017) as opposed to the presence/absence of a probable TBI (study 1), or the presence/severity of a probable TBI (study 2), may have contributed to the differences across studies. Considering research demonstrating the cumulative deleterious effects of multiple TBIs on cognitive control (McKee et al., 2009) and PTSS (e.g., Bryan & Clemans, 2013), it is reasonable to suggest that the blunting effect of low AS cognitive concerns on the relationship between TBI and PTSS may only occur among individuals with more severe TBI histories, which the measures of TBI used in the present study were unable to assess. This discrepancy calls for further examination of the association of TBI and PTSS among those with low AS cognitive concerns.

Both studies also supported the hypothesis that AS cognitive concerns would have a stronger relationship with PTSS among those with a probable TBI. We propose two equally probable, and non-mutually exclusive interpretations. First, individuals with a TBI history are more likely to experience symptoms of cognitive dyscontrol (Dimoska-Di Marco, McDonald, Kelly, Tate, & Johnstone, 2011 ; Dockree & Robertson, 2011 ; Ryan & Warden, 2003) that are feared by those with elevated AS cognitive concerns, thereby making these misinterpretations more prevalent. Second, TBI related damage to cognitive control systems may enhance the influence of AS cognitive concerns on PTSS. This interpretation is consistent with other research showing that psychopathological vulnerability is intensified in the presence of poor cognitive control (Fergus, Bardeen, & Orcutt, 2012 ; Jones, Fazio, & Vasey, 2012 ; Richey, Keough, & Schmidt, 2012). More specifically, poor attentional control (a form of cognitive control) has strengthened the relationship between AS and PTSS in community (Albanese et al., in press, study 1 ; Bardeen & Fergus, 2015) and clinical (Albanese et al., in press, study 2) samples.

The present findings may also have clinical implications. Individuals with probable TBI histories appear to be at greater risk for elevations in PTSS if they also have heightened AS cognitive concerns. Thus, reducing AS cognitive concerns could be particularly important for individuals with previous TBIs. Fortunately, AS cognitive concerns can be effectively reduced via computerized psychoeducational and exposure-based interventions (Schmidt, Capron, Raines, & Allan, 2014) and computerized cognitive bias modification interventions (Capron, Norr, Allan, & Schmidt, 2017 ; Capron & Schmidt, 2016). Moreover, AS cognitive concerns interventions have shown efficacy for reducing PTSS (Allan, Short, Albanese, Keough, & Schmidt, 2015) further underscoring the need to test if these interventions may mitigate PTSS among those with probable TBI histories.

The current findings need to be considered in the context of several limitations. First, the measures of TBI history relied on participant self-report. Though this limits the generalization of the results, past research demonstrating the convergence of self-reported TBIs with interview-based diagnosis of TBI (Diamond, Harzke, Magaletta, Cummins, & Frankowski, 2007 ; Matthews et al., 2012 ; Richardson, Cyr, Nelson, Elhai, & Sareen, 2014 ; Shu, Onton, O'Connell, Simmons, & Matthews, 2014) lends confidence to these conclusions. The TBI measures also lacked an assessment of the number of total lifetime

TBIs or the presence of a TBI of greater than mild severity. Therefore, the present study is unable to determine if the interactive effects would differ with a more severe TBI population. Future research should utilize interview-based methods to gather more data on TBI severity and TBI history, such as the Ohio State University TBI Identification Method (Corrigan & Bogner, 2007). In addition, the current studies were also cross-sectional, precluding causal inferences, and relied exclusively on self-reported symptoms of depression, anxiety, and PTSS.

Although extending the previous findings (Albanese et al., 2017) to a civilian sample was an objective of the primary study, it is worth noting that the samples used were both derived from larger clinical trials aimed at reducing cognitive-affective risk factors. In study 1, subjects were recruited based on elevations of AS total score and their desire to quit smoking cigarettes. In study 2, subjects were chosen for their elevations of one of several risk factors for suicidality, including AS cognitive concerns. Further, both samples were treatment-seeking, but neither sample were recruited based on their desire to reduce PTSS, specifically, which could limit the generalizability of the present findings to individuals seeking treatment to reduce PTSS. That both samples recruited for elevations in either AS total score (study 1) or AS cognitive concerns (study 2) could have also influenced results by limiting the range in AS scores. However, this limitation is mitigated by the consistent findings across study 1 ($M_{AS\text{ cognitive}} = 3.33$, $SD_{AS\text{ cognitive}} = 4.31$) and study 2 ($M_{AS\text{ cognitive}} = 9.22$, $SD_{AS\text{ cognitive}} = 6.97$) despite considerable differences in mean AS cognitive concerns scores.

Despite these limitations, the replication of the two-way interaction of AS cognitive concerns and probable TBI status further underscores the utility of understanding the relationship between TBI and PTSS in the context of well-researched cognitive-affective risk factors. In addition to the use of longitudinal designs and improved TBI measurement, future research that elucidates the mechanisms via which TBI moderates and is moderated by AS cognitive concerns (e.g., specific facets of cognitive control; Miyake et al., 2000) would be a substantial contribution to our understanding of this considerable public health burden in urgent need of mitigation.

Acknowledgments

Funding: Study 1 was funded in part by a grant from the NIH (R01-MH076629).

Study 2 was in part supported by the Military Suicide Research Consortium (MSRC), an effort supported by the Office of the Assistant Secretary of Defense for Health Affairs under Award No. W81XWH-10-2-0181. Opinions, interpretations, conclusions and recommendations are those of the authors and are not necessarily endorsed by the MSRC or the Department of Defense.

This work was also in part supported by the National Institute of Health Integrated Clinical Neuroscience Training for Translational Research (4T32MH093311-05). Opinions, interpretations, conclusions and recommendations are those of the authors and are not necessarily endorsed by the National Institute of Health.

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Figure 1.

TBI = Traumatic Brain Injury. ASCC = anxiety sensitivity cognitive concerns. The interactive effects of probable TBI status and AS cognitive concerns on PTSS among trauma-exposed daily smokers without ($n = 225$) or with ($n = 32$) a self-reported diagnosed TBI (Study 1). Results indicate that probable TBI is more closely related to PTSS among those with high, relative to low, ASCC.

Interactive effects of TBI and AS cognitive concerns on PTSS

Figure 2.

TBI = Traumatic Brain Injury. ASCC = anxiety sensitivity cognitive concerns. The interactive effects of probable TBI status and AS cognitive concerns on PTSS among trauma-exposed community members without ($n = 43$) or with ($n = 74$) a probable TBI (Study 2). Results indicate that TBI is more closely related to PTSS among those with high, relative to low, ASCC. Additionally, ASCC has a stronger relationship with PTSS among those with a more severe TBI history compared to less severe or no probable TBIs.

Table 1**Study 1 – Descriptive statistics and zero-order correlations**

Note. n = 257. TBI status = Probable TBI diagnosis. PDS = Post-traumatic Stress Diagnostic Scale total symptom score. ASI-3 = Anxiety

	M (SD) or Frequency	1	2	3	4	5	6	7	8	9
1. TBI Status	32	-	-	-	-	-	-	-	-	-
2. PDS	8.50 (9.90)	.06	-	-	-	-	-	-	-	-
3. ASI-3 Total	15.33 (12.64)	-.04	.42**	-	-	-	-	-	-	-
4. ASI-3 Cognitive	3.33 (4.31)	-.06	.39**	.88**	-	-	-	-	-	-
5. ASI-3 Physical	4.67 (4.88)	.00	.35**	.86**	.64**	-	-	-	-	-
6. ASI-3 Social	7.33 (5.22)	-.06	.37**	.89**	.70**	.63**	-	-	-	-
7. IDAS-GD	41.81 (14.35)	-.00	.62**	.58**	.56**	.44**	.52**	-	-	-
8. PSWQ Total	43.62 (14.74)	-.02	.53**	.53**	.49**	.42**	.50**	.73**	-	-
9. Age	39.84 (12.54)	-.07	-.13*	-.10	-.16**	.02	-.12	-.16*	-.16*	-
10. Gender	1.49 (.50)	-.06	.20**	.08	.08	.06	.05	.19**	.31**	.08

Sensitivity Index – 3. IDAS-GD = Inventory of Depression and Anxiety Scale, General Depression subscale. PSWQ = Penn State Worry Questionnaire.

* = $p < .05$,

** = $p < .01$.

Table 2
Study 1 Interaction of TBI status with AS total and subscale scores predicting PTSS among daily smokers.

A. Interaction with AS Total					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status	2.54	1.47	1.73	0.08	-0.35 5.43
ASI-3 Total	0.08	0.05	1.58	0.11	-0.02 0.17
TBI*ASI-3 Total	0.25	0.14	1.74	0.08	-0.03 0.53
IDAS-GD	0.31	0.05	6.03	<.001	0.21 0.42
PSWQ	0.08	0.05	1.63	0.1	-0.02 0.18
Age	-0.03	0.04	-0.85	0.39	-0.11 0.04
Sex	1.60	1.03	1.56	0.12	-0.42 3.62

B. Interaction with AS Cognitive Concerns					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status	2.88	1.48	1.94	0.05	-0.04 5.78
ASI-3 Total	0.17	0.14	1.26	0.21	-0.10 0.45
TBI*ASI-3 Cognitive concerns	1.03	0.45	2.27	0.02	0.14 1.92
IDAS-GD	0.32	0.05	6.15	<.001	0.22 0.42
PSWQ	0.10	0.05	1.96	0.05	-0.003 0.20
Age	-0.03	0.04	-0.85	0.4	-0.11 0.04
Sex	1.55	1.02	1.52	0.13	-0.45 3.56

C. Interaction with AS Physical Concerns					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status	2.08	1.46	1.42	0.16	-0.80 4.95
ASI-3 Total	0.17	0.11	1.53	0.13	-0.05 0.39
TBI*ASI-3 Physical concerns	0.13	0.30	0.44	0.66	-0.46 0.72
IDAS-GD	0.33	0.05	6.50	<.001	0.23 0.43
PSWQ	0.08	0.05	1.59	0.11	-0.02 0.18

C. Interaction with AS Physical Concerns

	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI	ULCI
Age	−0.03	0.04	−0.81	0.42	−0.11	0.05
Sex	1.50	1.03	1.46	0.15	−0.52	3.52

D. Interaction with AS Social Concerns

	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI	ULCI
TBI status	2.59	1.48	1.75	0.08	−0.32	5.51
ASI-3 Total	0.11	0.11	1.01	0.32	−0.11	0.33
TBI*ASI-3 Social concerns	0.55	0.34	1.64	0.10	−0.11	1.21
IDAS-GD	0.33	0.05	6.42	<.001	0.23	0.43
PSWQ	0.09	0.05	1.76	0.08	−0.01	0.19
Age	−0.03	0.04	−0.74	0.46	−0.11	0.05
Sex	1.58	1.03	1.53	0.13	−0.45	3.60

Note. TBI status = Probable TBI diagnosis. PDS = Post-traumatic Stress Diagnostic Scale total symptom score. ASI-3 = Anxiety Sensitivity Index – 3. IDAS-GD = Inventory of Depression and Anxiety Scale, General Depression subscale. PSWQ = Penn State Worry Questionnaire.

Table 3

Study 2 – Descriptive statistics and zero-order correlations.

<i>Note. n = 117. TBI Status/Severity = Absence/Presence of a probable TBI and the severity of present probable TBIs. PCL-5 = Post-traumatic Stress</i>										
	M (SD)	1	2	3	4	5	6	7	8	9
1. TBI Status/Severity	1.22 (1.26)	-	-	-	-	-	-	-	-	-
2. PCL-5	46.21 (17.40)	.13	-	-	-	-	-	-	-	-
3. ASI-3 Total	29.72 (16.30)	-.15	.47**	-	-	-	-	-	-	-
4. ASI-3 Cognitive	9.22 (6.97)	-.06	.52**	.88**	-	-	-	-	-	-
5. ASI-3 Physical	8.92 (6.11)	-.13	.36**	.83**	.58**	-	-	-	-	-
6. ASI-3 Social	11.57 (6.04)	-.21*	.31**	.85**	.63**	.56**	-	-	-	-
7. IDAS-GD	52.17 (12.20)	.07	.62**	.36**	.46**	.18	.27**	-	-	-
8. STAI-T	53.00 (9.80)	-.11	.57**	.60**	.61**	.33**	.58**	.62**	-	-
9. Age	38.83 (16.07)	.46**	.11	-.18	-.11	-.07	-.28**	.01	-.10	-
10. Gender	1.53 (.50)	-.23*	-.10	.13	.12	.05	.18	.01	.09	-.46**

Checklist total symptom score. ASI-3 = Anxiety Sensitivity Index – 3. IDAS-GD = Inventory of Depression and Anxiety Scale, General Depression subscale. STAI-T = Spielberger State Trait Anxiety Inventory – Trait subscale. In the current sample, 43 individuals reported no probable TBI history, 36 individuals reported a probable TBI without LoC, 15 reported a probable TBI with LoC < 1 minute, 15 reported a probable TBI with LoC between 1 and 20 minutes, and 8 participants endorsed a probable TBI with LoC > 20 minutes.

* = $p < .05$,

** = $p < .01$.

Table 4
Study 2 Interaction of TBI status with AS total and subscale scores predicting PTSS in a clinical sample.

A. Interaction with AS Total					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status/severity	1.62	1.05	1.54	0.13	-0.47 3.70
ASI-3 Total	0.27	0.09	2.96	0.00	0.09 0.44
TBI*ASI-3 Total	0.10	0.06	1.69	0.09	-0.02 0.21
IDAS-GD	0.57	0.12	4.66	<.001	0.33 0.82
STAI-T	0.39	0.18	2.17	0.03	0.03 0.75
Age	0.07	0.09	0.77	0.45	-0.11 0.25
Sex	-3.93	2.63	-1.50	0.14	-9.14 1.28

B. Interaction with AS Cognitive Concerns					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status/severity	1.32	1.04	1.26	0.21	-0.75 3.39
ASI-3 Total	0.65	0.21	3.07	0.003	0.23 1.07
TBI*ASI-3 Cognitive concerns	0.3	0.14	2.1	0.038	0.02 0.58
IDAS-GD	0.53	0.12	4.3	<.001	0.29 0.78
STAI-T	0.42	0.17	2.43	0.02	0.08 0.77
Age	0.06	0.09	0.65	0.52	-0.12 0.23
Sex	-4.45	2.64	-1.68	10	-9.69 0.79

C. Interaction with AS Physical Concerns					
	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI ULCI
TBI status/severity	1.62	1.05	1.55	0.12	-0.45 3.69
ASI-3 Total	0.63	0.20	3.17	0.00	0.24 1.03
TBI*ASI-3 Physical concerns	0.26	0.16	1.66	0.10	-0.05 0.57
IDAS-GD	0.58	0.12	4.77	<.001	0.34 0.83
STAI-T	.50	0.16	3.11	0.002	0.18 0.82

C. Interaction with AS Physical Concerns

	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI	ULCI
Age	0.04	0.09	0.49	0.62	-0.13	0.22
Sex	-3.49	2.61	-1.34	0.18	-8.67	1.68

D. Interaction with AS Social Concerns

	<i>B</i>	<i>SE</i>	<i>t</i>	<i>p</i>	LLCI	ULCI
TBI status/severity	1.60	1.11	1.44	0.15	-0.61	3.80
ASI-3 Total	0.26	0.26	1.03	0.30	-0.24	0.77
TBI*ASI-3 Social concerns	0.21	0.17	1.23	0.22	-0.13	0.54
IDAS-GD	0.59	0.13	4.56	<.001	0.33	0.84
STAI-T	0.52	0.19	2.72	0.008	0.14	0.89
Age	0.07	0.09	0.73	0.47	-0.12	0.25
Sex	-3.34	2.71	-1.23	0.22	-8.73	2.04

Note. TBI Status/Severity = Absence/Presence of a probable TBI and the severity of present probable TBIs. PCL-5 = Post-traumatic Stress Checklist total symptom score. ASI-3 = Anxiety Sensitivity Index – 3. IDAS-GD = Inventory of Depression and Anxiety Scale, General Depression subscale. STAI-T = Spielberger State Trait Anxiety Inventory – Trait subscale.