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Latent Factor Structure of PTSD Symptoms in Veterans with a History of Mild Traumatic Brain Injury and Close-Range Blast Exposure

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Abstract

Objective: Confirmatory factor analysis (CFA) has previously been employed to examine the latent factor structure of posttraumatic stress disorder (PTSD) symptoms with mixed results. A limited number of studies examined PTSD factor structure among veterans of recent military conflicts. This study examined the relationship between PTSD factor structure and the hallmark conditions of these conflicts, mild traumatic brain injury (mTBI) and close-range blast exposure (CBE).

Method: The fit of previously-proposed PTSD factor models was compared in a cohort of 387 combat-exposed veterans, with stratified analyses comparing factor structure models between those with a history of military-related mTBI and CBE (n=106) and those without either of these antecedents (n=151). CFA were conducted using criteria from the *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (*DSM-IV*).

Results: The 4-factor *emotional numbing (EN)* model yielded the best fit when using a clinician-administered assessment of PTSD symptoms regardless of mTBI/CBE exposure status. However, when using a self-report measure of PTSD symptom severity, the *EN* model yielded best fit for

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Clinical Impact Statement

This study found differences in the model of best fit for post-traumatic stress disorder (PTSD) factor structure in veterans depending on history of key deployment-related injuries and the type of PTSD assessments used. The results of this study show the importance of considering both injury history and diagnostic tools when examining PTSD latent factor structure.

those with mTBI/CBE exposure history while the 5-factor *dysphoric arousal (DA)* model was preferable among combat-exposed veterans with no history of mTBI/CBE exposure.

Conclusions: Factors including mTBI and blast exposure and type of assessment tools must be considered when determining preferable PTSD latent factor structure models.

Introduction

Post-traumatic stress disorder (PTSD) is the most frequent psychiatric condition among veterans returning from conflicts in Iraq and Afghanistan, with as many as 30% of combat-exposed veterans meeting diagnostic criteria for this disorder at different times after deployment (Thomas et al., 2010). One key epidemiological factor among this cohort is co-occurrence of PTSD and mild traumatic brain injury (mTBI; Hoge et al., 2008). Veterans with a history of mTBI have higher rates of PTSD compared to veterans with other injuries (Schneiderman, Braver, & Kang, 2008). Further, coexisting PTSD, depression, and a history of military mTBI constitute a triad that is associated with functional disability (Lippa et al., 2015) and unemployment (Amick et al., 2017). There is also evidence that close-range blast exposure (CBE) produces brain changes that are independent of the presence of concussive symptoms defining mTBI. Specifically, Robinson et al. (2015) reported decreased functional connectivity in neural regions associated with PTSD, and Grande et al. (2018) found poorer verbal memory performance in veterans with CBE.

Studies examining the latent factor structure of PTSD symptoms through confirmatory factor analysis (CFA) do not agree in a factor arrangement that adequately corresponds to the data. The Diagnostic and Statistical Manual 4th edition diagnostic criteria (DSM-IV; American Psychiatric Association, 1994) identified 3 factors: re-experiencing, avoidance/emotional numbing, and hyperarousal. While models ranging from one to seven factors have been examined for goodness of fit compared to the DSM-IV model, three models have shown the most consistent findings (Armour, Miillerova, & Elhai, 2016). First, a four-factor *Emotional Numbing (EN)* model splitting avoidance and numbing symptoms into two separate factors was shown to improve fit over the DSM-IV model (King, Leskin, King, & Weathers, 1998). A second four-factor model that improves goodness of fit over the DSM-IV model is referred to as the *Dysphoria (D)* model. This model combined EN symptoms with three hyperarousal symptoms (i.e., sleeping difficulties, irritability or anger, and difficulty concentrating) into a separate non-specific *D* factor (Simms, Watson, & Doebbelling, 2002). Finally, a five-factor *Dysphoric Arousal (DA)* model separated avoidance and numbing and split hyperarousal symptoms into a DA factor (i.e., sleeping difficulties, irritability and difficulty concentrating) and an anxious arousal factor (hypervigilance and exaggerated startle response; (Pietrzak et al., 2015). A systematic review by Armour and colleagues (2016) found that 29 of 36 studies that compared the *EN, D*, and *DA* models showed superior fit for the *DA* model, 6 showed no difference between the models, and one study showed superior fit for the *EN* model over the *D* and *DA* models.

The diagnostic criteria for PTSD were revised in the fifth edition of the DSM (DSM-5) in 2013 (American Psychiatric Association, 2013). The DSM-5 model closely resembled the *EN* model, although it reviewed some DSM-IV symptoms and added 3 new symptoms.

Despite changes in criteria, there are several reasons why examination of PTSD factor structure using the DSM-IV remains warranted. First, a study examining the validity of the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5) published in 2018 showed a strong correspondence between the CAPS-5 and the CAPS-IV when a minimum severity score was used to calibrate diagnosis between the two measures (κ = .84; Weathers, et al., 2018). In addition, studies that demonstrated the superiority of the *DA* model were not published in time to influence the DSM-5 revisions. Further, there are few studies published examining PTSD factor structure in the OIF/OEF/OND population (e.g., Boasso, et al., 2016), and longitudinal studies collecting DSM-IV PTSD data initiated before 2013 will keep the DSM-IV criteria relevant for years to come.

Analysis of the factor structure of PTSD helps identify different dimensions in the construct that have a specific neurobiological substrate defined by genetic, neuroanatomic and system neuroscience characteristics. Ultimately, this information would allow clinicians to select therapeutic options according to the needs of an individual patient. For instance, anxious arousal has been associated with the neurobiology of panic disorder and, thus, these symptoms may have a modest clinical response to treatment with common antidepressants or may require specific interventions as part of a comprehensive psychotherapeutic plan.

Another caveat to the literature of PTSD factor structure is the dearth of studies using validated clinician-administered measures (i.e., CAPS). (Weathers, Keane, & Davidson, 2001). Most CFA studies of PTSD symptoms used the PTSD Checklist (PCL; e.g., Marshall, Schell, & Miles, 2013). The PCL is a self-report measure that, while possessing good psychometric properties, has been shown to overestimate PTSD prevalence (Wilkins, Lang, & Norman, 2011). The use of the PCL or CAPS may affect which model provides best fit. For instance, a recent study showed superior fit of the *EN* model when using the CAPS and superior fit of the *D* model when using the PCL (Elhai et al., 2011).

Some CFA studies used the CAPS in military personnel and veterans, including the seminal study supporting the *EN* model by King et al. (1998). One study compared the *EN* and *D* models, finding them to be statistically equivalent (Harrington et al., 2012). In contrast, a study of trauma-exposed active-duty Marines compared all three DSM-IV alternative models with the CAPS and found that the *DA* model was superior to the *EN* and *D* models (Boasso et al., 2016). The literature, however, has not addressed the potential effect of neurological alterations due to mTBI and CBE. This may have implications for PTSD diagnosis, treatment planning, and understanding the neurological substrate of these symptoms.

The aim of this study was to compare the DSM-IV model, the 4-factor *EN model*, the 4-factor *D* model, and the 5-factor *DA* model among a large cohort of veterans to determine if differences exist in the latent factor structure of PTSD symptoms for those with or without a history of deployment-related mTBI and CBE. Based on previous studies, it was predicted that the three alternative models would significantly improve the fit of the DSM-IV model, and the greatest improvement was expected in the *DA* mode. In addition to the association between PTSD, mTBI, and CBE, there is evidence that PTSD diagnosis status may affect symptom structure. The majority of PTSD CFA studies include individuals without a PTSD diagnosis (Biehn, Elhai, Fine, Seligman, & Richardson, 2012), arguing that including

individuals with subclinical PTSD symptoms increases heterogeneity in the sample and enhances precision and generalizability of the results (King et al., 1998). Thus, we followed this approach in our primary analysis while secondary CFAs were conducted including only those individuals with a PTSD diagnosis. In addition, we also stratified by individuals with a history of both mTBI and CBE compared to those without such history.

Methods

Participants and Procedure

The [removed for blind review] is a longitudinal prospective study, which recruits participants from the [removed for blind review] area at community events for veterans and reserves, through flyers posted in public areas of the VA medical center, and through word of mouth. At the time of this current study, 481 veterans were enrolled for participation.

Our study group may differ from the general OIF/OEF/OND population in terms of prevalence of PTSD, TBI and blast exposure. However, demographics including age, gender, or branch of service were not significantly different from OEF/OIF/OND veterans utilizing the VA healthcare system (U.S. Department of Veterans Affairs, 2012), active duty enlisted individuals, or reserve members (U.S. Department of Defense, 2012).

All study procedures were approved by the Institutional Review Board of Human Studies Research at the [removed for blind review]. The evaluation included a comprehensive history of injuries and traumatic life experiences, a neurological and full psychiatric assessment, biomedical and genomic data, and magnetic resonance imaging. For the purposes of this study, only background information and data from the neurological and psychiatric assessments from each participant's first site visit were considered. Participants qualified for enrollment in the study if they were between 18 and 65 years of age and if they were deployed to OIF, OEF, or OND or were scheduled for deployment. Exclusionary criteria included a history of lifetime moderate or severe TBI (n=18), a history of neurological illness other than TBI (n=2); a low estimated pre-morbid cognitive functioning (n=1); meeting diagnostic criteria for a current, non-trauma-related psychotic disorder or bipolar disorder, a history of non-trauma-related seizures, current active suicidal or homicidal ideation requiring intervention (n=4); and below-threshold performance on the Medical Symptom Validity Test (MSVT). The final sample size following these exclusions was N=387. The final sample had a mean age of 31.98 years (SD=8.43) and was predominantly male (351 males) and white (white: n=289; black: n=30; Hispanic: n=59; other: n=9), with most individuals having served in the Army (Army: n=248; Marines: n=94; Air Force: n=26; Navy: n=14; Coast Guard: n=1). See Table 1.

Individuals were grouped by whether they had a history of military mTBI and/or close-range blast exposure (CBE), which was defined as proximity to a blast within less than 10 meters. This distance range was chosen because of previous evidence of harmful effects of blast exposure on neurological and neuropsychological functioning at this close range (Robinson et al., 2015). Among this study sample, 106 individuals had a history of military mTBI and CBE (mTBI/CBE group), and 151 individuals had neither a history of military mTBI nor CBE (no mTBI/CBE group). Sixty-five participants had a history of mTBI but no CBE and

65 had CBE with no military mTBI. These 130 individuals were not included in analyses stratified by injury groups. Only those with a history of both military mTBI and CBE were included to better differentiate symptom profiles between groups.

Measures

Background information including demographics, military service branch, length and number of deployments, and presence of difficulties with sleep and pain was collected via self-report questionnaires. Due to the prolonged and repetitive nature of psychological trauma and blast exposure experienced by veterans, the interval since returning from the last deployment was used as an approximation for length of time since the trauma/injury took place.

Criteria used to classify mTBI for this study were consistent with the criteria of the American Congress of Rehabilitation Medicine (Head, 1993)

The Boston Assessment of TBI-Lifetime (BAT-L; Fortier et al., 2014),was administered to collect comprehensive data regarding history of TBI and blast exposure. The CAPS for DSM-IV was administered to obtain frequency and intensity ratings for PTSD symptoms (Blake et al., 1996). The PCL-C was administered as an additional self-report measure of PTSD symptoms (Weathers, Huska, & Keane, 1991). The Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; First, Spitzer, Gibbon, & Williams, 1996) was administered to diagnose mood, anxiety, and substance use disorders, while sleep disturbance was assessed with the Pittsburgh Sleep Quality Index (PSQI; Carpenter & Andrykowski, 1998) and pain was assessed with the Short Form-McGill Pain Questionnaire (SF-MPQ; Melzack, 1987). Please see Supplemental Materials for further detail regarding these measures.

Data Analysis

Confirmatory factor analysis (CFA) was used to study the latent structure underlying the 17 CAPS severity scores and 17 PCL symptom ratings, with separate models for CAPS and PCL. We adopted the maximum likelihood with robust standard errors (MLR) method, which can facilitate inference in the presence of non-normality (Rhemtulla, Brosseau-Liard, & Savalei, 2012). For each hypothetical model, we examined a range of model fit criteria, including the root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), standardized root mean square residual (SRMR), as well as the Akaike information criterion (AIC) and the Bayesian information criteria (BIC). Model fit was regarded as acceptable if RMSEA and SRMR were 0.08 or lower, and the TLI and CFI were 0.9 or higher. Model fit was viewed as excellent if RMSEA was 0.06 or lower, SRMR was 0.05 or lower, and TLI and CFI were 0.95 or higher (Brown, 2014; Hu & Bentler, 1999). Smaller AIC and BIC values relative to other models are preferred, as they indicate desirable model fit and model parsimony. The Satorra-Bentler Scaled Chi-Square test (Satorra & Bentler, 2010) was used to examine whether a smaller model nested within a larger model can achieve similar fit as that offered by the larger model. We primarily relied on RMSEA, BIC, Satorra-Bentler test, TLI and CFI to determine the model with best fit.

Similar CFA analyses were also conducted for PCL items, and the same set of hypothetical models were examined.

Next, to determine whether the latent factor structure differs between participants with and without a history of military mTBI and CBE, we conducted separate CFA analyses of the CAPS severity scores for the mTBI/CBE subgroup and no-mTBI/CBE subgroup, respectively. The hypothetical models were evaluated for model fit within each subgroup. Furthermore, we conducted measurement invariance analysis (Brown, 2014) to examine whether the factor loadings and intercepts differ between the two subgroups using the Satorra-Bentler Scaled Chi-Square test. All CFA analyses were conducted in Mplus, version 7.4 (Muthén & Muthén, 2014).

Results

Study Sample Characteristics

Differences between groups in demographics, injury and deployment characteristics, and psychiatric features are summarized in Table 1. Participants in the mTBI/CBE group had greater average number of deployments, longer deployment duration, greater reported levels of combat exposure, and longer average time since last deployment. PTSD was frequent, with 60.47% (n=234) of the overall sample meeting diagnostic criteria. Individuals in the mTBI/CBE group had a significantly higher rate of PTSD (80.19%) compared to the no-mTBI/CBE group (66.34%). Additionally, the mTBI/CBE group had significantly higher prevalence of mood disorders and were more likely to be taking antidepressants. However, differences between groups in prevalence of anxiety and substance use disorders did not reach statistical significance. In addition, the between-groups difference in mean number of pre-military mTBIs and post-military mTBIs were not statistically significant.

Confirmatory Factor Analysis

Table 2 presents the results of CFAs for CAPS and PCL items for the whole sample and stratified by mTBI/CBE group. CFA results for the CAPS including the whole sample yielded adequate levels of fit for all models per RMSEA, CFI, TLI, and SRMR criteria. Similarly, all models fit well when including only individuals in the No mTBI/CBE group. In the mTBI/CBE group, however, the DSM-IV model and the *D* model did not meet criteria for adequate goodness of fit when using CFI and TLI criteria.

The *EN* and *DA* models demonstrated superior goodness of fit regardless of group. When examining the whole sample as well as the mTBI/CBE and No mTBI/CBE groups separately, analyses indicated that the *EN* model yielded a statistically significant improvement in fit over the DSM-IV model [Whole: $\chi^2 = 90.86$, df=3, $p < .001$; mTBI/CBE group: $\chi^2 = 31.86$, df=3, $p < .001$; No TBI/CBE group: $\chi^2 = 46.86$, df=3, $p < .001$], while the *DA* model did not significantly improve goodness of fit over the *EN* model [Whole: $\chi^2 = 8.69$, df=4, $p = .069$; mTBI/CBE group: $\chi^2 = 2.77$, df=4, $p = .596$; No mTBI/CBE group: $\chi^2 = 7.89$, df=4, $p = .096$], The test results agreed well with the BIC, which were the smallest (i.e., best) for the *EN* model in both the overall analysis and subgroup analyses (see Table 3).

CFA results using the 17 PCL item-ratings demonstrated differences in preferable models compared to those observed using the CAPS. When examining the whole sample and the No mTBI/CBE group, all models yielded adequate levels of fit. However, CFA results with the TBI/CBE group showed adequate goodness of fit for the *EN* and *DA* models only. Analyses of the whole sample and the No mTBI/CBE group demonstrated the *DA* model to have the best fit per AIC and BIC values, while analyses of the mTBI/CBE group revealed the *EN* model to have the best fit. Nested comparisons between *EN* and *DA* models differed by group, with the *DA* model significantly improving goodness of fit over the *EN* model with the whole study sample [$\chi^2 = 51.18$, df=4, $p < .001$], as well as within the No mTBI/CBE group [$\chi^2 = 36.28$, df=4, $p < .001$] but not yielding a significant improvement within the mTBI/CBE group [$\chi^2 = 7.17$, df=4, $p = .127$].

To evaluate the CFAs of CAPS items between the mTBI/CBE and No mTBI/CBE subgroups, we compared a configural model (same factor pattern but different intercepts and slopes) to a metric invariance model. The results suggested different factor loadings between the two subgroups ($\chi^2 = 26.04$, df= 13, $p < 0.05$). Further testing by examining one factor at a time suggested that the difference in loadings was mainly in the re-experiencing (p=.004) and avoidance factors (p=.005), driven by symptom B3 (flashbacks; higher factor loading for the No mTBI/CBE group) for the re-experiencing factor and symptom C1 (avoiding thoughts of trauma; higher factor loading for the mTBI/CBE group) for the avoidance factor (see Table 3).

Secondary CFA Analysis, individuals with PTSD Diagnosis

Secondary CFAs including only individuals with a PTSD diagnosis differed in terms of the preferred model for the CAPS and the PCL items (Table 4). When CAPS symptom severity ratings were used in CFAs, the *EN* model was found to have the best fit both with the whole sample and between subgroups. Nested comparisons showed a statistically significant improvement in goodness of fit for the *EN* model over the *DSM-IV* model regardless of grouping [Whole: $\chi^2 = 56.825$, df=3, $p < .001$; mTBI/CBE group: $\chi^2 = 10.670$, df=3, p=.014; No mTBI/CBE group $\chi^2 = 26.87$, df=3, $p < .001$], while the *DA* model was found to not significantly improve goodness of fit over the *EN* model with CAPS items grouping [Whole: $\chi^2 = 1.908$, df=4, p =.753; mTBI/CBE group: $\chi^2 = 1.996$, df=4, p=.737; No mTBI/CBE group $\chi^2 = 6.467$, df=4, p = .167].

CFAs using PCL item ratings also showed an improvement in goodness of fit by the *EN* model over the *DSM-IV* model (Whole: $\chi^2 = 188.597$, df=3, $p < .001$; mTBI/CBE group: $\chi^2 = 115.84$, df=3, $p < .001$; No mTBI/CBE group $\chi^2 = 39.283$, df=3, $p < .001$], but ultimately the *DA* model significantly improved goodness of fit over the *EN* model regardless of grouping [Whole: $\chi^2 = 32.755$, df=4, $p < .001$; mTBI/CBE group: $\chi^2 = 11.284$, df=3, p=.024; No mTBI/CBE group $\chi^2 = 17.331$, df=4, $p < .01$].

Discussion

The goal of this study was to examine the latent factor structure of DSM-IV PTSD symptoms among a large sample of combat-exposed veterans with or without a history of mTBI and CBE. Results of CFAs using CAPS items indicated that the *EN* model provided

better fit than the DSM-IV *D*, and *DA* models in the entire sample and both the mTBI/CBE Exposure group and no mTBI/CBE Exposure group. Follow-up comparisons of CFAs of CAPS items using the *EN* model found that factor loadings for the re-experiencing and avoidance factors differed significantly between the two subgroups (Table 3).

CFA results using PCL-C items indicated that while the *EN* model provided the best fit for the mTBI/CBE Exposure group, the *DA* model provided best fit across the entire study sample and for the No mTBI/CBE group. Previously, Palmieri et al. (2007) also found a difference in preferred factor models relative to the instruments of assessment, with the *EN* model demonstrating best fit with the CAPS and the *D* model demonstrating best fit with the PCL. Our study provides further evidence for the contribution of instrumentation on the heterogeneity seen in PTSD factor analysis studies.

The relative superiority of the *EN* model was notable, as a recent meta-analysis of studies comparing these models found that the *DA* model showed superiority of fit over the two 4-factor models (Armour et al., 2016). For instance, Boasso et al. (2016), the only other CFA study of OIF/OEF/OND veterans using both the CAPS and PCL for DSM-IV, concluded that the disaggregation of hyperarousal symptoms into anxious arousal and dysphoric arousal may be particularly suited to a military population. The contrasting results may be related to differences between study samples. Boasso et al. study was restricted to veterans and active duty members of the highly selective Marine Corps, some of whom did not had a deployment at the time testing and, overall, with a lower prevalence of PTSD. The difference in our results could also reflect the greater heterogeneity in demographics and current level of functioning within our study sample suggesting other source of factor structure variability of PTSD among veterans. The significant difference in factor loadings for re-experiencing and avoidance factors between TBI subgroups has some interesting clinical and etiological implications. The difference in re-experiencing symptoms was driven primarily by a higher loading of flashback symptoms among the No mTBI/CBE group compared to the mTBI/CBE group. This may be related to loss of consciousness, post-traumatic amnesia, and altered mental status experienced by individuals in the mTBI/CBE group around the time of injury. While the cognitive alterations that occur with mTBI are not protective against the development of PTSD, they have been previously found to decrease the prominence of flashbacks in symptomatic presentation (Bryant et al., 2009). The difference in avoidance factor loadings was driven by a higher factor loading for avoiding thoughts of trauma in the mTBI/CBE group, which may relate to higher levels of anhedonia and social isolation frequently seen in TBI patients.

Recent network analysis of PTSD symptoms at various times throughout the chronic phase may provide further insight into the PTSD construct. Bryant et al. prospectively studied a group of 1138 PTSD patients early after trauma and at 12 months of follow-up (Bryant et al., 2017). In the acute phase, network analysis disclosed a core network of re-experiencing and avoidance symptoms whose connectivity strengthened with time while incorporating hypervigilance and dysphoric symptoms. Furthermore, acute re-experiencing and avoidance symptoms consistently predict PTSD in the chronic phase (Haag, Robinaugh, Ehlers, & Kleim, 2017). This core group of PTSD symptoms is plausibly related to disruption of the

fear processing system, particularly in respect to the discrimination of threat and safety cues and the consolidation of traumatic memories.

This core cluster of symptoms appears to have a similarly prominent role among our chronic patients with a history of mTBI/CBE, years after the traumatic events. It is conceivable that alterations in prefrontal regulation associated with mTBI contributes to the enhancement and persistence of this symptomatic core. For instance, rodent models of concussive injury suggest that mTBI is associated with an increase in fear conditioning and overgeneralization of learned fear to novel stimuli (Reger et al., 2012). Exaggerated fear responses have also been observed in chronic models of repetitive blast exposures (Perez-Garcia et al., 2016).

The updated PTSD diagnostic criteria in the DSM-5 includes four clusters: re-experiencing, avoidance, emotional negative alterations in cognitions and mood, and alterations in arousal and reactivity (APA, 2013). This symptom structure is in many ways equivalent to the *EN* model that showed better goodness of fit in the present sample of combat veterans. However, there is still no consensus regarding whether DSM-5 conceptualization of PTSD constitute an advancement over the one from DSM-IV (Hoge et al., 2016).

This study had limitations that should be noted. This was a primarily male sample, which did not allow us to examine a gender effect. The study cohort had a higher rate of PTSD than is typically seen in the population at-large, which may affect the generalizability of these results. In addition, retrospective bias to assess military TBI and CBE is an unavoidable limitation in the OIF/OEF/OND population. Additionally, as this study began administering the CAPS-5 and PCL-5 for DSM-5 when those updated instruments became available, the sample size was not yet adequate for conducting CFA using the new instruments. As sample size increases, future studies directly comparing the latent structure of DSM-IV and DSM-5 diagnostic criteria will be possible. Regardless, the results of this study provide clinical support for the splitting of avoidance and emotional numbing symptoms into two distinct clusters in the DSM-5, a change that was influenced by the *EN* model. Future directions would include a longitudinal analysis of PTSD latent structure in the study cohort. This analysis would shed light on the stability of the *EN* model over time. Finally, it would be of interest to directly examine whether alterations in prefrontal regulation associated with mTBI, as assessed with multimodal imaging, contributes to the enhancement and persistence of this symptomatic core.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

American Psychiatric Association. (1994). Diagnostic and statistical manual of mental disorders (4th ed). Washington, DC: Author.

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders: DSM-5. Washington, DC: Author.

Amick MM, Meterko M, Fortier CB, Fonda JR, Milberg WP, & McGlinchey RE (2017). The Deployment Trauma Phenotype and Employment Status in Veterans of the Wars in Iraq and Afghanistan. The Journal of Head Trauma Rehabilitation.

Armour C, Műllerová J, & Elhai JD (2016). A systematic literature review of PTSD's latent structure in the Diagnostic and Statistical Manual of Mental Disorders: DSM-IV to DSM-5. Clinical Psychology Review, 44, 60–74. [PubMed: 26761151]

Bay E, & de-Leon MB (2011). Chronic stress and fatigue-related quality of life after mild to moderate traumatic brain injury. Journal of Head Trauma Rehabilitation, 26, 355–363. doi:10.1097/HTR.0b013e3181f20146 [PubMed: 21169862]

Bentler PM, & Bonett DG (1980). Significance tests and goodness of fit in the analysis of covariance structures. Psychological Bulletin, 88(3, 588.

Biehn TL, Elhai JD, Fine TH, Seligman LD, & Richardson JD (2012). PTSD factor structure differences between veterans with and without a PTSD diagnosis. Journal of Anxiety Disorders, 26(3, 480–485. 10.1016/jjanxdis.2012.01.008 [PubMed: 22387183]

Blake D, Weathers F, Nagy L, Kaloupek D, Klauminzer G, Charney D, & Keane T (1990). A clinician rating scale for assessing current and lifetime PTSD: The CAPS-1.

Blake D, Weathers FW, Nagy LM, Kaloupek DG, Charney DS, & Keane TM(1996). Clinician Administered PTSD Scale for DSM-IV: current and lifetime diagnostic version. Boston: National Center for Posttraumatic Stress Disorder.

Boasso AM, Steenkamp MM, Fox AB, Nash WP, Larson JL, & Litz BT (2016).The structure of PTSD in active-duty marines across the deployment cycle. Psychological Trauma: Theory, Research, Practice, and Policy, 8(2, 127.

Brown TA (2014). Confirmatory factor analysis for applied research. Guilford Publications.

Bryant RA, Creamer M, O'Donnell M, Silove D, Clark CR, & McFarlane AC (2009). Post-traumatic amnesia and the nature of post-traumatic stress disorder after mild traumatic brain injury. J int Neuropsychol Soc, 75(8), 862–867.

Bryant RA, Creamer M, ODonnell M, Forbes D, McFarlane AC, Silove D, & Hadzi-Pavlovic D (2017). Acute and chronic posttraumatic stress symptoms in the emergence of posttraumatic stress disorder: a network analysis. JAMA Psychiatry, 74(2, 135–142. [PubMed: 28002832]

Carpenter JS, & Andrykowski MA (1998). Psychometric evaluation of the Pittsburgh Sleep Quality Index. Journal of Psychosomatic Research, 45, 5–13. doi: 10.1016/s00223999(97)00298-5 [PubMed: 9720850]

Elhai JD, Biehn TL, Armour C, Klopper JJ, Frueh BC, & Palmieri PA (2011). Evidence for a unique PTSD construct represented by PTSD's D1–D3 symptoms. Journal of Anxiety Disorders, 25(3), 340–345. [PubMed: 21094021]

First MB, Spitzer RL, Gibbon M, & Williams JB (1996). Structured Clinical Interview for the DSM-IV Axis I Disorders. Washington, DC: American Psychiatric Press.

Fortier CB, Amick MM, Grande L, McGlynn S, Kenna A, Morra L, ... McGlinchey RE (2014). The Boston assessment of traumatic brain injury–lifetime (BAT-L) semistructured interview: Evidence of research utility and validity. The Journal of Head Trauma Rehabilitation, 29(1, 89. [PubMed: 23535389]

Grande LJ, Robinson ME, Radigan LJ, Levin LK, Fortier CB, Milberg WP, &McGlinchey RE (2018). Verbal Memory Deficits in OEF/OIF/OND Veterans Exposed to Blasts at Close Range. Journal of the International Neuropsychological Society, 1–10. 10.1017/S1355617717001242

Green P (2004). Medical Symptom Validity Test (MSVT) for Microsoft Windows: User's manual. Paul Green Pub.

Haag C, Robinaugh DJ, Ehlers A, & Kleim B (2017). Understanding the Emergence of Chronic Posttraumatic Stress Disorder Through Acute Stress Symptom Networks. JAMA Psychiatry, 74(6, 649–650. [PubMed: 28492863]

Harrington KM, Miller MW, Wolf EJ, Reardon AF, Ryabchenko KA, & Ofrat S(2012). Attention-deficit/hyperactivity disorder comorbidity in a sample of veterans with posttraumatic stress

disorder. Comprehensive Psychiatry, 53(6), 679–690. https://doi.Org/10.1016/j.comppsych.2011.12.001 [PubMed: 22305866]

Head J (1993). Definition of mild traumatic brain injury. J Head Trauma Rehabil, 5(3), 86–87.

Higgins DM, Kerns RD, Brandt CA, Haskell SG, Bathulapalli H, Gilliam W, & Goulet JL (2014). Persistent pain and comorbidity among operation enduring freedom/operation Iraqi freedom/operation new dawn veterans. Pain Medicine, 75(5), 782–790.

Hoge CW, Castro CA, Messer SC, McGurk D, Cotting DI, & Koffman RL (2004). Combat Duty in Iraq and Afghanistan, Mental Health Problems, and Barriers to Care. New England Journal of Medicine, 357(1), 13–22. 10.1056/NEJMoa040603

Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, & Castro CA (2008). Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq. New England Journal of Medicine, 358(5, 453–463. 10.1056/NEJMoa072972 [PubMed: 18234750]

Hoge CW, Yehuda R, Castro CA, McFarlane AC, Vermetten E, Jetly R, ... Rauch SA (2016). Unintended consequences of changing the definition of posttraumatic stress disorder in DSM-5: critique and call for action. JAMA Psychiatry, 73(7), 750–752. [PubMed: 27224895]

Hu L, & Bentler PM (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal, 6(1), 1–55.

Jakupcak M, Cook J, Imel Z, Fontana A, Rosenheck R, & McFall M (2009).Posttraumatic stress disorder as a risk factor for suicidal ideation in Iraq and Afghanistan War veterans. Journal of Traumatic Stress, 22(4), 303–306. 10.1002/jts.20423 [PubMed: 19626682]

King DW, Leskin GA, King LA, & Weathers FW (1998). Confirmatory factor analysis of the clinician-administered PTSD Scale: Evidence for the dimensionality of posttraumatic stress disorder. Psychological Assessment, 10(2, 90.

Lippa SM, Fonda JR, Fortier CB, Amick MA, Kenna A, Milberg WP, & McGlinchey RE (2015). Deployment-Related Psychiatric and Behavioral Conditions and Their Association with Functional Disability in OEF/OIF/OND Veterans: Disability in Returning Veterans. Journal of Traumatic Stress, 28(1, 25–33. 10.1002/jts.21979 [PubMed: 25703936]

Marshall GN, Schell TL, & Miles JN (2013). A multi-sample confirmatory factor analysis of PTSD symptoms: what exactly is wrong with the DSM-IV structure? Clinical Psychology Review, 33(1), 54–66. [PubMed: 23128035]

McDonald SD, Beckham JC, Morey R, Marx C, Tupler LA, & Calhoun PS (2008). Factorial invariance of posttraumatic stress disorder symptoms across three veteran samples. Journal of Traumatic Stress, 27(3), 309–317.

McGlinchey RE, Milberg WP, Fonda JR, & Fortier CB (2017). A methodology for assessing deployment trauma and its consequences in OEF/OIF/OND veterans: The TRACTS longitudinal prospective cohort study. International Journal of Methods in Psychiatric Research.

Melzack R (1987). The short-form McGill pain questionnaire. Pain, 30(2, 191–197. [PubMed: 3670870]

O'Toole BI, & Catts SV (2008). Trauma, PTSD, and physical health: an epidemiological study of Australian Vietnam veterans. Journal of Psychosomatic Research, 64(1, 33–40. [PubMed: 18157997]

Palmieri PA, Weathers FW, Difede J, & King DW (2007). Confirmatory factor analysis of the PTSD Checklist and the Clinician-Administered PTSD Scale in disaster workers exposed to the World Trade Center Ground Zero. Journal of Abnormal Psychology, 116(2, 329–341. https://doi.Org/10.1037/0021-843X.116.2.329 [PubMed: 17516765]

Perez-Garcia G, Sosa MAG, De Gasperi R, Lashof-Sullivan M, Maudlin-Jeronimo E, Stone JR, ... Elder GA (2016). Chronic post-traumatic stress disorder-related traits in a rat model of low-level blast exposure. Behavioural Brain Research.

Pietrzak RH, Tsai J, Armour C, Mota N, Harpaz-Rotem I, & Southwick SM (2015). Functional significance of a novel 7-factor model of DSM-5 PTSD symptoms: Results from the National Health and Resilience in Veterans Study. Journal of Affective Disorders, 174, 522–526. [PubMed: 25556669]

Polusny MA, Kehle SM, Nelson NW, Erbes CR, Arbisi PA, & Thuras P (2011). Longitudinal effects of mild traumatic brain injury and posttraumatic stress disorder comorbidity on postdeployment outcomes in national guard soldiers deployed to Iraq. Archives of General Psychiatry, 68(1), 79–89. [PubMed: 21199967]

Reger ML, Poulos AM, Buen F, Giza CC, Hovda DA, & Fanselow MS (2012).Concussive brain injury enhances fear learning and excitatory processes in the amygdala. Biological Psychiatry, 77(4), 335–343.

Rhemtulla M, Brosseau-Liard PE, & Savalei V (2012). When can categorical variables be treated as continuous? A comparison of robust continuous and categorical SEM estimation methods under suboptimal conditions. Psychological Methods, 77(3), 354.

Robinson ME, Lindemer ER, Fonda JR, Milberg WP, McGlinchey RE, & Salat DH (2015). Close-range blast exposure is associated with altered functional connectivity in Veterans independent of concussion symptoms at time of exposure. Human Brain Mapping, 36(3, 911–922. [PubMed: 25366378]

Satorra A, & Bentler PM (2010). Ensuring positiveness of the scaled difference chi-square test statistic. Psychometrika, 75(2), 243–248. [PubMed: 20640194]

Schneiderman AI, Braver ER, & Kang HK (2008). Understanding Sequelae of Injury Mechanisms and Mild Traumatic Brain Injury Incurred during the Conflicts in Iraq and Afghanistan: Persistent Postconcussive Symptoms and Posttraumatic Stress Disorder. American Journal of Epidemiology, 167(12), 1446–1452. 10.1093/aje/kwn068 [PubMed: 18424429]

Simms LJ, Watson D, & Doebbelling BN (2002). Confirmatory factor analyses of posttraumatic stress symptoms in deployed and nondeployed veterans of the Gulf War. Journal of Abnormal Psychology, 777(4), 637.

Thomas JL, Wilk JE, Riviere LA, McGurk D, Castro CA, & Hoge CW (2010). Prevalence of mental health problems and functional impairment among active component and National Guard soldiers 3 and 12 months following combat in Iraq. Archives of General Psychiatry, 67(6, 614–623. [PubMed: 20530011]

Weathers FW, Huska JA, & Keane TM (1991). PCL-C for DSM-IV. Boston: National Center for PTSD-Behavioral Science Division.

Weathers FW, Keane TM, & Davidson JR (2001). Clinician-Administered PTSD Scale: A review of the first ten years of research. Depression and Anxiety, 13(3, 132–156. [PubMed: 11387733]

Weathers FW, Bovin MJ, Lee DJ, Sloan DM, Schnurr PP, Kaloupek DG, ... & Marx BP (2018). The Clinician-Administered PTSD Scale for DSM-5 (CAPS-5): Development and initial psychometric evaluation in military veterans. Psychological Assessment, 30(3, 383. [PubMed: 28493729]

Wilkins KC, Lang AJ, & Norman SB (2011). Synthesis of the psychometric properties of the PTSD checklist (PCL) military, civilian, and specific versions. Depression and Anxiety, 25(7), 596–606. 10.1002/da.20837

Table 1.

Demographic, Injury, Deployment, Psychiatric, and Behavioral Characteristics of Sample and TBI/CBE Groups.

	Overall (n=387)		mTBI/CBE (n=106)		No mTBI/CBE (n=151)		
	n or *M*	% or SD	*n* or *M*	% or SD	*n* or *M*	% or SD	χ^2 or *t*
Age	31.98	8.43	30.11	7.12	32.41	8.77	4.97*
Gender (*n* males)	351	90.7%	100	94.3%	130	86.1%	4.51*
Ethnicity							
White (*n*)	289	74.7%	90	84.9%	106	70.2%	8.19*
Black (*n*)	30	7.6%	4	3.8%	16	10.6%	
Hispanic (*n*)	59	15.3%	10	9.4%	26	17.2%	
Other (*n*)	9	2.3%	2	1.9%	3	2.0%	
Years of Education (*n*)	13.96	1.96	13.57	1.90	14.09	1.92	
Branch of Service							5.32
Army (*n*)	248	64.1%	70	66.0%	96	63.6%	
Navy (*n*)	14	3.6%	6	5.7%	5	3.3%	
Marines (*n*)	94	24.3%	30	28.3%	30	19.9%	
Air Force (*n*)	26	6.7%	5	4.7%	15	9.9%	
Coast Guard (*n*)	1	0.3%	0	0.0%	1	0.7%	
Unit Type							
Active Duty (*n*)	215	55.6%	79	74.5%	71	47.0%	19.39***
National Guard (*n*)	119	30.8%	18	17.0%	54	35.8%	
Reserve (*n*)	53	13.7%	9	8.5%	26	17.2%	
Deployments							
Number	1.47	0.78	1.67	0.89	1.28	0.56	18.86**
Months	14.29	8.70	16.75	10.47	11.81	5.85	23.26**
Months since last	42.90	33.82	51.79	34.63	41.12	33.76	6.09*
Combat exposure (DRRI-C)	17.31	11.83	27.10	10.94	9.92	7.65	210.21***
n of military mTBIs	0.80	1.42	2.01	1.90	--	--	--
n of blast exposures	2.05	10.07	5.70	17.97	--	--	--
n of pre-military mTBIs	0.69	1.28	0.90	1.79	0.88	0.07	1.89
n of post-military mTBIs	0.07	0.29	0.08	0.37	0.06	0.26	0.64
PTSD (DSM-IV criteria)	234	60.47	85	80.19	67	66.34	33.07***
Total CAPS (current)	50.56	29.01	65.85	27.03	38.80	27.68	60.62***
Total PCL-C	43.25	17.24	52.44	15.78	35.30	14.77	37.65***
Current mood disorder (*n*)	104	26.9%	41	38.7%	28	18.5%	12.89***
Current anxiety disorder (*n*)	80	20.7%	25	23.6%	26	17.2%	1.59
Current substance use disorder (*n*)	56	14.5%	17	16.0%	22	14.6%	0.10
Taking ≥1 antidepressant (*n*)	103	26.6%	43	40.6%	26	17.2%	17.29***

	Overall (n=387)		mTBI/CBE (n=106)		No mTBI/CBE (n=151)		
	n* or *M	**% or SD**	***n* or *M***	**% or SD**	***n* or *M***	**% or SD**	**χ^2 or *t***
30-day average pain (SF-MPQ)	29.88	25.66	38.67	26.26	21.38	21.36	30.89***
Sleep disturbance (PSQI>5)	188	48.58	90	84.91	98	64.90	20.25***

* p<.05.

** p<.01.

*** p<.001.

Table 2.

Fit statistics Trauma Group and Measure Overall and by mTBI/CBE Group.

Measure	Sample	Model	AIC	BIC	RMSEA	CFI	TLI	SRMR
CAPS	Overall (*N*=387)	DSM-IV	27936	28150	0.07	0.93	0.91	0.05
		D	27878	28104	0.06	0.95	0.94	0.05
		EN *	27800	28026	0.04	0.97	0.97	0.04
		DA	27798	28039	0.04	0.97	0.97	0.04
	mTBI/CBE (*n*=106)	DSM-IV	7707	7851	0.09	0.88	0.85	0.07
		D	7707	7859	0.09	0.88	0.85	0.07
		EN *	7666	7818	0.07	0.93	0.92	0.06
		DA	7671	7834	0.07	0.93	0.91	0.06
	No mTBI/CBE (*n*=151)	DSM-IV	10647	10809	0.08	0.90	0.88	0.06
		D	10607	10779	0.06	0.94	0.92	0.06
		EN *	10578	10750	0.05	0.96	0.95	0.05
		DA	10577	10761	0.05	0.96	0.95	0.05
PCL	Overall (*N*=383)	DSM-IV	17625	17838	0.09	0.90	0.89	0.05
		D	17525	17750	0.08	0.92	0.91	0.05
		EN	17415	17640	0.07	0.95	0.93	0.05
		DA *	17364	17605	0.06	0.96	0.95	0.04
	mTBI/CBE (*n*=106)	DSM-IV	5009	5153	0.11	0.86	0.84	0.09
		D	5006	5157	0.11	0.87	0.84	0.09
		EN *	4944	5096	0.08	0.92	0.91	0.08
		DA	4944	5107	0.08	0.93	0.91	0.07
	No mTBI/CBE (*n*=148)	DSM-IV	6504	6666	0.09	0.89	0.87	0.07
		D	6421	6592	0.07	0.94	0.93	0.05
		EN	6424	6594	0.07	0.94	0.92	0.05
		DA *	6387	6570	0.06	0.96	0.95	0.05

* The best fitting model for each analysis group.

Table 3.

CAPS Parameter Estimates for EN Model by mTBI/CBE group.

	No mTBI/CBE (n=151)			mTBI/CBE (n=106)			
Symptom	**Loadings**[a]	**Intercept**	**Residual variance**	**Loadings**[a]	**Intercept**	**Residual variance**	**p**[b]
B1	1.71 (0.76)	2.18	2.14	1.76 (0.78)	4.21	1.95	0.004
B2	1.68 (0.68)	1.95	3.32	1.84 (0.71)	4.25	3.27	
B3	0.68 (0.46)	0.70	1.72	1.57 (0.63)	1.94	3.68	
B4	1.74 (0.78)	2.68	1.95	1.65 (0.78)	4.40	1.73	
B5	1.92 (0.80)	1.94	2.11	1.90 (0.73)	3.81	3.12	
C1	2.53 (0.90)	2.73	1.48	1.97 (0.80)	4.76	2.23	0.005
C2	1.87 (0.77)	2.21	2.41	2.15 (0.82)	4.26	2.31	
C3	0.68 (0.32)	1.13	3.89	0.67 (0.28)	1.86	5.41	0.777
C4	2.11 (0.81)	2.33	2.30	2.07 (0.76)	3.80	3.20	
C5	2.45 (0.87)	2.89	1.86	2.33 (0.89)	4.65	1.36	
C6	2.41 (0.88)	2.45	1.74	2.07 (0.73)	4.11	3.70	
C7	0.85 (0.49)	0.74	2.27	1.01 (0.48)	1.19	3.45	
D1	1.91 (0.62)	3.89	5.73	1.63 (0.68)	5.81	3.16	0.717
D2	1.53 (0.63)	3.31	3.52	1.56 (0.65)	4.33	3.38	
D3	1.62 (0.68)	2.24	3.02	1.23 (0.50)	3.73	4.48	
D4	1.86 (0.68)	3.70	4.05	1.59 (0.71)	5.31	2.51	
D5	1.39 (0.68)	1.75	2.18	1.42 (0.65)	3.43	2.81	

[a] Standardized loadings are included in parenthesis.

[b] The p-values are from Satorra-Bentler Chi-squares test for factor loading invariance.

NOTE: The overall p-value for the EN model was p=.017.

Table 4.

Fit Statistics for Individuals with a PTSD Diagnosis, Stratified by mTBI/CBE.

Measure	Sample	Model	AIC	BIC	RMSEA	CFI	TLI	SRMR
CAPS	Overall (*N*=234)	DSM-IV	17116.32	17302.90	0.065	0.834	0.805	0.067
		D	17095.92	17292.87	0.059	0.864	0.837	0.069
		EN *	17066.21	17263.17	0.049	0.907	0.888	0.057
		DA	17071.70	17282.47	0.051	0.903	0.879	0.057
	mTBI/CBE (*n*=85)	DSM-IV	6088.35	6220.26	0.082	0.803	0.769	0.084
		D	6084.25	6223.48	0.082	0.808	0.769	0.087
		EN *	6074.28	6213.51	0.074	0.843	0.811	0.079
		DA	6079.58	6228.58	0.078	0.832	0.791	0.078
	No mTBI/CBE (*n*=67)	DSM-IV	4966.35	5085.40	0.105	0.618	0.553	0.111
		D	4956.89	5082.55	0.099	0.674	0.608	0.108
		EN *	4947.09	5072.76	0.091	0.723	0.666	0.099
		DA	4946.69	5081.18	0.091	0.734	0.668	0.096
PCL	Overall (*N*=231)	DSM-IV	11137.09	11322.98	0.107	0.841	0.813	0.074
		D	11046.79	11243.01	0.092	0.885	0.862	0.074
		EN	10990.99	11187.20	0.080	0.913	0.895	0.063
		DA *	10965.25	11175.23	0.075	0.927	0.909	0.059
	mTBI/CBE (*n*=85)	DSM-IV	4049.94	4181.84	0.128	0.760	0.718	0.118
		D	4020.56	4159.79	0.115	0.809	0.770	0.116
		EN	3990.32	4129.55	0.101	0.853	0.823	0.096
		DA *	3987.10	4136.10	0.099	0.863	0.829	0.095
	No mTBI/CBE (*n*=65)	DSM-IV	3180.57	3297.99	0.099	0.855	0.830	0.085
		D	3153.90	3277.84	0.077	0.914	0.897	0.076
		EN	3152.26	3276.20	0.076	0.916	0.899	0.076
		DA *	3143.35	3275.98	0.065	0.941	0.926	0.072

* The best fitting model for each analysis group.

DSM-IV = DSM-IV Criteria; D = Dysphoria; EN = Emotional Numbing; DA = Dysphoric Arousal.