Journal of Affective Disorders 229 (2018) 63–68

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

Evaluating the stability of DSM-5 PTSD symptom network structure in a national sample of U.S. military veterans

Sophia H.H. von Stockert[a,b,e], Eiko I. Fried[b,e], Cherie Armour[c,e], Robert H. Pietrzak[d,e,*]

[a] *Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands*
[b] *Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands*
[c] *Psychology Research Institute, Ulster University, Coleraine Campus, Northern Ireland, UK*
[d] *United States Department of Veterans Affairs National Center for Posttraumatic Stress Disorder, VA Connecticut Healthcare System, West Haven, CT, USA*
[e] *Department of Psychiatry, Yale University School of Medicine, New Haven, CT, USA*

A R T I C L E I N F O

Keywords:
Posttraumatic stress disorder
Network structure
Veterans
DSM-5

A B S T R A C T

Background: Previous studies have used network models to investigate how PTSD symptoms associate with each other. However, analyses examining the degree to which these networks are stable over time, which are critical to identifying symptoms that may contribute to the chronicity of this disorder, are scarce. In the current study, we evaluated the temporal stability of DSM-5 PTSD symptom networks over a three-year period in a nationally representative sample of trauma-exposed U.S. military veterans.
Methods: Data were analyzed from 611 trauma-exposed U.S. military veterans who participated in the National Health and Resilience in Veterans Study (NHRVS). We estimated regularized partial correlation networks of DSM-5 PTSD symptoms at baseline (Time 1) and at three-year follow-up (Time 2), and examined their temporal stability.
Results: Evaluation of the network structure of PTSD symptoms at Time 1 and Time 2 using a formal network comparison indicated that the Time 1 network did not differ significantly from the Time 2 network with regard to network structure ($p = 0.12$) or global strength (sum of all absolute associations, i.e. connectivity; $p = 0.25$). Centrality estimates of both networks ($r = 0.86$) and adjacency matrices ($r = 0.69$) were highly correlated. In both networks, avoidance, intrusive, and negative cognition and mood symptoms were among the more central nodes.
Limitations: This study is limited by the use of a self-report instrument to assess PTSD symptoms and recruitment of a relatively homogeneous sample of predominantly older, Caucasian veterans.
Conclusion: Results of this study demonstrate the three-year stability of DSM-5 PTSD symptom network structure in a nationally representative sample of trauma-exposed U.S. military veterans. They further suggest that trauma-related avoidance, intrusive, and dysphoric symptoms may contribute to the chronicity of PTSD symptoms in this population.

1. Introduction

Exposure to traumatic events in military personnel often involves life-threatening interpersonal violence, combat, injuries, accidents, or loss (Wisco et al., 2014). While initial symptoms such as upsetting memories of the event or trouble sleeping are considered normal stress reactions that many veterans manage to overcome with time (Ehlers and Clark, 2003), a significant portion of around 8% of personnel develop post-traumatic stress disorder (PTSD: Kok et al., 2012; Wisco et al., 2014). PTSD is a chronic and disabling condition characterized by intrusive trauma-related memories, hypervigilance to and avoidance of trauma-related cues, and negative cognitions and mood (American Psychiatric Association, 2013).

Prior studies have often examined etiology, course, and treatment of PTSD based on the idea that the disorder is the common cause of PTSD symptoms (Borsboom and Cramer, 2013; Schmittmann et al., 2013). Network theory (Borsboom, 2017) complements this perspective. Here, the idea is that symptoms are correlated in a syndrome not because they have a shared origin, but because they directly activate and dynamically interact with each other (Armour et al., 2017; Fried et al., 2017; Mitchell et al., 2017; McNally et al., 2015, 2017; Borsboom and Cramer, 2013; Birkeland and Heir, 2017; Bryant et al., 2016; Spiller et al.,

* Corresponding author at: United States Department of Veterans Affairs National Center for Posttraumatic Stress Disorder, VA Connecticut Healthcare System, 950 Campbell Avenue 151E, West Haven, CT 06516, USA.
E-mail address: robert.pietrzak@yale.edu (R.H. Pietrzak).

https://doi.org/10.1016/j.jad.2017.12.043
Received 8 October 2017; Received in revised form 5 December 2017; Accepted 26 December 2017
Available online 27 December 2017
0165-0327/ Published by Elsevier B.V.

2017). For example, recurrent, intrusive memories of the traumatic event might lead to concentration and sleep difficulties, as well as avoidance of trauma memories, thus forming a causal symptom network. A recent network analysis of DSM-5 PTSD symptoms US military veterans with clinically significant PTSD symptoms (i.e., subthreshold or greater severity of symptoms) revealed that negative trauma-related emotions, flashbacks, detachment, and physiological reactivity were most central (i.e. interconnected) within the PTSD symptom network. Results further indicated particularly strong connections between trauma-related flashbacks and nightmares, detachment and restricted affect, and hypervigilance and exaggerated startle response (Armour et al., 2017).

While extant PTSD symptom network studies provide insight into structural connections of PTSD symptoms, the temporal stability of these symptom networks, particularly as they pertain to DSM-5 PTSD symptoms remains unknown. Several changes were introduced in the DSM-5 criteria for PTSD, which may influence the structure of symptom networks underlying this disorder. These changes include (1) the addition of three new symptoms—persistent and exaggerated negative beliefs about oneself, others, or the world; persistent distorted cognitions about the cause or consequences of the trauma; and reckless or self-destructive behavior; (2) wording changes to several symptoms carried over from the DSM-IV-TR; and (3) division of symptoms into four instead of three symptom clusters—intrusion symptoms, avoidance, negative alterations in cognitions and mood, and alterations in arousal and reactivity. Elucidation of symptoms that contribute to the maintenance and chronicity of PTSD is critical to informing prevention and treatment approaches for this disorder.

Bryant et al. (2016) evaluated the network stability of DSM-IV PTSD symptoms in a community-based sample of 852 people hospitalized for traumatic injury. DSM-IV PTSD symptoms were assessed upon admission and 12 months later. Results of this study revealed that re-experiencing symptoms, particularly intrusions and physiological reactivity, were central to other PTSD symptoms in the acute aftermath of trauma exposure. They further indicated that these network associations become stronger and thus more consolidated at the 12-month follow-up, with additional connections observed between physiological reactivity, hypervigilance, and exaggerated startle response; as well as between emotional numbing, detachment, and disinterest; and anger/irritability, sleep and concentration difficulties. Taken together, these findings suggest that fear and dysphoric PTSD symptoms emerge as connected symptom networks over time. They further underscore the potential importance of targeting intrusive memory and physiological reactivity to trauma cues in early intervention strategies for trauma-affected individuals.

In the current study, we sought to extend Bryant et al. (2016) results by evaluating the network structure of DSM-5 PTSD symptoms over a 3-year period in a nationally representative sample of trauma-exposed U.S. military veterans. Given that PTSD symptoms in general population samples of veterans range in severity, with only a minority screening positive for current PTSD (Wisco et al., 2014), we evaluated this aim in trauma-exposed veterans presenting with the full dimensional range of PTSD symptoms. Specifically, we (1) examined the network structure among 20 DSM-5 PTSD symptoms in a large, contemporary, and nationally representative US military veteran population sample of trauma-exposed veterans at baseline (Time 1) and at a three-year follow-up (Time 2); and (2) investigated whether this network structure is stable over a three-year period. To enhance generalizability of results of the broader population of trauma-exposed veterans, we included veterans presenting with the full dimensional spectrum of DSM-5 PTSD symptoms, ranging from a/minimally to severely symptomatic.

2. Methods

2.1. Participants

Participants were drawn from the second baseline cohort of the National Health and Resilience in Veterans Study (NHRVS), which surveyed a nationally representative sample of 1484 US veterans. The cohort was recruited in September and October 2013 from a research panel of US households developed and maintained by GfK, Inc (Menlo Park, California). Panel members were recruited using a sampling procedure that includes listed and unlisted phone numbers; telephone, non-telephone, and cellphone–only households; and households with or without Internet access, offering coverage of approximately 98% of US households. Post-stratification weights were applied based on demographic distributions (gender, age, race/ethnicity, education, Census region, and metropolitan area). Three-year follow-up assessments were obtained from 611 veterans in September and October 2016; this sample included trauma-exposed veterans presenting with the full dimensional spectrum of DSM-5 PTSD symptoms. All participants provided informed consent, and the Human Subjects Sub-committee of the Veterans Affairs (VA) Connecticut Healthcare System and VA Office of Research & Development approved the study.

2.2. Assessments

2.2.1. Trauma exposure

The Trauma History Screen (THS) is a self-report measure that assesses occurrence of 13 traumatic events across the lifespan (Carlson et al., 2011). Evaluated traumas include physical or sexual assault during childhood or adulthood, traumatic events during military service, accidents, and unexpected loss of a loved one. In addition, the item “life-threatening illness or injury” was added in the NHRVS.

2.2.2. DSM-5 PTSD symptoms

The PTSD Checklist-5 (PCL-5) is a 20-item self-report questionnaire that assesses DSM-5 PTSD symptoms experienced in the past month (Weathers et al., 2013). At baseline and at three-year follow-up assessment, participants were instructed to complete the PCL-5 in relation to their self-nominated “worst” stressful experience identified on the baseline THS. Participants who did not endorse history of trauma on the THS were not administered the PCL-5. Participants rated how much they had been bothered by each of the 20 symptoms in the past month (probable past-month PTSD) on a scale from 0 (Not at all) to 4 (Extremely). Probable PTSD was operationalized as a score ≥ 31 (Bovin et al., 2015). Sub-threshold was defined as endorsement of 2 or 3 B-E symptom criteria, or all 4 B-E symptom criteria but not 1-month symptom duration and/or functional impairment (Mota et al., 2016). The PCL-5 demonstrated excellent internal consistency at both baseline and 3-year assessments (Cronbach $\alpha = 0.95$ and 0.96, respectively).

2.3. Statistical analysis

The statistical software R (version 3.4.0) was used to conduct statistical analyses. Packages used included *qgraph, bootnet* (Epskamp and Fried, 2016), *mgm* (Haslbeck and Waldorp, 2016) and *NetworkComparisonTest* (NCT; van Borkulo, 2016). As differential drop-out was absent in the effective sample, missing cases were handled with listwise deletion to ensure that the same number of participants was analyzed at Time 1 and Time 2; this was important because regularization techniques employed in network analysis methodology (see below) is proportional to sample size, and networks estimated on smaller samples will often be more sparser (i.e. feature fewer connections) than networks estimated in larger samples. The same sample size is also necessary to compare network structures over time using the NCT. The final analytic sample contained 611 participants. To estimate and compare the network structure of 20 DSM-5 PTSD symptoms in 611 participants at Time 1 and Time 2, we first estimated a network for both time points, then analyzed network structure in terms of edge accuracy and symptom centrality, and finally compared networks with respect to structure and level of connectivity. All R code is available in the Supplementary materials.

2.3.1. Network estimation

To construct the PTSD symptom network for Time 1 and Time 2, we estimated two Gaussian Graphical Models (GGMs) using *qgraph* (Epskamp et al., 2012). GGMs are based on the correlation matrix of items. Since PCL-5 symptoms were measured on an ordinal scale and displayed skew, model estimation had to be based on either polychoric or Spearman correlations. Polychoric correlations represent the more common technique but can only be used when cells feature a sufficient number of observations (Epskamp and Fried, 2017). As this was not the case in our data, we estimated GGMs based on Spearman correlations. In the networks, PTSD symptoms are illustrated as nodes. Edges between nodes constitute regularized partial correlations, implying that we investigated the unique relationship items after controlling for the influence of all other items. To avoid estimating false positive associations, GGMs were estimated using the least absolute shrinkage and selection operator (LASSO, Tibshirani, 1996; for a tutorial see Epskamp and Fried, 2017). This procedure shrinks edge weights and sets small edges exactly to zero.

2.3.2. Network Inference

For network inference, we calculated centrality and predictability estimates for all nodes. To determine which nodes were central in each network, we estimated node strength, a measure that indicates the sum of the absolute values of all edge weights that a node is connected to (Opsahl et al., 2010). To determine the extent to which variance in a given symptom node could be predicted by its neighbors (i.e. connected nodes), we investigated predictability estimates of each node (which can be interpreted similar to R^2: Haslbeck and Fried, 2017; Haslbeck and Waldorp, 2017).

2.3.3. Network comparison

The network comparison test (NCT, van Borkulo et al., 2016) was used to evaluate whether the network structure among 20 DSM-5 PTSD symptoms remained stable over a three-year period. Specifically, we applied two tests. First, we used an omnibus test to investigate whether the network structure was invariant across time. In the case that network structures were significantly different from each other, we used post-hoc tests for all individual edges to see which ones differed specifically. Second, we tested whether the networks had equal global strength (ie. connectivity) by investigating whether they displayed the same sum of absolute edge weight values. The NCT has been validated for network models based on Pearson correlations. Given that we worked with Spearman correlations, we investigated the similarity between the data´s Pearson and Spearman correlation matrices for Time 1 and Time 2 which resulted in a correlation coefficient of r = 0.93 for Time 1 and r = 0.96 for Time 2. We thus used the NCT that is based on Pearson correlations to compare the network for 611 participants at baseline with the network for 611 participants at three-year follow-up.

2.3.4. Edge weight accuracy and centrality stability

To estimate edge weight accuracy as well as centrality stability for each network we used *bootnet*, a package that applies bootstrapping routines to edge weights and centrality indices (Epskamp et al., 2017). Details of the stability analyses can be found in the Supplementary materials.

3. Results

3.1. Sample characteristics

A total of 1268 veterans endorsed one or more trauma exposures at the baseline assessment. Of these, 611 (48.2%) completed the 3-year follow-up assessment (Wave 2). Wave 2 responders did not differ with respect to sex, race, marital status, combat veteran status, number of traumas, PCL-5 score, or prevalence of probable PTSD (all *p's* > 0.05). On average, the Wave 2 sample was 62.1 years of age (SD = 13.7, range = 23–94), predominantly male (89.7%), White (76.1%), married/partnered (70.8%), and non-combat veterans (60.6%); many had served in the Army (41.4%) or Navy (25.8%). Most commonly endorsed index traumas were sudden death of close family member or friend (33.2%), life-threatening illness or injury (14.0%), and saw something horrible or was badly scared during military service (10.0%). The mean number of years since trauma exposure was 25.7 (SD = 19.4, range = 0–78). The weighted prevalence of probable PTSD was 7.9% at baseline and 8.5% at 3-year follow-up; an additional 11.8% and 12.4% of the sample had sub-threshold PTSD at baseline and 3-year follow-up, respectively. The remaining participants were trauma-exposed but did not screen positive for subthreshold or threshold PTSD.

3.2. PTSD symptom networks

Fig. 1 shows the networks of 20 PTSD symptoms for 611 participants at baseline (Time 1, panel A) and three-year follow up (Time 2, panel B). Out of 190 possible edges, 111 were present at Time 1 and 116 were present at Time 2, implying a very similar level of sparsity. With the exception of three negative edges in the Time 1 network, all edge weights of both time points were positive. Node strength estimates are visualized in Fig. 1, panel C. and were correlated: r = 0.86 for networks at Time 1 and Time 2. Avoidance of thoughts, avoidance of reminders, detachment, difficulty concentrating, emotional as well as physical cue reactivity, restricted affect, and negative trauma-related emotions were among the more central nodes in both networks. Physical cue reactivity (B5) scored highest on predictability at Time 1 (R^2 = 69.6%), indicating that nearly 70% of variance in this item could be explained by nodes with which it connected. Similarly, emotional cue reactivity (B4) scored highest on predictability at Time 2 (R^2 = 73.5%). Mean predictability across all nodes was $R^2 = 0.56$ ($SD = 0.13$) in the Time 1 network and $R^2 = 0.59$ ($SD = 0.12$) in the Time 2 network. An overview of all predictability estimates can be found in the Supplementary materials.

3.3. Edge weight accuracy and centrality stability

In relation with the moderately large sample size, accuracy analyses revealed moderate confidence intervals for edge weights in both networks. Both networks showed stable estimates of the order of strength centrality, with a correlation coefficient of 0.75, exceeding the recommended cutoff of at least 0.5 (Epskamp, Borsboom and Fried, 2017). Further details, including results of edge weights and centrality difference tests, are available in the Supplementary materials.

3.4. Network comparison

Results from the network comparison test showed that the Time 1 network did not differ significantly from the Time 2 network regarding network structure ($p = 0.12$) or global strength ($p = 0.25$). Both networks were thus similar with respect to structure and the level that nodes were connected with each other. Adjacency matrices were correlated r = 0.69.

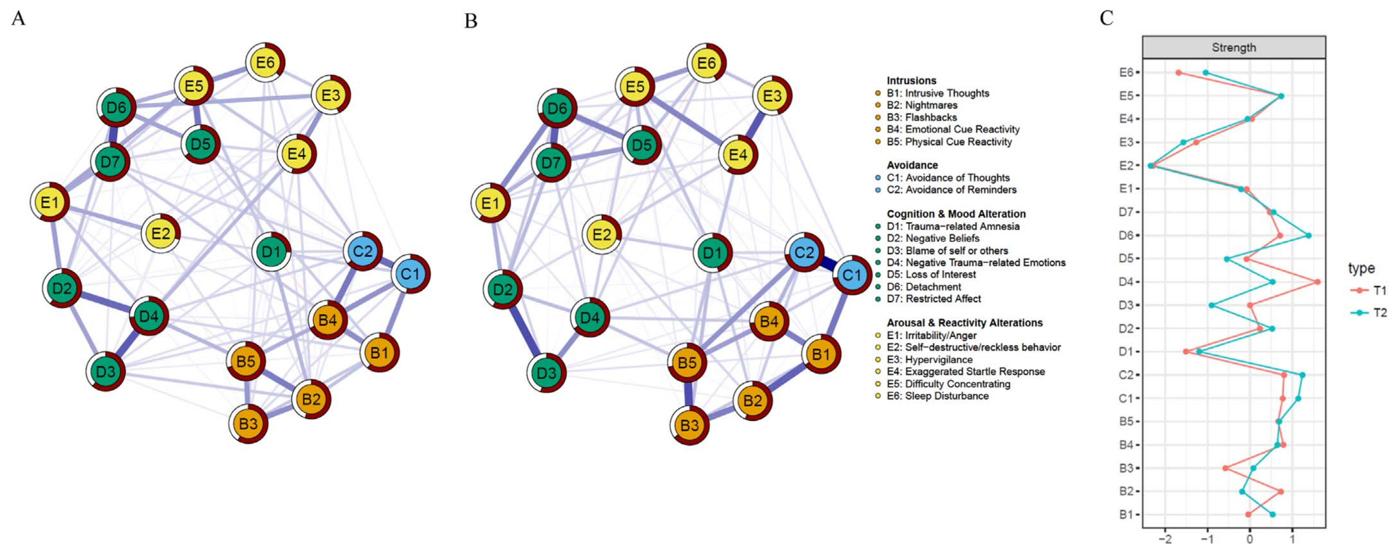

Fig. 1. DSM-5 PTSD Symptom Network at Baseline (Time 1) and 3-Year Follow-up Assessment (Time 2). Fig. 1 **A and B**: PTSD symptom network with 611 participants at Time 1 (left) and Time 2 (middle); nodes convey PTSD symptoms; blue edges constitute positive partial correlations between symptoms whereas red edges constitute negative partial symptom correlations between symptoms; circles around nodes convey variance in a given PTSD item with shadowed parts displaying that part of the variance that is explained by its connecting nodes. **C**: standardized node strength estimates at Time 1 (red) and Time 2 (blue). Strongly connected nodes were placed closer together through application of the Fruchterman-Reingold algorithm (Fruchterman and Reingold, 1991); the layout was constrained across the two figures to allow for comparisons. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

4. Discussion

To our knowledge, the current study is the first to evaluate the longitudinal stability of DSM-5 PTSD symptom network structure. Using baseline and three-year follow-up assessments of PTSD symptoms in a nationally representative sample of trauma-exposed U.S. military veterans, PTSD symptom networks were found to be similar with respect to network structure, level of connectivity, and symptom centrality over the three-year study period. Consistent with prior cross-sectional network studies of a broad range of trauma survivors (Armour et al., 2017; Birkeland and Heir, 2017; Bryant et al., 2016; Mitchell et al., 2017; McNally et al., 2015, 2017; Spiller et al., 2017), avoidance symptoms, trauma-related cue reactivity and negative emotions were among the most central to PTSD symptom networks at both baseline and three-year follow-up assessments. Collectively, these findings suggest that trauma-related avoidance, intrusive, and dysphoric symptoms may contribute to the chronicity of PTSD symptoms in this population. They further underscore the importance of targeting these symptoms in prevention and treatment efforts for PTSD in U.S. military veterans and other trauma-affected populations.

Our study resembles the analysis performed by Bryant et al. (2016) in that both studies investigated the stability of PTSD symptom networks over time and featured fairly large samples ($n = 611$ and $n = 852$, respectively). However, while Bryant and colleagues (2016) focused on DSM-IV PTSD symptoms, we evaluated the longitudinal stability of DSM-5 PTSD symptom structure. This is an important distinction given that the new DSM-5 criteria as established in 2013 comprise several changes, including the addition of three new symptoms (American Psychiatric Association, 2013). Moreover, assessment points were three years apart in the current study whereas this prior study employed a shorter follow-up period of 12 months. This is pertinent as stability assessment over a longer period of time contributes to insight regarding maintenance and longitudinal stability of PTSD symptom networks. It is also noteworthy that the first PTSD symptom assessment in the analysis by Bryant et al. (2016) occurred during the acute phase of traumatic injury. In contrast, in our sample, a substantially longer period of time—an average of 26 years—had elapsed after exposure to trauma and the nature of trauma exposure was mixed. Endorsement of PTSD symptoms is subject to change particularly in the first few years after exposure; in the first year, symptoms often decline substantially, as most survivors recover without treatment (Yehuda et al., 2015). At the same time, approximately one third of survivors who are initially symptomatic remain symptomatic over a course of three years (Ehlers and Clark, 2003). It is conceivable that symptom endorsement in the study of Bryant et al. (2016) as assessed immediately after exposure as well as at 12 months follow-up was more malleable as compared to symptom state in our sample, which likely reflects more chronic PTSD symptoms. Indeed, structure and level of connectivity of PTSD DSM-5 symptom networks in our sample did not significantly change over a course of three years, while Bryant et al. (2016) found increased network connectivity 12 months after exposure. Finally, Bryant et al. (2016) investigated network differences with a focus on connectivity level. We extended this analysis to also examine differences in network structure as statistical tools to address such a question have recently become available (van Borkulo et al., 2016). Taken together, results of our study add to a burgeoning body of literature on the network structure of PTSD symptoms by demonstrating the longitudinal stability of DSM-5 PTSD symptom networks in a nationally representative sample of U.S. military veterans.

The high temporal stability of PTSD symptom networks observed in the current study is not only of substantive clinical interest, but also gives confidence into the precision of parameter estimates of network models. If network models—with the number of observations and items reported here that generalize fairly well to the prior literature (Haslbeck and Fried, 2017)—were highly susceptible to sampling variability, it would be extremely unlikely to find temporal stability of network structures, as observed in this study. This finding also aligns with confirmatory factor analytic studies demonstrating the factorial invariance of PTSD symptom clusters over time (e.g., Krause et al., 2007; Wang et al., 2012; Wang et al., 2017).

Results of the current study should be interpreted in light of several limitations. First, we estimated networks based on symptom correlations across all trauma-exposed veterans at each time-point in a sample that exhibited the full dimensional range of DSM-5 PTSD symptoms. While approximately 20% of the sample screened positive for full or sub-threshold PTSD, the majority did not. As a result, analyses may not generalize to clinical populations of individuals with PTSD but may instead inform the average network structure and network structure stability of PTSD symptoms in the broader population of trauma-affected veterans. Given the dimensional nature of PTSD (Armour et al., 2016), this can be considered a particular strength. At the same time, future studies are required to investigate network stability in clinical PTSD samples. Second, our sample was comprised predominantly of older white male veterans. Further research is needed to evaluate whether networks replicate across more diverse populations (Fried and Cramer, 2017). Third, we relied on self-report data of the 20 DSM-5 criterion symptoms for PTSD and not structured clinical interviews. It should be noted that the DSM-IV version of the PCL demonstrated moderate-to-high concordance rates with structured diagnostic interviews for PTSD in previous analyses (Hopwood et al., 2008; Harrington and Newman, 2007); further work is needed to assess the extent to which this is the case for DSM-5-based instruments. Fourth, the nature of index traumas used in the current study was heterogeneous. This may be an advantage because findings can be considered representative of the broader population of trauma-affected individuals and the traumas to which they have been exposed. At the same time, future work may complement this approach. Given that trauma exposure may be linked to differential expression of PTSD symptoms (Armour and Shevlin, 2013; Kelley et al., 2009), it may prove useful to compare PTSD symptom networks in populations that differ in index trauma. In relation to that, it should be noted that previous research has shown that PTSD symptom levels around 2–4 weeks after exposure predict symptom development better than levels directly after exposure (Ehlers and Clark, 2003). Stability of PTSD symptom network structures may thus be investigated with the first symptom assessment taking place during this acute time window. Fifth, given that we analyzed data from the entire sample of trauma-exposed veterans, results do not provide information about individual variability in response to trauma, which may be characterized by chronic, recovering, resilient, and delayed symptom courses (e.g., Bonanno and Mancini, 2008); further longitudinal research using larger samples is needed to assess how PTSD symptom network structures may change as a function of common PTSD symptom trajectories.

More research is needed to examine the predictive utility of network models of DSM-5 PTSD symptoms, as well as how treatment may influence these symptom networks. Stability analyses may also be useful in predicting the course of mental disorders. For example, a recent study of depressed individuals found that, relative to those with remitted symptoms, those with persistent symptoms over a 2-year period exhibited a more densely connected symptom network (van Borkulo et al., 2015). Accordingly, it may be useful for future research on PTSD symptom networks to evaluate the prognostic utility of network structures in predicting chronicity and remission of symptoms in trauma survivors, and whether treatment of highly affected individuals may alter the symptom network structure in this population.

Acknowledgements

The authors thank the veterans who participated in the National Health and Resilience in Veterans Study.

Role of the funding source

The funding source had no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the paper for publication.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jad.2017.12.043.

References

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders, 5th ed. Author, Arlington, VA.
Armour, C., Fried, E.I., Deserno, M.K., Tsai, J., Pietrzak, R.H., 2017. A network analysis of DSM-5 posttraumatic stress disorder symptoms and correlates in US military veterans. J. Anxiety Disord. 45, 49–59.
Armour, C., *Műllerová, J., Elhai, J.D., 2016. A systematic literature review of PTSD's latent structure in the diagnostic and statistical manual of mental disorders: DSM-IV to DSM-5. Clin. Psychol. Rev. 44, 60–74.
Armour, C., Shevlin, M., 2013. Assessing the specificity of PTSD's dysphoric items within Simms et al.'s latent structure. J. Nerv. Ment. Dis. 201, 907–914.
Birkeland, M.S., Heir, T., 2017. Making connections: exploring the centrality of posttraumatic stress symptoms and covariates after a terrorist attack. Eur. J. Psychotraumatology 8 (Sup3), 1333387.
Bonanno, G.A., Mancini, A.D., 2008. The human capacity to thrive in the face of potential trauma. Pediatrics 121, 369–375.
Borsboom, D., 2017. A network theory of mental disorders. World Psychiatry 16, 5–13.
Borsboom, D., Cramer, A.O., 2013. Network analysis: an integrative approach to the structure of psychopathology. Annu. Rev. Clin. Psychol. 9, 91–121.
Bovin, M.J., Marx, B.P., Weathers, F.W., Gallagher, M.W., Rodriguez, P., Schnurr, P.P., Keane, T.M., 2015. Psychometric properties of the PTSD checklist for diagnostic and statistical manual of mental disorders–fifth edition (PCL-5) in veterans. Psychol. Assess. 28 (11), 1379.
Bryant, R.A., Creamer, M., O'donnell, M., Forbes, D., McFarlane, A.C., Silove, D., Hadzi-Pavlovic, D., 2016. Acute and chronic posttraumatic stress symptoms in the emergence of posttraumatic stress disorder: a network analysis. JAMA Psychiatry 74 (2), 135–142.
Carlson, E.B., Smith, S.R., Palmieri, P.A., Dalenberg, C., Ruzek, J.I., Kimerling, R., Spain, D.A., 2011. Development and validation of a brief self-report measure of trauma exposure: the trauma history screen. Psychol. Assess. 23 (2), 463.
Ehlers, A., Clark, D., 2003. Early psychological interventions for adult survivors of trauma: a review. Biol. Psychiatry 53 (9), 817–826.
Epskamp, S., Cramer, A.O., Waldorp, L.J., Schmittmann, V.D., Borsboom, D., 2012. qgraph: network visualizations of relationships in psychometric data. J. Stat. Softw. 48 (4), 1–18.
Epskamp, S., Fried, E.I., 2016. bootnet: Bootstrap methods for various network estimation routines. Retrieved from http://cran.r-project.org/web/packages/bootnet/index.html.
Epskamp, S., Fried, E., 2017. A tutorial on regularized partial correlation networks. Psychol. Methods (in press). https://arxiv.org/abs/1607.01367.
Epskamp, S., Borsboom, D., Fried, E.I., 2017. Estimating psychological networks and their accuracy: a tutorial paper. Behav. Res. Methods 1604, 08462 (arXiv preprint, arXiv:1604.08462).
Fried, E.I., van Borkulo, C.D., Cramer, A.O., Boschloo, L., Schoevers, R.A., Borsboom, D., 2017. Mental disorders as networks of problems: a review of recent insights. Social. Psychiatry Psychiatr. Epidemiol. 52 (1), 1–10.
Fried, E.I., Cramer, A.O.J., 2017. Moving forward: challenges and directions for psychopathological network theory and methodology. Perspect. Psychol. Sci. 〈https://osf.io/bnekp〉.
Fruchterman, T.M., Reingold, E.M., 1991. Graph drawing by force-directed placement. Softw.: Pract. Exp. 21 (11), 1129–1164.
Harrington, T., Newman, E., 2007. The psychometric utility of two self-report measures of PTSD among women substance users. Addict. Behav. 32 (12), 2788–2798.
Haslbeck, J.M.B., Waldorp, L.J., 2016. mgm: structure estimation for time-varying mixed graphical models in high-dimensional data. arXiv preprint, page. arXiv preprint arXiv:1510.06871.
Haslbeck, J.M.B., Waldorp, L.J., 2017. How well do network models predict future observations? On the importance of predictability in network models. arXiv preprint arXiv:1610.09108.1v3.
Haslbeck, J.M.B., Fried, E.I., 2017. How predictable are symptoms in psychopathological networks? A reanalysis of 18 published datasets. Psychol. Med.
Hopwood, C.J., Morey, L.C., Edelen, M.O., Shea, M.T., Grilo, C.M., Sanislow, C.A., McGlashan, T.H., Daversa, M.T., Gunderson, J.G., Zanarini, M.C., Markowitz, J.C., Skodol, A.E., 2008. A comparison of interview and self-report methods for the assessment of borderline personality disorder criteria. Psychol. Assess. 20 (1), 81–85.
Kelley, L., Weathers, F., McDevitt-Murphy, M.E., Eakin, D., Flood, A., 2009. A comparison of PTSD symptom patterns in three types of civilian trauma. J. Trauma. Stress 22 (3), 227–235.
Kok, B.C., Herrell, R.K., Thomas, J.L., Hoge, C.W., 2012. Posttraumatic stress disorder associated with combat service in Iraq or Afghanistan: reconciling prevalence differences between studies. J. Nerv. Ment. Dis. 200 (5), 444–450.
Krause, E.D., Kaltman, S., Goodman, L.A., Dutton, M.A., 2007. Longitudinal factor structure of posttraumatic stress symptoms related to intimate partner violence. Psychol. Assess. 19, 165–175.
McNally, R.J., Heeren, A., Robinaugh, D.J., 2017. A Bayesian network analysis of posttraumatic stress disorder symptoms in adults reporting childhood sexual abuse. Eur. J. Psychotraumatology 8 (Sup3), 1341276.
McNally, R.J., Robinaugh, D.J., Wu, G.W., Wang, L., Deserno, M.K., Borsboom, D., 2015. Mental disorders as causal systems a network approach to posttraumatic stress disorder. Clin. Psychol. Sci. 3 (6), 836–849.
Mitchell, K.S., Wolf, E.J., Bovin, M.J., Lee, L.O., Green, J.D., Rosen, R.C., Marx, B.P., 2017. Network Models of DSM-5 Posttraumatic Stress Disorder: Implications for ICD-11. J. Abnorm. Psychol. 126 (3), 355.
Mota, N.P., Tsai, J., Sareen, J., Marx, B.P., Wisco, B.E., Harpaz-Rotem, I., Pietrzak, R.H.,

2016. High burden of subthreshold DSM-5 posttraumatic stress disorder in US military veterans. World Psychiatry 15 (2), 185–186.
Opsahl, T., Agneessens, F., Skvoretz, J., 2010. Node centrality in weighted networks: generalizing degree and shortest paths. Soc. Netw. 32 (3), 245–251.
Schmittmann, V.D., Cramer, A.O., Waldorp, L.J., Epskamp, S., Kievit, R.A., Borsboom, D., 2013. Deconstructing the construct: a network perspective on psychological phenomena. New Ideas Psychol. 31 (1), 43–53.
Spiller, T.R., Schick, M., Schnyder, U., Bryant, R.A., Nickerson, A., Morina, N., 2017. Symptoms of posttraumatic stress disorder in a clinical sample of refugees: a network analysis. Eur. J. Psychotraumatology 8 (Sup3), 1318032.
Tibshirani, R., 1996. Regression shrinkage and selection via the lasso. J. R. Stat. Soc. Ser. B 58, 267–288.
van Borkulo, C.D., Boschloo, L., Borsboom, D., Penninx, B.W.J.H., Waldorp, L.J., Schoevers, R.A., 2015. Association of symptom network structure with the course of longitudinal depression. JAMA Psychiatry 72 (12), 1219. http://dx.doi.org/10.1001/jamapsychiatry.2015.2079.
van Borkulo, C.D., 2016. NetworkComparisonTest: Statistical Comparison of Two Networks Based on Three Invariance Measures. Retrieved from https://cran.r-project.org/web/packages/NetworkComparisonTest.
Wang, M., Elhai, J.D., Dai, X., Yao, S., 2012. Longitudinal invariance of posttraumatic stress disorder symptoms in adolescent earthquake survivors. J. Anxiety Disord. 26, 263–270.
Wang, L., Cao, X., Cao, C., Fang, R., Yang, H., Elhai, J.D., 2017. Factor structure of DSM-5 PTSD symptoms in trauma-exposed adolescents: examining stability across time. J. Anxiety Disord. 52, 88–94.
Weathers, F.W., Litz, B.T., Keane, T.M., Palmieri, P.A., Marx, B.P., Schnurr, P.P., 2013. The PTSD Checklist for DSM-5 (PCL-5). Scale available from the National Center for PTSD at. 〈www.ptsd.va.gov〉.
Wisco, B.E., Marx, B.P., Wolf, E.J., Miller, M.W., Southwick, S.M., Pietrzak, R.H., 2014. Posttraumatic stress disorder in the US veteran population: results from the national health and resilience in veterans study. J. Clin. Psychiatry 75 (12), 1338–1346.
Yehuda, R., Hoge, C., W., McFarlane, A., C., Vermetten, E., Lanuis, R., Hyman, S., 2015. Primer: post-traumatic stress disorder. Nature 1 (1), 1–22.