Moral injury symptoms and related problems among service members and Veterans: A network analysis

Natasha Benfer[a], Maya Bina N. Vannini[a], Breanna Grunthal[a], Benjamin C. Darnell[a], Gadi Zerach[b], Yossi Levi-Belz[c] and Brett T. Litz[a]

ABSTRACT

Introduction: Whether moral injury (MI) is distinct from posttraumatic stress disorder (PTSD) has been debated. Both result from events that often definitionally overlap (a potentially morally injurious event [PMIE] for MI, a Criterion A event for PTSD) and may promote similar dysfunctional experiences. Depressive symptoms may also follow such events and include outcomes common to both MI and PTSD. This study investigated the ways in which MI may be distinct from, and related to, PTSD and depression by examining networks consisting of MI-related outcomes (trust violation, shame, functioning), PTSD symptom clusters, and depression among those who reported experiencing a PMIE and those who did not. **Methods:** Two networks were estimated, consisting of PTSD symptoms, MI-shame-related outcomes, MI-trust-related outcomes, MI-related functioning, and depression in a sample of military personnel who did (n = 508) and did not (n = 123) experience a PMIE. **Results:** In both PMIE and non-PMIE networks, stronger connections existed within, versus across, constructs. The PMIE network was denser than the non-PMIE network and driven by more connections across constructs. Negative alterations in cognitions and mood (NACM) clusters of PTSD and MI-related functioning were strong bridges connecting PTSD, MI, and depression. **Discussion:** MI, PTSD, and depression appear to be distinct but related clinical phenomena. NACM and MI-related functioning partially explain the co-occurrence in these constructs and thus may be important treatment targets. The greater connections across constructs in the PMIE network supports the hypothesis that experiencing a PMIE may trigger dynamic interactions among PTSD, MI-related outcomes, and depression.

Key words: depression, military, moral injury, network analysis, PMIE, posttraumatic stress disorder, potentially morally injurious events, PTSD, Veterans

RÉSUMÉ

Introduction : La distinction entre le préjudice moral (PM) et le trouble de stress post-traumatique (TSPT) a fait l'objet de débats. Tous deux découlent d'événements qui, d'après leur définition, se chevauchent souvent (à titre d'événement au potentiel préjudiciable sur le plan moral [ÉPPM] provoquant des PM et d'événement du critère A du TSPT) et peuvent promouvoir des expériences dysfonctionnelles semblables. Des symptômes dépressifs peuvent également en découler et entraîner des résultats cliniques communs tant aux PM qu'au TSPT. Cette étude a porté sur les manières dont les PM peuvent se distinguer ou se rapprocher du TSPT et de la dépression par l'examen des réseaux composés des résultats cliniques des PM (abus de confiance, honte, fonctionnement), des grappes de symptômes du TSPT et de la dépression chez les personnes qui déclaraient avoir vécu des ÉPPM ou non. **Méthodologie :** Les chercheurs(ses) ont estimé deux réseaux, composés des symptômes de TSPT, des résultats cliniques de la honte, de la confiance ou du fonctionnement liés aux PM et de la dépression dans un échantillon de membres du personnel militaire qui avaient vécu (n = 508) ou non (n = 123) un ÉPPM. **Résultats :** Tant dans les réseaux d'ÉPPM que sans ÉPPM, les liens étaient plus forts au sein des construits qu'entre eux. Le réseau d'ÉPPM était plus dense que celui sans ÉPPM et reposait sur plus de liens entre les construits. Les grappes d'altérations négatives persistantes des capacités cognitives et de l'humeur (ANCCH) du TSPT et du fonctionnement lié aux PM constituaient de solides ponts reliant le TSPT, les PM et la dépression. **Discussion :** Les PM, le TSPT et la dépression semblaient être des phénomènes cliniques distincts, mais reliés. Les ANCCH et le fonctionnement lié aux PM expliquent partiellement la cooccurrence de ces construits et pourraient dont être des

a Massachusetts Veterans Epidemiology Research and Information Center, VA Boston Healthcare System, Boston, Massachusetts, United States
b Department of Psychology, Ariel University, Ariel, Israel
c The Lior Tsfaty Center for Suicide and Mental Pain Studies, Ruppin Academic Center, Emek Hefer, Israel

Correspondence should be addressed to Natasha Benfer at Massachusetts Veterans Epidemiology Research and Information Center, VA Boston Healthcare System, 2 Avenue de Lafayette, Boston, Massachusetts, United States, 02111. Telephone: 857-364-4201. Email: natasha.benfer@va.gov

cibles thérapeutiques importantes. Les plus grands liens entre les construits du réseau d'ÉPPM appuient l'hypothèse selon laquelle un ÉPPM peut déclencher des interactions dynamiques entre le TSPT, les résultats cliniques liés aux PM et la dépression.

Mots-clés : analyse de réseau, dépression, ÉPPM, événements au potentiel préjudiciable sur le plan moral, militaire, préjudice moral, trouble de stress post-traumatique, TSPT, vétéran(e)s

LAY SUMMARY

Both moral injury (MI) and posttraumatic stress disorder (PTSD) can result from adverse experiences (potentially morally injurious events [PMIEs] for the former and Criterion A events for the latter) and may lead to similar symptoms. Thus, debate is ongoing as to whether MI and PTSD are distinct. Depressive symptoms can also follow these events and may also overlap with symptoms of MI and PTSD. This study investigated how distinct MI is from PTSD and depression by examining networks composed of MI-related outcomes (trust violation, shame, functioning), PTSD symptom clusters, and depression for participants who reported experiencing a PMIE and those who did not. This study is the first of its kind to use MI outcomes with PTSD and depression in a network analysis. The results suggest that MI, PTSD, and depression are distinct but related phenomena, with more connections between these phenomena present particularly among those who experienced a PMIE. Moreover, the negative alterations in cognition and mood cluster of PTSD and MI-related functioning appears to explain some of the co-occurrence among constructs.

INTRODUCTION

Military service members are at risk for experiencing a range of haunting events in war, including experiencing or witnessing actual or threatened death, serious injury, or sexual violence, which may result in posttraumatic stress disorder (PTSD; Criterion A) and a co-occurring depressive disorder.[1] These traumatic events can also violate service members' deeply held moral values, which are termed potentially morally injurious events (PMIEs). However, these events can also be non-overlapping, such that service stressors that do not meet Criterion A can be PMIEs, such as a commanding officer betraying the trust of a service member or a service member deciding to launch a drone strike that results in the death of civilians (but not witnessing the aftermath). Non-traumatic (i.e., PMIE events that do not meet Criterion A) and traumatic (i.e., PMIE events that do meet Criterion A) PMIEs can subsequently lead to negative psychic, social, and spiritual distress known as moral injury (MI).[2]

The symptoms of MI and PTSD also overlap, perhaps in part because events can meet both PMIE and Criterion A definitions and because MI and PTSD share symptoms. As with any high-magnitude life event, PMIEs can be haunting (leading to re-experiencing), and people are motivated to avoid situational and inner cues related to the experience. MI is also associated with shame, anger, altered core beliefs about the self and others, isolation, and risky or self-destructive behaviors,[2] all of which are symptoms of PTSD. The overlap, both in the events that lead to the distress and in the outcomes themselves, has led to debate as to whether MI should be subsumed under PTSD or considered its own phenomenon.[3,4] Although the overlap between depression and MI has garnered less attention, both can entail anhedonia, dysphoria, social isolation, and negative thoughts about the self and thus raise similar questions. If MI is distinct from PTSD and depression, treatments for MI are needed; otherwise, treatments for PTSD and depression may suffice.[5-7]

Despite similarities in symptoms, the syndrome of MI includes experiences, such as alterations in how individuals regard, understand, define, or see themselves (who they are) or see others or the world, with respect to their core moral beliefs and what they or others are capable of, changes in moral thinking (e.g., condemnation of the self or others), the prominence of moral emotions, and alterations in beliefs about life's meaning and purpose that are distinct or more prominent in MI than in PTSD or depression.[8] Moreover, the function of these symptoms is theorized to differ across these constructs. From a functional perspective, moral emotions (e.g., shame, anger) may lead to various psychological and social outcomes that overlap with PTSD and depression, such as isolation, risky behaviors, and so forth.[9] The overlap and high co-occurrence among MI, PTSD, and depression also does not mean these putatively separate problems necessarily develop in a similar pattern, have similar risk factors, or respond to the same treatments with equal effectiveness. Theoretical models suggest there may be important differences in the etiology and treatment of MI.[10] Because there is little evidence to support these ideas, it is important to examine the ways in which symptoms across these disorders are, or are not, related to clarify the nature of the construct overlap and inform treatment decisions. For example, if the symptoms that

comprise negative alterations in cognitions and mood (NACM; e.g., feeling isolated, anhedonia) are highly related to symptoms of MI (which appears to be true, on the basis of prior evidence),[11,12] then perhaps PTSD treatments that target NACM (e.g., behavioural activation with therapeutic exposure) may be helpful in reducing MI-related distress.[13] If, however, there are few relationships observed between symptoms across constructs, novel treatments for MI may be needed.

To date, examinations of the incremental validity of MI have treated PTSD and depression as separate latent constructs that putatively cause each disorder and, thus, their respective symptoms.[14,15] This is problematic in part because boundaries between disorders are indistinct, and the modally high rates of comorbidity between disorders has led researchers and clinicians to question whether the disorders are truly distinct or are reflective of some common-cause super-disorder.[16,17] However, mental and behavioural health phenomena constructs do not operate as independent systems, nor are they all caused by one categorical super-disorder; rather, these phenomena are related to one another in complex ways, within and across diagnostic categories.[14] For example, it is likely that insomnia can lead to difficulties concentrating (both symptoms of major depressive disorder), rather than the presence of both symptoms being explained by some latent construct of depression.

Network analysis examines the dynamic interplay among symptoms and experiences within and across constructs (e.g., MI, PTSD, depression), which can help elucidate the ways in which constructs are distinct and related. Under the network framework, putatively distinct disorders and clinical phenomena affect people across symptoms and experiences via complex causal pathways. For example, rather than a latent construct of PTSD emerging and activating the 20 symptoms that comprise PTSD, intrusive thoughts might lead to experiential avoidance efforts, which, in turn, lead to difficulties concentrating (a symptom of both PTSD and major depressive disorder), which can lead to other depressive symptoms. This framework is particularly helpful for understanding co-occurring conditions because comorbidities are theorized to be the result of naturally occurring relationships, rather than as a problem with diagnostic categories. When examining multiple constructs within a network, one can examine bridge variables, which connect symptoms from one disorder to another. Bridge variables may be present in both constructs or causally linked from one construct to another. To date, network analysis has been used to examine how PTSD interacts with depression,[18] borderline personality disorder,[19] suicidal thoughts and behaviors,[20] and alcohol use,[21] among others.

Using a sample of 191 Israeli combat Veterans, one study used a network framework to examine associations among PTSD, reports of exposure to combat stressors and PMIEs, and a measure of depressionogenic attributional style.[22] The authors used the Moral Injury Event Scale,[23] PTSD Checklist for *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM-5*) (PCL-5),[24] Depressive Attributes Questionnaire,[25] and Combat Experiences Scale.[26] They found that exposures to different types of PMIE were more closely related to each other than to PTSD symptom clusters, and they were primarily related to PTSD directly through negative attributional style. The authors speculated that these relationships are due to the overlap of MI-related outcomes (e.g., blame, shame, guilt) with depressionogenic thinking, which is problematic because only exposure to PMIEs was indexed. The conflation between exposure to PMIEs (the event) and MI (the outcome) is common, and it unfortunately assumes that PMIEs always result in putative MI symptoms, which is often not the case.[27]

In response to various problems with existing measures of MI as an outcome, a new measure was recently validated, the Moral Injury Outcomes Scale (MIOS),[8] which contains shame-related (MI-Shame) and trust-violation-related (MI-Trust) sub-scales and includes an index of the functional impact of MI. The present study extended the work of Levi-Belz et al. by using the MIOS to examine dynamic associations among MI-Shame, MI-Trust, MI-related functioning, depression, and PTSD sub-clusters using network analysis.[22] This study aimed to explore the ways in which MI, PTSD, and depression are related and distinct, thus providing an initial indication of whether MI should be subsumed under PTSD and depression. To do so, the authors examined the network of these constructs in two samples who did and did not endorse a PMIE, respectively. Few, but not zero, connections across constructs would support construct distinctiveness, and connections across constructs would explain the co-occurrence of these syndromes or disorders. Differences in network structure between those who have and have not experienced a PMIE, a precondition for MI, elucidates whether MI is a distinct clinical phenomenon and, thus, points to whether unique treatment approaches may be needed. If MI is

a distinct clinical phenomenon resulting from a PMIE, more connections (i.e., more activation in the network) should be observed within and across constructs for those who have experienced a PMIE.

The authors hypothesized that relationships within constructs would be stronger than relationships across constructs, indicating that constructs are distinct but related. The authors also hypothesized that NACM of PTSD would be the strongest bridge to other constructs, consistent with previous studies that found NACM to be particularly salient in MI.[11,12] Finally, the authors expected that, compared with the network from the sample of individuals who did not endorse a PMIE, the network among those who did endorse PMIE would have more connections within and across MI, indicating that a PMIE may ignite a network of mutually reinforcing, and thus related, problems.

METHODS

Participants

This secondary analysis used a sample of active-duty service members and Veterans from the Moral Injury Outcome Scale Project Consortium.[28] Military personnel from the United States, Australia, and Israel (N = 631) were recruited to participate in a study developing a measure for MI-related outcomes and subsequently completed an online self-report assessment battery. Participants were primarily aged 30-49 years (62.6%), mostly male (81.8%), and mostly of Veteran status (76.4%). Furthermore, 96.4% of the sample previously deployed, and 80.5% (n = 508) endorsed exposure to a PMIE. This research was approved by each site's human studies oversight committee.

Measures

PTSD Checklist for DSM-5

The PCL-5 is a 20-item self-report questionnaire used to assess PTSD symptom severity over the past month. [24] The PTSD diagnostic criteria of the *DSM-5* include 20 potential symptoms across four clusters (i.e., intrusions [PTSD-B], avoidance [PTSD-C], NACM [PTSD-D], and alterations in arousal and activity [PTSD-E]),[1,2] and each symptom corresponds to an item on the PCL-5. For each symptom, participants rate how bothered they have been by each symptom in the past month on a five-point Likert scale ranging from 0 to 4 (not at all, a little bit, moderately, quite a bit, and extremely). PCL-5 items can be summed to generate severity scores for each of the four clusters. The PCL-5 has demonstrated strong psychometric properties.[29] Among the PMIE endorser and non-PMIE endorser groups in this study, the internal consistency coefficients were excellent for the intrusion, NACM, and alterations in arousal and reactivity clusters (αs ≥ 0.91) and good for the avoidance cluster (αs ≥ 0.88).

Moral Injury Outcomes Scale

The MIOS is a 14-item self-report questionnaire used to assess psychosocial outcomes after exposure to a PMIE;[8] it has two sub-scales, a shame-related sub-scale (MI-Shame) and a trust-violation-related sub-scale (MI-Trust), each consisting of seven items. Participants rate how strongly they agree with each item on a five-point Likert scale ranging from 0 to 4 (strongly disagree, disagree, neither agree or disagree, agree, strongly agree. Sub-scale scores range from 0 to 28, with greater scores indicating greater negative outcomes. The MIOS has demonstrated good internal consistency (αs = 0.89-0.95) and acceptable test-retest reliability for the MIOS total score (r = 0.76) and the MI-Shame and MI-Trust sub-scales (rs = 0.86 and 0.57, respectively).[8] For the PMIE endorser and non-PMIE endorser groups in this study, internal consistency coefficients were excellent for the MI-Shame sub-scale (α ≥ 0.92) and good for the MI-Trust sub-scale (α ≥ 0.88).

After participants endorsed MI symptoms, they filled out the Brief Inventory of Psychosocial Functioning (B-IPF) to assess the functional impact of the MIOS symptoms endorsed over the past month across seven domains.[30] Items are rated on a seven-point Likert scale ranging from 0 to 6 (not at all, somewhat, extremely), and total scores range from 0 to 100, with greater scores indicating greater functional impairment. The B-IPF has demonstrated strong internal consistency (α = 0.84) and adequate test-retest reliability (r = 0.65).[30] For the PMIE endorser and non-PMIE endorser groups in this study, the B-IPF internal consistency coefficients were excellent (α ≥ 0.96).

Patient Health Questionnaire-9

The Patient Health Questionnaire-9 (PHQ-9) is a nine-item self-report questionnaire used to assess depressive symptom severity over the past two weeks.[31] Items are rated on a four-point Likert scale ranging from 1 to 4 (not at all, several days, more than half the days, nearly every day). Total scores range from 0 to 18, with higher scores indicating greater depressive symptom severity. The PHQ-9 has demonstrated high internal consistency

($\alpha = 0.89$) and test-retest reliability ($r = 0.84$).[31] For the PMIE endorser and non-PMIE endorser groups in this study, the PHQ-9 internal consistency coefficients were excellent ($\alpha \geq 0.93$).

Network analysis

Two Gaussian graphical model networks were estimated for participants who endorsed having experienced a PMIE (n = 508) and for those who did not (n = 123). These network models consisted of nodes, representing observed variables, and edges, representing the partial correlation coefficients (i.e., weights) between nodes, with the thickness of edges representing the strength of the correlation between nodes. In this study, nodes were assigned to their respective construct, PTSD, MI, and depression, called communities in network analysis. All network analyses were conducted with R (version 4.1.3; R Foundation for Statistical Computing, Vienna, Austria).

Network estimation

This study used the bootnet package with the graphical least absolute shrinkage and selection operator (LASSO) function and Extended Bayesian Information Criterion model selection.[32,33] The LASSO procedure sets very small edges to zero, thus reducing the chance of fraudulent correlations and creating a sparser but more specific network.[34] For both networks, the threshold was set to TRUE, which enforces even greater specificity at the cost of sensitivity.

Network inference

In addition to inspecting and describing the network, one can examine node centrality, which is an index of how influential each node is in the overall network. For the purposes of this study, bridge expected influence (BEI) was the main index of centrality. BEI is the sum of edge weights from one node in one community to all other nodes in other communities and thus provides a metric of how influential the node is to the other constructs in the network.[35,36] As described earlier, communities were pre-determined on the basis of the constructs they belonged to (PTSD, MI, depression).

Network accuracy

To estimate network accuracy, the authors followed the procedures outlined by Epskamp and colleagues using the bootnet package.[37] First, the authors estimated the edge weight accuracy by bootstrapping 95% confidence intervals around each of the edge weights. This non-parametric bootstrapping method repeatedly replaces sampled data with simulated data and creates plausible datasets. With this bootstrap, the authors also conducted difference tests to examine any statistically significant differences in edge weights.

Network stability

To assess the stability of the BEI metric, sub-setting bootstrap was conducted, in which participants are dropped from analyses to examine whether the central nodes remain stable in the network. A centrality stability coefficient (CS coefficient) is then calculated to examine the proportion of cases that can be removed while retaining a high correlation ($r = 0.70$) between the original and bootstrapped samples. The CS coefficient should not be below 0.25 and should preferably be above 0.50.[37]

RESULTS

Skewness and kurtosis for all variables using the full sample were between -2 and 2; thus, the data did not need to be transformed. Descriptive statistics for each variable are presented in Table 1. Demographic information for the samples, broken down by country, are presented in Tables 2 and 3.

Network estimation

The network structure for those who experienced a PMIE is presented in Figure 1, and that of those who did not experience a PMIE is presented in Figure 2. Both networks included exclusively positive connections. As hypothesized, for both networks, the within-construct connections were generally significantly stronger than the across-construct connections (see Appendix, Figures A1-A2). With 19 total connections, the PMIE network was denser than the non-PMIE network, which had 15 connections. The PMIE network also had more connections across constructs (11) than the non-PMIE network (7). As hypothesized, the PMIE network had more MI-related connections than the non-PMIE network. Specifically, the former had a total of 11 MI-related connections (3 within the MI construct itself, 6 between MI and PTSD, and 2 between MI and depression), and the latter had a total of 7 (2 within the MI construct, 2 between MI and PTSD, and 3 between MI and depression).

Bridge symptoms

In the PMIE network, depression, MI-Functioning, and PTSD-D had the greatest BEI between constructs (in that order; Figure 3). In the non-PMIE network,

depression had a greater BEI than any other node, with PTSD-D and MI-Shame equally high in BEI (Figure 4).

Network accuracy and stability

The edge weight bootstrapped confidence intervals for both networks show that the networks were accurately estimated (see Appendix, Figures A3-A4), such that most edges were truly non-zero (i.e., the 95% confidence intervals did not include 0). Stability analyses produced a CS coefficient of 0.75 for the PMIE network and 0.44 for the non-PMIE network, both of which are considered within the acceptable range (Appendix, Figures A5-A6).[37] Thus, both networks were stable enough to interpret centrality differences between variables.

DISCUSSION

This study used network analysis to model the relationships between the theorized factors of MI (i.e., trust violation related and shame related), MI-related functional outcomes, PTSD symptom clusters, and depressive symptoms in a sample of military personnel and Veterans who experienced a PMIE and those who had not. As expected, variables generally clustered together within their respective construct (e.g., the two MI factors clustered together, and the four PTSD symptoms clusters clustered together), suggesting that MI, PTSD, and depression are each distinct but related. Unexpectedly, in the PMIE and non-PMIE networks, MI-related functioning was not more closely tied to MI variables than to PTSD and depression.

As expected, all variables demonstrated more interconnectedness for the PMIE-exposed sub-sample than for the unexposed sub-sample. This is consistent with a previous network analysis that found strong connections between PMIEs and PTSD and depressive symptoms (although they did not assess MI outcomes),[22] indicating that exposure to PMIEs is related to the experience of these symptoms. Results indicated that experiencing a PMIE may initiate a cascade of outcomes that are mutually reinforcing for distinct but related MI, PTSD, and depressive syndromes.

The connections for MI-related functioning were diffuse in that MI-related functioning was not as closely associated with other MI variables. Instead, it appeared

Table 1. Descriptive Statistics in the PMIE (n = 508) and non-PMIE (n = 123) groups

Group and measure	Mean (SD)	Range	Bivariate correlations							
			1	2	3	4	5	6	7	8
PMIE group										
MI										
1. Shame	14.23 (7.79)	0-28	—							
2. Trust	15.62 (6.91)	0-28	0.81	—						
3. Function	61.19 (30.25)	0-100	0.66	0.64	—					
PTSD										
4. Cluster B	10.67 (5.82)	0-20	0.69	0.66	0.73	—				
5. Cluster C	4.65 (2.49)	0-8	0.63	0.61	0.65	0.81	—			
6. Cluster D	15.31 (7.92)	0-28	0.74	0.72	0.76	0.86	0.80	—		
7. Cluster E	13.38 (6.75)	0-24	0.69	0.67	0.72	0.85	0.76	0.90	—	
8. PHQ-9	12.97 (7.71)	0-27	0.69	0.64	0.68	0.73	0.65	0.77	0.76	—
Non-PMIE group										
MI										
1. Shame	7.02 (6.85)	0-27	—							
2. Trust	8.37 (6.78)	0-26	0.87	—						
3. Function	33.26 (34.57)	0-100	0.62	0.62	—					
PTSD										
4. Cluster B	4.92 (5.53)	0-18	0.70	0.67	0.72	—				
5. Cluster C	2.18 (2.32)	0-8	0.61	0.63	0.73	0.89	—			
6. Cluster D	6.66 (7.41)	0-25	0.77	0.72	0.73	0.92	0.86	—		
7. Cluster E	6.39 (6.59)	0-23	0.70	0.67	0.71	0.89	0.85	0.90	—	
8. PHQ-9	5.33 (6.22)	0-22	0.73	0.70	0.69	0.75	0.74	0.81	0.81	—

Note: All correlations significant at $p < 0.05$.
PMIE = potentially morally injurious event; MI = Moral Injury; Shame = Shame-Related sub-scale; Trust = Trust Violation-Related sub-scale; Function = Related Functioning sub-scale; PHQ-9 = Patient Health Questionnaire-9.

to be just as related to depression and PTSD. In fact, MI-related functioning was associated with all other variables except the PTSD-C and PTSD-E clusters. This is surprising, given that the MIOS attempts to limit reports of functioning to MI symptoms and thus would theoretically be especially associated with the MI factors. It is possible that this measure of functioning is de facto highly non-specific. Furthermore, because MI-related functioning was referenced to a PMIE, it is possible that the PMIE was also a Criterion A event, which would explain its connection to PTSD and depression clusters. Alternatively, it may also be that MI-related functional impairment reinforces other, non-MI-specific outcomes (e.g., depression), because the increased connectedness between this measure of functioning and all other constructs for the PMIE-exposed subsample indicates that these constructs are interrelated indirectly through MI-related functioning. To address these possibilities, more research is needed to determine whether the functioning questions in the MIOS are capturing the intended construct.

As hypothesized, the PTSD-D symptom cluster was central to connecting constructs and was the primary bridge from PTSD to MI constructs in both networks. This replicates previous research suggesting that the PTSD-D cluster may link MI and PTSD.[38] Indeed, there is substantial overlap between aspects of MI and the PTSD-D cluster; both may include experiences of blame

Table 2. Demographic and military characteristics of PMIE endorsers

	n (%)			
Characteristic	United States (n = 350)	Israel (n = 71)	Australia (n = 87)	Total (N = 508)
Age,* y				
18-19	2 (0.6)	0 (0)	0 (0)	2 (0.4)
20-29	20 (5.7)	64 (90.1)	0 (0)	84 (16.5)
30-39	148 (42.3)	6 (8.5)	20 (23)	174 (34.3)
40-49	144 (41.1)	1 (1.4)	26 (29.9)	171 (33.7)
50-59	32 (9.1)	0 (0)	26 (29.9)	58 (11.4)
60-69	4 (1.1)	0 (0)	11 (12.6)	15 (3)
70-79	0 (0)	0 (0)	4 (4.6)	4 (0.8)
Gender†				
Man	291 (83.1)	53 (74.6)	65 (74.7)	409 (80.5)
Woman	57 (16.3)	15 (21.1)	22 (25.3)	94 (18.5)
Transgender man	0 (0)	0 (0)	0 (0)	0 (0)
Transgender woman	1 (0.3)	0 (0)	0 (0)	1 (0.2)
Other	1 (0.3)	0 (0)	0 (0)	1 (0.2)
Prefer not to say	0 (0)	3 (4.2)	0 (0)	3 (0.6)
Race-ethnicity		NR	NR	N/A
White	264 (75.7)			
Black or African American	33 (9.4)			
Asian	6 (1.7)			
Hispanic or Latino	25 (7.1)			
American Indian or Alaskan Native	3 (0.9)			
Native Hawaiian or Pacific Islander	1 (0.3)			
Mixed	15 (4.3)			
Other	2 (0.6)			
Military status*				
Active duty	86 (24.6)	6 (8.5)	34 (39.1)	126 (24.8)
Veteran	264 (75.4)	65 (91.5)	53 (60.9)	382 (75.2)
Previous deployment*				
Yes	350 (100)	71 (100)	66 (75.9)	487 (95.5)
No	0 (0)	0 (0)	21 (24.1)	21 (4.1)

* χ^2 tests revealed significant differences, although small cell sizes warrant caution in interpretation.
† When gender was dichotomized as male versus other, there were no significant differences across samples.
PMIE = potentially morally injurious event; NR = not recorded; N/A = not applicable.

and shame after the index event.[20] Similarly, NACM is made up of social isolation and anhedonia, both of which are symptoms of depression. Although NACM had high bridge influence, depression had the highest BEI, and MI-related functioning was on par with NACM in the PMIE network. It is unsurprising that depression had the highest BEI because it is a one-node construct; thus, it is somewhat artificially absorbing all the influence, compared with if depression was broken up into subscales or nodes. The finding that MI-related functioning had high BEI is likely due to the explanations provided earlier, wherein the MI-related functioning variable may have captured general dysfunction rather than the intended MI-specific functioning problems.

Because of the limited sample size, it was not possible to examine a network model at the item or symptom level, which limits the degree to which the specific relationships between symptoms can be extrapolated (e.g., the study was insufficiently powered to examine the centrality of the NACM symptoms of shame and blame). A larger sample is needed for a more nuanced examination of the relationships among PTSD, MI, and depression. Moreover, the comparator sub-group unexposed to a PMIE was heterogeneous in that it included those who may or may not have otherwise experienced a *DSM-5* Criterion A event. To fully understand the similarities and distinctions between the etiologies of PTSD and MI, it will be necessary to parse that heterogeneity and

Table 3. Demographic and military characteristics of non-PMIE endorsers

	n (%)			
Characteristic	United States (n = 70)	Israel (n = 40)	Australia (n = 13)	Total (N = 123)
Age,* y				
18-19	0 (0)	0 (0)	1 (7.7)	1 (0.8)
20-29	4 (5.7)	40 (100)	0 (0)	44 (35.8)
30-39	24 (34.3)	0 (0)	1 (7.7)	25 (20.3)
40-49	24 (34.3)	0 (0)	1 (7.7)	25 (20.3)
50-59	7 (10)	0 (0)	6 (46.2)	13 (10.6)
60-69	7 (10)	0 (0)	0 (0)	7 (5.7)
70-79	4 (5.7)	0 (0)	4 (30.8)	8 (6.5)
Gender†				
Man	59 (84.3)	36 (90)	12 (92.3)	107 (87)
Woman	10 (14.3)	4 (10)	1 (7.7)	15 (12.2)
Transgender man	1 (1.4)	0 (0)	0 (0)	1 (0.8)
Transgender woman	0 (0)	0 (0)	0 (0)	0 (0)
Other	0 (0)	0 (0)	0 (0)	0 (0)
Prefer not to say	0 (0	0 (0)	0 (0)	0 (0)
Race-ethnicity		NR	NR	N/A
White	64 (91.4)			
Black or African American	5 (7.1)			
Asian	0 (0)			
Hispanic or Latino	0 (0)			
American Indian or Alaskan Native	1 (1.4)			
Native Hawaiian or Pacific Islander	0 (0)			
Mixed	0 (0)			
Other	0 (0)			
Military status*				
Active duty	17 (24.3)	1 (2.5)	5 (38.5)	23 (18.7)
Veteran	53 (75.7)	39 (91.5)	8 (61.5)	100 (81.3)
Previous deployment*				
Yes	70 (100)	40 (100)	11 (84.6)	121 (98.4)
No	0 (0)	0 (0)	2 (15.4)	2 (1.6)

* χ^2 tests revealed significant differences, although small cell sizes warrant caution in interpretation.
† When gender was dichotomized as male versus other, there were no significant differences across samples.
PMIE = potentially morally injurious event; NR = not recorded; N/A = not applicable.

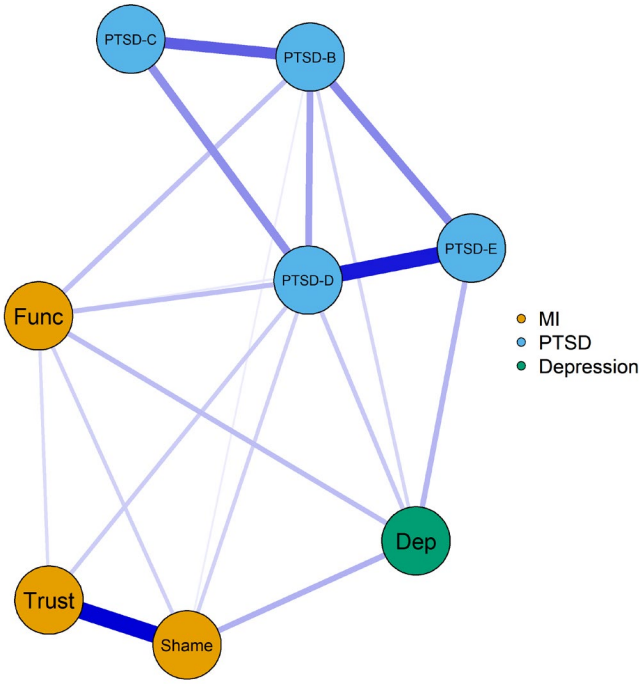

Figure 1. Visualization of the network structure with participants who experienced a potentially morally injurious event (n = 508)

PTSD = posttraumatic stress disorder; PTSD-B = cluster b, intrusion; PTSD-C = cluster C, avoidance; PTSD-D = cluster D, negative alterations in cognitions and mood; PTSD-E = cluster E, alterations in arousal and reactivity; MI = moral injury; Func = MI-related functioning; Trust = MI trust-related violations; Shame = MI-related shame; Dep = depression.

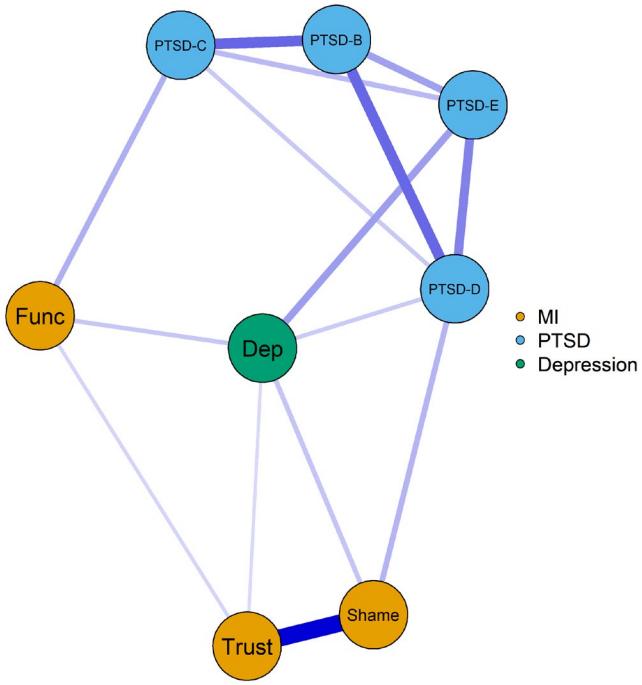

Figure 2. Visualization of the network structure with participants who did not experience a potentially morally injurious event (n = 123)

PTSD = posttraumatic stress disorder; PTSD-B = cluster B, intrusions; PTSD-C = cluster C, avoidance; PTSD-D = cluster D, negative alterations in cognitions and mood; PTSD-E = cluster E, alterations in arousal and reactivity; MI = moral injury; Func = MI-related functioning; Trust = MI trust-related violations; Shame = MI-related shame; Dep = depression.

examine differences in symptom network models across varying types of event exposure (and non-exposure).

Another limitation of this study is that all data were cross-sectional; as such, these models represent connections between outcomes in one moment in time after PMIE exposure (or the lack thereof) and cannot address causality or sequence. The sample used in this study was a primarily male sample of U.S. Veterans with high combat exposure. Idiosyncrasies in symptomatology have been documented across genders,[39,40] service status (e.g., Veterans vs. civilians),[40] and trauma types;[41] as such, these findings may not be generalizable to other populations or more heterogenous samples. Furthermore, although the use of multiple countries' data enhances the generalizability of results, there were demographic differences across samples (see Tables 2 and 3), which could have resulted in different network structures across samples. However, it was not possible to explore any differences by sample because of the small sample sizes (n = 111 and 100 in the Israeli and Australian samples, respectively).

Finally, although the use of network analysis is novel and an improvement on other cross-sectional latent variable approaches, it has limitations. The authors hypothesized that there would be few connections across constructs, supporting construct distinctiveness while acknowledging the co-occurrence of these diagnoses or syndromes. However, there is no empirical rule to determine how many connections would constitute few enough connections to support construct distinctiveness. In addition, the study was limited in extrapolating any causal relations from cross-sectional networks. Although nodes (i.e., variables) with high expected influence, or BEI, may point to the most fruitful treatment targets — because, theoretically, a decrease in a high expected influence node would lead to decreases in other nodes — it is unclear whether high expected influence nodes are the antecedents or consequences of other variables in the model. For example, NACM may be the result of MI-related shame, or MI-related shame may cause NACM. Results from this study suggest that targeting NACM could be a fruitful way to decrease MI

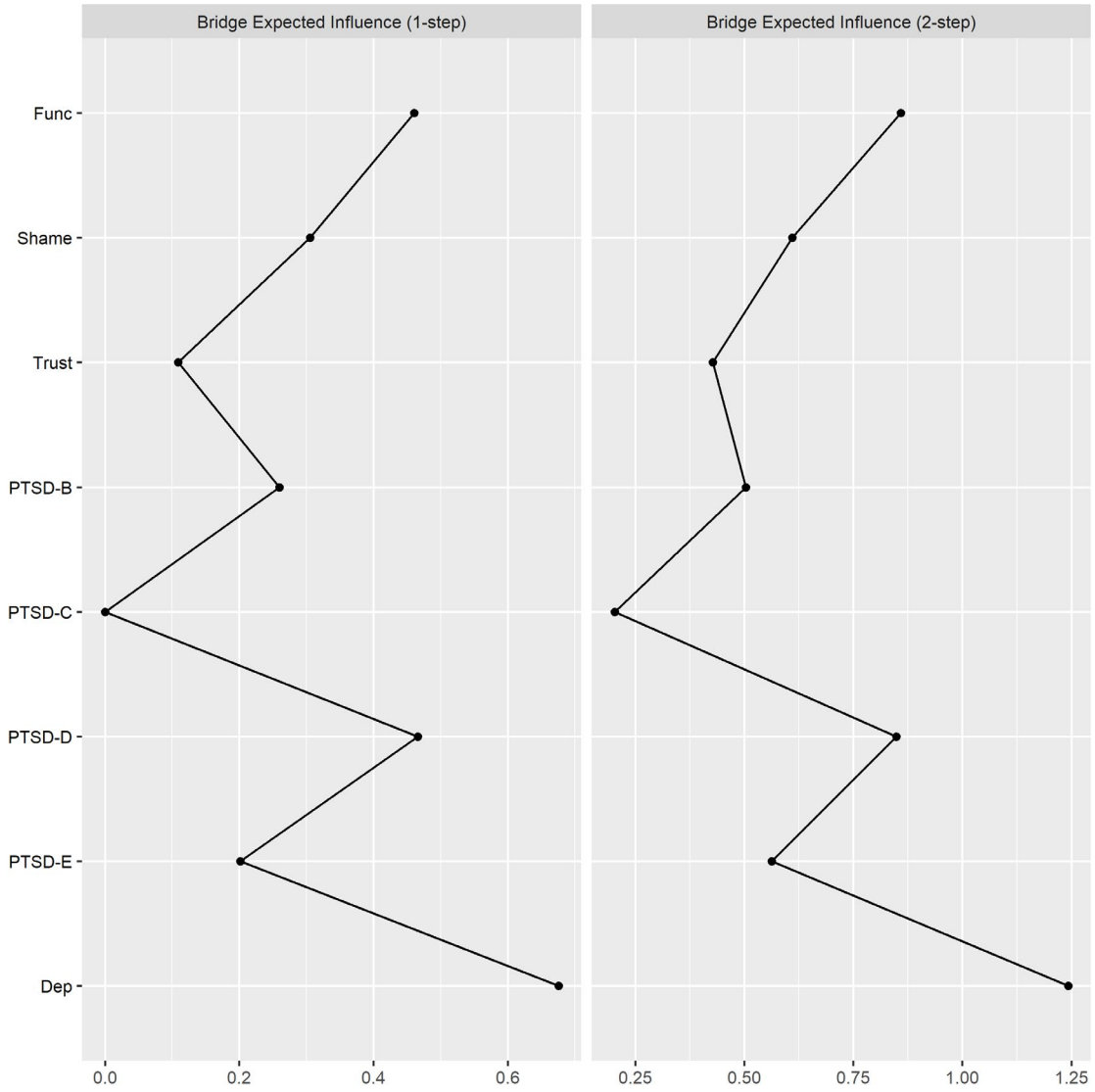

Figure 3. One-step bridge expected influence in the network structure with participants who experienced a potentially morally injurious event (n = 508)
PTSD-B = cluster B, intrusion; PTSD-C = cluster C, avoidance; PTSD-D = cluster D, negative alterations in cognitions and mood; PTSD-E = cluster E, alterations in arousal and reactivity; Func = MI-related functioning; Trust = MI trust-related violations; Shame = MI-related shame; Dep = depression.

and depressive symptoms, but this hypothesis needs to be tested in longitudinal or clinical trial research.

Notwithstanding these limitations, this study is the first examination of a network model of PTSD, MI as an outcome, depressive symptoms, and MI-related functional impairment. Results indicate that MI, PTSD, and depression are related through associations across symptoms, particularly the PTSD-D symptoms, but there are still distinct relationships within constructs. Furthermore, PMIE exposure may initiate a systematic cascade of mutually reinforcing symptoms that may promote comorbidity between these syndromes, with the PTSD-D symptom cluster, functioning, and to some extent depressive symptoms at the core. Questions remain regarding the relationships between specific symptoms in this network model, the role of PMIEs versus Criterion A events, and the generalizability of this model to other samples. Yet, the results are consistent with a study that found that NACM is the potential link among PTSD, MI, and depression.[38] An examination at the symptom level may reveal that symptoms within the PTSD-D cluster, such as shame, blame, or both, link the syndromes and may be valuable targets for clinical intervention.

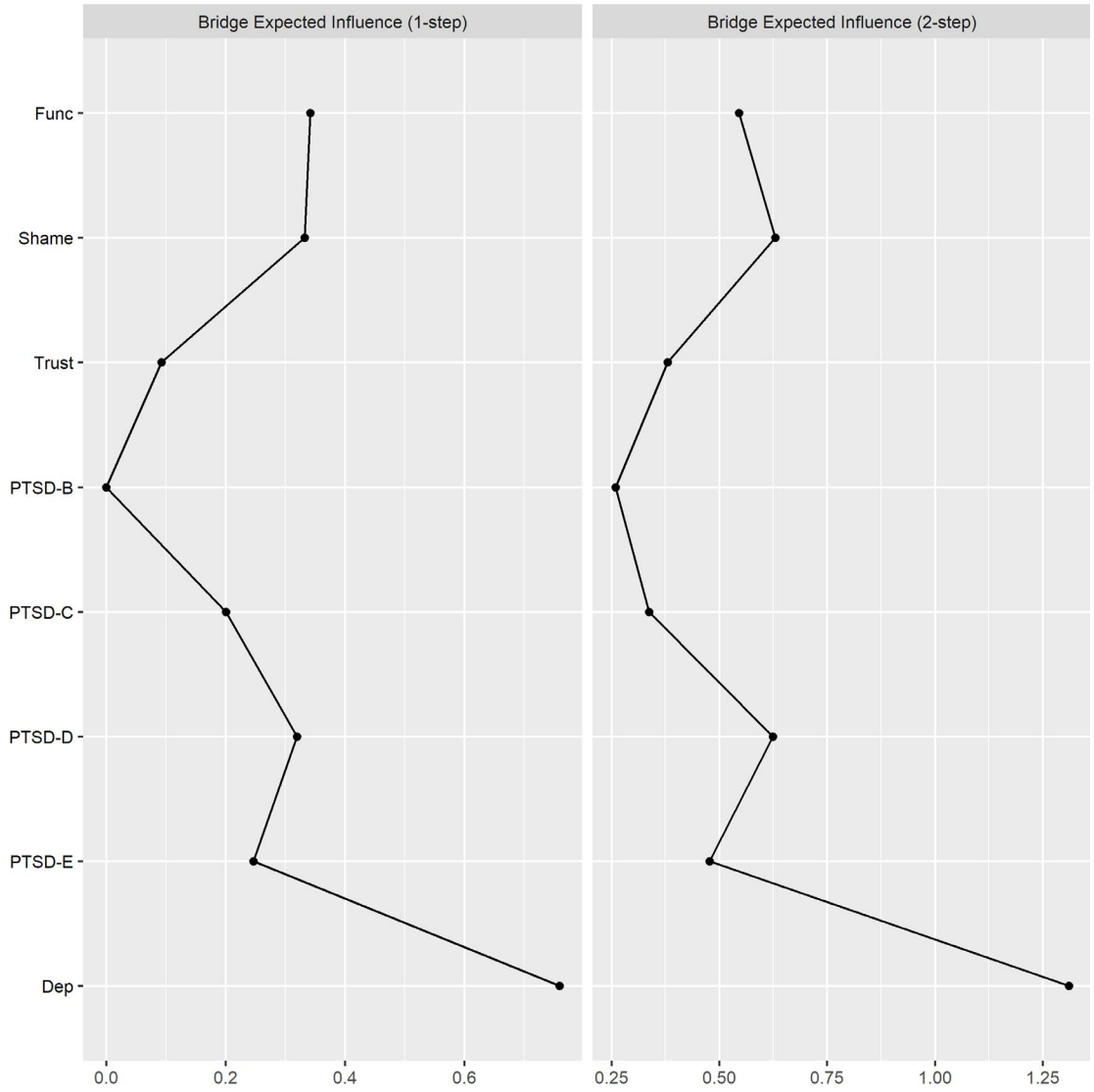

Figure 4. One-step bridge expected influence in the network structure with participants who did not experience a potentially morally injurious event (n = 123)
PTSD-B = cluster B, intrusion; PTSD-C = cluster C, avoidance; PTSD-D = cluster D, negative alterations in cognitions and mood; PTSD-E = cluster E, alterations in arousal and reactivity; Func = MI-related functioning; Trust = MI trust-related violations; Shame = MI-related shame; Dep = depression.

AUTHOR INFORMATION

Natasha Benfer, PhD, is a postdoctoral associate with the Mental Health Core of the Massachusetts Veterans Epidemiological Research and Information Center at the VA Boston Healthcare System. She recently earned her doctoral degree in clinical psychology from Auburn University.

Maya Bina N. Vannini, BS, earned her bachelor of science in clinical psychology from the University of California, San Diego, in 2021. She is currently a research assistant for Brett T. Litz at the VA Boston Healthcare System.

Breanna Grunthal, BA, is a clinical data manager at the Massachusetts Veterans Epidemiology Research and Information Center at the VA Boston Healthcare System in Boston, Massachusetts. She is currently pursuing a master of public health degree at Boston University School of Public Health, with a specific interest in mental health epidemiology.

Benjamin C. Darnell, PhD, is a post-doctoral scientist at the Massachusetts Veterans Epidemiology Research and Information Center of the VA Boston Healthcare System. His work primarily specializes in developing tools for evidence-based and transdiagnostic personalization of trauma-focused treatment.

Gadi Zerach, PhD, is a clinical psychologist and a full professor in the Department of Psychology at Ariel

University, Israel. His research focuses on psychological risk and protective factors contributing to the development, maintenance, and outcomes of posttraumatic stress disorder (PTSD) among diverse populations such as Veterans and helping professionals. He and his collaborators also study the phenomena of moral injury, secondary traumatization, and inter-generational transmission of war-related trauma and the effect of trauma and PTSD on victims' family environments.

Yossi Levi-Belz, PhD, is a clinical psychologist and the Chair of The Lior Tsfaty Center for Suicide and Mental Pain Studies at Ruppin Academic Center. His research interests include moral injury, psychological mechanisms of suicidal behaviour, and growth and depression processes among suicide-bereaved individuals.

Brett T. Litz, PhD, earned his PhD in clinical psychology from the State University of New York at Binghamton and did his clinical internship at the Palo Alto VA Medical Center. He is currently a professor in the Department of Psychiatry at Boston University School of Medicine and the Psychology Department at Boston University as well as Director of the Mental Health Core of the Massachusetts Veterans Epidemiological Research and Information Center at the VA Boston Healthcare System.

COMPETING INTERESTS

The authors have nothing to disclose.

CONTRIBUTORS

Conceptualization: N Benfer, MBN Vannini, B Grunthal, BC Darnell, and BT Litz

Formal Analysis: N Benfer and MBN Vannini

Resources: G Zerach, Y Levi-Belz, and BT Litz

Data Curation: MBN Vannini and B Grunthal

Writing — Original Draft: N Benfer, MBN Vannini, B Grunthal, and BC Darnell

Writing — Review & Editing: N Benfer, MBN Vannini, G Zerach, Y Levi-Belz, and BT Litz

Supervision: BT Litz

Project Administration: N Benfer, B Grunthal, and BT Litz

ETHICS APPROVAL

Ethics approval was not required for this article.

INFORMED CONSENT

N/A

REGISTRY AND REGISTRATION NO. OF THE STUDY/TRIAL

N/A

ANIMAL STUDIES

N/A

FUNDING

No funding was received for this article.

PEER REVIEW

This article has been peer reviewed.

REFERENCES

1. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5th ed. Washington (DC): American Psychiatric Publishing; 2013.
2. Litz BT, Stein N, Delaney E, et al. Moral injury and moral repair in war Veterans: a preliminary model and intervention strategy. Clin Psychol Rev. 2009 Dec;29(8):695-706. https://doi.org/10.1016/j.cpr.2009.07.003. Medline:19683376
3. Jones E. Moral injury in a context of trauma. Br J Psychiatry. 2020 Mar;216(3):127-8. https://doi.org/10.1192/bjp.2020.46. Medline:32345414
4. Smith ER, Duax JM, Rauch SA. Perceived perpetration during traumatic events: clinical suggestions from experts in prolonged exposure therapy. Cogn Behav Pract. 2013 Nov 1;20(4):461-70. https://doi.org/10.1016/j.cbpra.2012.12.002
5. Nazarov A, Fikretoglu D, Liu A, et al. Greater prevalence of post-traumatic stress disorder and depression in deployed Canadian Armed Forces personnel at risk for moral injury. Acta Psychiatr Scand. 2018 Apr;137(4):342-54. https://doi.org/10.1111/acps.12866. Medline:29504125
6. McEwen C, Alisic E, Jobson L. Moral injury and mental health: a systematic review and meta-analysis. Traumatology. 2021 Sep;27(3):303-325. https://doi.org/10.1037/trm0000287
7. Zerach G, Levi-Belz Y. Moral injury process and its psychological consequences among Israeli combat Veterans. J Clin Psychol. 2018 Sep;74(9):1526-44. https://doi.org/10.1002/jclp.22598. Medline:29528102
8. Litz BT, Plouffe RA, Nazarov A, et al. Defining and assessing the syndrome of moral injury: initial findings of the Moral Injury Outcome Scale. Front Psychiatry. 2022 Jul; 13: 923928. https://doi.org/10.3389/fpsyt.2022.923928. Medline:35873252
9. Farnsworth JK, Drescher KD, Evans W, et al. A functional approach to understanding and treating military-related moral injury. J Contextual Behav Sci. 2017 Oct;6(4):391-7. https://doi.org/10.1016/j.jcbs.2017.07.003

10. Barr N, Atuel H, Saba S, et al. Toward a dual process model of moral injury and traumatic illness. Front Psychiatry. 2022 Aug;13:883338. https://doi.org/10.3389/fpsyt.2022.883338. Medline:36090367
11. Koenig HG, Ames D, Youssef NA, et al. The Moral Injury Symptom Scale-Military Version. J Relig Health. 2018 Feb;57(1):249-65. https://doi.org/10.1007/s10943-017-0531-9. Medline:29196962
12. Currier JM, Farnsworth JK, Drescher KD, et al. Development and evaluation of the Expressions of Moral Injury Scale-Military Version. Clin Psychol Psychother. 2018 May;25(3):474-88. https://doi.org/10.1002/cpp.2170. Medline:29282787
13. Gros DF, Price M, Strachan M, et al. Behavioral activation and therapeutic exposure: an investigation of relative symptom changes in PTSD and depression during the course of integrated behavioral activation, situational exposure, and imaginal exposure techniques. Behav Modif. 2012 Jul;36(4):580-99. https://doi.org/10.1177/0145445512448097. Medline:22679240
14. Borsboom D, Deserno MK, Rhemtulla M, et al. Network analysis of multivariate data in psychological science. Nat Rev Methods Primers. 2021 Aug 19;1(1):1-8. https://doi.org/10.1038/s43586-021-00055-w
15. McNally RJ. Can network analysis transform psychopathology?. Behav Res Ther. 2016 Nov;86:95-104. https://doi.org/10.1016/j.brat.2016.06.006. Medline:27424882
16. Cramer AO, Waldorp LJ, Van Der Maas HL, et al. Comorbidity: a network perspective. Behav Brain Sci. 2010 Jun;33(2-3):137-50. https://doi.org/10.1017/s0140525x09991567. Medline:20584369
17. Robinaugh DJ, LeBlanc NJ, Vuletich HA, et al. Network analysis of persistent complex bereavement disorder in conjugally bereaved adults. J Abnorm Psychol. 2014 Aug;123(3):510-22. https://doi.org/10.1037/abn0000002. Medline:24933281
18. Duek O, Spiller TR, Pietrzak RH, et al. Network analysis of PTSD and depressive symptoms in 158,139 treatment-seeking Veterans with PTSD. Depress Anxiety. 2021 May;38(5):554-62. https://doi.org/10.1002/da.23112. Medline:33190348
19. Knefel M, Tran US, Lueger-Schuster B. The association of posttraumatic stress disorder, complex posttraumatic stress disorder, and borderline personality disorder from a network analytical perspective. J Anxiety Disord. 2016 Oct;43:70-8. https://doi.org/10.1016/j.janxdis.2016.09.002. Medline:27637074
20. Spitzer EG, Benfer N, Zuromski KL, et al. Examining unique and prospective relationships among self-injurious thoughts and behaviors and posttraumatic stress disorder: a network analysis in two trauma-exposed samples. Psychol Med. 2022 Mar;52(4):664-74. https://doi.org/10.1017/s0033291720002263. Medline:32605688
21. Afzali MH, Sunderland M, Batterham PJ, et al. Network approach to the symptom-level association between alcohol use disorder and posttraumatic stress disorder. Soc Psychiatry Psychiatr Epidemiol. 2017 Mar;52(3):329-39. https://doi.org/10.1007/s00127-016-1331-3. Medline:28013328
22. Levi-Belz Y, Greene T, Zerach G. Associations between moral injury, PTSD clusters, and depression among Israeli Veterans: a network approach. Eur J Psychotraumatol. 2020 Dec;11(1):1736411. https://doi.org/10.1080/20008198.2020.1736411. Medline:32313614
23. Nash WP, Marino Carper TL, Mills MA, et al. Psychometric evaluation of the Moral Injury Events Scale. Mil Med. 2013 Jun;178(6):646-52. https://doi.org/10.7205/milmed-d-13-00017. Medline:23756071
24. Weathers FW, Litz BT, Keane TM, et al. The PTSD Checklist for DSM-5 (PCL-5) [Internet]. Washington (DC): National Center for PTSD; 2013 [cited 2023 Jan 30]. https://www.ptsd.va.gov/professional/assessment/documents/PCL5_Standard_form.PDF
25. Kleim B, Gonzalo D, Ehlers A. The Depressive Attributions Questionnaire (DAQ): development of a short self-report measure of depressogenic attributions. J Psychopathol Behav Assess. 2011 Sep;33(3):375-85. https://doi.org/10.1007/s10862-011-9234-9. Medline:21909186
26. Hoge CW, Castro CA, Messer SC, et al. Combat duty in Iraq and Afghanistan, mental health problems, and barriers to care. N Engl J Med. 2004 Jul;351(1):13-22. https://doi.org/10.1056/nejmoa040603. Medline:15229303
27. Frankfurt S, Frazier P. A review of research on moral injury in combat Veterans. Mil Psychol. 2016 Jun;28(5):318-30. https://doi.org/10.1037/mil0000132
28. Yeterian JD, Berke DS, Carney JR, et al. Defining and measuring moral injury: rationale, design, and preliminary findings from the Moral Injury Outcome Scale Consortium. J Trauma Stress. 2019 Jun;32(3):363-72. https://doi.org/10.1002/jts.22380. Medline:30947372
29. Blevins CA, Weathers FW, Davis MT, et al. The Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5): development and initial psychometric evaluation. J Trauma Stress. 2015 Nov;28(6):489-98. https://doi.org/10.1002/jts.22059. Medline:26606250
30. Kleiman SE, Bovin MJ, Black SK, et al. Psychometric properties of a brief measure of posttraumatic stress disorder-related impairment: the Brief Inventory of Psychosocial Functioning. Psychol Serv. 2020;17(2):187-94. https://doi.org/10.1037/ser0000306. Medline:30299150
31. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med. 2001;16(9):606-13 https://doi.org/10.1046/j.1525-1497.2001.016009606.x. Medline:11556941

32. Tibshirani, R. Regression shrinkage and selection via the lasso. J R Stat Soc Series B Stat Methodol. 1996;58(1):267-88. https://doi.org/10.1111/j.2517-6161.1996.tb02080.x
33. Chen J, Chen Z. Extended Bayesian information criteria for model selection with large model spaces. Biometrika. 2008;95(3):759-71. https://doi.org/10.1093/biomet/asn034
34. Epskamp S, Fried EI. A tutorial on regularized partial correlation networks. Psychol Methods. 2018;23(4):617-34. https://doi.org/10.1037/met0000167. Medline:29595293
35. Jones PJ, Ma R, McNally RJ. Bridge centrality: a network approach to understanding comorbidity. Multivar Behav Res. 2021 Mar;56(2):353-67. https://doi.org/10.1080/00273171.2019.1614898. Medline:31179765
36. Ross J, Murphy D, Armour C. A network analysis of DSM-5 posttraumatic stress disorder and functional impairment in UK treatment-seeking Veterans. J Anxiety Disord. 2018 Jun;57:7-15. https://doi.org/10.1016/j.janxdis.2018.05.007. Medline:29886306
37. Epskamp S, Borsboom D, Fried EI. Estimating psychological networks and their accuracy: A tutorial paper. Behav Res Methods. 2018 Mar;50(1):195-212. https://doi.org/10.3758/s13428-017-0862-1. Medline:28342071
38. Currier JM, McDermott RC, Farnsworth JK, et al. Temporal associations between moral injury and posttraumatic stress disorder symptom clusters in military Veterans. J Trauma Stress. 2019 Jun;32(3):382-92. https://doi.org/10.1002/jts.22367. Medline:30715755
39. Meyer EC, Konecky B, Kimbrel NA, et al. Gender differences in associations between DSM-5 posttraumatic stress disorder symptom clusters and functional impairment in war Veterans. Psychol Serv. 2018;15(2):230. https://doi.org/10.1037/ser0000171. Medline:29723025
40. Lehavot K, Goldberg SB, Chen JA, et al. Do trauma type, stressful life events, and social support explain women Veterans' high prevalence of PTSD? Soc Psychiatry Psychiatr Epidemiol. 2018;53(9):943-53. https://doi.org/10.1007/s00127-018-1550-x. Medline:29936598
41. Litz BT, Contractor AA, Rhodes C, et al. Distinct trauma types in military service members seeking treatment for posttraumatic stress disorder. J Trauma Stress. 2018 Apr;31(2):286-95. https://doi.org/10.1002/jts.22276. Medline:29669185

APPENDIX

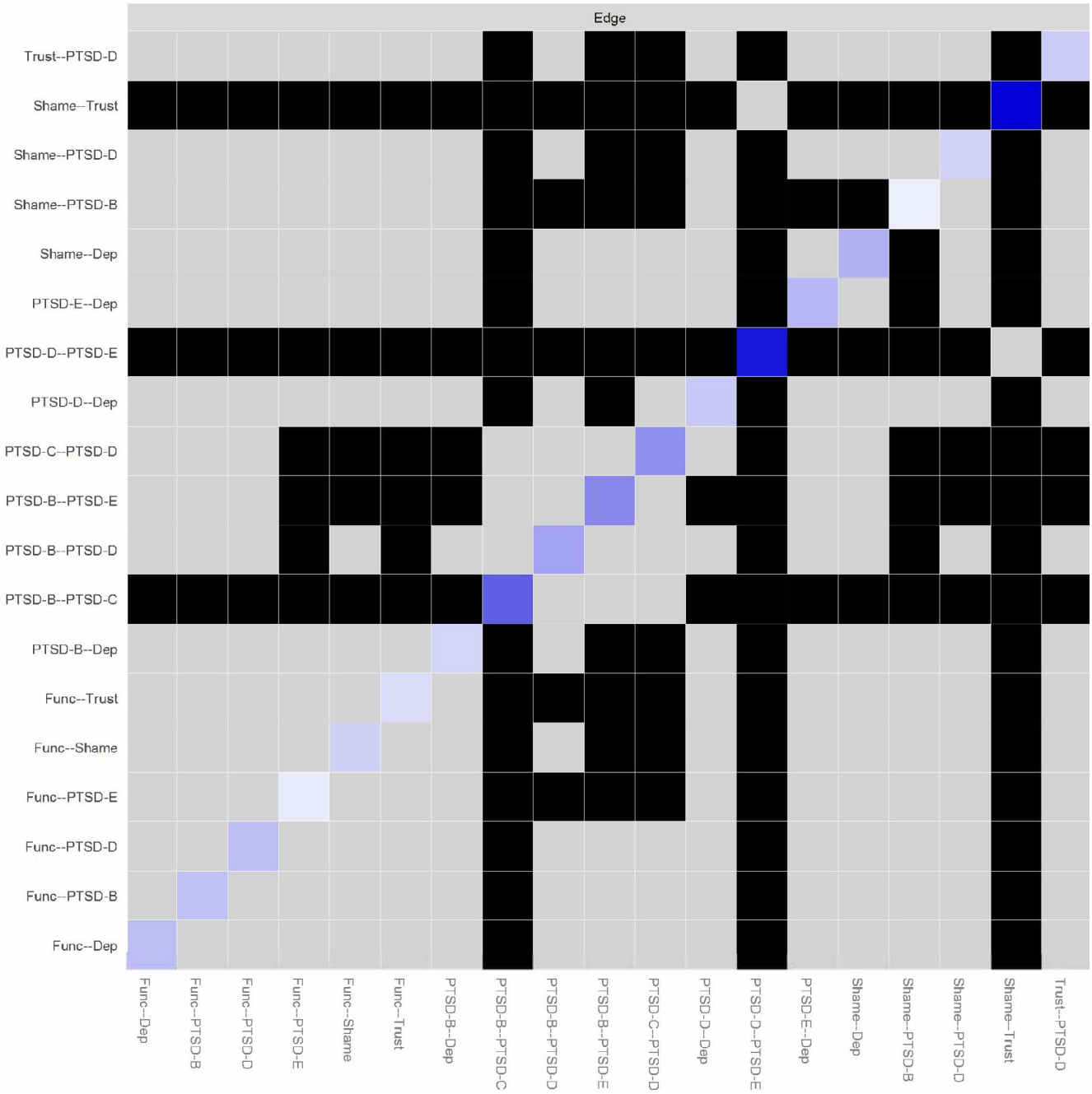

Figure A1. Edge weights difference test for the PMIE networ; black boxes represent significant differences between edge weights

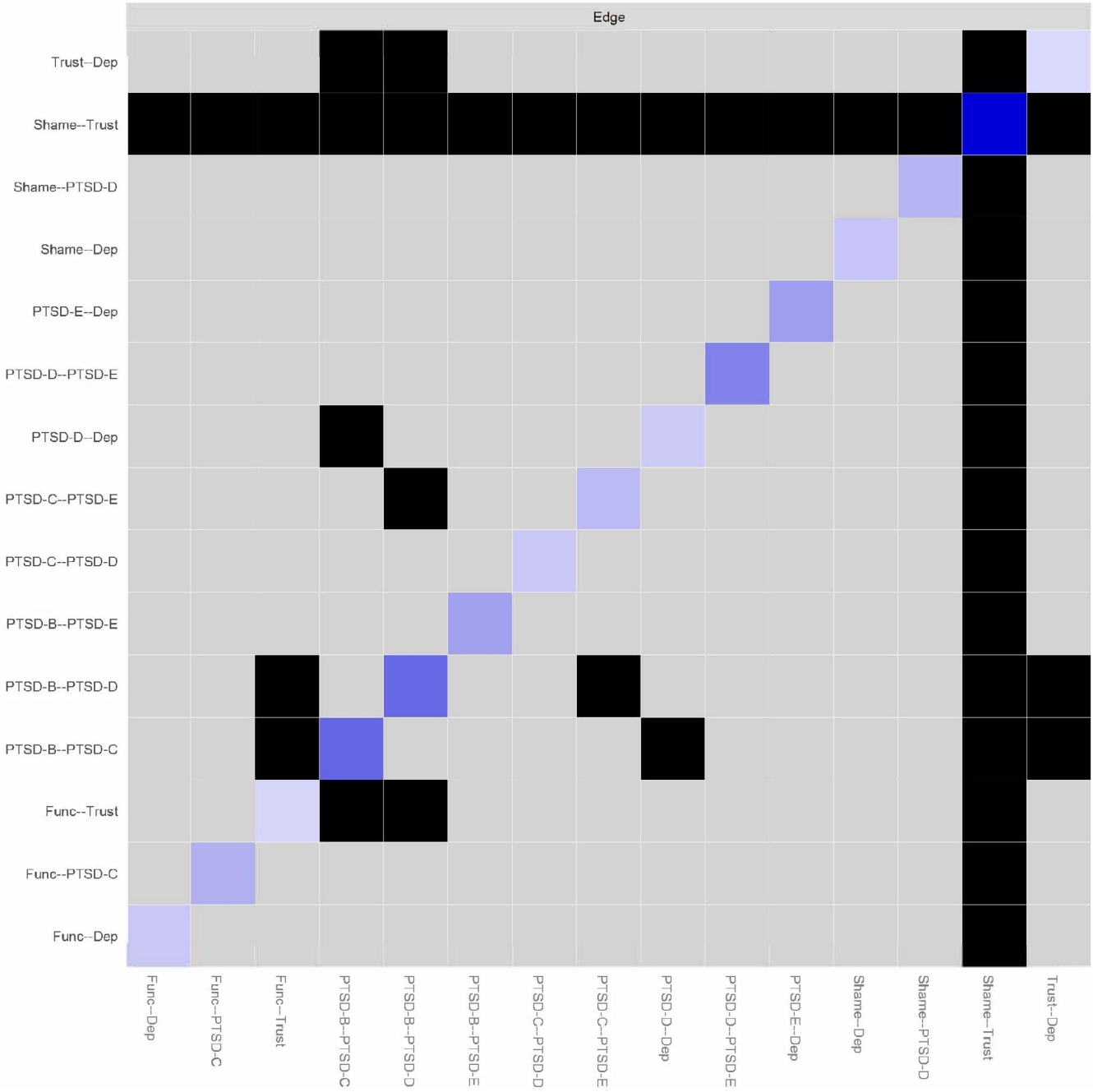

Figure A2. Edge weights difference test for the non-PMIE network; black boxes represent significant differences between edge weights

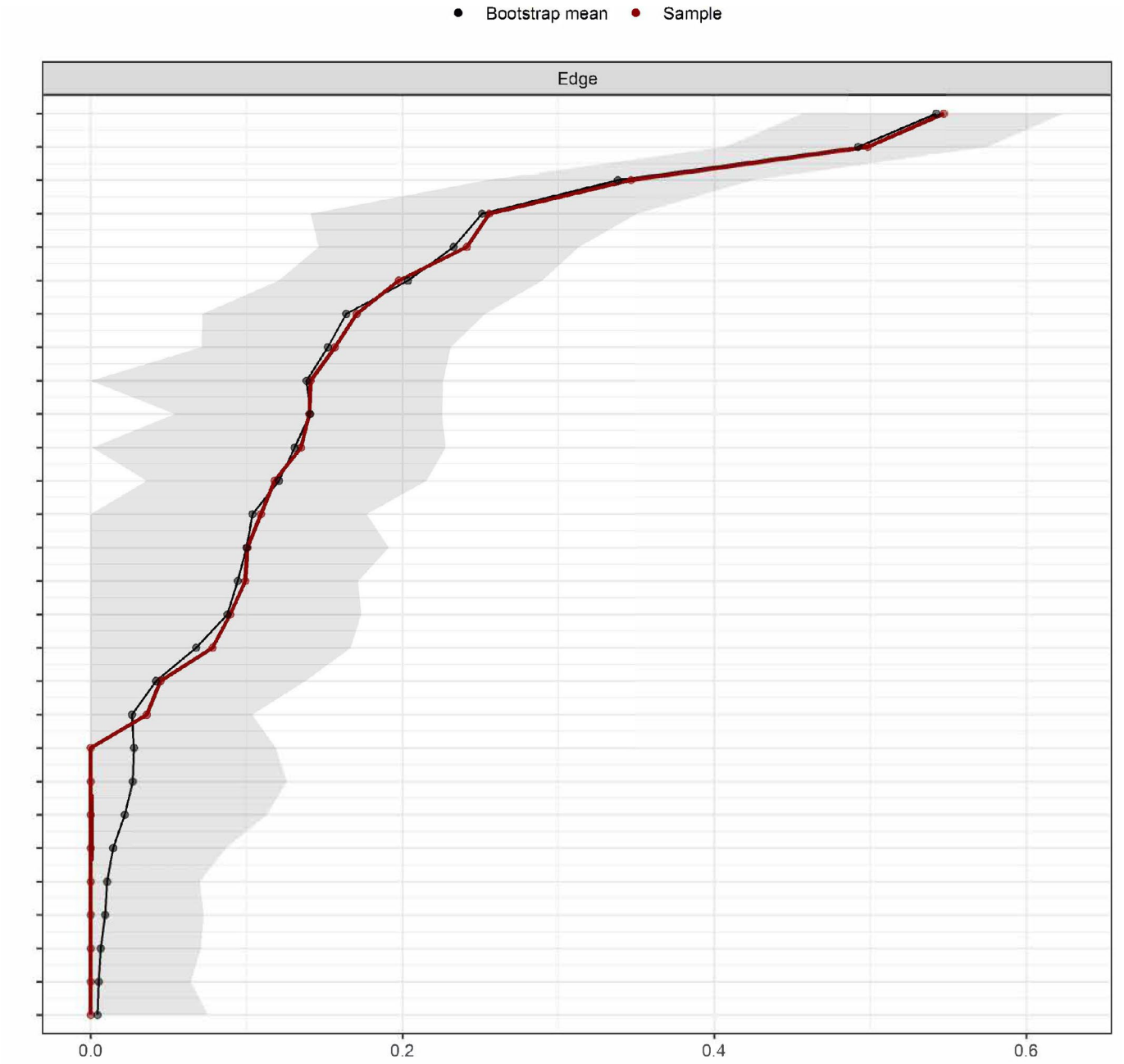

Figure A3. Edge weight bootstrapped confidence intervals for the PMIE network; the red line represents the edge weight values while the gray area represents the bootstrapped 95% confidence interval; each horizontal line indicates one edge of the network, ordered from highest to lowest edge weight

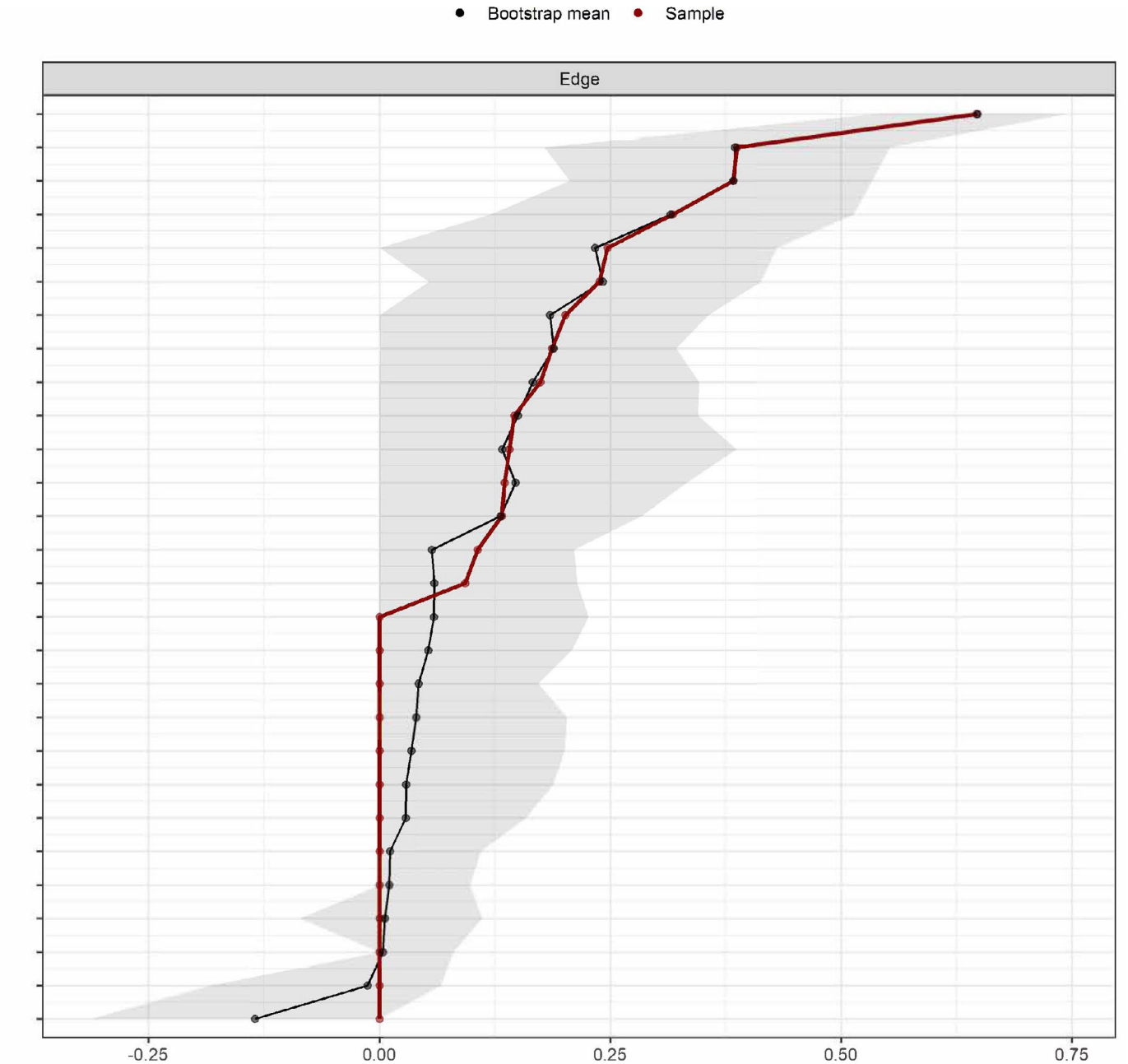

Figure A4. Edge weight bootstrapped confidence intervals for the non-PMIE network; the red line represents the edge weight values while the gray area represents the bootstrapped 95% confidence interval; each horizontal line indicates one edge of the network, ordered from highest to lowest edge weight

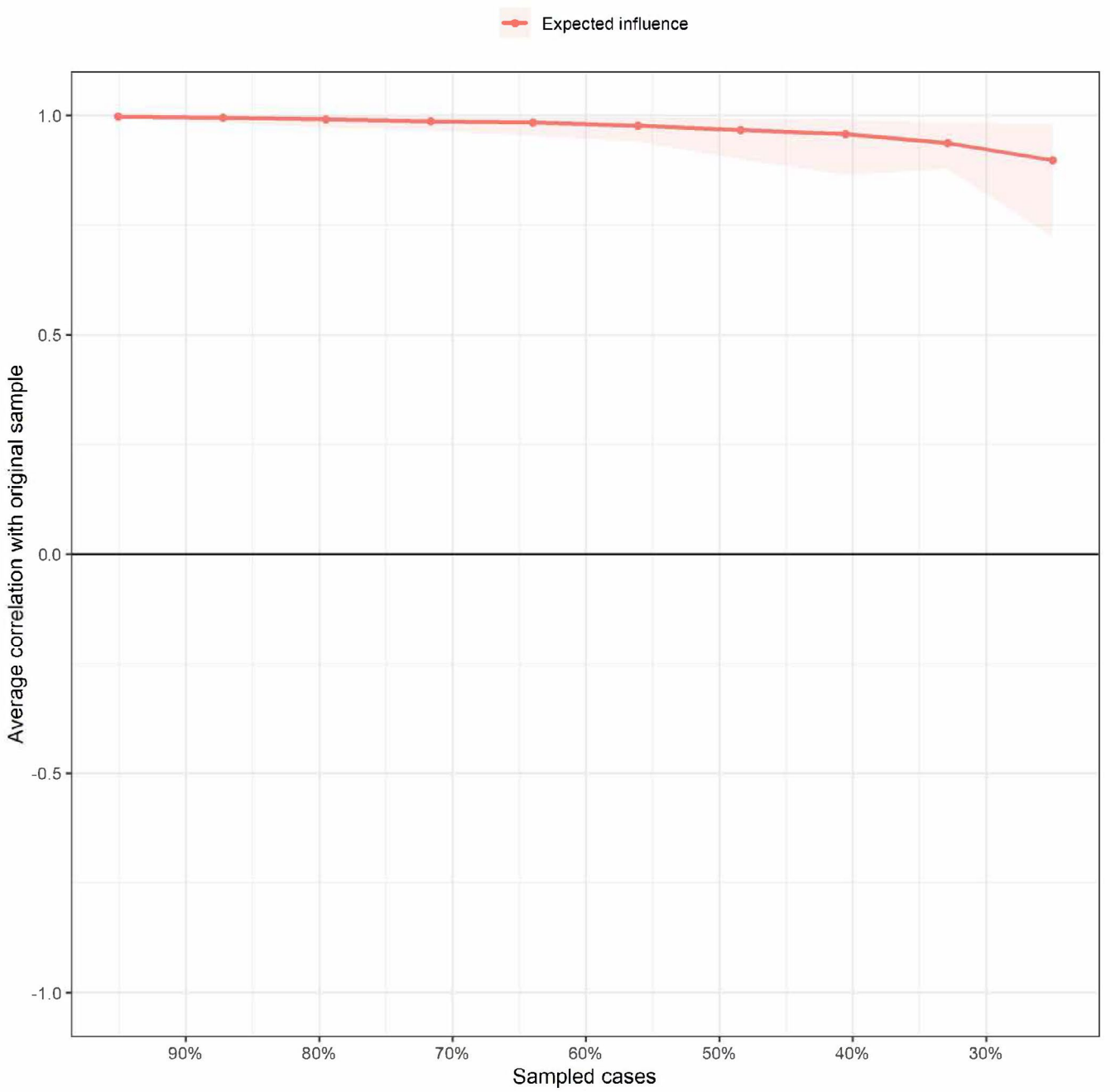

Figure A5. Subsetting bootstrap for the PMIE network; the red line represents the average correlation between the centrality index of the original network and that of networks estimated on increasingly smaller samples

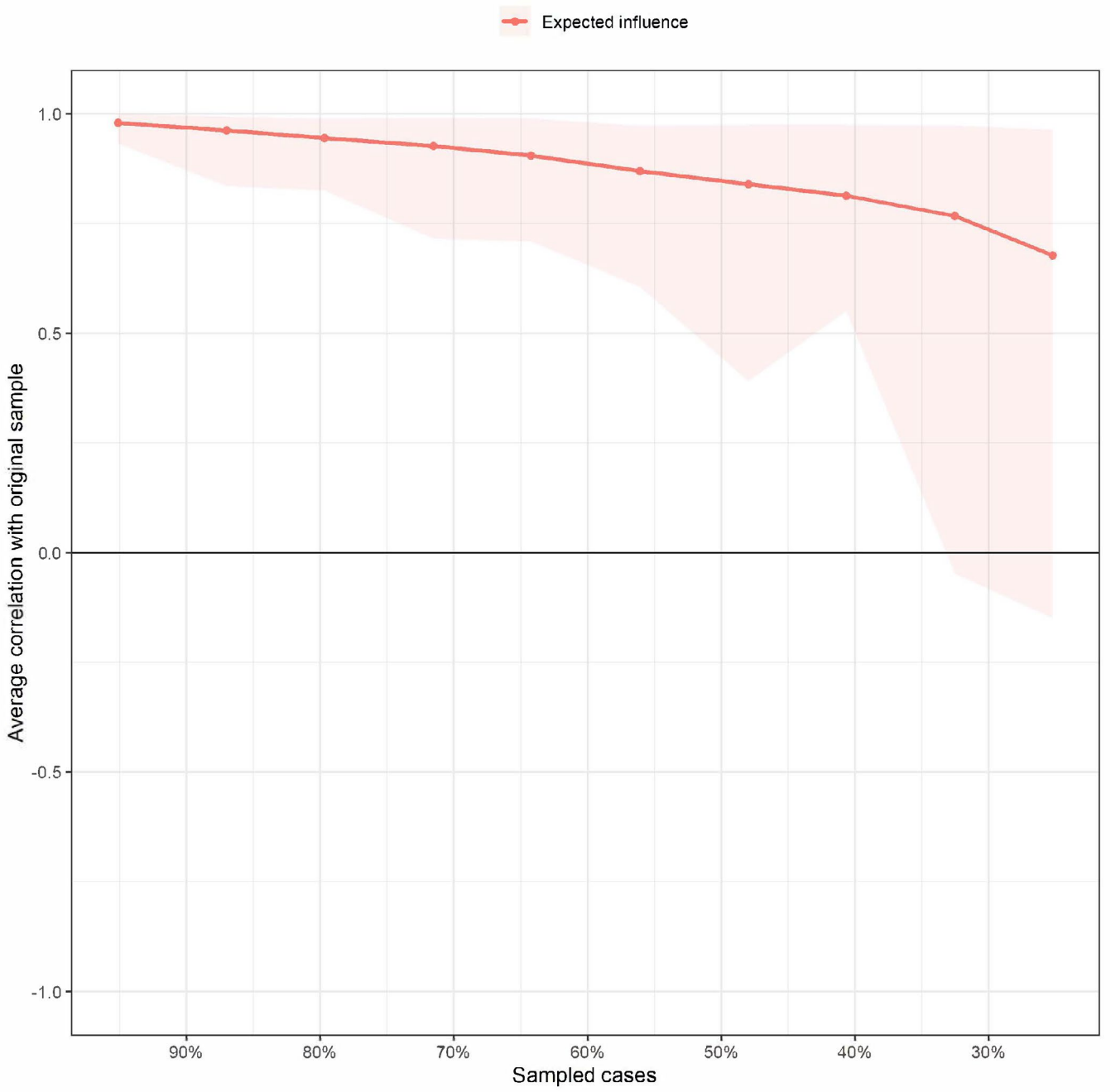

Figure A6. Subsetting bootstrap for the non-PMIE network; the red line represents the average correlation between the centrality index of the original network and that of networks estimated on increasingly smaller samples