Relation between PTSD Symptom Clusters and Positive Memory Characteristics: A Network Perspective

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Abstract

Positive memory characteristics relate to posttraumatic stress disorder (PTSD) severity. We utilized a network approach to examine relations between PTSD clusters (intrusions, avoidance, negative alterations in cognitions and mood [NACM], alterations in arousal and reactivity [AAR]) and positive memory characteristics (count, valence, vividness, coherence, time perspective, sensory details). We identified differential relations between PTSD clusters and positive memory characteristics, and central/bridging symptoms. Participants were an Amazon Mechanical Turk-recruited sample of 206 participants (M_{age} = 35.36; 61.20% females). We estimated a regularized Gaussian Graphic Model comprising four nodes representing the PTSD clusters and six nodes representing positive memory characteristics. Regarding cross-community relations, AAR (highest node strength) was negatively associated with positive memory count, valence, coherence, and access; avoidance was positively and negatively associated with positive memory vividness and count respectively. The NACM-AAR and intrusion-avoidance edges were significantly stronger than most edges. From the PTSD community, AAR and avoidance had the highest bridge strength and bridge expected influence respectively; from the positive memory community, coherence and vividness had the highest bridge strength and bridge expected influence respectively. Results indicate the potential pivotal role of AAR, avoidance, coherence, and vividness in the PTSD-positive memory relation, which renders them assessment/treatment targets pending further investigation.

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1. Introduction

Substantial evidence indicates that beyond traumatic memories, positive memory characteristics (processes such as retrieval difficulties and phenomenological qualities such as reduced accessibility of details) also contribute to posttraumatic stress disorder's (PTSD) etiology and maintenance (Bernsten & Rubin, 2007; Contractor, Brown, et al., 2018; Hauer, Wessel, Engelhard, Peeters, & Dalgleish, 2009). Further, traumatic memories differ from positive memories on important phenomenological qualities (Byrne, Hyman, & Scott, 2001; Peace & Porter, 2004). Yet, most clinical work primarily targets only traumatic memories (Bernsten & Rubin, 2007; Schnurr, 2017), and rarely are PTSD symptoms investigated in relation to positive memory characteristics (Bohanek, Fivush, & Walker, 2005). Addressing this gap, the current study explored associations between PTSD symptom clusters and positive memory characteristics.

Difficulties with positive memory characteristics may render the onset/maintenance of PTSD more likely post-trauma (vulnerability hypothesis), or may be consequences of trauma/ PTSD symptoms (scarring hypothesis; Williams et al., 2007). Examples of such positive memory characteristics include few salient pre-trauma positive experiences and corresponding memories (Hauer et al., 2009), genetic factors contributing to decreased encoding of positive memories (Dominique et al., 2012), difficulties retrieving and/or retaining positive memories (Porter & Peace, 2007; Williams et al., 2007), difficulties integrating positive memories with other autobiographical memories (Bernsten & Rubin, 2007; Berntsen & Rubin, 2006), attentional biases towards negative information and memories (Aupperle, Melrose, Stein, & Paulus, 2012; Fani et al., 2012; Sutherland & Bryant, 2005), rumination on negative memories cued by trauma reminders (Ehlers & Clark, 2000), and emotional numbing/dysregulation symptoms (Litz, Orsillo, Kaloupek, & Weathers, 2000; Weiss, Dixon-Gordon, Peasant, & Sullivan, 2018). Thus, there may be a bi-directional relation between positive memory characteristics and PTSD symptoms. Further, although not directly addressed, trauma theories implicitly reference positive memories in PTSD's etiology and/or treatment. As an example, for Janoff-Bulman's (1992) theory of shattered assumptions wherein traumatic events alter self-related beliefs, perhaps, eliciting positive memories may alter belief structures to facilitate a positive reframing of the trauma and posttraumatic growth (Brewin & Holmes, 2003). As another example, for conditioning and associative network theories, where integrating corrective information into the trauma memory is central to therapeutically weakening the fear network (Brewin & Holmes, 2003), perhaps eliciting positive and non-threatening memories (even those with conditioned stimuli) can aid therapeutic extinction and habituation. Unsurprisingly, intervention research supports an inverse relation between accessing specific (positive) memories and PTSD symptom severity (Moradi et al., 2014; Raes, Williams, & Hermans, 2009).

Indeed, trauma-exposed individuals with PTSD (McNally, Lasko, Macklin, & Pitman, 1995; Sutherland & Bryant, 2005), including those with probable PTSD as assessed by self-report measures (Megías, Ryan, Vaquero, & Frese, 2007), experience difficulties accessing positive memories. Beyond accessibility, other phenomenological qualities of positive memories have an established relation with trauma/PTSD severity; examples include valence (rating of memories as positive or negative), vividness (visual intensity and clarity), coherence (degree to which memories have a logical narrative), time perspective (ability to recall temporal information of an event), and sensory details (degree of re-experiencing non-visual sensory information during recall; Sutin & Robins, 2007). To elaborate, research indicates fewer emotional components (Porter & Birt, 2001), vividness (Peace, Porter, & Brinke, 2008), sensory details (Peace et al., 2008; Porter & Birt, 2001), and coherence (Berliner, Hyman, Thomas, & Fitzgerald, 2003; Fivush, Hazzard, Sales, Sarfati, & Brown, 2002) for positive vs. traumatic/negative memories among trauma-exposed samples; among these studies, only Berliner et al. (2003) reported number of individuals with a PTSD diagnosis (i.e., 5). Further, trauma-exposed participants have reported difficulties in remembering temporal details of positive memories (Peace & Porter, 2004); although such difficulties have been unrelated to PTSD severity (Megías et al., 2007).

However, some contradictory research indicates greater vividness in partly trauma-exposed samples (Byrne et al., 2001), sensory details in (partly or entirely) trauma-exposed samples (Berliner et al., 2003; Byrne et al., 2001), and coherence in samples reporting negative events (Bohanek et al., 2005; Porter & Birt, 2001; Waters, Bohanek, Marin, & Fivush, 2013) for positive vs. traumatic memories. For instance, Niziurski, Johannessen, and Berntsen (2018) found increasing coherence of positive memories with increasing PTSD severity in deployed soldiers. As an explanation, elevated emotional distress (Engelhard, van den Hout, & McNally, 2008; McNally, 2003) and affect intensity (Rubin, Boals, & Berntsen, 2008; Tull, Jakupcak, McFadden, & Roemer, 2007) among trauma-exposed samples may enhance the recall of positive memory phenomenological qualities. Complicating this issue, Bray, Brewer, Cameron, and Nixon (2018) found no comparative difference in the coherence of positive and negative narratives among children with high vs. low PTSD severity, Berliner et al. (2003) found that children receiving trauma intervention reported no difference in temporal details of their positive and traumatic memories, and some research indicates no comparative difficulties in recalling non-visual sensory details of positive and negative event memories (Byrne et al., 2001; Waters et al., 2013) even when comparing individuals with high vs. low PTSD severity (Megías et al., 2007).

This pattern of mixed findings may be attributed to differences in methodology and sample characteristics (Sotgiu & Mormont, 2008). Notably, few studies have examined PTSD severity in relation to positive memory characteristics (e.g., Gray & Lombardo, 2001; McKinnon, Brewer, Meiser-Stedman, & Nixon, 2017; Megías et al., 2007; Niziurski et al., 2018). Among such studies, none to our knowledge has examined the heterogeneous *DSM-5* PTSD symptom clusters (intrusions, avoidance, negative alterations in cognitions and mood [NACM], alterations in arousal/reactivity [AAR]) which differentially relate to clinical correlates (Contractor, Armour, Forbes, & Elhai, 2016; Contractor et al., 2014; Contractor, Frankfurt, Weiss, & Elhai, 2017; Contractor, Greene, Dolan, & Elhai, 2018). Lastly, in investigating relations of singular positive memory characteristics to PTSD severity,

interrelationships are discounted wherein the influence of all variables on each other is not considered, thus, yielding incomplete and/or un-interpretable results (Byrne et al., 2001; Waters et al., 2013). Addressing these limitations and drawing from an established relation between PTSD and positive memory characteristics with the nature of their relation being debatable/uncertain, the current study used network modeling to examine inter-relationships between PTSD symptom clusters and positive memory characteristics.

A network framework has been widely applied to the cross-sectional study of PTSD symptoms (Afzali et al., 2017; Armour, Fried, Deserno, Tsai, & Pietrzak, 2017; Ross, Murphy, & Armour, 2018). Relevant to the current study, PTSD symptoms and positive memory characteristics can be viewed as a network of mutually interacting and reinforcing symptoms which may/may not be causally connected in a direct manner (Epskamp, Borsboom, & Fried, 2018; McNally et al., 2015). For example, PTSD AAR symptoms may diminish one's cognitive capacity reducing count/details of retrieved positive memories (Contractor, Banducci, Dolan, Keegan, & Weiss, in press; Harvey, Bryant, & Dang, 1998); this in turn, may increase or maintain negative affect/cognitions, intrusion of traumatic memories, and PTSD severity. Thus, certain PTSD symptoms may contribute to deficits in positive memory characteristics, while some positive memory characteristics may enhance the risk of developing/maintaining PTSD severity; such PTSD symptoms and positive memory characteristics would be considered bridge symptoms of this network (Cramer, Waldorp, van der Maas, & Borsboom, 2010b). An added advantage of a network framework is the ability to account/control for the influence of all variables when examining unique relations between two singular symptoms within or across constructs such as PTSD AAR symptoms and count of positive memories (i.e., partial correlations; Borsboom & Cramer, 2013). Such an approach further permits examining the influence of two variables on a third variable beyond just a direct relation between any two variables (Pearl, 2000), and considers the interaction between all symptoms in understanding construct co-occurrence (Fried & Cramer, 2017). Notably, PTSD network research, so far, has indicated least centrality (fewer and weaker connections) for PTSD's memory impairment symptom (Armour et al., 2017; McNally et al., 2015), as supported by corresponding factor-analytical research (Contractor, Caldas, Dolan, Lagdon, & Armour, 2018; Contractor, Caldas, Dolan, Natesan, & Weiss, 2019). However, the amnesia symptom is specific to a traumatic memory; positive memory characteristics have not been examined in relation to PTSD severity using network analyses.

The current study, thus, examined the utility of the network methodology to examine the relation between PTSD symptom clusters and positive memory characteristics within a cross-sectional framework. We investigated (1) differential relations of PTSD symptom clusters with positive memory characteristics; and (2) most central (strongly connected) symptoms accounting for overall connectedness in the network as well as symptoms with the strongest cross-community/construct connections (bridge centrality). By incorporating critical correlates such as positive memory characteristics beyond PTSD-related symptoms in the network system (Fried & Cramer, 2017) and examining central symptoms (including bridge centrality) and differential relations in a network (Ross et al., 2018), results may outline possible mechanisms underlying their co-occurrence and inform future studies examining onset/maintenance of these constructs (Cramer, Waldorp, van der Maas, & Borsboom, 2010a; Fried & Cramer, 2017).

2. Methods

2.1. Procedure and Participants

The study was approved by [redacted] Institutional Review Board and was conducted in accordance with the Declaration of Helsinki. We recruited participants via Amazon's Mechanical Turk (MTurk) platform and described the study as an examination of the relation between positive memory recall/processes and emotional distress indicators among individuals experiencing stressful life events. Inclusionary criteria were: >/=18 years, working knowledge of English, endorsement of a stressful life experience, and no current/previous diagnosis of sleep apnea. Participation was restricted to MTurk individuals from the US with a > 90% approval rating (i.e., proportion of MTurk surveys completed by a participant that were approved by researchers) consistent with implemented practices to increase the validity of MTurk-obtained data (Hauser & Schwarz, 2016; Shapiro, Chandler, & Mueller, 2013). Eligible participants who provided informed consent after reviewing a full description of study procedures and completed the entire survey validly received $1.50 as compensation.

2.2. Exclusions, Missing Data, and Sample Characteristics

A total of 695 participants attempted the survey; we excluded 299 responses because they were duplicates due to multiple attempts (remainder $n = 466$). We excluded 89 individuals who did not meet inclusionary criteria, 138 individuals for failing validity checks included to ensure attention and comprehension (Meade & Craig, 2012; Oppenheimer, Meyvis, & Davidenko, 2009), one individual for not endorsing any traumatic event on the Life Events Checklist for *DSM-5* (LEC-5; Weathers et al., 2013), and 32 individuals who did not follow the Memory Experiences Questionnaire–Short Form (MEQ-SF; Luchetti & Sutin, 2016) instructions. The final sample included 206 individuals who averaged 35.36 years of age ($SD = 11.50$); 126 were female (61.20%). Eighty-eight (42.70%) participants had probable PTSD based on the PTSD Checklist for *DSM-5* (PCL-5; F.W. Weathers et al., 2013) cut-off score > 31 (Bovin et al., 2016; Wortmann et al., 2016). Detailed information on demographics and psychopathology variables is provided in Table 1. The network was estimated using complete pairwise observations (i.e., using all available data).

2.3. Measures

2.3.1. Demographic information.—We obtained information on age, gender, income, relationship status, racial and ethnic status, educational level, and mental health treatment.

2.3.2. *Life Events Checklist for DSM-5* (LEC-5; Weathers et al., 2013).—The LEC-5 is a 17-item self-report measure that evaluates exposure to lifetime traumatic events. An 18th item evaluated the most distressing traumatic event, and the subsequent PTSD measure was completed in reference to this endorsed trauma. Participants indicated their exposure to each event on a 6-point nominal scale: happened to me, witnessed it, learned about it, part of my job, not sure, and does not apply. In the current study, endorsing either of the first four response options for LEC-5 items 1–16 was considered as a positive endorsement of a trauma consistent with the *DSM-5* Criterion A (American Psychiatric Association, 2013).

2.3.3. *PTSD Checklist for DSM-5* **(PCL-5; Weathers et al., 2013).—**The PCL-5 is a 20-item self-report measure assessing PTSD symptom severity referencing the past month. Response options range from 0 (*not at all*) to 4 (*extremely*). The PCL-5 has excellent psychometric properties (Bovin et al., 2016; Wortmann et al., 2016). Intrusions, avoidance, NACM, and AAR subscale scores were computed as an average of the items comprising each domain; Cronbach's α values were .90, .86, .89, and .87, respectively.

2.3.4. *Autobiographical Memory Test* **(AMT; Williams & Broadbent, 1996).—** The AMT examined the count of recalled positive memories. Participants viewed 10 positively-valenced cue words, specifically: friendly, happy, honest, kind, humorous, cheer, pleased, relieved, lively, and glorious (Kleim & Ehlers, 2008; McNally et al., 1995), and then received a prompt to recall one specific and meaningful memory of an event to each cue word within 60 seconds (J. M. Williams & Broadbent, 1996). Instructions for this task were adapted from previous studies examining autobiographical memory recall (Henderson, Hargreaves, Gregory, & Williams, 2002; Williams et al., 1996; Zinbarg, Rekart, & Mineka, 2006). All AMT responses were coded as *recalled* (specific [memory of an event that occurred in a certain place within one day], extended [memory of an event that lasted longer than one day], or categoric [memory as a summary of many repeated events]) or *failed to recall* (semantic associate [no personal memory], omission [did not recall the memory within 60 seconds or unable to recall a memory], or non-positive) based on previous studies (Griffith et al., 2009; Sutherland & Bryant, 2008). Following the Coding and Assessment System for Narratives of Trauma (CASNOT; Fernández-Lansac & Crespo, 2017), a memory description was coded as non-positive if the emotional tone and/or the emotional valence of the description was rated as mainly negative (i.e., scores of 3–4 on a scale from 0 [completely positive] to 4 [completely negative]). For the current study, the total number of AMT responses coded as *recalled* was used as the "count of positive memories" variable (range was 0–10 for each participant).

2.3.5. *Memory Experiences Questionnaire–Short Form* **(MEQ-SF; Luchetti & Sutin, 2016).—**The MEQ-SF examines 10 phenomenological qualities of a positive memory. For the current study, we specifically used six subscales assessing accessibility and content details (valence, vividness, time perspective, sensory details, coherence) based on the research questions and a small sample size insufficient to incorporate all 10 MEQ-SF subscales. Response options on each subscale ranged from 1 (*strongly disagree*) to 5 (*strongly agree*); subscale scores were calculated as an average of the items comprising each domain. In the current study, participants were asked to recall one specific, positively valanced memory based on adapted instructions from previous studies (Boyacioglu & Akfirat, 2015; Janssen, Hearne, & Takarangi, 2015; Wing, Schutte, & Byrne, 2006) before completing the MEQ-SF. MEQ-SF memory descriptions were coded using the CASNOT dimensions of emotional tone and valence (Fernández-Lansac & Crespo, 2017) to ensure that they were positively valanced. The MEQ-SF has demonstrated acceptable psychometric properties (Luchetti & Sutin, 2016). Cronbach's α values in the current study were as follows: accessibility = .82, valence = .71, vividness = .69, time perspective = .50, sensory details = .64, and coherence =.67.

2.4. Statistical Analyses

For a partial correlation network of 11 nodes, we had 55 parameters (Epskamp & Fried, 2018). Following the guidelines of at least 3 individuals per parameter, our sample size was sufficient for exploratory data-driven analyses (Epskamp & Fried, 2018).

2.4.1. Network Estimation, Visualization, and Accuracy.—None of the variables violated normality according to benchmarks of skewness >2 and/or kurtosis >7 (Curran, West, & Finch, 1996); PTSD subscales had skewness values ranging from .13 to .41 and kurtosis values ranging from −1.14 to −.78, and positive memory characteristics had skewness values ranging from −1.87 to −.49 and kurtosis values ranging from −.14 to 2.71. Thus, the appropriate Pairwise Markov Random Field (PRMF) model was the Gaussian Graphical Model (GGM; Costantini et al., 2015), which was used to estimate an undirected network (Cox & Wermuth, 1994; McNally et al., 2015). To reduce the likelihood of spurious edges and obtain a sparse/parsimonious network, we estimated a regularized partial correlation network structure (Pearson correlation) using the graphical least absolute shrinkage and selection operator (glasso; Epskamp & Fried, 2018; Friedman, Hastie, & Tibshirani, 2008), with Extended Bayesian Information Criterion (EBIC; Chen & Chen, 2008) to select a value for the tuning parameter. In the current network, a node indicated a variable of interest (PTSD symptom clusters; count of recalled positive memories; positive memory phenomenological qualities of vividness, valence, coherence, time perspective, sensory details, and accessibility) and an edge depicted a regularized partial correlation between two nodes after controlling statistically for other nodes in the network (Borsboom & Cramer, 2013). For each edge, we examined its weight reflecting strength and sign reflecting direction (Costantini et al., 2019); weights were graphically represented by line thickness (Borsboom & Cramer, 2013; Costantini et al., 2019). The network's graphical layout was based on the Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991) which placed connected nodes closer and unconnected nodes farther apart. We used the *bootnet* (Epskamp et al., 2018) and *qgraph* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012) packages in R. Finally, to examine network accuracy, we estimated confidence intervals (CIs) on the edge-weights (nonparametric bootstrapping with replacement; Supplementary Figure A. 1) and significant differences between edge-weights (bootstrapped difference test; Supplemental Figure A. 2; Epskamp et al., 2018).

2.4.2. Stability and Accuracy of the Centrality Index.—Using the R package *qgraph* (Epskamp et al., 2012), we examined the node centrality index to quantify the relative strength of each of the 11 nodes in the network (Costantini et al., 2019; McNally et al., 2015). We calculated node strength, which references the sum of weights (i.e., regularized partial correlation magnitudes) of each edge linked to the node (Epskamp & Fried, 2018) and created this centrality plot. Higher values reflected a node's greater centrality to the overall network (Epskamp & Fried, 2018). We further examined node strength *stability* under observing subsets of cases (case-dropping subset bootstrap; Supplemental Figure A. 3; Epskamp et al., 2018) by computing the correlation stability (CS) coefficient implemented in the R package *bootnet* (Epskamp et al., 2018). This index quantifies the proportion of data that can be dropped to retain a correlation of .70 with the original centrality coefficient at a 95% certainty level (Epskamp & Fried, 2018). Guidelines

suggest to not interpret a centrality index if the CS-coefficient is < .25, and a value of .50 indicates sufficient stability (Costantini et al., 2019; Epskamp & Fried, 2018). Lastly, to estimate node strength *accuracy*, we computed CIs on strength node and tested for their significant differences (bootstrapped difference test; Supplemental Figure A. 4; Epskamp et al., 2018).

2.4.3.   Bridge Centrality.—PTSD symptom clusters and positive memory characteristics represented two distinct communities of nodes based on theory and conceptual meaning. We examined bridge centrality values for nodes across these two communities to examine cross-community connectivity (Jones, Ma, & McNally, 2019, April 25). Using the *networktools* R package, we computed (1) bridge strength as the sum of absolute values of edges between a node of one community and all nodes of the second community (node's total connectivity with the other community), and (2) bridge expected influence as the sum of all edges between a node of one community and all nodes of the second community (node's overall positive connectivity with the other community accounting for positive and negative edges; Jones, 2018; Jones et al., 2019, April 25). Compared to bridge strength, bridge expected influence indicates overall increase in node activation considering that a node may be associated with an increase in activation with some nodes and/or decrease in activation with other nodes (Jones, 2018; Jones et al., 2019, April 25).

3.   Results

3.1.   Network Estimation, Visualization, and Accuracy.

Figure 1 indicates the regularized partial correlation network corresponding to Table 2 values. Examining the edge weights within the PTSD symptom clusters community, the strongest associations were between AAR and NACM (.51), intrusions and avoidance (.38), intrusions and NACM (.25), and intrusions and AAR (.27). Within the positive memory characteristics community, the strongest association were between sensory details and vividness (.31), coherence and valence (.25), coherence and accessibility (.23), and accessibility and sensory details (.24).

The cross-community connections were far weaker. Nevertheless, a number of edges were identified, most of which were negative. AAR was negatively associated with coherence of the recalled positive memory (−.07), valence of the recalled positive memory (−.06), count of recalled positive memories (−.04), and accessibility of the recalled positive memory (−.01). Avoidance was positively associated with vividness of the recalled positive memory (.02) and negatively associated with count of recalled positive memories (−.01).

Regarding network accuracy (Supplemental Figures 1 and 2), results indicated that the NACM-AAR edge weight was significantly stronger than other edge weights, excluding the intrusions-avoidance edge weight. Further, the intrusions-avoidance edge weight was significantly stronger than more than approximately two-third of the other edge weights. Additionally, the intrusions-AAR and vividness-sensory details edge weights were significantly stronger than approximately half of the other edge weights.

3.2.   Centrality Index Estimation (Stability and Accuracy; Supplemental Figures 3 and 4).

The *CS*-coefficient for node strength (*CS*[cor = 0.7] = 0.67) indicates interpretability and stability under subsetting cases. According to the centrality plot, there were no significant differences in centrality other than AAR with the highest node strength which was significantly greater than avoidance, count of recalled positive memories, and time perspective. Count of recalled positive memories and time perspective of the recalled positive memory were least central to the overall network.

3.3.   Bridge Centrality.

Standardized bridge centrality indices are presented in Figure 3. From the PTSD cluster community, AAR with the highest bridge strength value had the highest bridge associations with positive memory characteristics (in either direction). From the positive memory characteristics community, coherence of a recalled positive memory with the highest bridge strength had the highest bridging associations with PTSD symptom clusters (in either direction). In terms of positive connectivity with nodes of another community, avoidance (closely followed by intrusions and NACM) with the highest bridge expected influence value had the most bridge associations with positive memory characteristics, and vividness of a recalled positive memory with the highest bridge expected influence had the most bridge associations with PTSD symptom clusters.

4.   Discussion

PTSD symptoms have empirically-established associations with positive memory characteristics (e.g., Bernsten & Rubin, 2007; Gray & Lombardo, 2001; McKinnon et al., 2017; Megías et al., 2007; Niziurski et al., 2018; Porter & Birt, 2001). Uniquely, the current study implemented a network methodology to explore the relations between PTSD symptom clusters and positive memory characteristics (including central nodes within this network) among trauma-exposed community individuals. Results primarily indicated the potential pivotal role of PTSD's AAR and avoidance symptom clusters, coherence of the recalled positive memory, and vividness of the recalled positive memory in the PTSD-positive memory relationship.

Current study results indicated that PTSD's AAR symptom cluster was relatively central in the overall estimated network, including in influencing/being influenced (in a negative or positive direction) by positive memory characteristics, with the highest node strength (significantly greater than PTSD's avoidance, count of recalled positive memories, time perspective of the recalled positive memory, and valence of the recalled positive memory) and the highest bridge strength. Referencing intra-community connections, AAR's relation with other PTSD symptom clusters such as NACM and intrusions is consistent with evidence indicating its pivotal role in influencing other PTSD symptom clusters (Marshall, Schell, Glynn, & Shetty, 2006; Schell, Marshall, & Jaycox, 2004). Referencing cross-community connections, AAR was negatively associated with several positive memory characteristics (count of recalled positive memories, valence of the recalled positive memory, coherence of the recalled positive memory, accessibility of the recalled positive memory).

A strong AAR-NACM relation (one of the stronger edges in the estimated network) may explain AAR's negative relation with positive memory characteristics. Trauma-exposed individuals may expend cognitive/behavioral/emotional energy to manage arousal symptoms, thus reducing emotional resources and increasing NACM emotion dysregulation symptoms (Foa, Zinbarg, & Rothbaum, 1992; Litz, 1992; Tull & Roemer, 2003); alternatively, suppression of emotional expression (NACM symptoms) may lead to greater physiological arousal (Notarious & Levenson, 1979). Thus, AAR's association with greater negative affect (PTSD's NACM symptoms) may activate more negative vs. positive memories (Bower's associative network theory; Bower, 1981), and AAR's association with reduced positive affect (PTSD's NACM symptoms) may trigger reduced count and phenomenological qualities of positive memories (affect intensity theory; Larsen & Diener, 1987; Werner-Seidler & Moulds, 2011). Additionally, a strong AAR-intrusions relation (another relatively stronger edge in the estimated network) may also explain AAR's negative relation with positive memory characteristics. According to trauma theorists (Chemtob, Roitblat, Hamada, Carlson, & Twentyman, 1988; Foa & Kozak, 1986; Foa, Steketee, & Rothbaum, 1989; Foa et al., 1992), trauma-exposed individuals form new associations between previously unrelated factors, which they perceive as dangerous, and experience distressing intrusion and arousal symptoms on activation of the fear network by trauma reminders. Consequently, they attempt to block out activated and intrusive traumatic memories to avoid consequent negative emotions, thoughts, and physiological symptoms (Dalgleish, Rolfe, Golden, Dunn, & Barnard, 2008; Hermans, Defranc, Raes, Williams, & Eelen, 2005; Moradi et al., 2008). Simultaneously, they may also block out positively-valenced memories because they are unable to effectively regulate triggered positive emotions (Weiss et al., 2018).

Notably, PTSD's avoidance had the highest bridge expected influence, implying that it may play a critical role in positively influencing/being influenced by positive memory characteristics. In other words, activation of PTSD's avoidance symptom cluster may relate to activation of positive memory characteristics. Referencing more specific associations, while avoidance was negatively correlated with count of recalled positive memories as expected, it was positively associated with vividness of the recalled positive memory. Drawing from an executive control viewpoint (Dalgleish et al., 2007), trauma-exposed individuals who exercise cognitive control as evidenced by PTSD's avoidance symptoms to deal with distressing trauma-related information may perform well on the memory tasks eliciting (details of) positive memories (requires high amount of cognitive control; Moradi et al., 2008). Future research can investigate the moderating effect of cognitive control on PTSD's relation with positive memories.

Among positive memory characteristics, coherence and vividness were relatively central in the overall estimated network with high node strength (both significantly greater than time perspective). Referencing intra-community connections, the relation between vividness and sensory details was relatively stronger than several other relations, probably attributed to the fact that both of these phenomenological qualities reference sensory details of the recalled positive memory. Referencing cross-community connections, results indicated that positive memory characteristics were primarily related to PTSD symptom clusters via the effects of coherence (highest bridge strength) and vividness (highest bridge expected influence) of the

recalled positive memory. More specifically, perhaps, the current AMT and MEQ-SF tasks may have elicited/amplified a discrepancy between currently experienced negative belief/ affect and positive beliefs/affect experienced during the positive memory event; this discrepancy, negative beliefs associated with PTSD symptoms (Agar, Kennedy, & King, 2006; O'Donnell, Elliott, Wolfgang, & Creamer, 2007), and negative affect associated with PTSD symptoms (Bradley et al., 2011) may relate to reduced coherence of the recalled positive memory. Indeed, research has indicated that emotional state at retrieval impacts details of retrieved memories (Schaefer & Philippot, 2005); a sad mood state was related to reduced coherence of positive memories among trauma-exposed individuals with PTSD (Rubin, 2011). This reduced coherence of positive memories may contribute to a decrease in psychological well-being (Waters & Fivush, 2015) and greater psychiatric problems (Adler, Chin, Kolisetty, & Oltmanns, 2012), including an increase in PTSD severity. Further, activation of vividness may be positively related to activation of PTSD symptom clusters, possibly due to the cognitive control explanation as already elaborated.

Implications

Study results have important theoretical and clinical implications pending further empirical investigations and replications. First, although not directly examined, our results suggest that certain positive memory characteristics may be impaired in relation to AAR and avoidance severity. Thus, traumatic and non-traumatic memories both may be impaired among trauma-exposed individuals, consistent with the trauma equivalency theory of memory (Brewin & Holmes, 2003; Porter & Birt, 2001; Waters et al., 2013). Second, PTSD may be primarily related to and co-occur with positive memory characteristics via PTSD's AAR and avoidance symptoms and positive memory phenomenological qualities of vividness and coherence. Following from this, positive memory interventions (Arditte Hall, De Raedt, Timpano, & Joormann, 2018; Moradi et al., 2014; Raes et al., 2009; Steel et al., 2015) may benefit from addressing AAR and avoidance symptoms, in particular, to influence affect, cognitions, and post-trauma outcomes. Further, with evidence indicating that phenomenological qualities of memories are related to well-being/treatment indicators (Alvarez-Conrad, Zoellner, & Foa, 2001; Pennebaker, 1997; Pennebaker & Francis, 1996), a special assessment and treatment focus may be needed on positive memory characteristics of coherence and vividness to influence PTSD symptom severity. Indeed, trauma treatments work on increasing visual details (Tuerk et al., 2011) as well as coherence of the trauma narrative(s) (Robjant & Fazel, 2010) to effectively impact outcomes.

When considering the aforementioned implications, it must be noted that the cross-sectional nature of the current study implies (vs. does not examine) a dynamic nature of network symptoms and provides indications of the most central symptoms (e.g., PTSD's AAR and avoidance symptoms) contributing to onset/maintenance of co-occurring conditions and representing therapeutic targets (Borsboom & Cramer, 2013; McNally et al., 2015; Rhemtulla et al., 2016). Such potential central symptoms need to be explored within temporal models (Bringmann & Eronen, 2018) considering that central symptoms across PTSD network studies are not consistent (Contreras, Nieto, Valiente, Espinosa, & Vazquez, 2019) and central symptoms for an aggregated network may not apply to individuals (Fisher, Reeves, Lawyer, Medaglia, & Rubel, 2017). If PTSD's AAR and avoidance symptoms, and

positive memory qualities of coherence and vividness could be confirmed as central (bridge) nodes using time-series data and person-centered approaches (Fisher et al., 2017; Ross et al., 2018), they may be investigated as targets for trauma interventions (McNally et al., 2015), wherein a change in their severity may in turn alter the severity of other related symptoms, thus initiating/enhancing therapeutic benefits spreading to the entire network (McNally et al., 2015). Notably, such therapeutic propagating effects have not yet been shown in research (Rodebaugh et al., 2018), central symptoms may not be ideal intervention targets because feedback loops may re-activate central symptoms after they have been targeted successfully in treatment (Fried et al., 2018), and there is debate on whether the nature of central nodes as well as their rank-order is replicable/stable across studies (Forbes, Wright, Markon, & Krueger, 2017). Nevertheless, our results provide some direction for future longitudinal empirical examination.

Limitations and Future Research

Our study results need to be considered in light of limitations/concerns specific to a network perspective to disorders. First, there is an on-going debate on the theoretical foundations of network models. A network perspective has been contrasted with a latent variable approach to disorders in terms of their underlying premise of whether co-occurring symptoms interact dynamically to reflect a disorder vs. sharing a common underlying/latent cause (the disorder itself; Borsboom & Cramer, 2013). Recently, investigators are debating whether these differences are better represented (1) as being symptom-oriented vs. syndrome-oriented, and (2) as a dynamic vs. a static perspective to disorders (Bringmann & Eronen, 2018). Our study is not confined to any of these perspectives; rather our results can set the groundwork to explore the PTSD-positive memory relationship combining the network and latent variable perspectives within a temporal framework (Bringmann & Eronen, 2018; Forbes et al., 2017). Second, evidence indicates concerns about replicability of network models, primarily regarding estimates of edges, most central nodes, and rank-order of node centrality attributed to measurement error of nodes (Forbes et al., 2017). Relatedly, given that a network methodology is data-driven, and hence specific to the characteristics of this sample (Epskamp et al., 2018), replication in more demographically and clinically diverse samples is needed to ascertain generalizability of the current study findings.

Third, such cross-sectional network models are exploratory and generate hypothetical structures with potential causal effects to be explored in longitudinal/experimental studies (Epskamp & Fried, 2018); any non-zero relation between two variables can indicate a direct causal relation between them, a reciprocal causal relation between them, or the causal influence of both variables on a third variable (Pearl, 2000). Fourth, the current study did not investigate the 20 PTSD symptoms separately (vs. PTSD symptom clusters) which would have allowed us to explore more nuanced associations. To use the 20 PTSD symptoms, we would need a minimum sample size of 351 individuals (27 nodes). Given that a small and inadequate sample size has been shown to influence unstable networks and reduce reliability of results (Epskamp et al., 2018), we decided to use the four PTSD symptom clusters vs. the 20 PTSD symptoms for the current study. Relatedly, if using individual PTSD items, it would be important to consider the reliability of these single-item estimates because of measurement error (Fried & Cramer, 2017). In essence, longitudinal studies with larger

sample sizes are needed to examine causal inferences between these variables (Epskamp et al., 2018; Fried & Cramer, 2017).

Beyond limitations related to network models, it should be noted that poor/questionable internal consistencies of certain memory phenomenological qualities such as vividness, time perspective, sensory details, and coherence suggests that the combination of items in these domains may not accurately reflect these memory constructs; this may have negatively impacted the current study's statistical power to detect significant findings (Henson, 2001). Further, although excluding individuals making multiple attempts to complete the survey improves data quality, the rate of duplicate responses in the current study was higher compared to other MTurk studies (e.g., Martin, Reimann, & Norton, 2016; Wessling, Huber, & Netzer, 2017), which could have influenced the pattern of findings. Lastly, the moderating influences of factors such as cognitive skills (Gray & Lombardo, 2001), gender (Porter & Birt, 2001), retention interval (Waters et al., 2013), and trauma types (Contractor, Caldas, Fletcher, Shea, & Armour, 2018) could be examined in future research. Relatedly, it is important to consider that the valence of a memory may not be the only factor influencing all phenomenological qualities (Kensinger & Schacter, 2006; Porter & Birt, 2001); other memory-related characteristics such as physiological arousal associated with recall may be important to investigate in future research.

In conclusion, by focally highlighting the role of PTSD's AAR and avoidance symptoms, and positive memory characteristics of coherence and vividness, current study results extend research supporting a link between increasing PTSD severity and difficulties recalling specific positive memories (Contractor et al., in press; de Decker, Hermans, Raes, & Eelen, 2003; Hayes, VanElzakker, & Shin, 2012). This exploratory study indicated weak yet important trends worthy of further longitudinal investigation. Results inform trauma treatments that may capitalize on positive memories to improve treatment outcomes and retention (Contractor, Brown, et al., 2018), provide support to investigate sensation-focused (especially related to visual details) treatments for PTSD (Hinton et al., 2005), and contribute to the onset and maintenance hybrid models of PTSD (Fried & Cramer, 2017).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We conducted a PTSD-positive memory network analysis with 206 traumatized individuals.

- High bridge centrality PTSD nodes were arousal (strength) and avoidance (expected influence).

- High bridge centrality positive memory nodes were coherence (strength) and vividness (expected influence).

- Arousal was negatively associated with memory count, valence, coherence, and access.

- Avoidance was positively and negatively associated with memory vividness and count respectively.

Positive Memories
- Count: Count of Recalled Positive Memories
- Vivid: Vividness of Recalled Positive Memory
- Coherence: Coherence of Recalled Positive Memory
- Time persp: Time Perspective of Recalled Positive Memory
- Sensory: Sensory Details of Recalled Positive Memory
- Valence: Valence of Recalled Positive Memory
- Access: Accessibility of Recalled Positive Memory

DSM-5 PTSD Symptom Clusters
- Int: Intrusions Cluster
- Avoid: Avoidance Cluster
- NACM: Negative Alterations in Cognitions and Mood Cluster
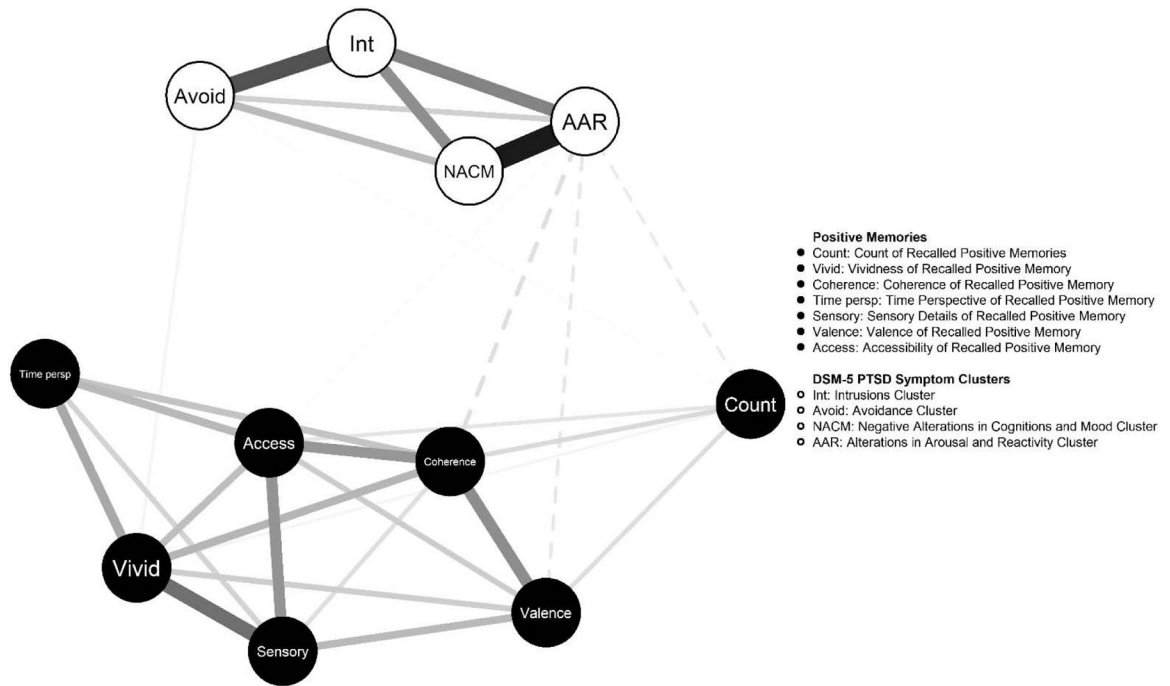- AAR: Alterations in Arousal and Reactivity Cluster

Figure 1.
Regularized partial correlation network

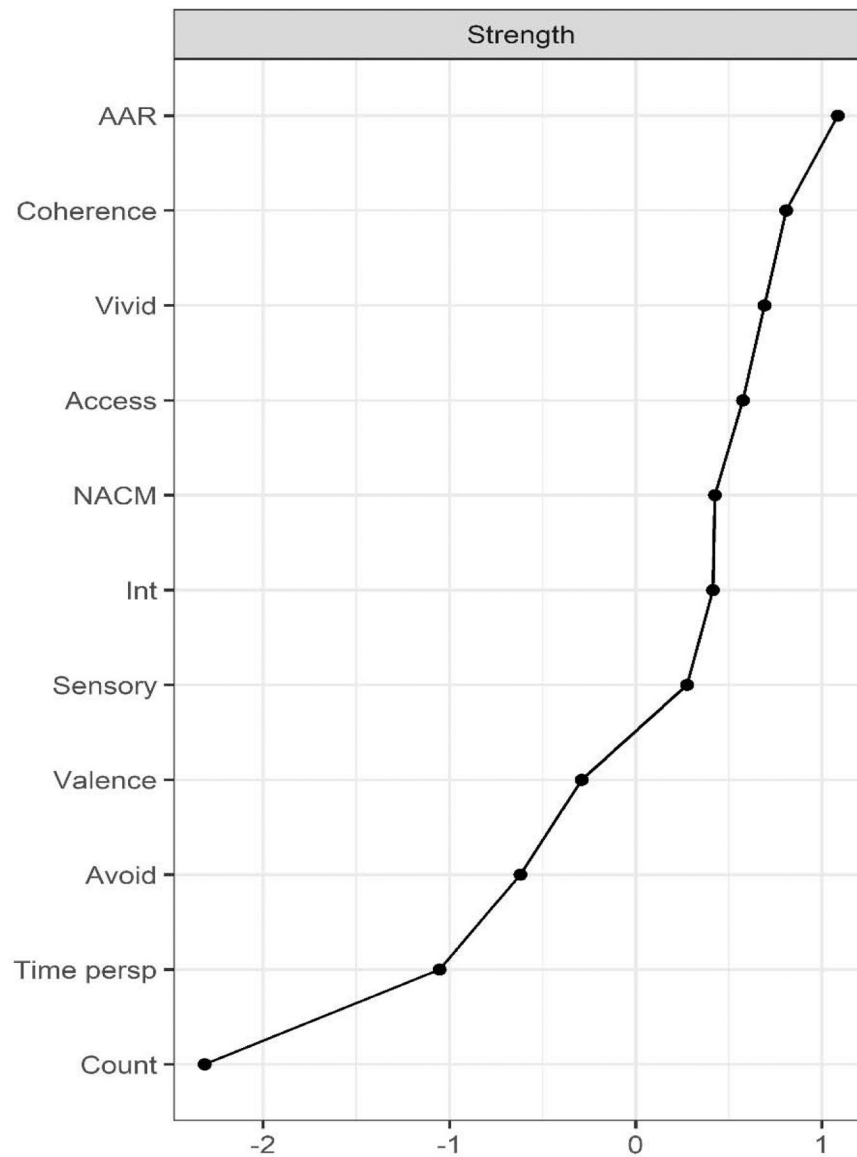*Note.* Solid lines indicate positive associations; dashed lines indicate negative associations.

Figure 2.
Strength centrality

Note. AAR is PTSD's anxious alterations in arousal and reactivity cluster; NACM is PTSD's negative alterations in cognitions and mood cluster; Int is PTSD's intrusions cluster; Avoid is PTSD's avoidance cluster; coherence is the coherence phenomenological quality of positive memories; vivid is the vividness phenomenological quality of positive memories; access is the accessibility phenomenological quality of positive memories; sensory is the sensory details phenomenological quality of positive memories; valence is the valence phenomenological quality of positive memories; time persp is the time perspective phenomenological quality of positive memories; count is the count of recalled positive memories.

Figure 3.
Bridge centrality
Note. AAR is PTSD's anxious alterations in arousal and reactivity cluster; NACM is PTSD's negative alterations in cognitions and mood cluster; Int is PTSD's intrusions cluster; Avoid is PTSD's avoidance cluster; coherence is the coherence phenomenological quality of positive memories; vivid is the vividness phenomenological quality of positive memories; access is the accessibility phenomenological quality of positive memories; sensory is the sensory details phenomenological quality of positive memories; valence is the valence phenomenological quality of positive memories; time persp is the time perspective phenomenological quality of positive memories; count is the count of recalled positive memories.
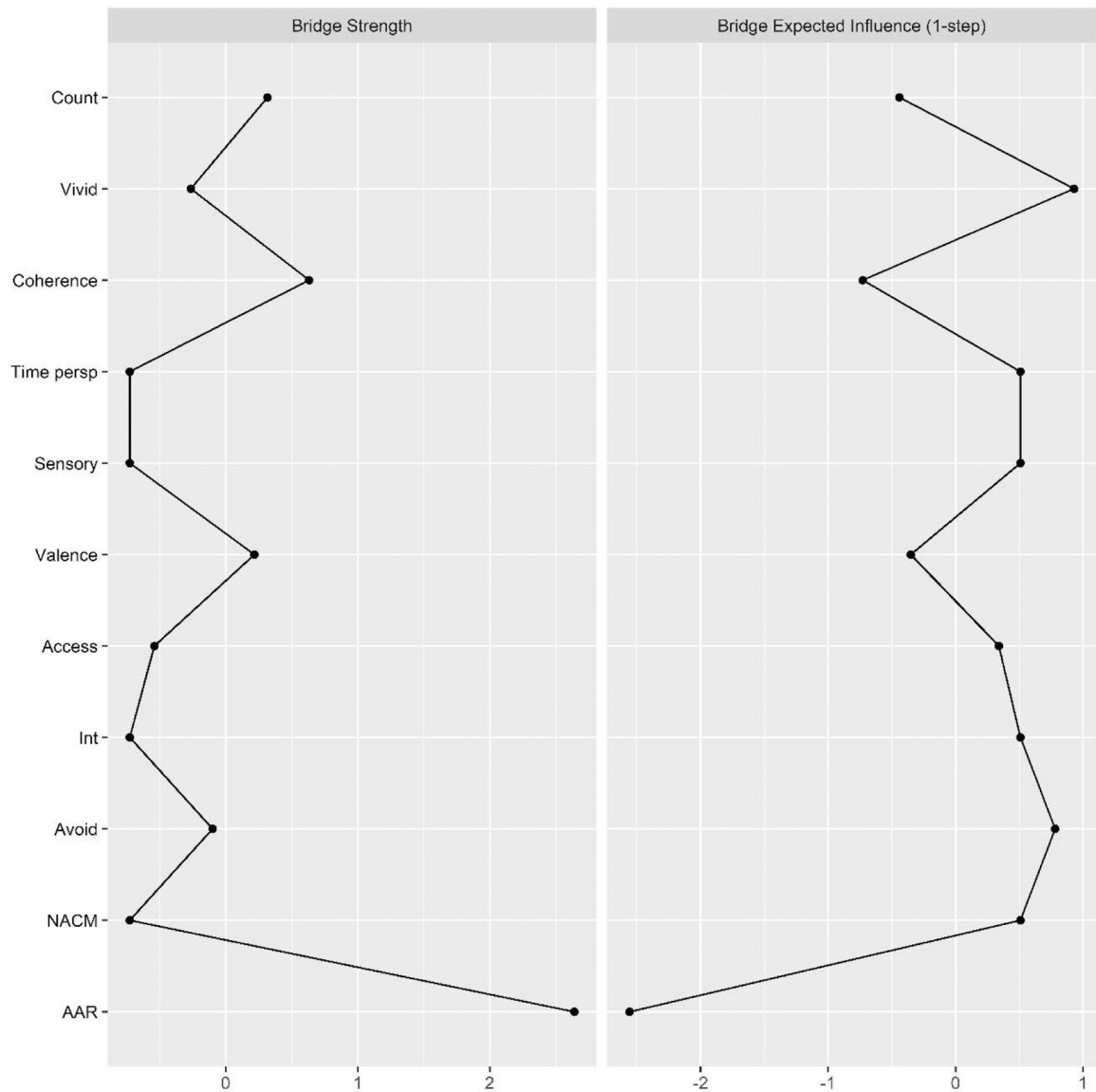
Table 1

Descriptive characteristics of the sample

Variable	Mean (SD)
Age	35.36 (11.50)
Years of schooling	15.37 (2.36)
Count of recalled positive memories	7.56 (2.11)
Accessibility of positive memory	4.36 (0.87)
Valence of positive memory	4.60 (0.68)
Vividness of positive memory	4.39 (0.76)
Coherence of positive memory	4.19 (0.79)
Time perspective of positive memory	3.96 (0.84)
Sensory details of positive memory	4.01 (0.78)
PTSD intrusions	1.47 (1.07)
PTSD avoidance	1.68 (1.25)
PTSD NACM	1.29 (1.04)
PTSD AAR	1.28 (1.02)
	n (%)
Gender	
Male	78 (37.90%)
Female	126 (61.20%)
Transgender	1 (.50%)
Gender queer	1 (.50%)
Employment status	
Part time	31 (15.00%)
Full time	146 (70.90%)
Retired	4 (1.90%)
Unemployed	20 (9.70%)
Unemployed student	5 (2.40%)
Relationship status	
Single	65 (31.60%)
Living with significant other	36 (17.50%)
Married	84 (40.80%)
Divorced	18 (8.70%)
Separated	2 (1.00%)
Widowed	1 (.50%)
Ethnicity	
Hispanic or Latino	17 (8.30%)
Not Hispanic or Latino	186 (90.30%)
Unknown	3 (1.50%)
Racial status (could endorse more than one category)	

Variable	Mean (SD)
Caucasian or White	171 (83.00%)
African American or Black	27 (13.10%)
Asian	8 (3.90%)
American Indian or Alaskan Native	7 (3.40%)
Native Hawaiian/other Pacific Islander	1 (.50%)
Unknown	1 (.50%)
Income	
Less than $15,000	15 (7.30%)
$15,000 – $24,999	26 (12.60%)
$25,000 – $34,999	18 (8.70%)
$35,000 – $49,999	43 (20.90%)
$50,000 – $64,999	43 (20.90%)
$65,000 – $79,999	24 (11.70%)
$80,000 and higher	37 (18.00%)
Treatment for mental health/emotional problem (could endorse more than one category)	
Currently in therapy	29 (14.10%)
Been in therapy in the past	90 (43.70%)
Currently taking medications for mental health/emotional problem	44 (21.40%)
Have taken medications in the past for mental health/emotional problem	59 (28.60%)
Never received treatment (therapy/medications) for mental health/emotional problem	78 (37.90%)
Worst traumatic event endorsed on the LEC-5	
Natural disaster	26 (12.60%)
Fire or explosion	5 (2.40%)
Transportation accident	33 (16.00%)
Serious accident at work/home/during recreational activity	9 (4.40%)
Exposure to a toxic substance	0 (0%)
Physical assault	16 (7.80%)
Assault with a weapon	7 (3.40%)
Sexual assault	34 (16.50%)
Other unwanted/uncomfortable sexual experience	8 (3.90%)
Combat or exposure to war	1 (.50%)
Forced captivity	0 (0%)
Life-threatening illness	11 (5.30%)
Severe human suffering	3 (1.50%)
Sudden, violent death	15 (7.30%)
Sudden, accidental death	15 (7.30%)
Serious injury/harm/death you caused to someone else	4 (1.90%)
None of these events happened to me	19 (9.20%)

Note. PTSD is posttraumatic stress disorder; NACM is negative alternations in cognitions and mood; AAR is alterations in arousal and reactivity; LEC-5 is Life Events Checklist for DSM-5; valid percentages were used to account for missing data.

Table 2

Regularized partial correlation matrix

	1	2	3	4	5	6	7	8	9	10	11
1. Count of positive memory recall	0	.06	.07	.02	.08	0	0	0	–.01	0	–.04
2. Accessibility		0	.11	.14	.23	.16	.24	0	0	0	–.01
3. Valence			0	.11	.25	.07	.15	0	0	0	–.06
4. Vividness				0	.16	.19	.31	0	.02	0	0
5. Coherence					0	.13	.07	0	0	0	–.07
6. Time perspective						0	.09	0	0	0	0
7. Sensory Details							0	0	0	0	0
8. PTSD intrusion								0	.38	.25	.27
9. PTSD avoidance									0	.15	.10
10. PTSD NACM										0	.51
11. PTSD AAR											0

Note. NACM is PTSD's negative alterations in cognitions and mood cluster; AAAR is PTSD's alterations in arousal and reactivity cluster.