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A categorical framework is used in most research and clinical settings to diagnose individuals with posttraumatic stress disorder (PTSD), leaving a subset of individuals who do not endorse the full criteria for PTSD, but who do express functional impairment and distress, under-researched and without therapeutic direction. These individuals are thought to have subthreshold PTSD (subPTSD). Researchers have demonstrated that people with subPTSD experience functional impairment to a similar degree as those with PTSD. However, researchers have not yet investigated how symptom-level associations vary between these diagnostic levels, which is important to understand how the experiences of subPTSD and PTSD are similar and different. The current study uses a statistical tool called network analysis to compare the symptom network structures of subPTSD to the symptom networks of the two diagnostic extremes (i.e., PTSD and trauma-exposed controls), as well as to model a network using the full sample. Centrality indices of strength, closeness, and betweenness were measured to determine which symptoms were most influential in the networks; the Network Comparison Test was used to statistically compare the networks; and tests were run to determine the stability and reliability of the networks. The strength index was reliably estimated for the full sample, and the most central nodes were difficulty concentrating, flashbacks, and physiological reactivity. Of these, physiological reactivity has been found to be a central symptom in the literature most often. All indices of centrality for the PTSD and trauma-exposed control groups were unreliable; even though the strength index of centrality was reliable

for subPTSD, the results of this network could not be compared to the others. Although the results of this study did not produce reliable results for the networks of the subsamples, conceptualizing mental illness using the network model has the potential to inspire new hypotheses and lead to advances in our understanding of mental illness.

A COMPARISON OF PTSD AND SUBTHRESHOLD PTSD SYMPTOM NETWORK STRUCTURES

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CHAPTER I

INTRODUCTION

In 1999, Mexico declared a state of emergency for the towns experiencing record-breaking rains, mudslides burying entire homes, and wild floods sweeping away neighbors and pets. For months following the mudslide, soldiers were working nonstop to unearth bodies, repair towns, and provide safe shelter for the victims. Some victims and soldiers recovered fully from this event, others returned to work and their families with an altered perspective of fear, and others were unable to reinstate any sense of normal functioning. With so many gradations in trauma responses, questions arise like, "why do people experience different symptoms?", "how are symptoms related to one another?", and "are there constellations of symptoms that can be classified as a typical response to trauma?"

Trauma exposure, defined by events that involve actual or threatened death; serious injury; threat to physical integrity; or sexual assault, is common worldwide and can lead to serious distress and disability (American Psychiatric Association [APA], 2013; Kessler, 2000). While rates of exposure vary across civilian samples, it is common to see rates well above 50% (e.g., 58% in Creamer, Burgess, & McFarlene, 2001; 56% in Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995; 69% in Norris, 1992; and 69% in Resnick, Kilpatrick, Dansky, Saunders, & Best, 1993). The psychological and physical impact of trauma exposure can be devastating and impairing for some, leading to problems such as posttraumatic stress disorder (PTSD). PTSD is a serious psychiatriccondition estimated to occur in about 8% of the general population (APA, 2013); estimates are even higher for certain ethnic groups like Latinos (14%; Pole, Best, Metzler, & Marmar, 2005). In the general population, PTSD has been associated with poor quality of life (Zhao, Wu, & Xu, 2013), negative health outcomes (Pacella, Hruska, & Delahanty, 2013; Scott et al., 2013), comorbid psychiatric disorders (Brady, Killeen, Brewerton, & Lucerini, 2000; Rytwinski, Scur, Feeny, & Youngstrom, 2013), and increased risk for suicidal thoughts and behaviors (Tarrier & Gregg, 2004). Because of the potential for such profound negative impact, a more thorough understanding of the effects of trauma and PTSD is crucial.

PTSD and SubPTSD

Typically in diagnostic, treatment, and clinical research settings, a categorical framework is used to diagnose individuals with PTSD (e.g., the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* [*DSM-5*], APA, 2013; the tenth edition of the *International Classification of Diseases* [*ICD-10*], World Health Organization [WHO], 1992). When a categorical framework is applied, people who meet the criteria for PTSD will receive a diagnosis and people who do not meet the criteria will not; it is a binary system. Consequently, there is a subset of individuals who experience some symptoms of PTSD and notable functional impairment (i.e., disturbance in social, occupational, or other important areas of functioning) without endorsing enough symptoms to receive a diagnosis of PTSD. These people, who are sometimes described as having "subthreshold PTSD" (subPTSD; Mylle & Maes, 2004), are under-researched

(Schmidt, 2015), without empirically based therapeutic support (Costanzo et al., 2014), and unable to meet insurance requirements for reimbursement (Schmidt, 2015; Szmukler, 2014). Increasing knowledge about subPTSD could inform potential remedies for these issues.

Most of the research that examined various definitions of subPTSD is based on the *DSM-IV* criteria for PTSD, as the newest edition of the manual was published in 2013 (e.g., Blanchard, Hickling, Taylor, Loos, & Gerardi, 1994; Breslau, Lucia, & Davis, 2004; Franklin, Sheeran, & Zimmerman, 2002; Schnurr, Friedman, & Rosenberg, 1993). In order to receive a *DSM-IV* PTSD diagnosis, individuals must meet several criteria, including exposure to a Criterion A traumatic event. A Criterion A stressor is one in which a person "has experienced, witnessed, or been confronted with an event or events that involve actual or threatened death or serious injury, or a threat to the physical integrity of oneself or others" and whose response involved "intense fear, helplessness, or horror" (APA, 2013). Furthermore, individuals must meet at least one Criterion B "re-experiencing" symptom (i.e., recurrent and intrusive distressing recollections of the trauma, nightmares related to the trauma, flashbacks to the trauma, intense psychological distress to trauma reminders, and physiological reactivity to trauma reminders), three or more Criterion C "avoidance/numbing" symptoms (i.e., avoiding trauma-related thoughts and feelings, avoiding trauma-related people and places, trauma-related amnesia, diminished interest in activities, feelings of detachment from others, restricted range of affect, and sense of foreshortened future), and two or more Criterion D "hyperarousal" symptoms (i.e., difficulty sleeping, irritability and anger, difficulty concentrating, hypervigilance, and exaggerated startle). Lastly, Criterion B, C, and D symptoms must be present for at least one month as outlined in Criterion E and individuals must endorse clinically significant distress or impairment as outlined in Criterion F.

Several definitions of subPTSD derive from *DSM-IV* criteria. Criteria A and E are required across all subPTSD definitions (Blanchard et al., 1994; Breslau et al., 2004; Schnurr et al., 1993). One definition requires at least one symptom from Criterion B, one from Criterion C, and one from Criterion D (Breslau et al., 2004; Pietrzak, Goldstein, Southwich, & Grant, 2011; Stein, Walker, Hazen, & Forde, 1997). Another definition requires that people either (1) meet at least one Criterion B, C, and D symptom, (2) meet Criterion B and D fully, or (3) meet the requisite number of Criterion B, C, and D symptoms, but with some symptoms rated as subthreshold by a clinical interviewer (Schnurr et al., 1993). A final definition of *DSM-IV* subPTSD requires that individuals meet either Criteria B and C fully or Criteria B and D fully (Blanchard et al., 1994). In other words, people have to meet at least one Criterion B and three Criterion C or one Criterion B and two Criterion D symptoms. Unfortunately, empirically based rationales for these various definitions are lacking, although one study found that the diagnostic hit rates across subPTSD definitions was best for the Blanchard et al. (1994) definition (Franklin et al., 2015). Moreover, the definition proposed by Blanchard et al. (1994) is the most widely used and has demonstrated adequate sensitivity and specificity in diagnostic settings (Franklin et al., 2015; Kornfield, Klaus, Mckay, Helstrom, & Oslin, 2012).

People with subPTSD often experience distressing symptoms and exhibit high levels of functional impairment. Jakupcak et al. (2007) noted increased anger, aggression, and hostility in a sample of veterans with subPTSD. Furthermore, when compared to individuals without PTSD, individuals with subPTSD show decrements in psychosocial functioning (e.g., Cukor, Wyka, Jayasinghe, & Difede, 2010; Marshall et al., 2001; Pietrzak et al., 2012) and occupational functioning (Breslau et al., 2004). Some evidence suggests that people with subPTSD can experience impairment in social and occupational domains comparable to the impairment associated with PTSD (Breslau et al., 2004; Stein et al., 1997; Zlotnick, Franklin, & Zimmerman, 2002). Additionally, subPTSD has been associated with higher rates of suicidal ideation even after controlling for depression and anxiety disorders (OR=1.73; Marshall et al., 2001) and higher rates of alcohol use/dependence (OR=2.38; Adams, Boscarino, & Galea, 2006) when compared to individuals with no PTSD. Accordingly, a growing body of evidence suggests that the impact of subPTSD can be clinically significant and impairing.

However, evidence also suggests clinical differences between individuals with PTSD and subPTSD. For example, Zlotnick et al. (2002) found that participants with PTSD were significantly more likely to have at least one prior psychiatric hospitalization (40% in the PTSD group and 21% in the subPTSD group) and poorer levels of global functioning (mean difference of .31). Additionally, some findings suggest that people with PTSD experience a wider range of *DSM-IV* avoidance/numbing symptoms compared to people with subPTSD (Schützwohl & Maercker, 1999; Zlotnick et al., 2002). Generally, it is thought that individuals with subPTSD lie on a continuum between those with PTSD and those without PTSD (Schnurr, 2014). A more thorough understanding of the similarities and differences between the symptom structures of subPTSD and PTSD is needed to help clinicians and researchers understand how comparable the experiences of subPTSD and PTSD are, and to inform an empirically based definition of subPTSD, a particularly timely endeavor as researchers start looking toward definitions of *DSM-5* subPTSD.

The Network Approach

Although researchers have examined appropriate definitions of subPTSD and the magnitude of impairment in individuals with subPTSD, the relationships among specific symptoms are poorly understood. Network analysis offers a technique to describe the complex relationships among PTSD symptoms. Network analysis is a statistical tool that provides visual and quantitative information about the role of individual symptoms in a network. As nodes in a network, PTSD symptoms are treated as interdependent entities that are positioned specifically to reflect their associations with other symptoms in the network and their influence on the overall network (Fried & Nesse, 2014). This approach can be used to identify and compare the symptoms that are core or central to the networks of subPTSD and PTSD and to shed light on symptoms that might be influencing the syndrome the most.

In psychiatry and clinical psychology, the network approach to psychometrics is often juxtaposed to the more common latent variable approach (e.g., Borsboom & Cramer, 2013; McNally et al., 2015; Hofmann, Curtiss, & McNally, 2016). Examples of classical latent variable models in statistics are factor analysis, structural equation models, and mixed effects models. Fundamental to these statistics is the assumption that there is a small set of latent variables that cause the observable symptoms. If the underlying cause is identified and treated, the experienced symptoms will dissipate. McNally et al. (2015) provides a good example of the latent variable model in medicine where the increase in pressure caused by an intracranial tumor causes headaches, seizures, fatigue, and more superficial indicators of illness. The symptoms would not exist without the presence of the tumor, and, thus, the tumor is the underlying cause that needs to be treated. The authors also mention that for some mental health conditions, such as the 19th century disorder known as general paresis of the insane (syphilis) and trisomy 21 (Down syndrome), the latent variable model has been successful in identifying an underlying common cause with a physical referent for the various symptoms of those conditions; however, this model has its limitations in psychology research (McNally et al., 2015). The difficulty of identifying latent variables is compounded in psychology and psychiatry where underlying causes are difficult, and sometimes impossible, to probe (Borsboom & Cramer, 2013). Therefore, Borsboom and Cramer (2013) proposed a new conceptual approach based on network theory in order to emphasize the interrelatedness between symptoms. Broadly, network approaches to psychopathology theorize that mental disorders are constellations of causally connected symptoms that trigger and maintain one another. A hypothetical example is that trauma exposure might lead to trauma-related nightmares that, in turn, impair sleep quality, which results in concentration difficulties that allow for intrusive thoughts of the trauma, which maintain nightmares, resulting in a feedback loop.

Network approaches to symptom-level associations produce structures that are only as good as the input data, and, ideally, all relevant symptoms would be included in the model. Even though network analyses are exploratory in nature, it is critical to theoretically and empirically consider how individual symptoms being modeled could affect the structure. A relevant empirical question under investigation is the extent to which *DSM* PTSD and subPTSD definitions capture symptomatic responses to trauma for people outside of the U.S. A substantial body of evidence demonstrates that PTSD is a syndrome experienced in societies around the world, but universal or culturally specific features of the syndrome are not well established. Researchers assert that some PTSD symptoms, such as physiological arousal, avoidance, and intrusive thoughts, are experienced universally but mediated by ethnocultural influences (Marsella, 2010; Summerfield, 2004). Marsella (2010) proposed the "trauma event-person ecology" model as a foundation on which to investigate different ethnocultural factors that shape perceptions, experiences, clinical expressions, and treatment responses to trauma within and across cultures. Broadly, the model proposes that cultural socialization and constructions (i.e., external artifacts, roles, settings, and institutions) that people encounter throughout development shape their views of reality, including what they come to expect from the world and how they respond to events in their lives.

In large part, Marsella (2010) proposed the trauma event-person ecology model in response to researchers applying and/or assuming that Western ideas about trauma and PTSD are comparable from one cultural milieu to the next, an etic perspective. Norris, Perilla, and Murphy (2001a) tested a potential aspect of cultural variation by investigating if a structural model of *DSM-IV* PTSD fit data of a Mexican sample as well as it fit data of a U.S. sample. The authors found that the structure of *DSM-IV* PTSD applied equally to the two samples. However, when the authors controlled for the severity of trauma, the Mexican sample reported more intrusion and avoidance symptoms, and the U.S. sample reported more arousal symptoms. Nonetheless, the results support extending the *DSM-IV* conceptualization of PTSD to Mexican samples. Furthermore, a qualitative study that coded free-response answers given by Mexicans from Guadalajara, Jalisco; Homestead, Florida; and Puerto Angel, Oaxaca provides converging evidence that *DSM-IV* PTSD criteria accurately reflect the post-traumatic symptoms experienced by these participants (Norris et al., 2001b), replicating the findings of the first study. Taken together, the results provide a solid rationale for using measures of *DSM-IV* PTSD in Mexican samples to study the effects of PTSD and subPTSD in people from Latin American communities. To date, there have been no published studies investigating the PTSD symptom network structure in Latinos. However, doing so would generate hypotheses about potential causal associations between symptoms, as well as symptoms that are the most central in this population. The proposed advantage to uncovering central symptoms is that it elucidates symptoms that might be the most important on which to intervene.

The application of network analysis to psychiatric disorders frequently relies on three main indices of centrality to identify which symptoms are core to the network. Strength centrality is the sum of the partial correlations of a symptom to all other symptoms with which it is associated. Betweenness centrality measures how often a symptom falls on the shortest path length between two other connected symptoms. Finally, closeness centrality measures the average distance of one symptom to the remaining symptoms in the network. High scores on centrality indices suggest that the symptom is important to the network.

Several studies have examined symptoms of PTSD using network analysis. Overall, the symptoms identified as the most central to the PTSD network vary across studies (see Table 1 for a summary of the literature). The three symptoms reported most frequently among the top three central symptoms were physiological cue reactivity (emerging four times), intrusive thoughts (emerging three times), and detachment (emerging three times). Otherwise, core symptoms ranged greatly with a total of 13 other symptoms reported as highly central without corroboration from more than one other study (Armour, Fried, Deserno, Tsai, & Pietrzak, 2017; Bryant et al., 2016; Epskamp et al., 2016; Fried et al., 2017; McNally et al., 2015; McNally et al., 2017; Moshier et al., under review; Mitchell et al., 2017; Skogbrott, Birkeland, & Heir, 2017; Spiller et al., 2017). Inconsistent results may be due to the small samples sizes used to estimate a large number of parameters, systematic error and noise influencing the reliability of item-level analyses, and differences across studies in variables like trauma type, sample size, symptom measure, and sample characteristics.

Typically an important sample characteristic in clinical research is the diagnosis of participants; to date, every study investigating the network structure of PTSD has used the data of all trauma-exposed participants, whether or not they exhibited diagnosable or probable PTSD. Thus, it is possible that the proportions of participants with PTSD, with subPTSD, and without PTSD in the datasets are contributing to the inconsistent findings across studies. Without directly comparing a PTSD network structure to a subPTSD network structure and no PTSD network structure, we cannot know if the previously published networks are truly representative of a PTSD network and how/if including a combined sample affects the network structure. Directly comparing the symptom network structure of subPTSD, PTSD, and trauma-exposed controls and testing for significant differences using the Network Comparison Test (NCT; van Borkulo et al., 2017) is an important next step in building an evidence base that supports or does not support the standard practice of using unrestricted or combined samples.

Furthermore, the initial research using network analysis in clinical psychology has focused primarily on describing patterns of symptom networks within a single disorder or set of disorders (e.g., Armour et al., 2017; McNally et al., 2015; Sullivan et al., 2016). However, there is interest in the field in comparing networks (e.g., Bryant et al., 2017; van Borkulo et al., 2017). The current study is one of the first studies to use a novel statistical test called the Network Comparison Test to compare statistically the networks of subPTSD and PTSD. This test is used to determine if the subPTSD and PTSD symptom patterns differ significantly in global network structure (the way in which the overall network is connected) and global network strength (the sum of the strength of the associations between all nodes in the network).

The application of network approaches in clinical psychology is relatively new and a current challenge lies in understanding how accurate psychological networks are and how stable inferences drawn from those networks are. For example, every study but one (i.e., Spiller et al., 2017) found that only node strength could be reliably interpreted after using bootstrap methods to assess accuracy and stability of the estimated networks and centrality indices (Armour et al., 2017; Epskamp et al., 2016; Fried et al., 2017; McNally et al., 2017; Moshier et al., under review; Mitchell et al., 2017; Skogbrott Birkeland & Heir, 2017; note that McNally et al. (2015) did not report stability and accuracy tests, which were not widely available at the time). Additionally, the figures and tables presented in several studies reveal large confidence intervals around the majority of the edge weights (i.e., the partial correlations among the symptoms), indicating that the order of node centrality (i.e., ranking of how central or important a node is in the network) should be interpreted with caution (e.g., Bryant et al., 2017; Mitchell et al., 2017). As the interpretation of networks is still in its early stages and replicability is a profound issue in clinical psychology research (Forbes, Wright, Markon, & Krueger, 2017; Open Science Collaboration, 2015), it is critical for those who use this statistical tool to analyze and report clearly the accuracy and stability of the modeled networks in the main results section.

Goals and Hypotheses

The present study had four aims: (1) to compare visually and statistically the networks of PTSD, subPTSD, and trauma-exposed controls to better understand similarities and differences between subPTSD and the two diagnostic extremes, and to lend credence to either collapsing across or parsing out the subsamples in future network analyses, (2) to model a network using the full sample to see if it resembles the networks derived from the subsamples, (3) to expand cross-cultural understanding of PTSD by employing network modeling to a data set of individuals from different Latin American communities, and (4) to add to the relatively new literature examining the accuracy and stability of psychological network models. Network analysis is a data-driven technique that is exploratory in nature, however I hypothesized that there would be significant differences between the three networks (i.e., PTSD, subPTSD, and trauma-exposed controls) in global strength, where the PTSD network would show the greatest global strength and the trauma-exposed control network would show the weakest global strength, and that the strength index of centrality would be a reliable marker of centrality across networks.

CHAPTER II

METHOD

Participants

Data for the current study was taken from larger studies conducted by Fran H. Norris, Arthur D. Murphy, and colleagues examining epidemiological factors of mental health, specifically PTSD, following natural disasters and accidents in Mexico and Ecuador (Norris, Murphy, Baker, & Perilla, 2003a; Jones et al., 2013). Details of the sampling procedures for the studies in Mexico (Norris et al., 2003a) and Ecuador (Jones et al., 2013) have been presented elsewhere. Original data were collected from 1,358 individuals. Participants included in the analyses were 1,104 adults who were divided into PTSD, subPTSD, and trauma-exposed control groups matched on sample size, age, gender, and trauma site.[1] Sample size was kept constant across the networks, because the sample size can influence the number of edges in the estimated network (Epskamp, Borsboom, & Fried, 2016). Because the study of network analysis is in its early stages, it is unclear whether sample characteristics like age, gender, and trauma type influence the associations between nodes; although there is no direct evidence to suggest an effect, these variables were matched across networks in order to control for potential variability

[1] As a rule of thumb it is argued that you need at least as many observations as you have parameters (Epskamp, Borsboom, & Fried, 2016).

that might arise as a result of differences in sample characteristics across the networks. The matching procedure involved separating the participants into three distinct groups based on diagnosis of PTSD, subPTSD, or trauma-exposed control, and, then, matching participants from each group by age, gender, and trauma site. Individuals were diagnosed with PTSD if they met all criteria outlined in the *DSM-IV*. Following the procedures outlined by Blanchard et al. (1994) and Franklin, Sheeran, and Zimmerman (2002), people were diagnosed with subPTSD if they met *DSM-IV* Criterion A, Criterion B, either Criterion C or D, Criterion E, and Criterion F. The final sample consisted of 368 participants with PTSD, 368 with subPTSD, and 368 trauma-exposed controls (see Table 2).[2]

In Mexico, data were collected in San Pedro Benito Juárez following a volcanic eruption, in Teziutlan and Villahermosa following mudslides and flooding, and in Hermosillo following a fire at a day care facility. In Ecuador, data were collected in Penipe Viejo, Pillate, San Juan, Pusuca, and Penipe Nuevo following a volcanic eruption. See Jones et al. (2013) for city characteristics of the five Ecuadorian cities and San Pedro Benito Juárez and see Jones, Gupta, Murphy, and Norris (2011) for city characteristics of Teziutlan, Villahermosa, and Hermosillo.

Procedures

Local study personnel were trained to recruit and complete socioeconomic and mental health interviews with participants. Training consisted of teaching the interviewers how to solicit participation in the study, how to protect participants' rights,

[2] Information on socioeconomic status was not provided in the datasets.

how to complete the standardized questionnaire, how to ask personal questions respectfully, and how to be sensitive to respondent distress. Fieldwork managers checked all interviews for accuracy of selection procedures, completeness, and quality. After obtaining informed consent, interviewers administered a one-hour sociodemographic interview to the male or female head of the household and a two-hour comprehensive psychological interview to a randomly selected adult household member. Demographic data were taken from the sociodemographic interview. Data were collected in four waves – immediately after the trauma, six months post trauma, one-year post trauma, and two years post trauma. The current study analyzed the second wave of data.

The fully-structured, lay-administered Composite International Diagnostic Interview (CIDI) – Version 2.1, developed and translated into Spanish by the World Health Organization (1997), was used to establish the presence (an item score of "1") or absence (an item score of "0") of the 17 *DSM-IV* PTSD symptoms and level of functional impairment experienced in the past month, as well as to establish comorbid *DSM-IV* Major Depression Disorder (APA, 1994). The WHO translation protocol was used to translate the interview. While the typical approach is to skip out once a criterion is not met, the protocol for administering the CIDI was modified slightly so that participants who met Criterion A were asked all questions in the CIDI PTSD module. In part, the rationale for this was to assess the epidemiology of trauma, PTSD, and subPTSD in a Latin American sample (Norris et al., 2003a). The CIDI is widely used and has strong psychometric properties (Breslau, Kessler, & Peterson, 1998).

Statistical Analyses

The networks of the full sample and PTSD, subPTSD, and trauma-exposed control subsamples were estimated, and, for those networks, the nodes represent the 17 *DSM-IV* PTSD symptoms and the weighted edges between pairs of nodes represent the coefficients from a logistic regression examining each PTSD symptom as a predictor of each other PTSD symptom, controlling for all other symptoms in the network. All networks were estimated using eLasso (package 'Ising Fit' in R; van Borkulo & Epskamp, 2014). This network analysis technique is based on Ising models appropriate for binary data and combines *l*1-regularized logistic regression (Ravikumar,Wainwright, & Lafferty, 2010; Tibshirani, 1996) with Bayesian neighborhood selection (Chen & Chen, 2008; Foygel & Drton, 2011) to define connections between symptoms in the network. Because analyses cannot handle missing data, the 14 missing values in the dataset were estimated manually by substituting the missing value with the median value endorsed in that subject's particular group for that symptom (i.e., 0 or 1). Participants with missing data represent about 0.01% of the sample.

The centrality indices that were used to examine the relative importance and influence of a symptom to its network were node strength, closeness, and betweenness. The R package qgraph was used to calculate and plot the centrality indices (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). In addition, qgraph was used to visualize the PTSD, subPTSD, and trauma-exposed controls networks. Green edges reflect positive associations, red edges reflect negative associations, and thicker edges reflect stronger associations. An edge was selected in the model using the AND-rule, meaning that both regression coefficients of Symptom X_i on Symptom X_j and Symptom X_j on Symptom X_i, while controlling for all other symptoms, are statistically significantly nonzero ($\beta_{ij} \neq 0$ AND $\beta_{ji} \neq 0$). Additionally, the gamma hyperparameter (i.e., "the strength of the extra penalty on the number of neighbors;" van Borkulo et al., 2014) was set to .25 for the model based on recommended values (Chen & Chen, 2008). Sparsity, a characteristic of networks based on the number of edges in the network compared to the total number of edges possible, was also measured. Sparsity ranges from 0 to 1, with values closer to 1 indicating more sparse networks (Gribonval, 2015).

Accuracy (i.e., how prone a network is to sampling variation) and stability (i.e., how similar an interpretation is with fewer observations) of the estimated networks were assessed using case-dropping bootstrap standard errors on IsingFit network models (package 'bootnet' in R; Epskamp, Borsboom, & Fried, 2016). Each network's accuracy was determined by estimating 95% confidence intervals (CIs) on edge-weights, assessing the stability of the order of centrality indices after observing random samples of the data, and testing for significant differences between the centrality of nodes and between edge-weights. The correlation stability coefficient (*CS-coefficient*) was used to quantify the stability of the centrality indices of each network; the *CS-coefficient* represents the maximum proportion of cases that can be dropped so that the correlation between the centrality indices in the full sample and the centrality indices in the subsets is at least 0.7 with 95% probability (Cohen, 1977; Epskamp et al., 2016). The minimum threshold that is recommended for interpretation is a *CS-coefficient* of 0.25 (Epskamp et al., 2017).

Lastly, I used the Network Comparison Test (NCT; van Borkulo et al., 2017; van Borkulo, Boschloo, Borsboom, Penninx, Waldorp, & Schoevers, 2015) to test whether the trauma-exposed controls and subPTSD, trauma-exposed controls and PTSD, and subPTSD and PTSD networks differ significantly from each other on network structure and global strength. The NCT tests the null hypotheses that there is no difference between the connection strength matrices of the networks, which are comprised of the specific edge weights connecting pairs of nodes (i.e., testing network structure) and that there is no difference between overall level of connectivity of the networks (i.e., testing global strength). The NCT produces a p-value for *M*, which is the difference between the network structures, and *S*, which is the difference in global strength.

CHAPTER III

RESULTS

Sample Characteristics

After matching the PTSD, subPTSD, and trauma-exposed controls groups on sample size, age, gender, and trauma site, the final sample consisted of 1,104 participants with 368 participants in each group. Table 2 presents sample characteristics for the groups, and Table 3 presents the percent of participants in each group that endorsed each of the 17 PTSD symptoms.

Full Sample Network

The network structure for the full sample is presented in Figure 1a. The network shows that all 17 *DSM-IV* PTSD symptoms were connected, either directly or indirectly via other symptoms. The network had a total of 59 non-zero edges of 136 possible edges; all edges in the network were positive with the exception of one edge that connects the nodes amnesia and sleep (indicated in red). The CIs for the bootstrapped edge weights showed substantial overlap with one another (see Figure 1c). However, the strongest edge weights, which were between nightmares and sleep impairment, between hypervigilance and startle, and between avoiding thoughts/feelings and avoiding people/places, were significantly stronger than many other edges. In other words, the strongest associations between a pair of nodes in this network were between nightmares and sleep impairment, between hypervigilance and startle, and between avoiding thoughts and feelings and avoiding people and places. The subset bootstrap analysis suggested that the strength centrality index was stable (*CS*(cor = 0.7) = 0.59), but indicated poor stability for the closeness (*CS*(cor = 0.7) = 0.05) and betweenness (*CS*(cor = 0.7) = 0.00) estimates (see Figure 1d).

Figure 1b depicts the standardized estimates of the centrality indices of node strength, betweenness, and closenesses used to measure the potential spreading of activity through the network. Although plots of betweenness and closeness were computed, they did not produce reliable and stable indicators of node centrality. Given this, only the strength index is discussed (Epskamp et al., 2016). The most central symptoms that emerged from analyses of the strength index were difficulty concentrating, flashbacks, and physiological reactivity. The symptoms of amnesia and feeling upset were least central.

PTSD Network

The network structure for the participants diagnosed with PTSD is presented in Figure 2a and the standardized estimates of the centrality indices are presented in Figure 2b. As indicated visually and in the centrality plots, the PTSD network shows a highly sparse network (sparsity = 0.93) with a large number of disconnected nodes (see Figure 2a). Eight out of seventeen nodes were disconnected from the network and only ten non-zero edges emerged connecting the remaining nine nodes. In exploratory efforts to decrease sparsity, the gamma hyperparameter was set to zero so that no penalty was given for the number of neighbors. However, changing the value of gamma did not increase the number of connections in the network, and the results are reported from the analyses where $\gamma = .25$. All of the CIs for the bootstrapped edge weight overlapped with one another, which indicates that the edges were not significantly different from one another (see Figure 2c). The subset bootstrap analysis suggested poor stability for strength (*CS*(cor = 0.7) = 0.21 and betweenness (*CS*(cor = 0.05) = 0.00; see Figure 2d), meaning that the order of node strength or betweenness cannot be determined. The stability coefficient for closeness is zero as a result of disconnected nodes in the network.

Subthreshold PTSD Network

The network structure for the participants with subPTSD is presented in Figure 3a and the standardized estimates of the centrality indices are presented in Figure 3b. The subPTSD network was less sparse than the PTSD network. However, the network was still highly sparse with three disconnected nodes and only 19 non-zero edges (sparsity = .85). The CIs for the bootstrapped edge weight showed substantial overlap with one another (see Figure 3c). However, the strongest edge weights were significantly stronger than the weakest ones. The subset bootstrap analysis showed that the strength centrality index reached stability (*CS*(cor = 0.7) = 0.28), while the betweenness index did not (*CS*(cor = 0.13) = 0.00; see Figure 3d). Again, the stability coefficient for closeness is zero as a result of disconnected nodes in the network.

Trauma-exposed Control Network

The network structure for the trauma-exposed controls with no PTSD is presented in Figure 4a and the standardized estimates of the centrality indices is presented in Figure 4b. Although the trauma-exposed controls network produced a network with two disconnected nodes, the network was less sparse than both the PTSD and subPTSD networks (sparsity = .79). The trauma-exposed controls network contained 29 non-zero edges. All of the CIs for the bootstrapped edge weight overlapped with one another (see Figure 4c). Additionally, the stability coefficients for the strength and betweenness indices were below the threshold for stability at *CS*(cor = 0.7) = 0.21 and (*CS*(cor = 0.7) = 0.00 respectively (see Figure 4d). The stability coefficient for closeness is zero as a result of disconnected nodes in the network.

Network Comparison Tests

The network comparison tests could not be performed when the PTSD network was the comparison network, because the PTSD network was too sparse. However, the network comparison test testing the differences in global strength and network structure between the subPTSD and trauma-exposed control networks revealed that the trauma-exposed control network was statistically significantly stronger than the subPTSD network (S = 8.68, *p-value* = 0.03). Additionally, the subPTSD and trauma-exposed control networks varied significantly in global network structure (M = 1.57, *p-value* = 0.02).

CHAPTER IV

DISCUSSION

This study's primary aim was to compare the symptom networks of PTSD, subPTSD, and trauma-exposed controls in order to understand patterns of symptom-symptom associations in groups of people with varying levels of PTSD symptom severity. A secondary aim was to investigate how accurately networks generated from a sample that included all participants reflect the network of a specific diagnostic subsample, a concern researchers have expressed of PTSD network studies. All published PTSD network analyses to date have made inferences about PTSD symptom interactions based on data derived from individuals across diagnostic levels. The appeal of this approach is obvious; if the full sample and PTSD subsample produce similar networks, then including all participants would increase the power to reliably detect interactions. However, previous research has not confirmed that people with a diagnosis of PTSD have symptom network structures that are similar to the symptom network structures of people with less severe symptomatology. To explore this, the networks of specific diagnostic cohorts and the full sample were compared. A third aim was to expand cross-cultural understandings of PTSD by employing network modeling to a data set of individuals from Latin American communities, extending current work on participants from the U.S., China, and the Netherlands. A final, but crucial, goal of the study was to explore the reliability of the estimated network structures and centrality indices, because replicability is a challenge in psychological science, generally, and in PTSD networks, specifically. The application of network modeling to psychopathology remains under development; the results, specific study challenges, and a critical perspective of conventional techniques and perspectives are discussed while the field is still establishing best practices using this novel application of network statistics.

Replicability

Unexpectedly, the PTSD and trauma-exposed control networks did not produce any reliable measure of centrality, limiting the interpretation and impact of the study substantially. Based on the literature, it was expected that the strength index of centrality would be stable for all networks. Although it was surprising that strength was not stable in the PTSD and trauma-exposed control networks, it is likely that the study was underpowered to estimate the parameters from binary data reliably in the two subsamples. The number of participants used in this study was within the rule-of-thumb provided by leaders in the field and was on par with previous studies published. As a result, I recommend that researchers determine sample size considering the rule-of-thumb, but also data type (e.g., dichotomous, ordinal), method used to model the data (e.g., Ising, GGM), and type of network (e.g., association, concentration). The type of data collected is important, because dichotomous variables create less variability in the data than ordinal or continuous variables typically do, leading to sparser networks and increasing the chances of disconnected nodes. The statistical method used to estimate the network structure should be considered, because certain analyses, such as the Ising model, and parameters err on the side of specificity and can create sparser networks

(Borgatti, Everett, & Johnson, 2013). Finally, the type of network should be considered because the edges of some networks, like concentration networks, represent conditionally independent relationships between nodes, removing any shared variance between a pair of symptoms and all other symptoms in the network, and further reducing statistical power (Forbes et al., 2017).

The strength index of centrality for the networks of the full sample and subPTSD sample produced reliable results. Consequently, the network for the full sample is the target of discussion and the networks for the PTSD, subPTSD, and control groups are discussed conceptually as preliminary findings. Furthermore, betweenness and closeness indices were below the threshold for reliability in all four networks. These results are consistent with the results of other studies; primarily, results indicate that strength is stable and betweenness and closeness are not (Armour et al., 2017; Epskamp et al., 2016; Mitchell et al., 2017).

So, why might the CS-coefficients of closeness and betweenness consistently fall below the threshold of stability? Networks tend to produce closeness scores with little variance, providing ineffective discrimination between nodes and unstable estimates of closeness centrality (Borgatti, Everett, & Johnson, 2013). With regard to this study specifically, closeness is a problematic measure of centrality because the network contains disconnected nodes. The distance from a disconnected node to the network is undefined (i.e., infinity), since there is no path between them. Consequently, the CS-coefficient for the index goes to zero. Furthermore, it is likely the case that larger sample sizes are needed to reliably estimate closeness and betweenness centrality compared to strength centrality. Betweenness centrality is also affected by the sensitivity of the network (i.e., how accurately edges are being estimated given that they truly exist). Networks estimated by LASSO regularization with EBIC model selection, as these networks were, vary in sensitivity based on network structure, sample size, and the value of the hyperparameter gamma (Epskamp et al., 2016). Because dichotomizing data produces relatively sparse networks, the hyperparameter gamma is reduced to .25, which errs on the side of discovery (i.e., more ties are estimated, including potentially spurious ones). These features of the data and analyses are important to consider particularly in estimating centrality measures. For example, collecting continuous or ordinal data in a larger sample would provide more stable centrality measurements by increasing the amount of variability and reducing the confidence intervals around the edge weights.

Centrality

In this study, concentration difficulties, flashbacks, and physiological reactivity were among the most central symptoms in the network model of the full sample. The only overlap among central symptoms in the full and diagnostically segmented networks includes flashbacks in the full, PTSD, and control networks and concentration difficulties in the full and PTSD networks. Physiological reactivity was disconnected in the PTSD network, but was also a symptom endorsed by 81% of participants with PTSD. This indicates that a symptom without much variation in frequency or severity across participants will not predict the flow of information through a network well because there is not enough variability in the item to be significantly associated with other symptoms (that symptom would be unrelated to someone’s endorsement of other items). For this reason, continuous and ordinal scales will often be better than binary systems of measurement when analyzing the symptom networks of mental illness. Additionally, estimating an association network where the edges represent bivariate correlations (rather than a concentration network where the edges represent partial correlations or conditionally independent associations) might produce a more accurate reflection of the PTSD symptom network structure for this dataset (Christensen, Kenett, Aste, Silvia, & Kwapil, 2018).

Although the results of prior studies estimating PTSD networks are hard to compare because of the variability in sample size, study design, trauma type, and sample characteristics, some consistency between the results presented in the current study overlap with previous findings. Of note, physiological reactivity, a recurring central symptom in the literature, emerged as a highly central symptom in the full sample in this study. Furthermore, the network of the full sample in the current study and the networks in several previous studies have showed a strong association between hypervigilance and startle and a strong association between avoiding thoughts and feelings and avoiding people and places (Armour et al., 2017; Bryant et al., 2017; Epskamp et al., 2016; McNally et al., 2015; Mitchell et al., 2017). There are several interpretations for nodes with strong ties. One interpretation is that these symptoms almost certainly travel together, and the odds of having one symptom greatly increase someone's odds of having the other. Another explanation is that these symptoms are redundant in determining PTSD and/or predicting the co-occurrence of other symptoms. A third interpretation is that these pairs of symptoms are challenging for participants to distinguish from one another. For example, someone experiencing hypervigilance or an exaggerated startle response, which are both symptoms of increased arousal, might endorse both symptoms even though they are experiencing only one because they lack the insight or understanding to differentiate the symptoms properly. Based on theories of PTSD (Foa & Kozak, 1986; Rauch & Foa, 2006), empirical evidence supporting the diagnostic criteria (Wisco et al., 2016) and interview measures (Wilson & Keane, 2004), and anecdotes from clinical experience, it is likely that the main reason, although probably not the sole reason, for such strong associations between these pairs of nodes is that the symptoms frequently travel together.

Interestingly, a pattern emerged between the highly central nodes in the full sample and the highly central nodes in the subsamples. If a node was highly central in the full sample network, but not in the subsample networks, it was connected to the most highly central nodes in the subsample networks. For example, physiological reactivity shared an edge with both nightmares and sleep impairment in the subPTSD network, which were two highly central symptoms in the subPTSD network. This suggests that patterns of associations between nodes can be consistent despite unstable and inconsistent strength, betweenness, and closeness results. Perhaps, eigenvector centrality, which is another method of computing node centrality, would provide more precise quantitative information about these patterns of associations; the eigenvector centrality of a node is the sum of the centrality values of the nodes it is connected with. Hence, a node that shares ties with nodes that are well-connected in the network will have high eigenvector centrality, even if that node is only weakly associated with the others (Borgatti et al., 2013). Eigenvector centrality might be an index that provides more stable information about symptom-level associations and disease progression than the current measures of centrality, particularly closeness and betweeness.

Network Comparison Test

While the PTSD network was too sparse to compare to the other networks using the NCT, the subPTSD network and the trauma-exposed control networks were compared. As expected, the subPTSD network and trauma-exposed control networks differed significantly in global network strength and structure. Counterintuitively, the direction of network structure (i.e., denser) and strength (i.e., stronger) favored the trauma-exposed control network. This finding should be interpreted with caution, as it is likely an artifact of the data. The PTSD symptoms of trauma-exposed controls are expected to relate to each other in a random way, particularly compared to participants with subPTSD and PTSD. As such, there was more variability in the data of trauma-exposed controls, which lead to more connections among symptoms, a more densely connected global network, and a more strongly connected global network.

Strengths, Limitations, and Future Directions

A methodological strength of the study is that it holds the trauma type (natural disaster or accident) constant across the diagnostic categories and population (Latin Americans). In addition, trained personnel conducted diagnostic interviews, which could potentially result in more accurate interpretations of symptom endorsement than self-report questionnaires. However, two related limitations include that the CIDI relies on a binary system of measurement that produces less nuanced measures of symptom severity and frequency than other clinical interviews of PTSD (e.g., PSS-I; CAPS). Additionally, the CIDI is administered by a trained layperson and not a clinician.

Another study strength is that the study uses data from a Latin American sample, helping to expand the field's understanding of PTSD symptom presentation and associations in a sample that is ethnically different from prior studies of PTSD networks. However, networks are based entirely on their input and the results are only as good as the data analyzed. Previous research indicates that *DSM-IV* PTSD criteria perform well in samples of Latin Americans, supporting the use of *DSM-IV* PTSD criteria for this study (Norris et al., 2001a; Norris et al., 2001b). Despite these findings, there may be cultural considerations to take into account, particularly when performing network analyses. *DSM-IV* PTSD symptoms might not be fully reflective of PTSD symptomatology in Latin American communities. In fact, the network of the full sample in this current study, where concentration difficulties was a highly central node, is inconsistent with the qualitative study conducted by Norris and colleagues (2001b) showing that survivors of natural disasters in Latin American communities did not endorse concentration difficulties, foreshortened future, or exaggerated startle without prompting from the interviewee. In addition, there are culturally-bound syndromes that are not part of the *DSM-IV* definition of PTSD that are important idioms of distress in Latin American communities, such as *nervios* (De Snyder, Diaz-Perez, & Ojeda, 2000); *ataque de nervios* (Norris et al., 2001b); and *susto* (Nogueira, Mari, & Razzouk, 2015). In a review article discussing cultural issues in mental health diagnoses, the authors found that *Nervios, Susto* and *Ataques de Nervios* frequently are comorbid with posttraumatic stress disorder in Latin American countries, perhaps because of the somatic and physiological symptoms characteristic of these syndromes (Nogueira et al., 2015). Including symptoms of *Nervios, Susto* and *Ataques de Nervios* as nodes in the network might change the network structure and reflect a more accurate PTSD network for individuals in Latin American communities.

A limitation of this study is that the PTSD networks were modeled using *DSM-IV* PTSD criteria and not the latest PTSD criteria outlined in the *DSM-5*. Several key changes were made to the *DSM-5* symptom criteria for PTSD. First, Criterion C "avoidance and numbing" in the *DSM-IV* was parsed into Criterion C "avoidance" and Criterion D "negative alterations in cognitions and mood" in the *DSM-5*. As such, four symptom clusters exist in the *DSM*-5: Criterion B "re-experiencing", Criterion C "avoidance", Criterion D "negative alterations in cognitions and mood", and Criterion E "arousal." Additionally, significant wording changes were introduced for several symptoms, and three symptoms were added, including two to Criterion D (i.e., negative thoughts about oneself and the world and negative affect after the trauma) and one to Criterion E (i.e., reckless or self-destructive behavior). A diagnosis of *DSM-5* PTSD requires at least one symptom from Criterion B, at least one symptom from Criterion C, at least two symptoms from Criterion D, and at least two symptoms from Criterion E, in addition to meeting Criteria A, F, and G. McLaughlin et al. (2015) recommended subPTSD be defined as fully meeting two or three *DSM-5* Criteria B-E specifications. Once a *DSM-5* based measure of PTSD has been translated to Spanish and validated in Latin American communities, it is recommended that researchers model the PTSD symptom networks using these new criteria, as the results are likely to change with the inclusion of more symptoms.

Generally, more research is needed to understand how variations across studies affect network results. In addition, statistical techniques that model the flow of information through dynamic networks over time are needed. This would help elucidate the direction of information between symptoms and disease progression. Lastly, future studies with large enough samples to reliably estimate clinical subsamples will be important in determining networks of mental illness.

Conceptualizing symptoms of mental illness as networks of directly related entities, as this study does with PTSD, is an alternative approach to the more traditional latent variable model. Although the application of network modeling to psychopathology is in its early stages and still needs to be refined, it offers a radical shift in thinking that has the potential to inspire new hypotheses and lead to advances in our understanding of mental illness. If and when results become more replicable, the results from studies employing network analyses could be used to elucidate specific patterns of comorbidity, improve diagnostic sensitivity and specify, and direct researchers to particular symptoms for more efficacious, targeted interventions.

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APPENDIX A

TABLES AND FIGURES

Table 1. Summary of the PTSD Symptom Network Literature

First Author	Year	Trauma Type	N	Sample Characteristics	DSM Version	PTSD Measure	Strength (Most central)	Strength (Least central)	CS-coefficient (Strength)	Betweenness	Closeness
Armour	2017	Combat or warzone exposure	221	U.S. Military Veterans	DSM-5	PCL-5	Negative trauma-related emotions Detachment Physiological cue reactivity	Avoidance of thoughts Trauma-related amnesia	0.36	Not stable	Not stable
Bryant	2017	Complex trauma	852	Australian hospital trauma patients	DSM-IV	CAPS	Difficulty concentrating Exaggerated startle response Future	Trauma-related amnesia Loss of interest	Not reported	Not reported	Not reported

							foreshortening			
Epskamp	2016	Mixed traumas	359	Women enrolled in community-based substance abuse treatment programs across the U.S.	DSM-IV	PSS-SR	Emotional cue reactivity Irritability/anger Sleep disturbance	Did not report	0.44	Not stable	Not stable
Fried	2017	Mixed traumas	2,782	Treatment seeking veterans, refugees, civilians living in Denmark or the Netherlands	16 symptoms based on DSM-IV	Reformatted HTQ, PSS-SR, and PCL-C	Physiological cue reactivity Detachment Intrusive thoughts	Trauma-related amnesia	0.62	Not stable	Not stable
Gay	2018	Natural disaster;	1,104	Latin Americans	DSM-IV	CIDI	Difficulty concentrati	Trauma-related	0.59	Not stable	Not stable

		Accident /fire		living in Mexico or Ecuador			ng Flashbacks Physiological cue reactivity	amnesia			
McNally	2017	Childhood Sexual Abuse	179	Adults with histories of CSA; 84% female sample	DSM-IV	PSS-SR	Nightmares Future foreshortening Physiological cue reactivity	Trauma-related amnesia	0.13	Not stable	Not stable
McNally	2015	Natural Disaster	362	Wenchuan, China earthquakesurvivors	DSM-IV	PCL-C	Nightmares Difficulty concentrating Intrusive thoughts	Trauma-related amnesia	Analyses were not run	Analyses were not run	Analyses were not run
Mitchell	2017	Combat or warzone exposure	1,458	U.S. Military Veterans	DSM-5	PCL-5	Intrusive thoughts Nightmares	Trauma-related amnesia	0.439	Not stable	Not stable

							Avoidance of reminders				
Moshier	under review	Combat or warzone exposure	357	U.S. Military Veterans	DSM-5	CAPS-5	Intrusive thoughts	Trauma-related amnesia	0.44	Not stable	Not stable
Moshier	under review	Combat or warzone exposure	357	U.S. Military Veterans (same sample as above)	DSM-5	PCL-5	Detachment	Trauma-related amnesia	0.59	Not stable	Not stable
Skogbrott Birkeland	2017	Bombing	190	Norweigan ministerial employees	DSM-IV	PCL-S	Numb	Trauma-related amnesia Avoidance of thoughts	0.28	Not stable	Not stable
Spiller	2017	Complex trauma	151	Treatment seeking refugees and asylum seekers in Switzerland; 70% male sample	DSM-5	PDS	Emotional cue reactivity	Trauma-related amnesia	0.45	Not stable	Stable at CS-coefficient of .25 but not reported

Table 2. Participant Characteristics (*N*=1,104)

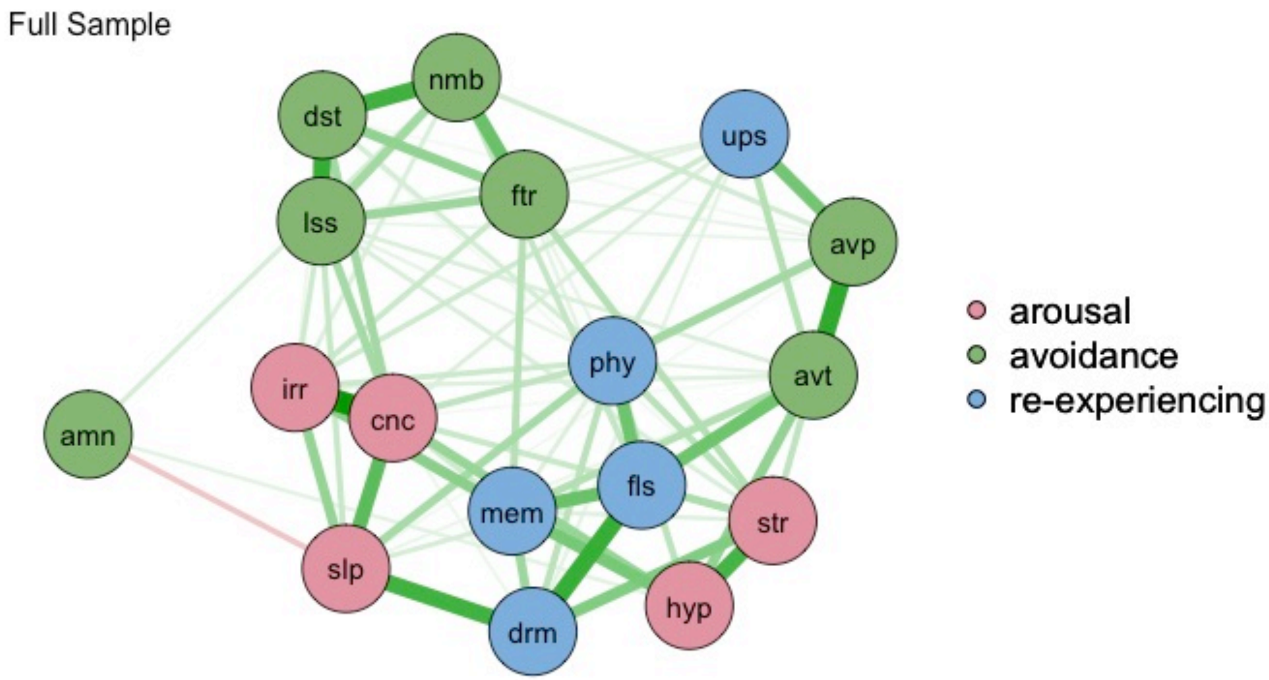
	PTSD *n* = 368	SubPTSD *n* = 368	Controls *n* = 368
	N (%)	*N* (%)	*N* (%)
Trauma type			
Eruption in Ecuador	98 (27%)	80 (22%)	106 (29%)
Eruption in Mexico	29 (8%)	19 (5%)	46 (13%)
Daycare Fire	78 (21%)	53 (14%)	60 (16%)
Flood/Mudslide	163 (44%)	216 (59%)	156 (42%)
Age			
Range	18-94	18-89	18-87
Mean (SD)	40.47 (±14.8)	38.72 (±14.7)	38.81 (±16.4)
Sex			
Male	107 (29%)	137 (37%)	133 (36%)
Female	261 (71%)	231 (63%)	235 (64%)

Table 3. Frequency of PTSD Symptoms Across Groups

PTSD Symptoms	PTSD	SubPTSD	Controls
Intrusive memories	94%	94%	61%
Nightmares	71%	62%	25%
Flashbacks	73%	60%	27%
Feeling upset	54%	36%	14%
Physiological reactivity	81%	57%	29%
Avoiding internal cues	79%	53%	26%
Avoiding external cues	65%	36%	18%
Amnesia	36%	30%	30%
Loss of interest	80%	37%	17%
Feeling distant	81%	34%	20%
Numbing	65%	27%	15%
Future foreshortening	57%	19%	11%
Sleep impairment	71%	55%	23%
Irritability/anger	70%	51%	17%
Concentration impairment	85%	61%	23%
Hypervigilance	96%	95%	73%
Easily startled	84%	64%	33%

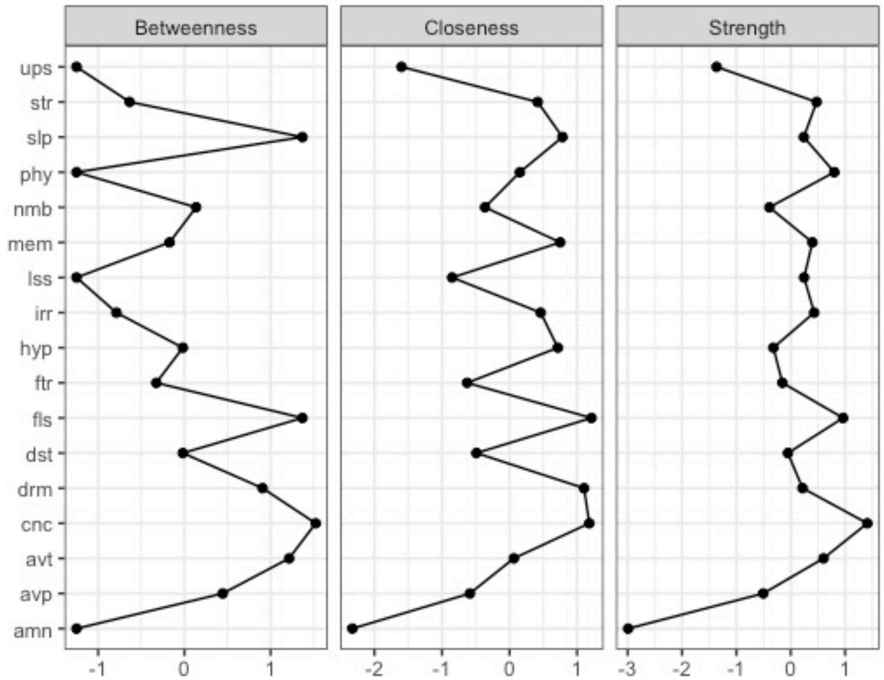
Note: Table 3 contains the percent of participants in the PTSD, subPTSD, and trauma-exposed controls who endorsed each *DSM-IV* PTSD symptom

Figure 1a. Full Sample Network.



Note: Blue nodes represent Criterion B "intrusive recollections;" Green nodes represent Criterion C "avoidant/numbing symptoms;" Red nodes represent Criterion D "hyper-arousal symptoms." Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 1b. Standardized Centrality Indices of Betweenness, Closeness, and Strength for the 17 DSM-IV PTSD Symptoms of the Full Sample Network.



Note: For disconnected nodes, closeness values are not graphed as the distance between disconnected nodes and other nodes in the network is infinity. Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 1c. The Graph Indicates Edge-weights and the 95% Confidence Intervals Around These Edge-weights in the Full Sample Network.

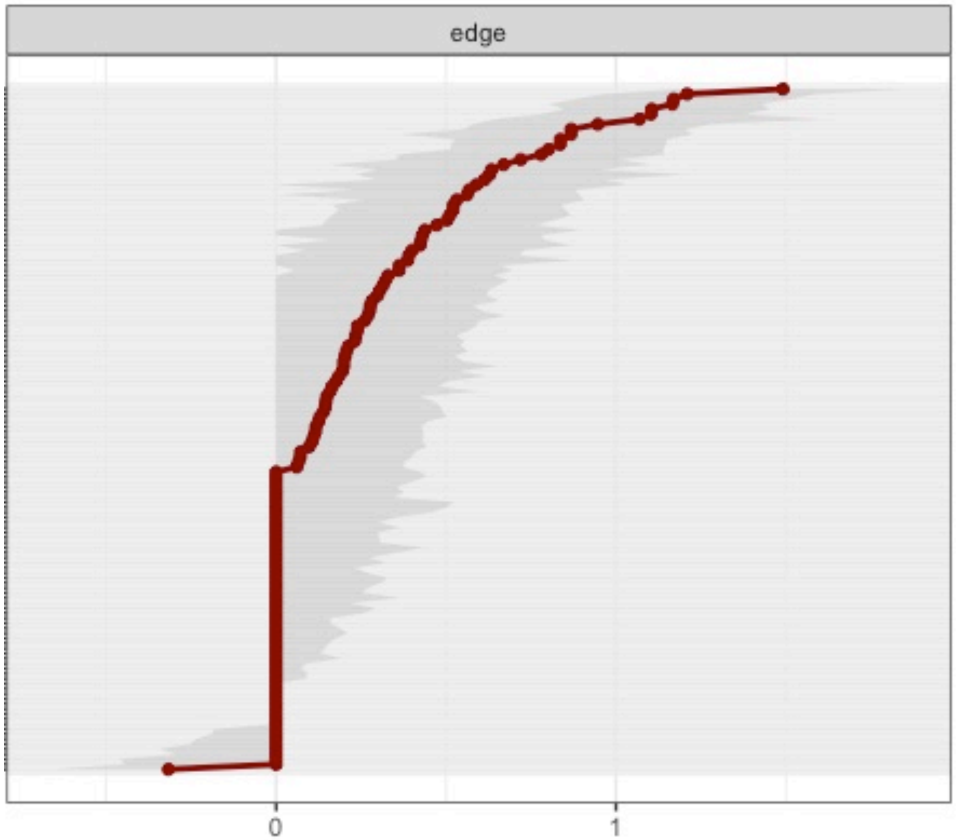


Figure 1d. The Plot Represents the Correlation of Strength, Closeness, and Betweenness of the Full Sample Network with Strength, Closeness, and Betweenness of Networks Sampled While Dropping Participants.

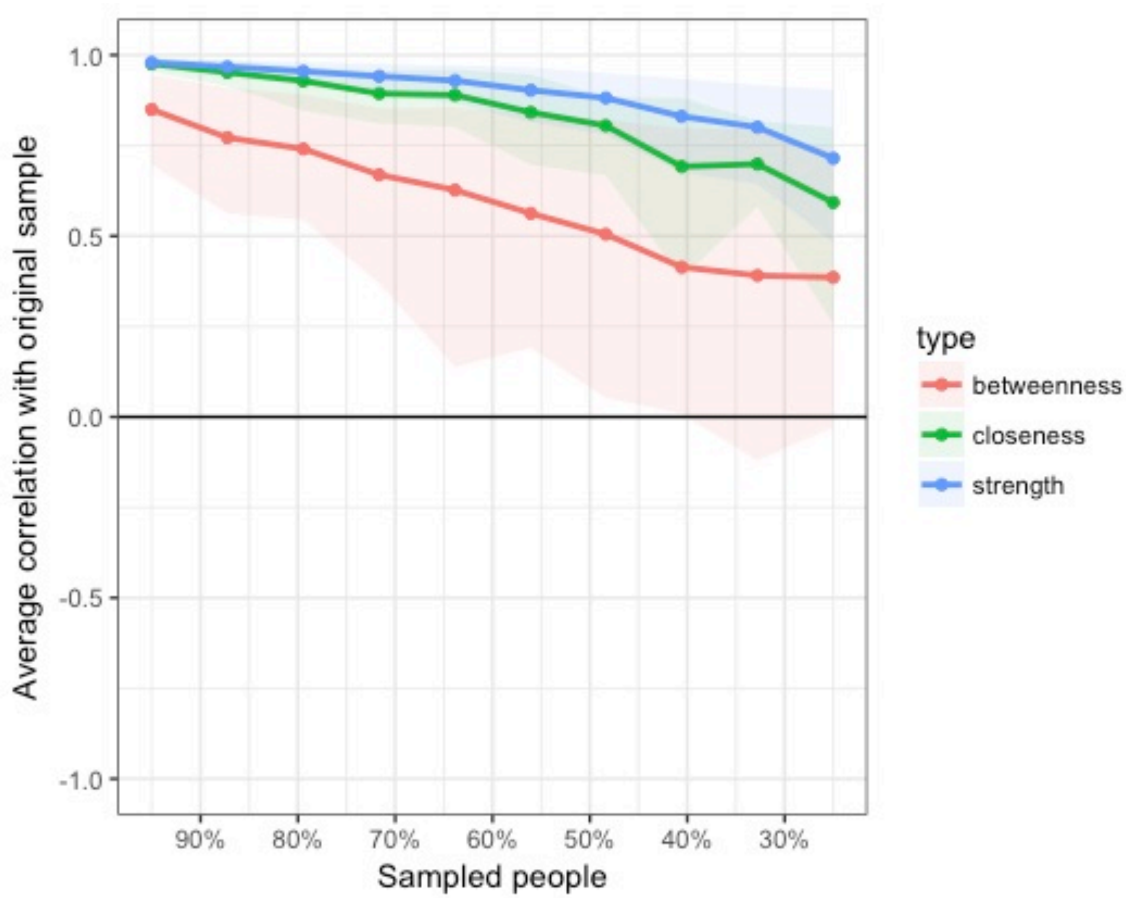
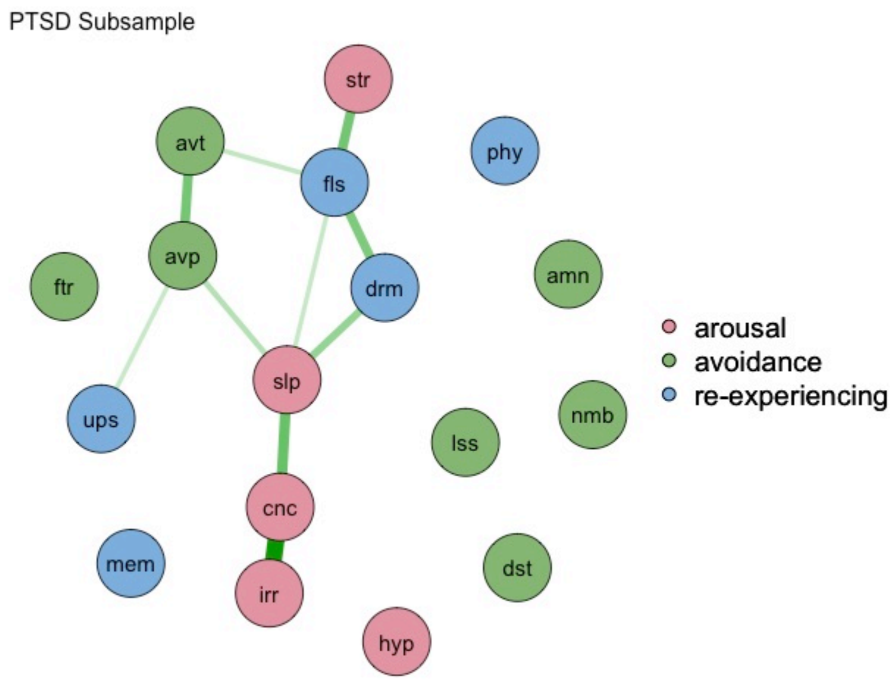
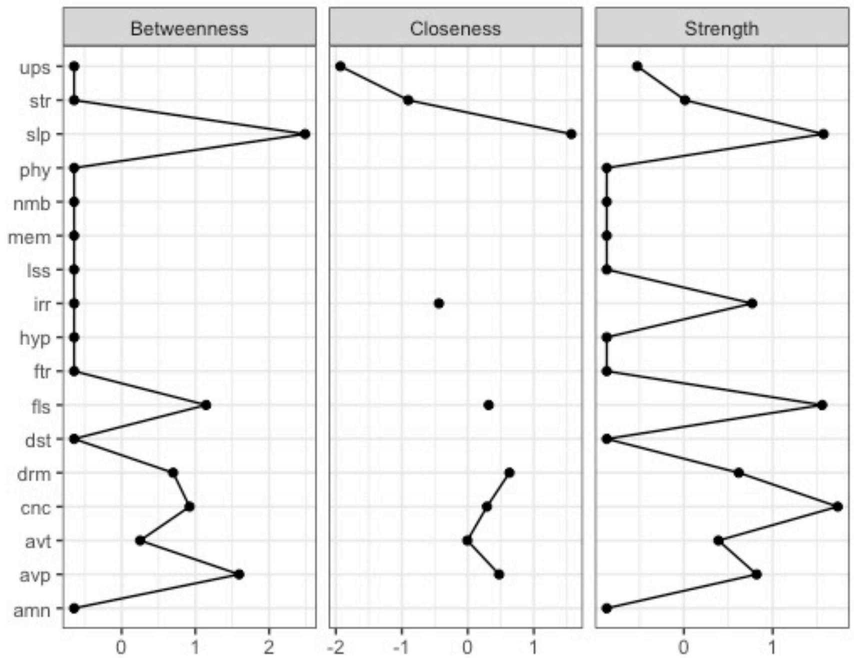


Figure 2a. PTSD Network.



Note: Blue nodes represent Criterion B “intrusive recollections;” Green nodes represent Criterion C “avoidant/numbing symptoms;” Red nodes represent Criterion D “hyper-arousal symptoms.” Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 2b. Standardized Centrality Indices of Betweenness, Closeness, and Strength for the 17 DSM-IV PTSD Symptoms of the PTSD Network.



Note: For disconnected nodes, closeness values are not graphed as the distance between disconnected nodes and other nodes in the network is infinity. Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 2c. The Graph Indicates Edge-weights and the 95% Confidence Intervals Around These Edge-weights in the PTSD Network.

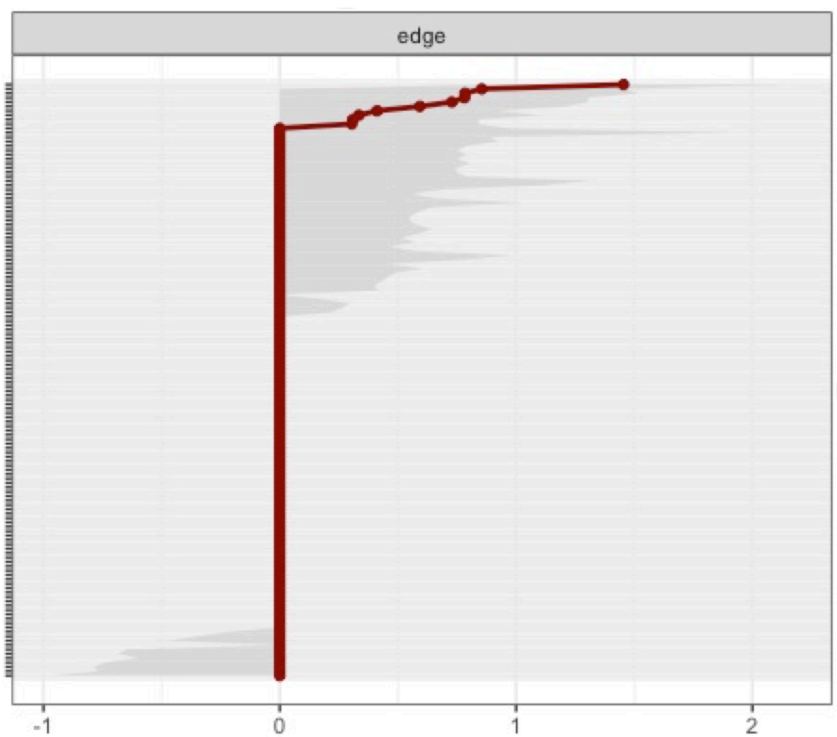
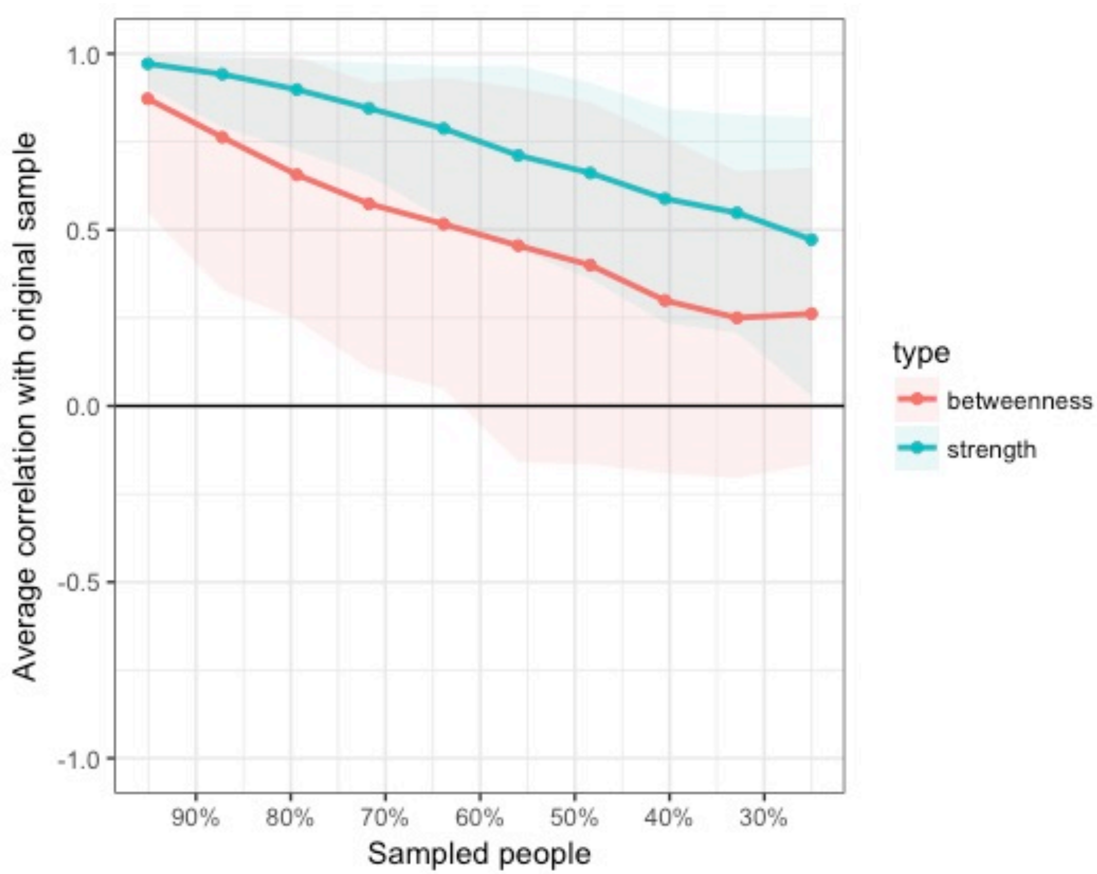
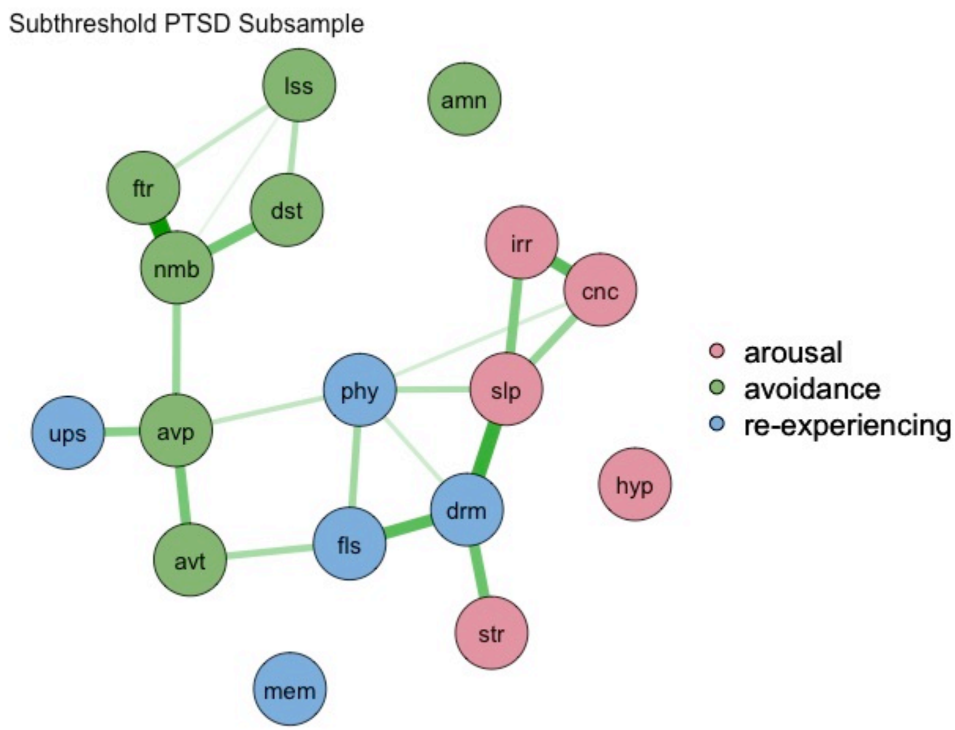


Figure 2d. The Plot Represents the Correlation Between Strength and Betweenness of the PTSD Sample Network with Strength and Betweenness of Networks Sampled While Dropping Participants.



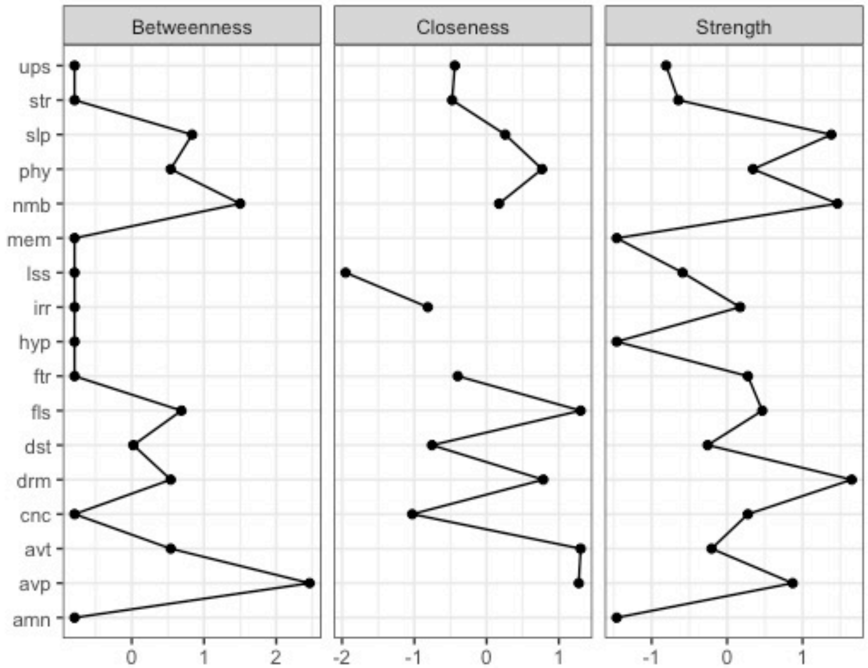
Note: Closeness was not used in these analyses because the network contains disconnected nodes.

Figure 3a. SubPTSD Network.



Note: Blue nodes represent Criterion B "intrusive recollections;" Green nodes represent Criterion C "avoidant/numbing symptoms;" Red nodes represent Criterion D "hyper-arousal symptoms." Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 3b. Standardized Centrality Indices of Betweenness, Closeness, and Strength for the 17 DSM-IV PTSD Symptoms of the SubPTSD Network.



Note: For disconnected nodes, closeness values are not graphed as the distance between disconnected nodes and other nodes in the network is infinity. Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 3c. The Graph Indicates Edge-weights and the 95% Confidence Intervals Around These Edge-weights in the SubPTSD Network.

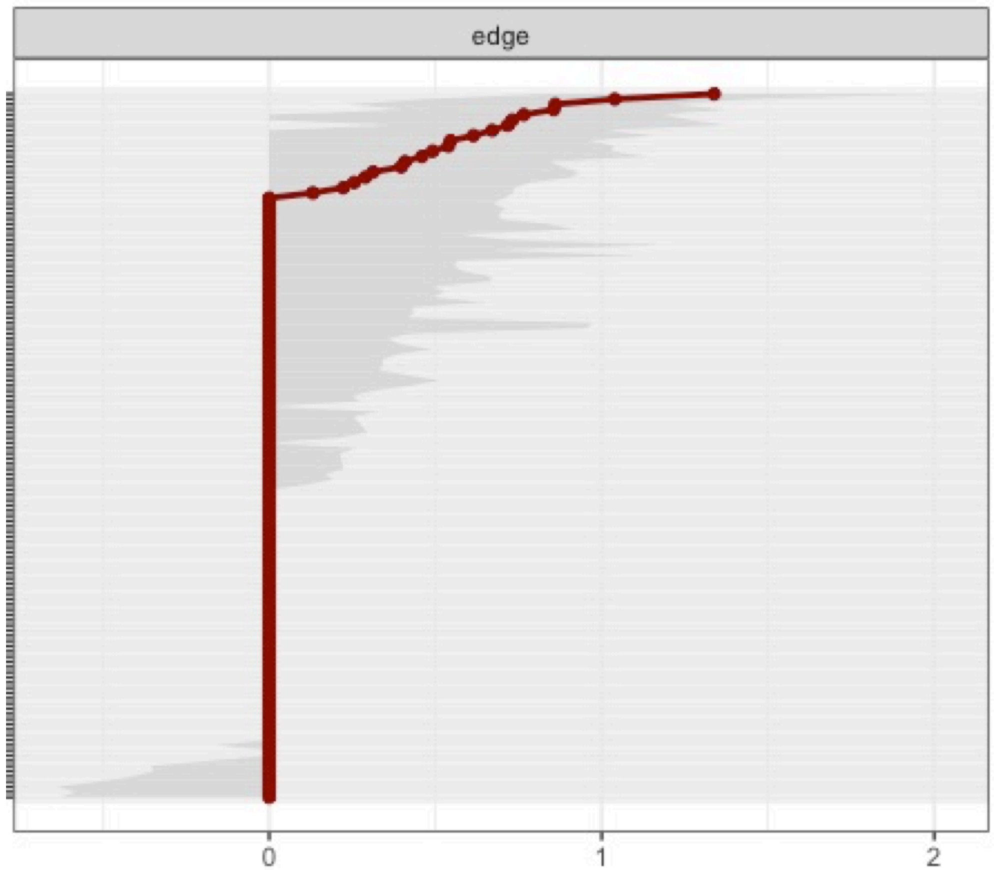
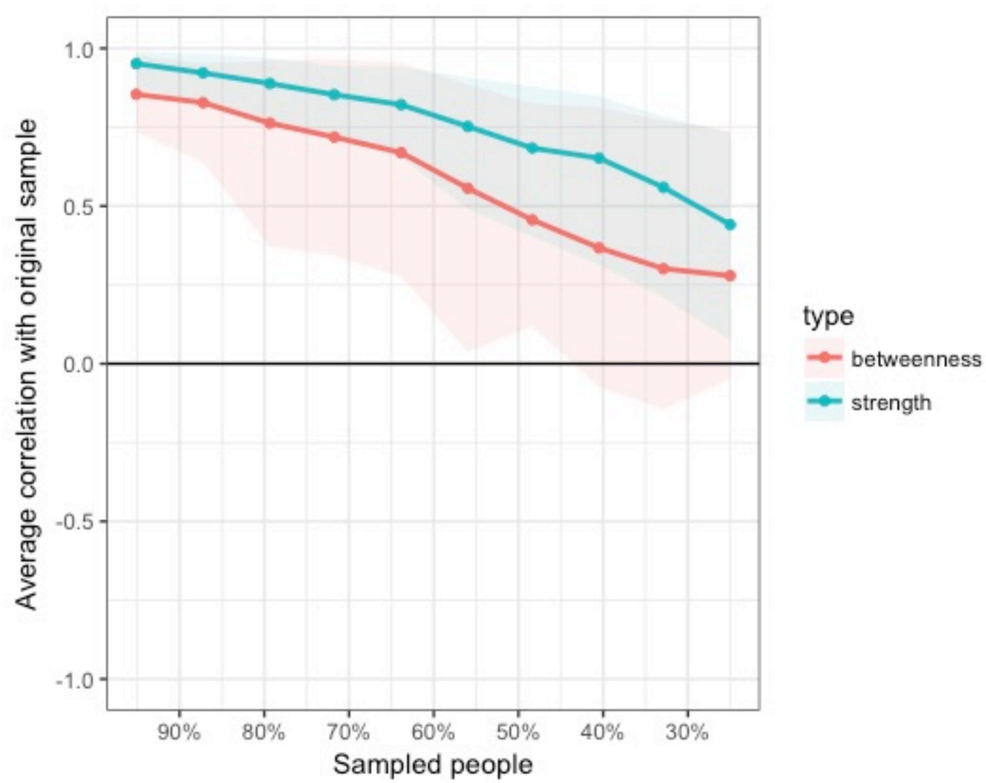
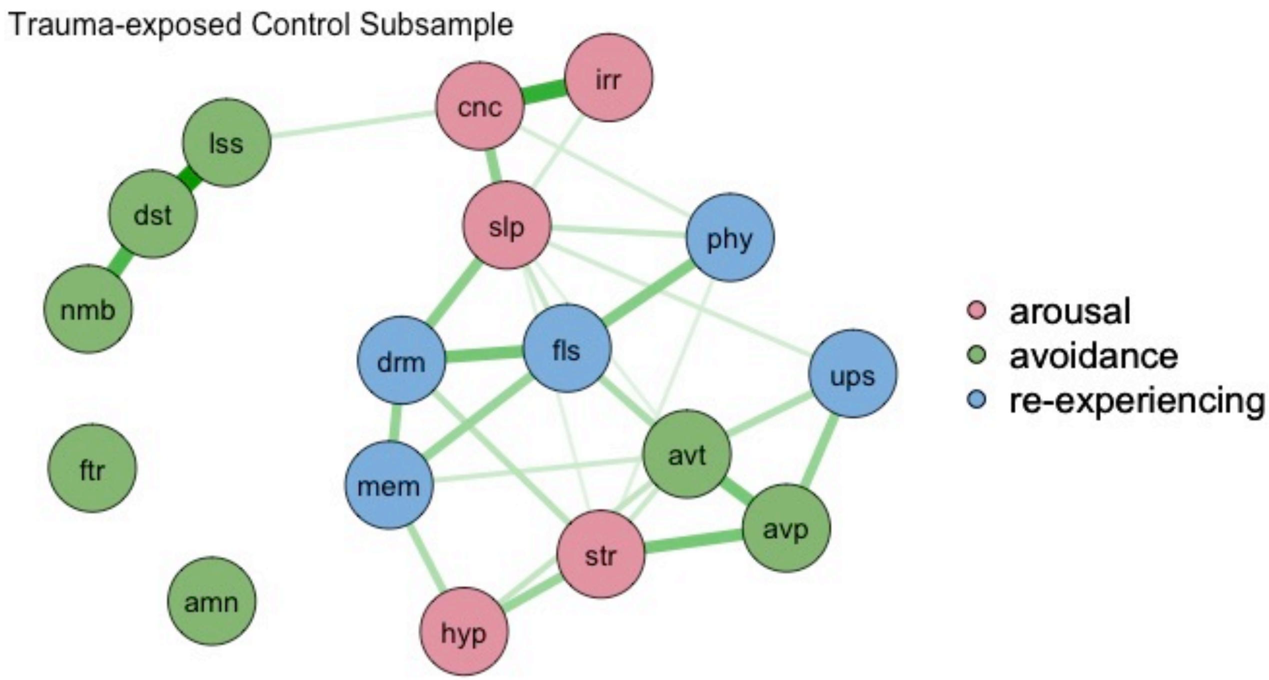


Figure 3d. The Plot Represents the Correlation Between Strength and Betweenness of the SubPTSD Sample Network with Strength and Betweenness of Networks Sampled While Dropping Participants.



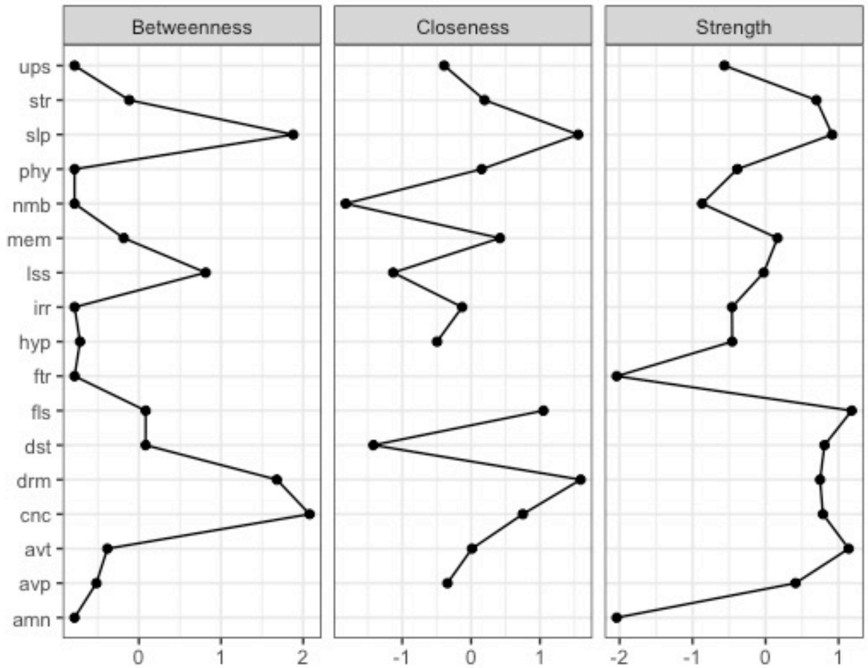
Note: Closeness was not used in these analyses because the network contains disconnected nodes.

Figure 4a. Trauma-exposed Control Network.



Note: Blue nodes represent Criterion B "intrusive recollections;" Green nodes represent Criterion C "avoidant/numbing symptoms;" Red nodes represent Criterion D "hyper-arousal symptoms." Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 4b. Standardized Centrality Indices of Betweenness, Closeness, and Strength for the 17 DSM-IV PTSD Symptoms of the SubPTSD Network.



Note: For disconnected nodes, closeness values are not graphed as the distance between disconnected nodes and other nodes in the network is infinity. Node abbreviations are as follows: *mem* = intrusive memories; *drm* = nightmares; *fls* = flashbacks; *ups* = feeling upset in response to trauma reminders; *phy* = physiological reactivity to trauma reminders; *avt* = avoidance of thoughts and/or feelings about the trauma; *avp* = avoidance of people or places reminiscent of the trauma; *amn* = trouble remembering parts of the traumatic experience; *lss* = loss of interest in previously enjoyed activities; *dst* = feeling distant from people; *nmb* = feeling emotionally numb; *ftr* = future foreshortening; *slp* = difficulty falling or staying asleep; *irr* = felling irritable or angry; *cnc* = difficulty concentrating; *hyp* = hypervigilance; *str* = easily startled.

Figure 4c. The Graph Indicates Edge-weights and the 95% Confidence Intervals Around These Edge-weights in the Trauma-exposed Control Network.

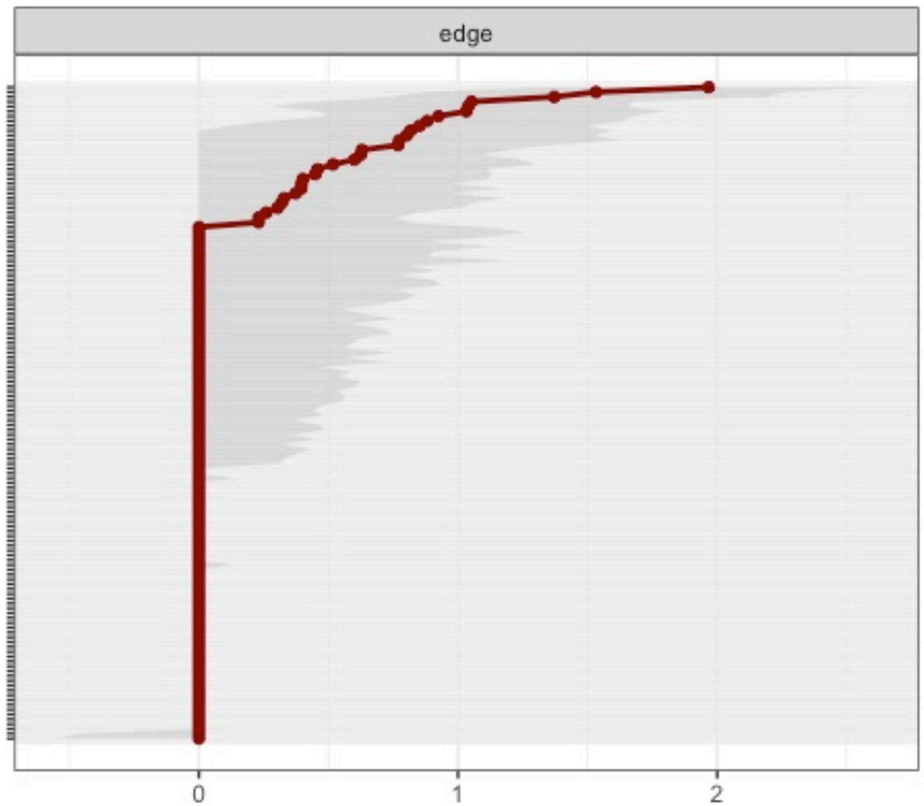
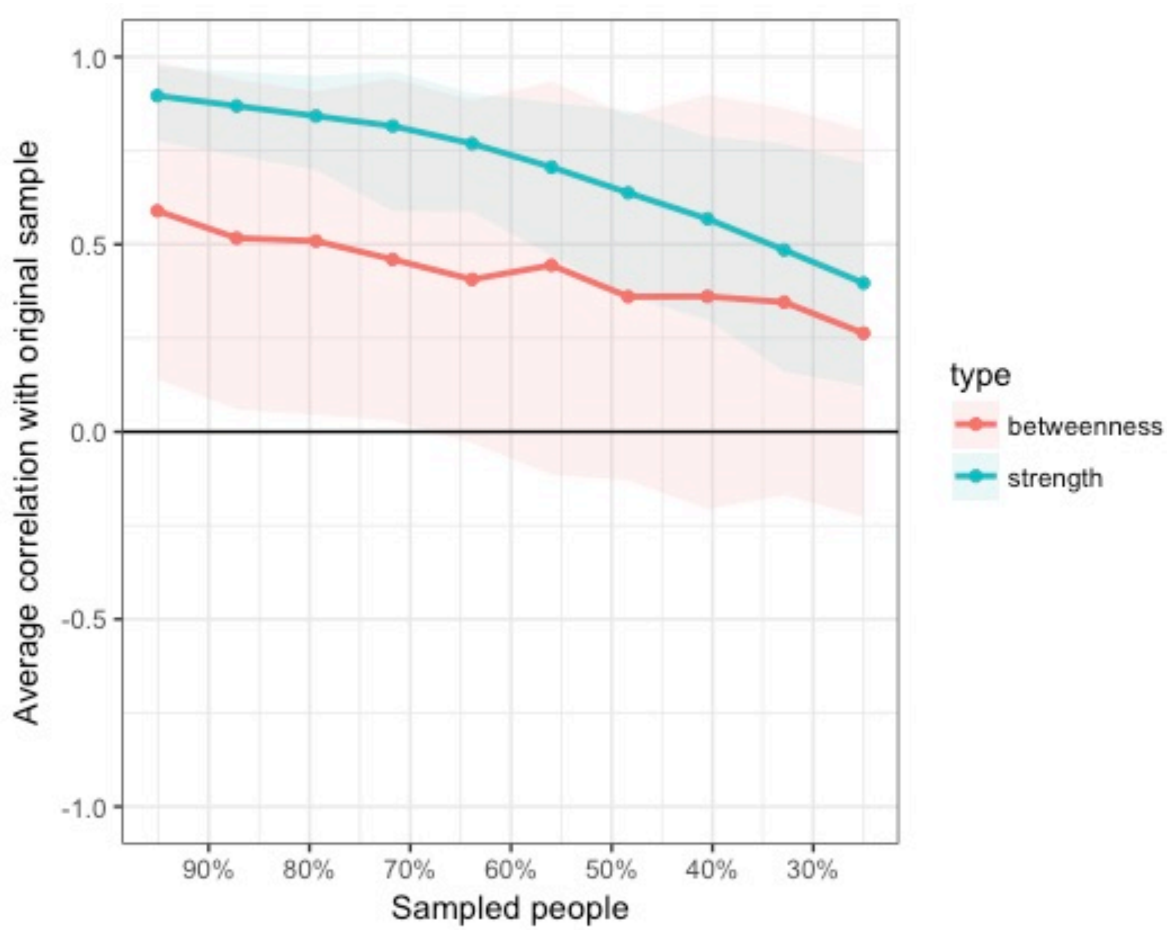


Figure 4d. The Plot Represents the Correlation Between Strength and Betweenness of the Trauma-exposed Control Network with Strength and Betweenness of Networks Sampled While Dropping Participants.



Note: Closeness was not used in these analyses because the network contains disconnected node