Symptom Centrality and Bridge Symptoms in Self-Injurious Thoughts and Behaviors and Posttraumatic Stress Disorder: A Multi-Sample Network Analysis in Trauma-Exposed Adults

by

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Abstract

As self-injurious thoughts and behaviors (SITB) remain a pressing public health concern, research continues to focus on risk factors, such as posttraumatic stress disorder (PTSD). Prior research on SITB and PTSD has primarily been conducted using a regression framework and structural equation modeling to understand the relationship between these constructs and confirmatory factor analysis to understand how individual symptoms are related to one another. This body of literature has demonstrated a consistent, yet weak, relationship between SITB and PTSD and has not offered specific treatment targets. Network analysis has recently been applied to psychopathology as an alternative conceptualization of individual symptom comorbidity between different forms of psychopathology. Using network analysis, symptoms that are most central (i.e. have the strongest and largest number of connections to other symptoms and play the largest role in the network) to the network of SITB and PTSD symptoms, as well as bridge symptoms (i.e., symptoms that connect sets of symptoms in a network) between SITB and PTSD can be identified. In the current study, we used network analysis to further elucidate the relationship between SITB and PTSD symptoms in two distinct samples of individuals. The first sample consists of 349 adults who have experienced a *DSM-5* Criterion A traumatic event and lifetime suicide ideation, and the second sample consists of 1,307 combat-exposed OEF/OIF/OND Veterans. Three PTSD symptoms were identified as the most central in both networks: persistent negative emotional state, physiological reactions of the trauma, and unwanted memories, suggesting that these symptoms have the greatest influence in the overall network of SITB and PTSD. In addition, three symptoms were identified as the strongest bridges in both networks: negative beliefs, risky behaviors, and suicidal ideation, suggesting that these symptoms may play an important role in the development of the co-occurrence of symptoms across SITB and PTSD. We also discuss the most influential symptoms and symptoms that played the greatest bridging role in each sample as well as clinical treatment implications and future directions for research.

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Suicide is a pressing health concern in the United States, as it is the 10th leading cause of death, and the suicide rate significantly increased in 44 states from 1999 to 2016 (Stone et al., 2018). In addition, in 2016, an estimated 9.8 million U.S. adults had serious thoughts of suicide, and 1.3 million U.S. adults attempted suicide (Substance Abuse and Mental Health Services Administration, 2017). To reduce the rate of suicide, many researchers have attempted to identify risk factors for self-injurious thoughts and behaviors (SITB; i.e., non-suicidal self-injury [NSSI], suicide ideation, suicide attempt, and death by suicide; Franklin et al., 2017), and one posited risk factor for SITB is posttraumatic stress disorder (PTSD). Although there is an established and consistent relationship between SITB and PTSD in both civilian and Veteran/military samples (e.g., Jakupcak et al., 2010; Krysinka & Lester, 2010; Panagioti, Gooding, & Tarrier, 2012), the existing literature does not offer consistent or compelling information on symptoms that may contribute to the development of comorbid SITB and PTSD, maintain this relationship, or be amenable treatment targets to reduce symptomology and prevent relapse. As Franklin et al. (2017) discussed, the use of traditional statistical approaches (e.g., linear regression, structural equation modeling) to identify risk factors, including PTSD, has not yielded clinically significant information over the past 50 years of research. Specifically, given the low base rate of suicidal behaviors, identifying factors that increase risk by 10-30% does not offer clinically meaningful information about which individuals will go on to engage in suicidal behaviors (Franklin et al., 2017). However, Franklin et al. (2017) repeatedly emphasize that "traditional risk factors are poor predictors of [suicidal thoughts and behaviors] within the narrow methodological constraints of the existing literature, but it is unknown how these risk factors perform outside of these narrow methodological limits," (p. 217). The authors called for new methods that can lead to better prediction and more clinically relevant information for the prevention of suicide (Franklin et al., 2017). One such method that has yet to be applied to SITB beyond suicidal ideation (Armour, Fried, Deserno, Tsai, & Petrazak, 2017; Simons et al., 2019) is network analysis. Network analysis conceptualizes psychiatric disorders such as PTSD as systems of causally connected symptoms instead of a construct with a common biopsychosocial etiology. Network analysis may offer a new perspective to the relationship between SITB and PTSD that has been lacking from previous literature and may identify treatment targets for individuals with SITB and PTSD.

A Brief Review of SITB and PTSD

Past literature has demonstrated a strong and consistent relationship between SITB and PTSD. In fact, the National Comorbidity Survey illustrated that lifetime incidence of suicidal ideation in patients was PTSD was second only to individuals with depression, lifetime incidence of suicide attempts in patients with PTSD was third to depression and bipolar disorder, and individuals with PTSD were six times more likely to attempt suicide than matched controls (Kessler, Borges, & Walters, 1999; Sareen, Houlahan, Cox, & Asmundson, 2005). Meta-analyses have also shown a moderate, positive association between SITB (including suicidal thoughts and both non-fatal and fatal suicidal behaviors) and PTSD (Bentley et al., 2016; Panagioti et al., 2012; Panagioti, Gooding, Triantafyllou, & Tarrier, 2015). Furthermore, in a systematic review, Krysinka and Lester (2010) concluded that there was a moderate association between suicidal ideation and PTSD after controlling for demographic variables, sexual assault history, traumatic life events, alcohol dependence, a lifetime diagnosis of depression, and attention-deficit hyperactivity disorder. In addition, one study using a nested case-control study design with the entire population of Denmark demonstrated that individuals with a diagnosis of PTSD had a significantly higher rate of suicide compared to individuals without PTSD even after controlling for the strongest identified confounding variables (i.e., depression, marital status, and income quartiles; Gradus et al., 2010). Overall, the relationship between SITB and PTSD is consistent and statistically significant across many samples and is not spurious, as it remains statistically significant after controlling for many other confounding variables in these samples.

SITB and PTSD at the Symptom Cluster and Symptom Level

While it is important to note the consistent and statistically significant relationship between SITB and PTSD at the diagnostic level, it is also necessary to acknowledge that this relationship has not been shown to be clinically significant in the existing literature with its noted methodological limitations (Franklin et al., 2017). In the most comprehensive meta-analysis on risk factors of SITB to date, Franklin et al. (2017) argue that most risk factors that have been identified and examined, including PTSD, are weak predictors of SITB with a weighted mean odds ratio below 3.0. In a more detailed follow-up analysis of the PTSD-relevant papers included in the Franklin et al. (2017) meta-analysis, Bentley et al. (2016) demonstrate that when taking the rate of suicide attempts in the US in a given year for adults (0.4%) and multiplying this by 2.25 (i.e. the increased odds for individuals with PTSD), the probability of a suicide attempt would be 0.9% for the next year. They argue that since the odds of a suicide attempt in the next year are still close to zero, the knowledge of the relationship between PTSD and suicide attempts does not provide meaningful information for clinicians.

Yet, the aforementioned meta-analyses examined PTSD at the diagnostic level. By only examining PTSD at the diagnostic level, the heterogeneity of this diagnosis and the differential relationships between SITB and specific symptoms may be obscured (Krysinska & Lester, 2010). It is possible that certain symptoms or combinations of symptoms more strongly predict SITB. This is particularly salient as PTSD is complex and heterogeneous (Elhai & Palmieri, 2011). Specifically, there are 636,120 possible combinations of PTSD symptoms that could meet diagnostic criteria according to *DSM-5.* Even within symptom clusters for PTSD, there are ample possible combinations (i.e., 31 possible combinations of intrusion symptoms, 3 possible combinations of avoidance symptoms, 120 possible combinations of cognitive-mood symptoms, and 57 possible combinations of hyperarousal symptoms; Galatzer-Levy & Bryant, 2013). Given the heterogeneity of PTSD, it is necessary to look beyond the diagnostic level when evaluating the relationship between SITB and PTSD to determine if certain presentations or particular symptoms of PTSD account for the relationship between SITB and PTSD.

Accordingly, researchers have investigated the relationship between SITB and PTSD symptom clusters and individual symptoms. These findings, however, are less consistent than those at the diagnostic level. For instance, at the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, text revised (DSM-IV-R;* American Psychiatric Association, 2000) symptom cluster level, suicidal ideation, attempts, and death by suicide have been shown to be related to the reexperiencing symptom cluster (Bell & Nye, 2007; Jurisic & Marusic, 2009; Kotler, Iancu, Efroni, & Amir, 2001), the avoidance and numbing symptom cluster (Guerra & Calhoun, 2011; Hellmuth, Stappenbeck, Hoerster, & Jakupcak, 2012), and the hyperarousal symptom cluster (Ben-Ya'acov & Amir, 2004; Panagioti, Angelakis, Tarrier, & Gooding, 2017). Yet, some studies have demonstrated a negative or non-significant relationship between suicidal ideation and the avoidance and numbing symptom cluster of PTSD (Bell & Nye, 2007; Kotler et al., 2001). To our knowledge, only three studies have examined the relationship between suicidality and individual symptoms of PTSD. At the symptom level, using *DSM-IV* criteria, one study found that the symptom of detachment/estrangement (e.g., feeling distant or cut off from other people) was the PTSD symptom with the strongest relationship to suicidal ideation (Davis, Witte, & Weathers, 2013). Another study found that three specific *DSM-IV* symptoms of PTSD (i.e., physical reactions to reminder of the trauma, unable to recall an important aspect of the trauma, and sense of foreshortened future) were significantly related to a suicide attempt following PTSD diagnosis after controlling for common confounding variables (Selaman, Chartrand, Bolton, & Sareen, 2014). Using *DSM-5* (APA, 2013) criteria, Legarreta et al. (2015) also found that suicidal ideation was positively related to experiencing feelings of alienation (the same symptom labeled detachment/estrangement in the Davis et al., 2013 study) and found that suicide attempts were positively related to one of the symptoms identified by Selaman et al. (2014; inability to recall an important aspect of the trauma), and four unique symptoms: avoidance of thoughts and feelings, persistent negative beliefs (a symptom added in *DSM-5*), diminished interest, and feelings of alienation.

Given the inconsistent findings at the symptom cluster and symptom level, it is important to consider the limitations of these studies that may have obscured the full nature of the relationship between SITB and PTSD. As discussed by Franklin et al. (2017), the most significant limitation of all risk factor research for suicide, including the aforementioned studies, is the methodology used. Specifically, these studies have used narrow and homogeneous methods (e.g., linear regression with limited numbers of predictors) and “have not allowed for tests that approximate how [suicidal thoughts and behavior] risk may work in nature,” (Franklin et al., 2017, p. 217). In addition, PTSD symptoms and symptom clusters have been found to be highly correlated with one another across multiple measures of PTSD, and when using multiple factor models of PTSD, leading to problems with multicollinearity and suppression (Elhai et al., 2011; Witte, Domino, & Weathers, 2015). When multiple predictors that are correlated with one another are added into the regression model, the beta weight for each predictor takes into account the pairwise correlations between the predictors as to not multiply count the variance which obscures the unique relationship between each predictor and the dependent variable (Courville & Thompson, 2001). Due to concerns of inflated factor intercorrelations for PTSD factor models, Witte et al. (2015) discuss the need for research using less restrictive models of PTSD symptom structure. It is especially important to utilize new models and approaches to PTSD that can address concerns of multicollinearity when examining the unique relationship of PTSD symptoms on other variables, such as SITB.

With the call for new approaches to studying correlates and risk factors of suicide and for studying PTSD, one approach that may offer insight is network analysis. The conceptual framework of the network approach offers a novel way to observe the nature of the data (Borsboom, 2017a). As will be described in more detail below, network analysis assumes that psychiatric disorders are a network of interrelated symptoms that have a direct effect on one another (Borsboom & Cramer, 2013) and that there are causal relationships between symptoms (e.g., sleep loss causes fatigue in major depressive disorder; McNally, 2016). This approach aligns well with literature suggesting PTSD symptoms are highly related and have a direct causal effect on one another (Mitchell et al., 2017). For instance, intrusion symptoms have been hypothesized to lead to the development of avoidance symptoms (Creamer, Burgess, & Pattison, 1992). In addition, Cramer et al. (2010) argued that network analysis offers an approach that more closely resembles how psychopathology and comorbidity exist in nature (Cramer, Waldrop, van der Maas, & Borsboom, 2010). Specifically, network analysis allows for symptoms to arise from multiple etiological processes that interact with one another and allows for direct relationships between overlapping symptoms in comorbid disorders. It also accounts for the heterogeneity of symptom makeup in disorders (Cramer et al., 2010). Due to the importance of the relationship between individual symptoms in the theory of network analysis, this model allows the full complexity of symptom relations to be examined.

How Do Network Analysis and Traditional Approaches Differ in Their Conceptualization of Psychiatric Disorders?

As mentioned above, in network analysis, psychiatric disorders are conceptualized as systems of causally connected symptoms, where symptoms can be reciprocally reinforcing (Borsboom & Cramer, 2013; Kendler et al., 2011). This perspective is in contrast to the diagnostic perspective that is the basis for the *DSM-5* (APA, 2013). The diagnostic perspective assumes that an unobservable latent entity or "disorder" causes the development and covariance of psychopathology symptoms (McNally, 2016). This assumption implies that symptoms are independent of one another except for their common etiology from the underlying disorder and that covariance between symptoms should not be due to interactions between symptoms, which is known as the assumption of local independence (Borsboom, 2017b; McNally, 2016). Yet, in latent variable modeling (e.g., structural equation modeling, latent class analysis), which is commonly used to examine psychopathology in the diagnostic model, symptoms are commonly modeled as covarying (Cai & Kurokii, 2012). This discrepancy between the theoretical and the statistical approach used in latent variable modeling is the basis of network theorists' objection to this approach in psychopathology. Specifically, network analysis researchers believe that latent variable modeling violates the assumption of local independence that is necessary to conceptualize symptoms of psychiatric disorders as having an underlying common cause (i.e., the disorder; e.g., Borsboom & Cramer, 2013; McNally, 2016). Some argue that this problem is overstated by network theorists because latent variable models can accommodate correlations between items independent of their relationship with the latent variable. However, network theorists argue that when factor models violate the assumption of local independence through direct associations between items, the factor analysis does not offer reliable interpretations for identifying underlying causes (Cramer et al., 2012). Thus, by allowing for associations in the model that are in contrast to the theory of local independence, the model does not accurately test the theory (Cramer et al., 2012). In addition, McNally (2016) discussed that allowing direct relations between symptoms is common and occurs as more often than not, instead of as an exception.

In contrast, network analysis posits that there are direct causal connections between symptoms and does not assume that these connections have the same basis. For instance, the relationships may be biologically based, related to societal norms, a psychological process, or a number of other reasons (Borsboom, 2017b). Those who have applied network analysis to psychopathology argue that symptoms can cause each other and may create feedback loops that cause the state of prolonged symptom activation traditionally conceptualized as a mental health diagnosis (Cramer et al., 2010). For instance, an “activated” symptom may lead to another symptom which can reinforce the initial symptom and/or lead to other symptoms. In this manner, the network of symptoms spreads and the symptoms reinforce or maintain each other.

In sum, network analysis departs from the view that symptoms of a psychiatric disorder have a common etiology and are reflective of an underlying disorder, but rather suggests that the causal interactions between symptoms constitute the disorder (Borsboom, 2017b; Borsboom & Cramer, 2013; McNally, 2016).

Since network analysis assumes that symptoms cause and maintain one another, it is also assumed that the symptoms correlate with one another (McNally, 2016). However, while symptoms may have high correlations with each other, correlation provides insufficient information to draw causal conclusions (Cramer, 2013). As is true with all cross-sectional data, symptoms may be related due to direct effects that are unidirectional or bi-directional or due to shared relationship with another variable; thus, it is not possible for cross-sectional networks to model causality.

It is important to note that network analysis and latent variable models can be mathematically equivalent (Bringmann & Eronen, 2018), yet the conceptual framework of network analysis offers a novel, and arguably more compelling, way to conceptualize psychopathology (Borsboom, 2017a). In other words, the central problem of the latent variable modeling approach is not mathematical, but instead lies in the underlying theory (i.e., that disorders share a common etiology and that symptoms arise from this underlying latent variable independent of one another). Network theorists contend that the important difference between latent variable modeling and network analysis is that network analysis more closely matches theory to statistics (Borsboom, 2017a; Bringmann & Eronen, 2018). In addition, network theorists also posit that the latent variable approach does not offer a compelling explanation for the frequently observed associations between symptoms (Bringmann & Eronen, 2018).

Comorbidity. The network approach to comorbidity also contrasts the latent variable approach. In network analysis, disorders are conceptualized as sets of interrelated symptoms, including sets of interrelated symptoms that are not necessarily classified as psychiatric disorders in the *DSM-5* (e.g., SITB); thus, throughout this document, we use the term *disorder* to reflect the network conceptualization of disorder. In the latent variable approach, the direct relation, such as a large correlation, between two latent variables is indictive of comorbidity. In contrast, in network analysis, the direct relationship between *symptoms* of multiple disorders is the basis for comorbidity, wherein each disorder represents a complex set of interrelated symptoms (Borsboom et al., 2011; Cramer et al., 2010). This allows for hypotheses regarding development, maintenance, and treatment targets of the comorbid disorders (Mitchell et al., 2017). In a comorbidity network, the between-disorder symptom connections are called *bridges* or *bridge symptoms*, which can be both overlapping symptoms between disorders (e.g., fatigue is a symptom of both major depressive disorder and generalized anxiety disorder) or symptoms that have the most connections to symptoms from both disorders (Afazli et al., 2017; Mitchell et al., 2017). Bridge symptoms are considered essential to the co-occurrence of the comorbid disorders and have clinical implications from early stage assessment to post-treatment monitoring (Afazli et al., 2017). In early stage assessment of the course of an identified disorder, bridge symptoms can be used to screen patients for higher risk of developing a comorbid disorder. Bridge symptoms can also suggest symptoms that are integral to the comorbid relationship between disorder that may be prioritized in treatment. By deactivating bridge symptoms, there may be a significant decrease in both within disorder and between disorder symptom relationships (Afazli et al., 2017). Lastly, bridge symptoms can be identified as warning signs of relapse in post-treatment monitoring (Afzali et al., 2017; McNally et al., 2015).

Overview of Key Concepts in Network Analysis

In network analysis, interactions between symptoms comprise the network, where symptoms are *nodes* and the interactions between symptoms are the connections (i.e., *edges*) between nodes (Borsboom, 2017b). The edges between nodes in a network represent the mean connection strength between those symptoms, which can provide information on the symptoms that may be most important within a network (Borsboom & Cramer, 2013). The stronger the connection or correlation, the thicker the edge will be represented in the network. Nodes are only connected when they directly activate one another. Edges can be *directed*, meaning that there is a one-way effect between nodes, or *undirected*, indicating some mutual relationship (Epskamp, Borsboom, & Fried, 2018). Network models also give a visual representation of direct associations between symptoms (Mitchell et al., 2017). The visual representation allows for examination of "clustering" within a network, which occurs when some symptoms have stronger interactions with each other than with other symptoms (Borsboom, 2017b).

Furthermore, network analytic methods provide information on which symptoms are most central to a network. In psychopathology, *node centrality* can demonstrate which symptoms are most essential to a diagnosis, provide the most information about other symptoms in the network, and may also have the greatest implications for treatment, as treating the most central symptoms should, in theory, affect the larger network (Mitchell et al., 2017; van Borkulo et al., 2015). There are five common metrics of node centrality: *degree, strength, expected influence, closeness, and betweenness* (McNally, 2016). Degree refers to the number of edges connected to the node; thus, the higher the degree, the more central the node is in the network. Degree centrality is most informative for unweighted networks, such as social networks that have connections between nodes without any magnitude associated with the connections. Strength signifies the sum of the magnitude of the correlations between nodes. Expected influence is a newer metric proposed by Robinaugh and colleagues (2016) that takes into account negative associations between nodes (as the metric of strength signifies absolute magnitude). Expected influence accounts for both positive and negative associations between nodes as a sum of magnitudes (Robinaugh, Millner, & McNally, 2016). Closeness refers to the mean distance from a node to all other nodes in the network. Betweenness measures how often a node is located on the shortest path between two other nodes (McNally, 2016). Some have raised the concern that low endorsement of a symptom (i.e., restricted variability in responses to an item) will affect metrics of centrality. To account for this, it has been recommended to assess for concerns of distorted centrality by ensuring that there is not a significant correlation between skewness and centrality (McNally, Heeren, & Robinaugh, 2017).

While node centrality identifies highly influential nodes in the network, *node bridge influence* identifies symptoms with the greater influence on the nodes of the other disorder (Heeren, Jones, & McNally, 2018). Node bridge influence examines which nodes act as the strongest bridges between comorbid disorders. Since comorbidity is thought to arise as a consequence of bridge symptoms that can transmit activation from one disorder to another, these symptoms may have important implications for understanding the cooccurrence of disorders (Cramer et al., 2010; Fried & Cramer, 2017). In particular, bridge expected influence provides two metrics for examining the bridges with the greatest influence. First, *one-step bridge expected influence* measures the sum of edge-weights from a given node to all nodes of the opposite disorder with which it is immediately connected (i.e. the direct relationship). Second, *two-step bridge expected influence* takes into account the secondary influence of a node through other associated nodes (i.e. the indirect relationships), as well as the influence from one-step (Heeren et al., 2018; Jones, 2018; Robinaugh et al., 2016). For both types of bridge expected influence, higher values denote greater influence on the nodes of the opposite disorder (Jones, 2018).

Strongly connected networks remain activated due to feedback loops between symptoms. These feedback loops that maintain symptoms are referred to as hysteresis. Symptoms continue to activate one another even after the initial triggering event from the external field has subsided

(Borsboom, 2017b; Cramer, 2013; Cramer et al., 2016). Borsboom (2017b) argues that hysteresis is the final phase of the development of psychiatric disorders from a network perspective and the phase that maintains the disorder until interventions are applied (Borsboom, 2017b). In this view, phase 1 is when there are no symptoms present, but there is vulnerability for symptoms. In phase 2, an event in the external field triggers one or more symptoms in the network. In phase 3, symptoms activate one another in the network and activation continues to spread through the symptom connections. Phase 4 is when hysteresis occurs, in which symptoms maintain each other. This concept outlines why the removal of a triggering external event may not de-activate the network (Borsboom, 2017b). Thus, in order to deactivate a network, highly central symptoms that activate other symptoms need to be treated. This concept can also be extended to comorbidity networks, wherein phase 3 bridge symptoms activate otherwise non-related symptoms that lead to the development of a comorbid disorder. In a network that includes symptoms from multiple disorders, hysteresis functions in the same manner in that symptoms would continue to maintain both disorders until bridge symptoms are deactivated.

While advocates of network analysis in psychopathology discuss the advantages of identifying nodes with high centrality and identifying bridge symptoms from cross-sectional, symptom-level data, others have warned against overstating the clinical relevance of highly central symptoms in a network. Fried et al. (2018) contends that while centrality may be an effective heuristic for identifying treatment targets, there are possible explanations for high centrality that would not translate to a symptom being amenable to intervention. For instance, if a symptom is activated by numerous other symptoms, it may have numerous connections but be an endpoint instead of a catalyst. In addition, if a symptom is highly central but is part of a feedback loop, an intervention targeting only that symptom may not have lasting effects, if that symptom is continuously activated by other symptoms in the network. Lastly, a symptom with high centrality, whether or not it causally impacts other symptoms in the network, may be difficult to treat and thus have low clinical utility (Fried et al., 2018). Taking into consideration these limitations, champions of network analysis suggest researchers use centrality metrics to form realistic and testable hypotheses regarding the relationship between symptoms and the onset, maintenance, and treatment of disorders that are not accommodated by the assumptions of latent variable modeling (Borsboom & Cramer, 2013; Cramer et al., 2010; Forbes, Wright, Markon, & Krueger, 2017). Thus, symptoms that are highly central to a network can be identified as potential primary targets for intervention in future studies designed to test how de-activating central symptoms affects the broader network of symptoms.

Network Analysis in PTSD

While network analysis has only recently been applied to psychopathology, there have been several recent papers exploring the network structure of PTSD (e.g., Afzali et al., 2017; Frewen, Schmittmann, Bringmann, & Borsboom, 2013; McNally et al., 2015; von Stockert, Fried, Armour, & Pietrzak, 2018). Three recent studies with large samples evaluating *DSM-5* symptoms of PTSD found similar symptoms with the highest strength centrality. All three studies identified persistent negative emotional state and inability to experience positive emotions as symptoms with high centrality (Benfer et al., 2018; Mitchell et al., 2017; von Stockert et al., 2018), and two of the studies also identified avoidance of thoughts and avoidance of external reminders as central nodes in the network (Mitchell et al., 2017; von Stockert et al., 2018) .

Although there are ample studies examining the network structure of PTSD, there are fewer studies examining comorbidity of disorders and correlates of PTSD in a network framework. Researchers have begun to use network analysis to study the comorbidity of PTSD with commonly co-occurring psychiatric disorders, such as alcohol use disorders (Afzali et al., 2016), depression (Afzali et al., 2017; Frewen, Schmittmann, Bringmann, & Borsboom, 2013), and others (e.g., borderline personality disorder; Knefel, Tran, & Lueger-Schuster, 2016). These studies have highlighted the important insights that network analysis can provide for comorbidity research. For example, in a study examining the comorbidity between PTSD and alcohol use disorders, Afzali et al. (2016) identified four highly central symptoms (i.e., time dedicated to alcohol consumption, having experienced physical or mental health problems as a result of alcohol use, problems at work resulting from alcohol use, and being highly distressed when reminded of the traumatic event) and four bridge symptoms (i.e., alcohol use in dangerous situations, physical or mental health problems as a result of alcohol use, loss of interest or reduced social activities, and reckless/self-destructive behavior). Informed by these findings, future research can test the hypotheses that 1) treatment response is related to the presence and persistence of these four highly central symptoms; 2) bridge symptoms are primary targets for preventing the emergence of the comorbid disorder; and 3) the likelihood of relapse may be related to both central and bridge symptoms due to the role of central symptoms in the maintenance of disorders and the role of bridge symptoms in spreading activation through the network (Afzali et al., 2016; Borsboom, 2017b). Since one symptom (i.e., physical or mental health problems resulting from alcohol use) was identified as both a symptom with high centrality and a bridge symptom, this symptom would be a particularly important target for future risk assessment and intervention studies.

When evaluating the comorbidity of PTSD and major depressive disorder, Afzali et al. (2017) demonstrated that both overlapping and non-overlapping symptoms can have major bridging roles between disorders. For instance, when including overlapping symptoms in the network, sleep problems, irritability, and concentration difficulties emerged as the bridge symptoms. When overlapping symptoms were removed, the bridge symptoms that emerged were feelings of guilt, flashbacks, thinking about death/sense of foreshortened future, and feelings of hopelessness (Afzali et al., 2017). By examining the features of both overlapping and non-overlapping bridge symptoms, Afzali et al. (2017) concluded that that the comorbidity between PTSD and major depressive disorder is characterized by distress and negative emotionality. In addition, the authors proposed that assessment of these bridge symptoms may help identify patients with PTSD who are at greater risk for developing major depressive disorder and for relapse once treatment has concluded (Afzali et al., 2017).

To date, only two studies have included both suicidal ideation and PTSD in network analysis. The first study found that when including seven correlates of PTSD, such as active suicidal ideation in the last two weeks, in a network of *DSM-5* PTSD symptoms, there was a positive partial correlation between the PTSD symptom of risky behaviors and active suicidal ideation (Armour et al., 2017). This finding is consistent with prior literature illustrating that externalizing psychopathology predicts suicidal thoughts and behaviors (Witte, Gauthier, Huang, Ribeiro, & Franklin, 2018). Of note, the Armour et al. (2017) study did not include other SITB symptoms or report centrality metrics for the network that included correlates of PTSD. Without centrality metrics, it is unknown if any of the seven correlates included in the PTSD network, such as suicidal ideation, were among the strongest in the network. As this network was not modeled as a comorbidity network, bridge expected influence was not assessed. A second study examined risk and protective factors of suicidal ideation using a network framework (Simons et al., 2019). This study found that suicidal ideation was positively associated with severity of depression, severity of PTSD, and severity of alcohol use disorder and was negatively associated with distress tolerance and social support. In this study, the authors examined a second network in which they constructed four symptom clusters using *DSM-IV* PTSD symptoms and reported that only the negative alterations in mood and cognition cluster was positively associated with suicidal ideation in the partial correlation network. However, there were some major limitations of this study. First, it did not include *DSM-5* PTSD symptoms. Given that new symptoms were added to *DSM-5* criteria for PTSD (i.e., distorted blame; persistent negative emotional state; and risky, reckless, or self-destructive behavior; Friedman, 2013) and that one of these new symptoms has been shown to be related to SITB in both meta-analyses (Witte et al., 2018) and one network analysis (Armour et al., 2017), it is important to examine the network associations of SITB and PTSD using current diagnostic criteria. Second, the authors did not assess centrality of nodes. The authors stated that since the networks included both risk and protective factors it would have complicated the interpretation of centrality metrics, such as strength. However, since risk factors were positively correlated with suicidal ideation and protective factors were negatively associated, using expected influence would have accounted for these relationships. Lastly, the authors used disorder severity (i.e., total scores of symptoms) in the first network and created symptom clusters in the second network instead of looking at individual symptoms. This decision limits the ability to understand the unique relationship between symptoms of disorders, such as PTSD, and suicidal ideation. While these two previous studies used clinical samples of Veterans, both samples were relatively small (i.e., 221 and 276, respectively). In addition, neither study included other SITB variables, such as suicide intent, planning, attempts, or NSSI behaviors. Thus, it remains unknown how other suicide variables may relate to PTSD in a network framework.

Although prior network analysis research with PTSD has shown encouraging new developments and offers a model for future studies, there are noted areas for improvement. Authors of a recent network analysis for PTSD argued that previous studies have only estimated networks of PTSD in one sample, which limits the authors' ability to comment on generalizability across populations, trauma types, and levels of clinical severity (Fried et al., 2018). Similarly, Forbes et al. (2017) maintained that the exploratory nature of networks in psychopathology, the large number of parameters estimated in these networks, and the conditionally independent relationships between symptoms may lead to overfitting data and reduce the ability to replicate networks. Regarding PTSD, there are 20 nodes in *DSM-5* and 190 possible edges between nodes (Forbes et al., 2017). The number of parameters estimated in networks only gets larger when considering comorbid symptoms or disorders, amplifying potential pitfalls. Fried et al. (2018) noted that many studies evaluating the network structure of PTSD have used relatively small samples of around 200 individuals (e.g., Armour et al., 2017; Birkeland & Heir, 2017; Knefel et al., 2016). With the large number of parameters in PTSD networks and even more parameters in comorbid networks, larger sample sizes are needed to have adequate sensitivity and specificity (Epskamp et al., 2018). In addition, Fried et al. (2018) noted that many studies have examined PTSD network models in unselected community samples (e.g., adult Facebook users in Afzali et al, 2017), which may limit the symptom severity represented in the samples. In addition, many studies evaluating PTSD networks use *DSM-IV* symptoms of PTSD (e.g., Afzali et al., 2017; Bryant et al., 2016; Fried et al., 2018; Simons et al., 2019), which limits the ability to draw conclusions about the nature of PTSD symptoms as conceptualized in the *DSM-5*.

The Current Study

The current study used the principles of network analysis to better understand the relationship between SITB and PTSD. Network analysis can illuminate unique aspects of the comorbidity between SITB and PTSD compared with traditional methodologies. Specifically, identifying symptoms with high centrality may offer important information about the development and maintenance of symptoms, as well as offer hypotheses for key symptoms to include in risk assessment and to target for intervention. In addition, identifying bridge symptoms may help elucidate the specific symptoms that contribute to the development of comorbidity. To our knowledge, there are no existing studies that evaluate the comorbidity of SITB and PTSD in a network model. While prior studies have demonstrated partial correlations between suicidal ideation and PTSD in network models (Armour, 2017; Simons et al., 2019), none have examined centrality or bridge symptoms between comorbid SITB and PTSD that would enable them to offer clinically relevant recommendations.

To account for prior limitations noted by Fried et al. (2018), the current study utilized two large samples drawn from distinct populations (i.e., a trauma-exposed community sample with a lifetime history of suicidal ideation and a sample of trauma-exposed, treatment-seeking US Veterans) and used *DSM-5* criteria for PTSD. As network analysis operates with unique assumptions from latent variable models and claims to more closely resemble how psychopathology symptoms exist in nature, hypotheses cannot be based on previous studies using regression framework. Furthermore, network analysis is an exploratory approach, as opposed to a predictive approach to psychopathology. Accordingly, researchers evaluating PTSD networks and comorbid networks have suggested possible implications of their findings but do not offer a priori hypotheses (e.g., Afzali et al., 2017; Fried et al., 2018). Likewise, this study took an exploratory approach to SITB and PTSD to identify the symptoms with highest centrality and the bridge symptoms between the symptoms related to SITB and those of *DSM-5* PTSD.

Methods

Sample 1

Participants and procedure for Sample 1 have been previously described (See Zuromski, Cero, & Witte, 2017 for more detail).

Participants and procedure. Participants were English-speaking US residents recruited through Amazon's Mechanical Turk (MTurk). MTurk allows researchers to recruit workers to participate in online research surveys for pay (Shapiro, Chandler, & Mueller, 2013). There are noted advantages of using MTurk workers over traditional undergraduate samples, including a more diverse sample in terms of demographic variables, more rapid data collection, and ability to screen large numbers of potential participants for variables of interest. For example, the current data from Zuromski et al. (2017), used a screening questionnaire to assess lifetime suicidal behavior to recruit participants that were more likely to have an elevated suicide risk. Of the 1,940 MTurk workers screened, 1,029 (54.04%) were invited to participate based on their endorsement of a lifetime history of suicide ideation, plan, or attempt. Of those invited to participate, 589 (57.24%) participated in the study. Data were collected over six waves, asking participants to complete surveys every three days for a 15-day period. Surveys were administered on Qualtrics with links available through MTurk.

For the purposes of this study, only data from Wave 1 were utilized, as measures related to PTSD were only administered at Wave 1. Participants received monetary compensation for their participation. They earned $0.10 for completing the initial screening questionnaire and earned $2.50 for completing Wave 1, which took approximately 30 minutes. For this study, only individuals who completed Wave 1, met *DSM-5* Criterion A for a traumatic event, and had at least partial data on the SITB and PTSD symptom measures were included in the network (see below for more detail), which yielded a final sample of 349 individuals. Sample demographics are presented in Table 1. Descriptive statistics for SITB and trauma variables are presented in Tables 2 and 3.

Measures.

Life Events Checklist for DSM–5 (LEC-5; Gray, Litz, Hsu, & Lombardo, 2004; Weathers et al., 2013). The LEC-5 is a two-part, self-report questionnaire that was administered at baseline to assess trauma exposure. During part one, participants were asked to indicate if they have experienced, witnessed, learned about, or were repeatedly exposed to 16 potentially traumatic events, as well as any other extraordinarily stressful event not listed in the survey. Participants could select as many traumatic events as applied. In part two, participants identified the worst event they endorsed and provided additional information about the event in a brief narrative. These narrative responses were then coded by two independent graduate clinician raters to assess if they meet *DSM-5* Criterion A for PTSD. There was 93.7% agreement (k=.78, p<.001) between raters on initial ratings. Disagreements were resolved through discussion and consensus between raters. In this sample, 349 individuals endorsed an experience that met Criterion A for a traumatic event.

PTSD Checklist for DSM–5 (PCL-5; Weathers et al., 2013). The PCL-5 is a 20-item, self-report measure that assesses *DSM–5* symptoms of PTSD in the past month. For each symptom, respondents are asked to rank the severity of distress associated with each symptom from 0 (*not at all*) to 4 (*extremely*). The PCL-5 has been shown to have strong psychometric properties in samples of trauma exposed undergraduates, including high internal consistency (α =

.94-.95) and good test-retest reliability (r=.91, 95% CI [.71,.89] for total scores). In addition, the PCL-5 demonstrated adequate fit with the four-factor *DSM-5* model of PTSD according to a confirmatory factor analysis (Blevins, Weathers, Davis, Witte, & Domino, 2015). The PCL-5 demonstrated similarly good psychometric properties in two independent samples of Veterans receiving treatment in the Veterans Affairs Medical Centers (VAMC; Bovin et al., 2016). In Sample 1, internal consistency of this scale was excellent (Cronbach's α = .96).

Depression Symptom Inventory - Suicide Subscale (DSI-SS; Joiner, Pfaff, & Acres, 2002). The DSI-SS is a four-item, self-report measure that assesses suicide ideation, plans, and impulses on a four-point scale. Participants were asked to consider their thoughts and behavior over the past two weeks. Previous studies have demonstrated the acceptable psychometric properties of this measure (e.g., Joiner et al., 2002; Metalsky & Joiner, 1997). Participants who endorsed a three or higher on this measure, indicating greater than low risk (Joiner et al., 2002) were immediately presented with instructions on how to make a coping card (Joiner, Van Orden, Witte, & Rudd, 2009; Rudd, Joiner, & Rajab, 2004). For analyses, a composite score of the DSI-SS was used in an effort to reduce the number of parameters in the model. Prior studies have also used the composite score from the DSI-SS (e.g., Witte, Holm-Denoma, Zuromski, Gauthier, & Ruscio, 2017). In Sample 1, internal consistency of this scale was good (Cronbach's α = .91).

Additional SITB Items. Additional items assessed if participants had prior experience with past suicide attempts and NSSI. These items assessed suicide attempt history (i.e., *How many times in your lifetime have you made an attempt to kill yourself during which you had at least some intent to die?*), medical response required for most lethal attempt (i.e., *Thinking about the most lethal attempt, describe the level of medical attention it required*), and intent to die during most recent attempt (i.e., *At the time, to what extent did you intent to die).* In addition, one item from Inventory of Statements about Self-Injury (ISAS; Klonsky & Olino, 2008) was included (i.e., *Please estimate the number of times in your life you have intentionally [i.e., on purpose] performed each type of non-suicidal self-harm [e.g., 0, 10, 100, 500]*: *banging/hitting self, biting, burning, carving, cutting, wound picking, needle-sticking, pinching, hair pulling, rubbing skin against rough surfaces, severe scratching, and swallowing chemicals*). This item was used to create two unique items: one item collapsed the numbers of instances of NSSI behaviors across behavior types and the second item counted how many different types of NSSI behavior the individual had engaged in in his/her lifetime.

Participant Characteristics. Basic demographic information was collected for participants, including age, gender, race, ethnicity, household income, relational status, and occupation.

Sample 2

Participants and procedure for Sample 2 are from the Project VALOR (Veterans' After-discharge Longitudinal Registry) dataset and have been previously described (See Rosen et al., 2012). This sample was previously used to examine the network structure of PTSD symptoms in the aforementioned Mitchell et al. (2017) study. However, there are some noted differences between the Mitchell et al. (2017) study and the current study. First, the current study examined a network of PTSD symptoms and SITB items. Thus, the centrality metrics indicate the symptoms most central to the overall network of PTSD and SITB as opposed to symptoms that are most central to the PTSD network. In addition, the current study identified bridge symptoms between PTSD symptoms and SITB symptoms. Furthermore, the Mitchell et al. (2017) study included all Veterans who completed the PCL-5 at Wave 2. The current study added the inclusion criterion of meeting Criterion A for a traumatic event according to clinician's rating on the Structured Clinical Interview for *DSM-5* (SCID-5).

Participants and procedures. Participants were combat-exposed Operation Enduring Freedom (OEF)/ Operation Iraqi Freedom (OIF)/ Operation New Dawn (OND) Veterans who have utilized clinical services in the Department of Veteran Affairs (VA) health care system. Inclusion criteria for this study included being separated from activity duty after serving in OEF/OIF/OND or having completed at least one Reserve/Guard deployment in support of OEF/OIF/OND; having undergone a mental health evaluation at a VA facility between July 2008 and December 2009; and not being currently enrolled in a clinical trial. Women (1:1) and Veterans with a recent diagnosis of PTSD in their medical records (3:1) were oversampled. Diagnostic, demographic, and service-related data were collected from existing medical and military records. Data on symptoms of PTSD, potential risk factors, and other diagnostic information was collected through telephone interviews with a doctoral level clinician and a self-administered questionnaire completed online or by mail. Follow-up data were collected every year for five years through medication records and phone interviews. For the purposes of this study, only data from Wave 2 of the study, when the PCL-5 was administered, were utilized. According to Wisco et al. (2014), 4,391 potential participants were contacted by phone. Of those contacted, 2,712 (61.8%) consented to participate and of those, 1,649 completed questionnaires and a telephone interview. For the present study, inclusion criteria were Veterans who met Criterion A for a traumatic event per *DSM-5* and completed the below SITB and PTSD measures. The final sample for the present study was 1,307 Veterans. Sample demographics are presented in Table 1. Descriptive statistics for SITB and trauma variables are presented in Tables 2 and 3.

Measures.

LEC-5 (Gray, Litz, Hsu, & Lombardo, 2004; Weathers et al., 2013). The LEC-5 was completed as part of the self-administered questionnaire packet. Only Part 1 of the LEC-5 was administered at Wave 2; thus, Criterion A exposure could not be determined using this measure, as was done in Sample 1. Part 1 of the LEC was used to describe the types of traumatic exposure endorsed by participants.

PCL-5 (Weathers et al., 2013). The PCL-5 was completed as part of the self-administered questionnaire packet. In Sample 2, internal consistency of this scale was excellent (Cronbach's $\alpha = .96$).

SCID-5 – PTSD Module (First, Williams, Karg, & Spitzer, 2015). The SCID-5 was administered over the phone by doctoral level clinicians to assess current (past month) PTSD diagnostic status. The SCID-5 has shown good psychometric properties for the PTSD module (inter-rater reliability κ=.69; Regier et al., 2013). Furthermore, as reported by Mitchell et al. (2017), interrater agreement was excellent for PTSD (κ=.82) among a random subset of interviews (n=100) for Project VALOR. In the present study, the item assessing if Criterion A was met in the SCID-5 PTSD Module was used to determine if participants met Criterion A for a traumatic event. SCID-5 PTSD Module items were not included in the network since the items in this measure are dichotomous and cannot be modeled in a partial correlation network with ordinal variables (Borsboom & Cramer, 2013).

Self-Injurious Thoughts and Behaviors Interview (SITBI; Nock, Holmberg, Photos, & Michel, 2007). The SITBI is a structured interview that assesses the presence, frequency, and severity of a wide range of self-injurious and suicidal thoughts and behaviors, including suicidal ideation, suicidal plans, suicidal gestures, NSSI, and suicide attempts. The SITBI has demonstrated strong psychometric properties, including strong inter-rater reliability (κ=.99), six-month test-retest reliability (κ=.70), and convergent validity with respect to other measures of suicide ideation (average κ=.54) and suicide attempt (κ=.65; Nock et al., 2007). For the current study, items from the SITBI were used to create one item that collapsed the numbers of instances of NSSI behaviors across behavior types and a second item that counted how many different types of NSSI behavior the individual had engaged in in his/her lifetime. In addition, the SITBI item assessing number of suicide attempts was used.

The Mini-International Neuropsychiatric Interview suicide subscale (MINI; Sheehan et al., 1998). The MINI was administered over the phone by doctoral level clinicians to assess suicide risk in the last month. The MINI Suicidal Scale is a subscale of the MINI, a short structured diagnostic interview that was developed and validated jointly by psychiatrists and clinicians in the United States and Europe for the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) and the *International Classification of Mental and Behavioural Disorders* (ICD-10) (Dunbar et al., 1997; Sheehan et al., 1998). The MINI Suicidal Scale has nine items and has been shown to categorize suicide attempters and non-attempters with a ROC-AUC of 0.84 in a retrospective study (Innamorati et al., 2011). Since dichotomous items cannot be combined with ordinal items in partial correlation networks, three dichotomous items related to suicide ideation were collapsed to create a single ordinal item for the level of suicide ideation. Specifically, the level of suicidal ideation item was created by taking the highest level of ideation endorsed in the last two weeks: 0 = negative response to all three items; 1= a *yes* only to the passive ideation question *Think you would be better off dead or wish you were dead?; 2=* a *yes* to the active ideation question *Think about suicide?*; and 3 = a *yes* to the suicide plan question *Have a suicide plan?* If an individual endorsed both passive ideation and active ideation, he/she received a score of 2 for active ideation. Likewise, if an individual endorsed both a suicide plan and active ideation, he/she received a score of 3 for suicide plan. In addition, we used two items that assessed frequency (*0= N/A, no ideation; 1= Occasionally, 2=Often, 3=Very Often)* and intensity (*0= N/A, no ideation; 1= Mild, 2=Moderate, 3=Severe)* of suicidal ideation in the past month.

Statistical Procedure

Missing data and non-normality. The maximum missing data for any one variable included in the network was 1.1% for Sample 1 and 1.7% for Sample 2. Pairwise deletion was employed with all data using the built-in pairwise deletion feature in the *qgraph* package in R (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). In addition, the nonparanormal transformation (Liu, Han, Yuan, Lafferty, & Wasserman, 2012) was applied before estimating the graphical models using the *huge* package in R (Zhao et al., 2015), as recommended by Epskamp et al. (2018).

Analytic plan. Cross-sectional networks for each sample were constructed separately. Both networks included the 20 PTSD symptoms measured by the PCL-5 and 6 items relating to SITB. In Sample 1, the six SITB items were: the numbers of instances of NSSI behaviors across behavior types from the ISAS, the number of different types of NSSI behavior the individual had engaged in in their lifetime from the ISAS, number of lifetime suicide attempts, level of medical attention required for the most lethal suicide attempt, the level of intent to die during the individual's most recent suicide attempt, and level of suicidal ideation in the past two weeks based on total score of DSI-SS. In Sample 2, the six SITB items were: the numbers of instances of NSSI behaviors across behavior types from the SITBI, the number of different types of NSSI behavior the individual had engaged in in their lifetime from the SITBI, number of lifetime suicide attempts from the SITBI, level of suicidal ideation in last month from the MINI, frequency of suicidal ideation in last month from the MINI, and the intensity of suicidal ideation in the last month from the MINI.

We used the R package *qgraph* (Epskamp et al., 2012) to visualize networks. Each network was estimated using the least absolute shrinkage and selection operator (LASSO). Graphical LASSO networks use regularized partial correlations among all variables where each edge represents the relationship between two nodes independent from all other variables in the network (Epskamp & Fried, 2016; Friedman, Hastie, & Tibshirani, 2008). LASSO in *qgraph* uses the Extended Bayesian Information Criteria (EBIC) to select the best network by optimizing fit. LASSO networks control for spurious associations and provide more parsimonious networks (Mitchell et al., 2017).

For the visual representation of the models, we used the averageLayout from the qgraph package. This layout allows for an easier visual comparison between two networks, as it constrains the layout to be equal for both networks meaning that nodes are placed in the same location across networks (Epskamp & Fried, 2016). Since graphical LASSO networks are weighted graphs, the thickness of the edges will signify the magnitude of the association between nodes. If two nodes do not directly interact (i.e., the partial correlation is zero), there will be no edge between them, suggesting that the two variables are independent after controlling for all other variables in the network. In *qgraph*, red lines indicate negative partial correlations and green lines indicate positive partial correlations (Epskamp et al., 2012).

Using *qgraph*, we used expected influence as our centrality index due to the presence of negative associations in both networks (Robinaugh et al., 2016). Thus, we created centrality plots to depict these findings. We also report stability of edge-weights and central metrics. To address concerns that low endorsement of particular symptoms (i.e., restricted variability) would affect metrics of centrality, we examined correlations between skewness and centrality (McNally, Heeren, & Robinaugh, 2017). One-step and two-step bridge expected influence was calculated using the *bridge* function of the *networktools* R packacge (Jones, 2018).

Power analysis. While there is no agreed upon method to determine a priori power in network analysis, it has been suggested that the number of observations needs to exceed the number of parameters (Epskamp et al., 2018). For 26 nodes (i.e. 20 PTSD symptoms plus six SITB symptoms), there are 325 possible parameters to estimate. In both samples, the sample exceeded 325 participants. For post hoc power analysis, the R package bootnet was used to construct confidence intervals around edges in the network models and to determine the stability of the centrality indices (Epskamp et al., 2018).

Results

Network Estimation

Sample 1. The regularized partial correlation network for Sample 1 is depicted in Figure 1. In Sample 1, there were no isolated nodes in the network; all symptoms were connected, either directly or indirectly via other symptoms. In addition, 137 of 325 possible edges between symptoms (42.2%) were estimated to be non-zero, with all but one edge being positive (i.e., negative edge between distressing dreams [PCL2] and total number of NSSI incidents [NSSIfreq]). Within PTSD symptoms, 107 of 190 possible edges (56.3%) were estimated to be above zero. For SITB symptoms, 13 of 15 possible edges (86.7%) were estimated to be above zero. Of the possible edges connecting the two disorders, only 17 of 120 (14.2%) possible edges were non-zero.

Sample 2. The regularized partial correlation network for Sample 2 is depicted in Figure 1. Similar to in Sample 1, there were no isolated nodes in the network in Sample 2; all symptoms were connected, either directly or indirectly via other symptoms. In addition, 170 of 325 possible edges between symptoms (52.3%) were estimated to be non-zero. There were 155 positive edges and 15 negative edges in Sample 2, in contrast to the one negative edge in Sample 1. Within PTSD symptoms, 124 of 190 possible edges (65.3%) were estimated to be non-zero, including 2 negative edges (i.e., Distorted Blame of Oneself or Others [PCL10] and Irritable Behavior [PCL15]; Avoid Reminders [PCL7] and Risky Behavior [PCL16]). For SITB symptoms, 11 of 15 possible edges (74.3%) were estimated to be non-zero. While the percentage of non-zero edges were similar for within PTSD and within SITB between the samples, Sample 2 had more non-zero edges including more negative edges than Sample 1 for edges between disorders. Specifically, of the possible edges connecting the two disorders, 35 of 120 (29.3%) possible edges were non-zero, including 13 negative edges.

Network Inference

Centrality. As noted above, expected influence takes into account negative associations between nodes for a sum of magnitude of edge-weights (compared to the metric of strength that signifies absolute-value magnitude; Robinaugh et al., 2016). Given that there are negative edge-weight(s) in both Sample 1 and Sample 2, we report expected influence as our metric of centrality. To avoid confusion with bridge expected influence, hereafter, we refer to this metric as *centrality expected influence*.

Sample 1. Figure 2 illustrates the centrality expected influence of the overall network for Sample 1. In Sample 1, strong startle reaction (PCL18), persistent negative emotional state (PCL 11), physiological reactions of the trauma (PCL 5), unwanted memories (PCL1), and detachment from others (PCL13) emerged as the nodes with the greatest centrality expected influence.

Sample 2. Figure 3 depicts the centrality expected influence of the overall network for Sample 2. Three of the symptoms with the greatest centrality expected influence were the same as those identified in Sample 1 (i.e., PCL11, PCL1, and PCL5). In addition, frequency of suicidal ideation in last month (SIfreq) and intensity of suicidal ideation in last month (Intensity) had high degrees of centrality expected influence.

Bridge Symptoms. Whereas centrality expected influence indicates the sum of the magnitude of edges for a node with all other nodes in the network, one-step bridge expected influence indicates the sum of the edges that exist between a node and all nodes that are not in the same disorder as that node. Figure 3 illustrates the one-step bridge expected influence for both samples. Similarly, while one-step bridge expected influence includes only edges between a node and the nodes from the other disorder, two-step bridge expected influence includes both direct influences and secondary influences or pathways from the node passing through direct connections. For instance, in Sample 1 the node for PCL9 had a direct association with SI and also has a secondary influence on SI through PCL16. Figure 4 depicts the two-step bridge expected influence for both samples.

Sample 1. In Sample 1, suicidal ideation (SI), risky behaviors (PCL16), negative beliefs (PCL9), inability to experience positive emotions (PCL14), and number of different types of NSSI (NSSItype) had the greatest one-step and two-step bridge expected influence between the PTSD symptoms and the SITB symptoms.

Sample 2. In Sample 2, number of suicide attempts (SA), level of suicidal ideation (SI), distorted blame of oneself or others (PCL10), unwanted memories (PCL1), and negative beliefs (PCL9) emerged as the nodes with the greatest one-step and two-step expected influence between the PTSD symptoms and the SITB symptoms. Two symptoms (i.e. SI and PCL9) overlapped with the greatest one-step and two-step bridge expected influence from Sample 1. Of note, the symptom with the next highest one-step and two-step bridge expected influence in Sample 2 was risky behaviors (PCL16), which overlaps with Sample 1.

Network Accuracy

As outlined by Epskamp et al. (2018), methods to ensure the accuracy of edge-weights and the stability of centrality indices in the estimated network structure should be applied after a network has been estimated. Nonparametric bootstrapping was used to calculate confidence intervals around edge-weights. Results revealed overlapping confidence intervals for many edge-weights, indicating that their relative magnitude should be interpreted with care. Furthermore, current guidelines suggest that to interpret centrality metrics the centrality stability coefficient (CS -coefficient) should not be below 0.25; however, it has been noted that "these cutoff scores emerge as recommendations from this simulation study; however, they are somewhat arbitrary and should not be taken as definite guidelines," (Epskamp et al., 2018, p. 200). In both Sample 1 and Sample 2, stability coefficients for strength (.10) and edge-weights (.10) were equally reliable, albeit somewhat below this established guideline. To date, there are no available centrality metrics for expected influence. Previously published networks of PTSD have reported levels of stability below or just at the recommended threshold (e.g., Armour et al., 2017; Benfer et al., 2018; McNally et al., 2017).

To address concerns that low endorsement of particular symptoms (i.e., restricted variability) would affect metrics of centrality, correlations between skewness and centrality metrics were examined. In both samples, the correlations between skewness and centrality were not statistically significant, suggesting that the centrality metrics are reliable.

Discussion

To our knowledge, this study represents the first network analysis study of PTSD and SITB comorbidity among both a community sample and a combat Veteran sample who experienced a Criterion A traumatic event. From the visual representation of the networks, it is clear that PTSD symptoms cluster together and SITB symptoms mostly cluster together, separate from PTSD symptoms. Within PTSD, the symptoms were strongly connected to other symptoms within *DSM-5* symptom clusters, especially for intrusion symptoms and avoidance symptoms. Within SITB, related symptoms clustered together, such as items related to ideation versus NSSI versus attempts. In Sample 1, there was one notable cluster of symptoms between disorders with strong associations. Suicidal ideation, inability to experience positive emotions, and risky behaviors were strongly connected to one another. This interconnected cluster of symptoms may suggest a feedback loop that could be evaluated with future longitudinal studies. Through visual inspection, no such cluster of interconnected symptoms between disorders was present in Sample 2.

Network Inference: Centrality Expected Influence

In regard to overall centrality metrics, three symptoms emerged as having the highest centrality expected influence in both networks (i.e., persistent negative emotional state, physiological reactions of the trauma, and unwanted memories). Nodes with high centrality expected influence may disproportionately activate other symptoms, intensify the connectedness of the network, and prevent deactivation of other nodes due to their interconnectedness (Robinaugh et al., 2016). Thus, identifying these symptoms allows for the development of hypotheses that can be tested with longitudinal or time series models. For instance, treating physiological reactions of the trauma and unwanted memories through prolonged exposure (PE;

Foa, Hembree, & Rothbaum, 2007) should cause a decrease in other PTSD symptoms, as well as SITB symptoms. Consistent with this hypothesis derived from our network model, prolonged exposure leads to a decrease in physiological reaction of the trauma (e.g., Boudewyns & Hyer, 1990), unwanted memories (e.g., Hackmann, Ehlers, Speckens, & Clark, 2004; Speckens, Ehlers, Hackmann, & Clark, 2006), and overall PTSD symptoms (Powers, Halpern, Ferenschak, Gillihan, & Foa, 2010); however, much less research has examined the effects of prolonged exposure on SITB. Many randomized controlled trials for prolonged exposure have excluded participants with recent or current SITB (van Minnen, Zoellner, Harned, & Mills, 2015). Of the few studies assessing SITB, one reported a significant decrease in suicidal ideation throughout treatment (Gradus, Suvak, Wisco, Marx, & Resick, 2013), and one study that had a large proportion of participants with a history of suicide attempts and/or medium to high risk of suicide reported no adverse events related to SITB during prolonged exposure therapy (van den Berg et al., 2015). Future studies should assess how targeting these central symptoms not only reduces PTSD symptoms, but also affects SITB symptoms.

As mentioned above, Mitchell et al., (2017)'s sample and Sample 2 overlapped considerably. In our network analysis, two of three symptoms identified as having the highest centrality expected influence overlapped with symptoms identified from the network in Mitchell et al. (2017; i.e., persistent negative emotional state and unwanted memories), with physiological reactions of trauma only being identified as highly central in our combined PTSD/SITB network. Given that Sample 2 included six SITB symptoms not included in Mitchell et al. (2017)'s network, this difference may indicate that physiological reactions of the trauma may be uniquely related to the co-occurrence of SITB and PTSD. This finding is consistent with Selaman et al.'s (2014) finding that physiological reactions of the trauma was associated with suicide attempts after controlling for sociodemographic factors, mood disorders, substance disorders, personality disorders, and anxiety disorder. Future studies should evaluate how changes in physiological reactions of the trauma affect SITB and PTSD symptoms.

Network Inference: Bridge Expected Influence

While centrality expected influence examines the overall connectedness of the network, bridge expected influence investigates the pathways between the two disorders. Centrality metrics, such as expected influence, may identify symptoms with a larger role in maintenance of the comorbidity between two disorders. Symptoms with stronger one-step and two-step bridge expected influence may be more directly involved in the activation or development of comorbidity. In both networks, one-step and two-step bridge expected influence identified the same five symptoms as highest within each sample. This finding suggests that even after including secondary influences or indirect effects from surrounding nodes, these symptoms remained the strongest bridges in the networks. Results highlighted the major bridging role of three symptoms in both samples – negative beliefs, risky behaviors, and suicidal ideation. This finding is especially notable given recent discussion of the lack of consistency across PTSD networks estimated across studies and data sets (e.g., Fried et al., 2018).

Negative beliefs and risky behaviors are new symptoms added to *DSM-5* criteria for PTSD, highlighting the importance of using current criteria for PTSD when examining the co-occurrence of SITB and PTSD. For instance, Simons et al. (2019) used *DSM-IV* PTSD symptoms in their network analysis of risk factors for suicidal ideation, limiting our ability to understand how these new symptoms would affect their examination of PTSD symptoms clusters with suicidal ideation.

While negative beliefs about oneself or the world following trauma is a newly added symptom to *DSM-5*, it has been researched in conjunction with PTSD for decades (e.g., Horowitz, 1976; Janoff-Bulman, 1994). Many studies have shown that negative beliefs about the self and world following traumatic events are associated with higher levels of PTSD symptoms (e.g., Agar, Kennedy, & King, 2006; Foa, Ehlers, Clark, Tolin, & Orsillo, 1999; Park, Mills, & Edmondson, 2012). Using a national sample, one study showed that the prevalence of the negative beliefs symptom was significantly higher for individuals who developed PTSD following a traumatic event compared to those that did not (Cox, Resnick, & Kilpatrick, 2014). In addition, the negative beliefs symptom has been previously shown to be related to suicide attempts (Legarreta et al., 2015). The present study's finding adds to the current literature by demonstrating that the negative beliefs symptom not only relates to lifetime history of PTSD, severity of PTSD, and suicide attempts, but also acts as a direct connection between PTSD symptoms as a whole and to numerous SITB symptoms. Thus, targeting negative beliefs through treatments such as cognitive processing therapy (CPT; Resick & Schnicke, 1993) and PE may prevent the co-occurrence of SITB symptoms from developing or may decrease these symptoms, in addition to PTSD symptoms. Similar to PE, CPT has also been shown to lead to a reduction in suicidal ideation (Gradus et al., 2013); however, the underlying mechanism leading to this reduction is unknown. It is plausible that reductions in posttraumatic cognitions may lead to reductions in suicidal ideation. Kleim et al. (2013) found that in CPT, changes in posttraumatic cognitions, such as negative beliefs about self and inappropriate blame, preceded changes in PTSD (Kleim et al, 2013). Further, a study of Veterans in a seven-week residential PTSD treatment found that change in negative beliefs preceded change in depression, change in depression preceded change in inappropriate blame, and change in depression preceded change in PTSD (Schumm, Dickstein, Walter, Owens, & Chard, 2015). It has also been demonstrated that changes in posttraumatic cognitions preceded decreases in both PTSD and depression symptoms in PE (Zalta et al., 2014). Thus, examining how SITB in addition to depression, changes with negative beliefs, inappropriate blame, and PTSD severity in CPT and PE may offer insight into reducing SITB risk in PTSD.

The risky behaviors symptom for PTSD includes behaviors such as NSSI and suicide attempts among other risky behaviors (e.g., substance use, reckless driving). Thus, the risky behavior symptom for PTSD is considered overlapping with items assessing NSSI and suicide attempts. This finding suggests that the only overlapping symptom between disorders was among the strongest bridges in both networks. Numerous studies have shown the strong associations between behaviors such as reckless driving, risky sexual behavior, suicidal behavior, and problematic substance use and PTSD (Friedman, 2013; Friedman, Resick, Bryant, & Brewin, 2011; James, Strom, & Leskela, 2014). It has been noted that risky and reckless behaviors were more likely endorsed by individuals with higher PTSD symptom severity (e.g., Kilpatrick, Resnick, Milanak, Miller, Keyes, & Friedman, 2013). In addition, risky and self-destructive behaviors have been shown to increase exposure to new adverse events, which may mediate the relationship between risky behaviors and future PTSD severity (Lusk, Sadeh, Wolf, & Miller, 2017). Not only have risky behaviors been shown to be associated with greater severity of PTSD, but they are also related to increased risk of SITB (Athey, Overholser, Bagge, Dieter, Vallender, & Stockmeier, 2018; Olfson et al., 2017; Witte et al., 2018). Using network analysis, Armour et al. (2017) reported that risky behaviors had a positive partial correlation with suicidal ideation. As can be seen in Figure 1, there was a positive edge (i.e., partial correlation) between suicidal ideation and risky behaviors in both samples in this study as well. However, by demonstrating that risky behaviors acts as a bridge between PTSD symptoms and a larger range of SITB than just suicidal ideation, our study demonstrates that risky behaviors may be important to the development of the co-occurrence of these symptoms. While there is an established relationship between risky behaviors, PTSD, and SITB, the underlying mechanism is less well understood. Prior studies have suggested that risky behaviors are related to emotion dysregulation (e.g., Leith & Baumeister, 1996; Weiss, Sullivan, & Tull, 2015). In particular, it has been suggested that engaging in risky behaviors may contribute to an increase in experience of more negative emotions, such as guilt and shame, that lead to more emotionally avoidant coping strategies (Weiss et al., 2015). Given that negative emotions (particularly guilt and shame) and avoidance are symptoms of PTSD, studying the role of emotion dysregulation in SITB and PTSD networks is important to fully understand the underlying mechanisms of these associations. Furthermore, given that risky behaviors were a strong bridge found in both samples, it is important to examine how treatments that target risky behaviors in PTSD affect other PTSD symptoms and future SITB. One pilot study has suggested that an eight-week group cognitive-behavioral treatment designed to reduce driving-related anger, aggression, and risky driving behaviors may be effective in reducing both risky behaviors and PTSD symptom severity (Strom et al., 2013). In addition, Dialectical Behavior Therapy (DBT; Linehan, 1993) has consistently shown reductions in risky behaviors (e.g., Gratz & Tull, 2011; Linehan, Schmidt, Dimeff, Craft, Janter, & Comtois, 1999; Linehan, 2018) and is one of the only treatments shown to reduce NSSI and suicide attempts (Panos, Jackson, Hasan, & Panos, 2014). Thus, DBT should be studied as a treatment to precede or augment PTSD treatment in the future, as reducing risky behaviors may destabilize the PTSD/SITB network.

It is noteworthy that suicidal ideation had high one-step and two-step bridge expected influence in both samples, despite the fact that it was measured differently (i.e. using the DSI-SS for the last two weeks in Sample 1; using the MINI for the last month in Sample 2). Across samples, recent suicidal ideation remained an important bridge between SITB and PTSD. It is widely agreed upon that suicidal ideation precedes suicide attempts (e.g., Klonsky & May, 2014; Joiner, 2005; Nock et al., 2008). Furthermore, suicidal ideation has been shown to related to NSSI (e.g., Brausch & Gutierrez, 2010). The finding from the current study extends the previous literature by demonstrating that suicidal ideation was strongly connected to PTSD in addition to other forms of SITB, suggesting the importance of assessment of recent suicidal ideation during the assessment and treatment of PTSD.

Whereas the above symptoms were identified in both samples for their strong bridging roles through one-step and two-step bridge expected influence, there were some unique symptoms that demonstrated strong bridging roles in only one sample. Since these findings did not replicate across samples, they should be interpreted with caution and should be examined in future network analysis research. In Sample 1, inability to experience positive emotions and number of different types of NSSI exhibited strong bridging roles (i.e., highest one-step and two-step bridge expected influence). Inability to experience positive emotions is related to emotional numbness, which has been posited to be related to NSSI (Bentley, Nock, & Barlow, 2014). The current finding suggests that this symptom may play a role in the development of the co-occurrence of SITB beyond NSSI and other PTSD symptoms. In regard to number of different types of NSSI having a strong bridging role in Sample 1, it should be noted that 81.4% of Sample 1 endorsed engaging in past NSSI, while only 11.1% endorsed a history of this behavior in Sample 2. This large difference between the samples may account for the unique finding of different types of NSSI having high bridge expected influence in Sample 1.

In Sample 2, suicide attempts, distorted blame of oneself or others, and unwanted memories were among the symptoms with the highest one-step and two-step bridge expected influence. Prior literature has shown that distorted blame of oneself was related to suicidal ideation for certain combat exposures (Bryan, Morrow, Etienne, & Ray-Sannerud, 2013). As over 90% of Sample 2 reported a combat trauma on the LEC-5, compared with less than 3% in Sample 1, the unique finding of distorted blame as a bridge symptom in this population may be related to trauma type. A recent review discussed how repetitive negative thinking patterns, including intrusive, unwanted memories, may be related to suicide and should be further investigated (Law & Tucker, 2018). This finding suggests that distorted blame and unwanted memories may play an important role in the network of PTSD and that along with other symptoms may lead to the activation or maintenance of SITB symptoms. Further investigation is required to examine if these findings replicate in other samples.

Interestingly, detachment from others and inability to recall an important aspect of the trauma were two nodes with low one-step and two-step bridge expected influence in both samples. Previous literature has shown that detachment from others was positively related to suicidal ideation (Davis et al., 2014; Legarreta et al., 2015) and that inability to recall can important aspect of the trauma was related to suicide attempts (Legarreta et al., 2015; Selaman et al., 2014). In this study, instead of looking at single associations between symptoms, symptoms that are most strongly related to all types of SITB were identified. Thus, while these symptoms may have direct associations with individual symptoms of SITB (e.g., ideation or past attempt), they do not demonstrate strong associations with the SITB symptoms overall. It should be noted, however, that detachment from others had moderately high centrality expected influence in both samples. This suggests that detachment from others is strongly connected to the overall network of PTSD and SITB, even though it does not act as a strong bridge between the disorders. This finding may be a result of detachment from others being strongly connected to many PTSD symptoms, increasing its centrality expected influence, while its bridge expected influence remains low.

Limitations

Study findings should be interpreted with caution in light of limitations. First, the stability of both networks was below the recommended threshold (i.e., *CS*-coefficients > 0.25; Epskamp et al., 2018). The low stability in this study may be due to the low base rate of SITB. While these samples did have higher than average rates of SITB, the rates are still lower than that of the PTSD symptoms. In addition, Mitchell et al., 2017 reported a 0.439 stability coefficient for strength. Given that these samples are very similar, it may indicate that the addition of SITB items reduced the stability of the network.

Second, when discussing similarities and differences in the two networks, it needs to be noted that the SITB items varied somewhat with respect to content and time frame. For suicidal ideation, Sample 1 assessed the last two weeks and used a total score from the DSI-SS which assesses thoughts, plan, control over thoughts, and impulses. Comparatively, in Sample 2, suicidal ideation was assessed for the last month and the level of suicidal ideation variable was created based on no ideation, passive ideation, active ideation, and having a suicide plan. Sample 2 also included two additional suicidal ideation variables (i.e., frequency and intensity), while Sample 1 included additional two items related suicide attempts (i.e., level of intent to die and medical attention required). These differences are especially notable for the visual representation of the networks using the *AverageLayout* function in R since this layout places nodes in the same position across samples. Three of the symptoms in each network are not identical to the other network (e.g., *level of intent to die* in Sample 1 and *frequency of suicidal ideation* in Sample 2 have the same node position); thus, it may be difficult to visually compare networks. Additionally, in Sample 2, items were assessing using a mix of self-report (i.e., PCL-5 and SITBI) and interview (MINI), while all of Sample 1 was collected via self-report.

Furthermore, the unique findings in each sample for bridge symptoms and most central symptoms may in part be due to the difference in the samples. While both samples were trauma-exposed, Sample 1 was a community that was screened for lifetime suicidal ideation, while Sample 2 consisted of treatment-seeking Veterans. The difference in populations may have also led to a difference in traumatic exposure. For instance, in Sample 1, the most common types of trauma were transportation accident, sexual assault and physical assault. In Sample 2, over 90% of the sample reported combat exposure, with the next most common traumas being transportation accident and physical assault. In regard to demographic variables, Sample 1 had a higher percentage of female participants. The difference in trauma type and demographics may explain some of the differences in the networks between samples and should be explored further in future studies.

Lastly, due to the cross-sectional nature of the study, the networks are undirected. Thus, the results do not provide information on if one symptom activates another symptom. To better understand the direction of causal relationships between symptom, longitudinal studies are needed.

Future Directions

Despite the above limitations, there are also noted strengths. For instance, this study examined two varied samples (i.e., community sample versus Veteran) with different trauma types and slightly different measures of SITB and still found many consistent results. The replication of the main findings suggests that these results are stable across different trauma types, different levels of clinical severity, and different populations within US adults. In addition, both samples included individuals with increased risk for suicide and that had experienced at least one *DSM-5* Criterion A traumatic event. Most important, this study uses the novel methodology of network analysis in two large samples to further our understanding of the comorbidity between SITB and PTSD. By examining the symptom-level associations between SITB and PTSD in this framework, a number of symptoms that may have important roles in the development and maintenance of this comorbidity were identified. When evaluating PTSD symptoms, it appears that risky behaviors and negative beliefs may be most consistently related to the development of SITB (i.e. served as bridge symptoms). These symptoms may be important for risk assessment and as potential treatment targets for individuals with trauma related symptoms. While not replicated in Sample 1, results from Sample 2 suggest that for individuals with a history of combat trauma, distorted blame of oneself or others and unwanted memories may also be strongly related to the development and maintenance of SITB.

Future studies should use a longitudinal network approach to examine if previously identified bridge and centrality symptoms are accurate in the prediction of future SITB. Future longitudinal network studies can also examine the development and course of symptoms and what role bridging symptoms play.

In conclusion, this study provides a crucial first step in understanding the symptom level relationships between SITB and PTSD. Across two samples, the same three PTSD symptoms (i.e., persistent negative emotional state, physiological reactions of the trauma, and unwanted memories) were identified as having the highest centrality expected influence and three symptoms were identified as the strongest bridges (i.e., negative beliefs, risky behaviors, and suicidal ideation). These findings offer new insights that may help to develop testable hypotheses for understanding the development, maintenance, and treatment of co-occurring SITB and PTSD.

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Appendix 1: Tables

Table 1: Sample Demographics

		Sample 1 (N=349) n, %	Sample 2 (N=1,307) n, %
Gender	Female	257 (73.6%)	666 (51.0%)
	Male	79 (22.6%)	641 (49.0%)
	Other	13 (3.7%)	--
Race	American Indian/Alaska Native	11 (3.2%)	44 (3.4%)
	Asian	18 (5.2%)	29 (2.2%)
	Native Hawaiian/ Other Pacific Islander	2 (0.6%)	9 (0.7%)
	Black or African American	32 (9.2%)	224 (17.1%)
	White	301 (86.2%)	1,025 (78.4%)
Ethnicity	Hispanic/Latino	35 (10%)	160 (12.2%)
Relationship Status	Single	100 (28.7%)	206 (15.8%)
	Dating	35 (10.0%)	--
	Living with Partner	72 (20.6%)	89 (6.8%)
	Married	110 (31.5%)	687 (52.6%)
	Separated, Divorced	29 (8.3%)	265 (20.3%)
	Widowed	3 (0.9%)	14 (1.1%)
	Other	--	41 (3.1%)
Served in Armed Forces	Yes	15 (4.3%)	1,307 (100%)
Highest Education Level	Some high school	4 (1.1%)	--
	High school or equivalent, GED	38 (10.9%)	93 (7.1%)
	Vocational, Technical school	8 (2.3%)	41 (3.1%)
	Some College or Associates Degree	135 (38.7%)	597 (46.0%)
	College Graduate, Bachelor's Degree	104 (29.8%)	346 (26.5%)
	Some Graduate or Professional School	15 (4.3%)	--
	Master's Degree	36 (10.3%)	206 (15.8%)
	Doctoral Degree	9 (2.6%)	14 (1.1%)
		mean (sd)	mean (sd)
Age		32.99 (10.59)	40.66 (9.77)

*-- indicates not collected in sample

Table 2: Descriptive Statistics of SITB Variables

	Sample 1 (N=349) n (%) Mean (SD); Range	Sample 2 (N=1,307) n (%) Mean (SD); Range
Non-Suicidal Self-Injurious Behavior (NSSI)		
Endorsed engaging in 1+ type of NSSI	284 (81.4%)	145 (11.1%)
Modal different types of NSSI	1	2
Suicidal Ideation		
DSI-SS (past two weeks)		
Total Score	1.5 (2.0); 0-10	--
At least some ideation (i.e., >=1)[a]	155 (44.4%)	--
MINI-Suicide Scale (past month)		
No ideation	--	1,013 (77.5%)
Passive ideation	--	79 (6.0%)
Active ideation	--	202 (15.5%)
Suicide plan	--	13 (1.0%)
Frequency of ideation[b]		
Occasionally	--	155 (11.9%)
Often	--	32 (2.4%)
Very Often	--	21 (1.6%)
Intensity of ideation[b]		
Mild	--	105 (8.0%)
Moderate	--	78 (6.0%)
Severe	--	25 (1.9%)
Suicide Attempt		
At least one lifetime suicide attempt	114 (32.3%)	322 (24.6%)
Lethality (most lethal attempt)[c]		
No medical attention required	59 (16.9%)	
Primary care doctor or nurse visit	7 (2.0%)	
Emergency room visit	26 (7.4%)	
Hospital admission to a general medical floor	15 (4.3%)	
Hospital admission to an Intensive Care Unit	7 (2.0%)	
Intent (most recent attempt)[c]		
I did not intent to die	7 (2.0%)	--
Part of me intended to die and part of me did not	58 (16.6%)	--
I intended to die	49 (14.0%)	--

[a]Only total score was included in the network for Sample 1; [b]Participants who denied suicidal ideation in last two weeks were not presented these questions; [c]Participants who denied a lifetime suicide attempt were not presented these questions. DSI-SS= Depression Symptom Inventory - Suicide Subscale; MINI= The Mini-International Neuropsychiatric Interview; SITB= self-injurious thoughts and behaviors

Table 3: Descriptive Statistics of Trauma Variables

	Sample 1 (N=349)	Sample 2 (N=1,307)
	Mean (SD); Range	Mean (SD); Range
PCL-5 total score severity	26.6 (20.4); 0-80	39.7 (20.1); 0-80
Number of different types of traumatic events*	7.5 (4.2); 1-29	9.3 (4.5); 0-34
	n (%)	n (%)
Met Criterion A for *DSM-5* traumatic event	349 (100%)	1,307 (100%)
Met provisional diagnosis of *DSM-5* PTSD**	127 (36.4%)	744 (56.9%)
Most highly endorsed LEC-5 events "happened to me"		
Combat or exposure to a war-zone	10 (2.9%)	1,217 (93.1%)
Transportation accident	235 (67.3%)	775 (59.3%)
Sexual assault	145 (41.5%)	380 (29.1%)
Other unwanted/uncomfortable sexual experience	197 (56.4%)	480 (36.7%)
Physical assault	186 (53.3%)	659 (50.4%)
Assault with weapon	54 (15.5%)	570 (43.6%)
Natural disaster	160 (45.8%)	518 (39.6%)
Most highly endorsed LEC-5 events "witnessed it"		
Transportation accident	143 (41.0%)	288 (22.0%)
Physical assault	130 (37.2%)	1,090 (83.5%)
Life-threatening illness or injury	146 (41.8%)	836 (64.0%)
Sudden violent death	39 (11.2%)	874 (66.9%)
Sudden accidental death	51 (14.6%)	1,043 (79.8%)

*Number of different types of traumatic events participants reported experiencing or witnessing on LEC-5. **Provisional diagnosis for PTSD was determined using PCL-5 symptom scores and based on *DSM-5* criteria, which was defined as experiencing at least one reexperiencing symptom, one avoidance symptom, two NACM symptoms, and two hyperarousal symptoms rated as 2=*moderately* or higher. LEC-5=Life Events Checklist for *DSM-5*, PCL-5= PTSD Checklist for *DSM–5*

Table 4: Node Name, Node Position, and Symptom Description for Both Samples

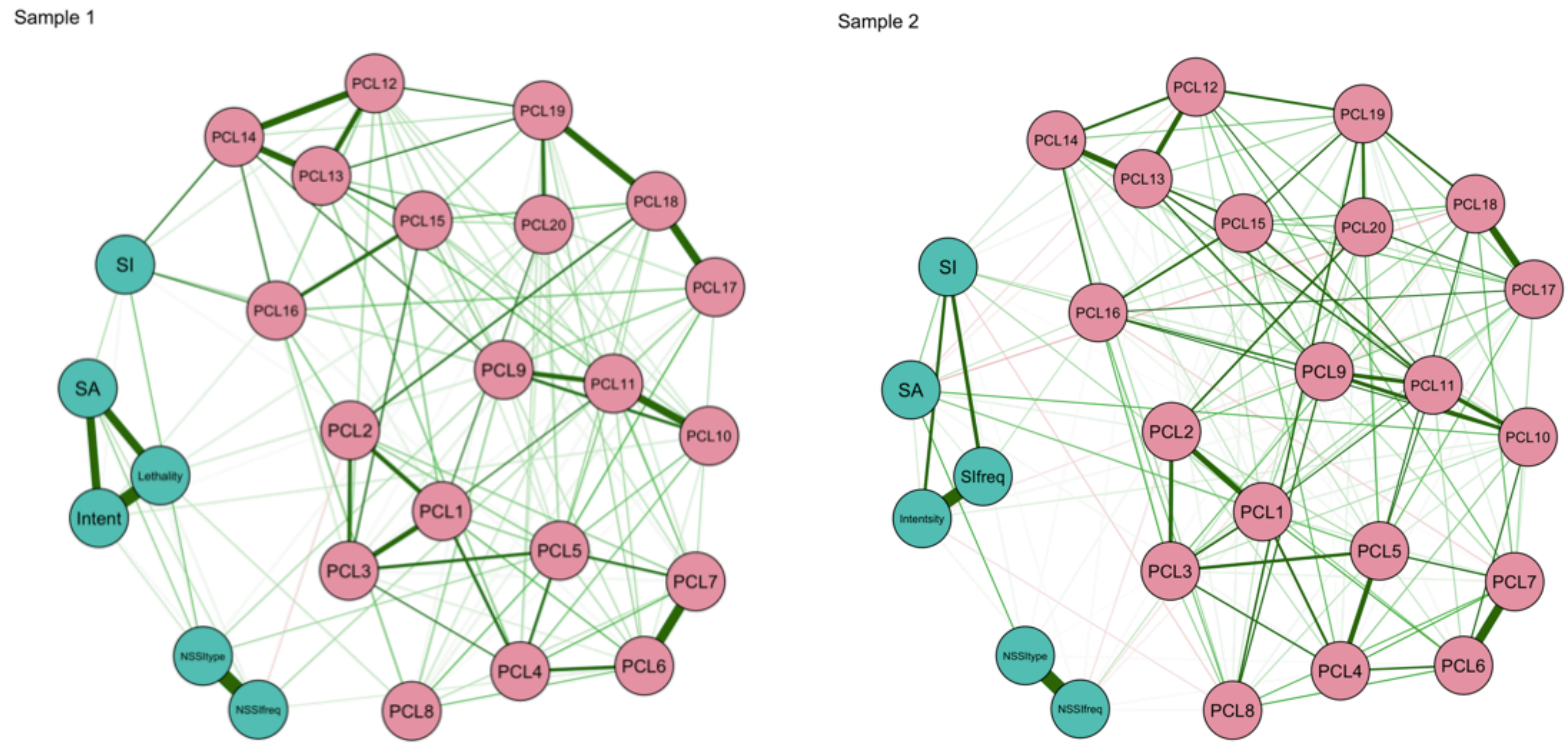
Overlapping symptoms across networks with matching nodal position*	
Node Name (Sample 1 and Sample 2)	Symptom Abbreviation (*DSM-5* Symptom Cluster)
PCL1	Unwanted Memories (B)
PCL2	Distressing dreams (B)
PCL3	Flashbacks (B)
PCL4	Psychological Distress (B)
PCL5	Physiological Reactions (B)
PCL6	Avoid Thoughts (C)
PCL7	Avoid Reminders (C)
PCL8	Inability to Recall Aspects of the Trauma (D)
PCL9	Negative Beliefs (D)
PCL10	Distorted Blame of Oneself or Others (D)
PCL11	Persistent negative emotional state (D)
PCL12	Anhedonia (D)
PCL13	Detachment from Others (D)
PCL14	Inability to experience positive emotions (D)
PCL15	Irritable Behavior (E)
PCL16	Risky Behavior (E)
PCL17	Hypervigilance (E)
PCL18	Startle (E)
PCL19	Problems with Concentration (E)
PCL20	Sleep Disturbance (E)
NSSIfreq	Number of Instances of NSSI
NSSItype	Number of Types of NSSI
SA	Number of Suicide Attempts

Differing symptoms across networks with matching nodal position*			
Node Name (Sample 1)	Symptom Abbreviation	Node Name (Sample 2)	Symptom Abbreviation
SI	Suicide Ideation in Last Two Weeks	SI	Level of Suicide Ideation in Last Month
Lethality	Level of Medical Attention Required	SIfreq	Frequency of Suicidal Ideation in Last Month
Intent	Level of Intent to Die	Intensity	Intensity of Suicidal Ideation in Last Month

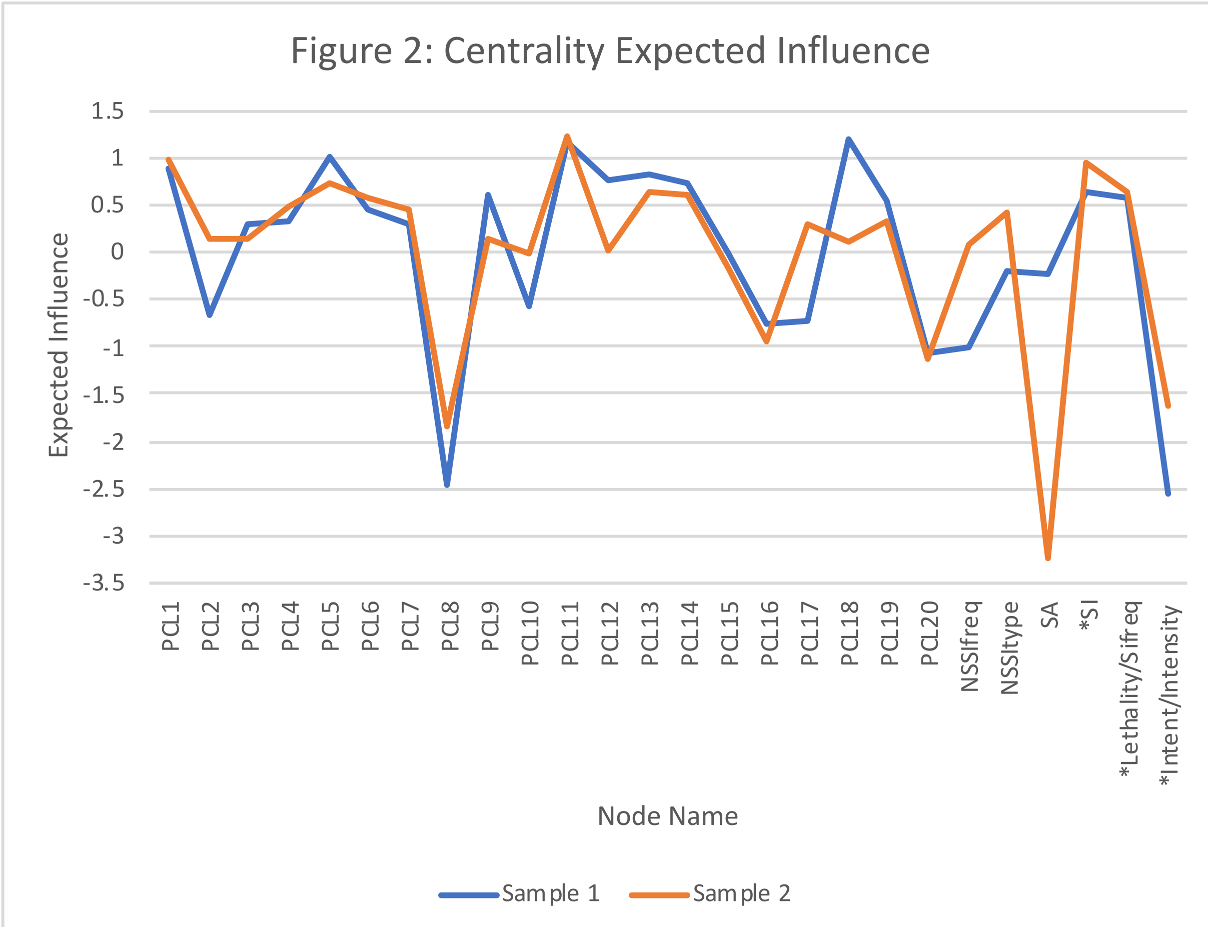
*Nodal position refers to the location of the node in the visual representation of the networks in Figure 1

Appendix 2: Figures

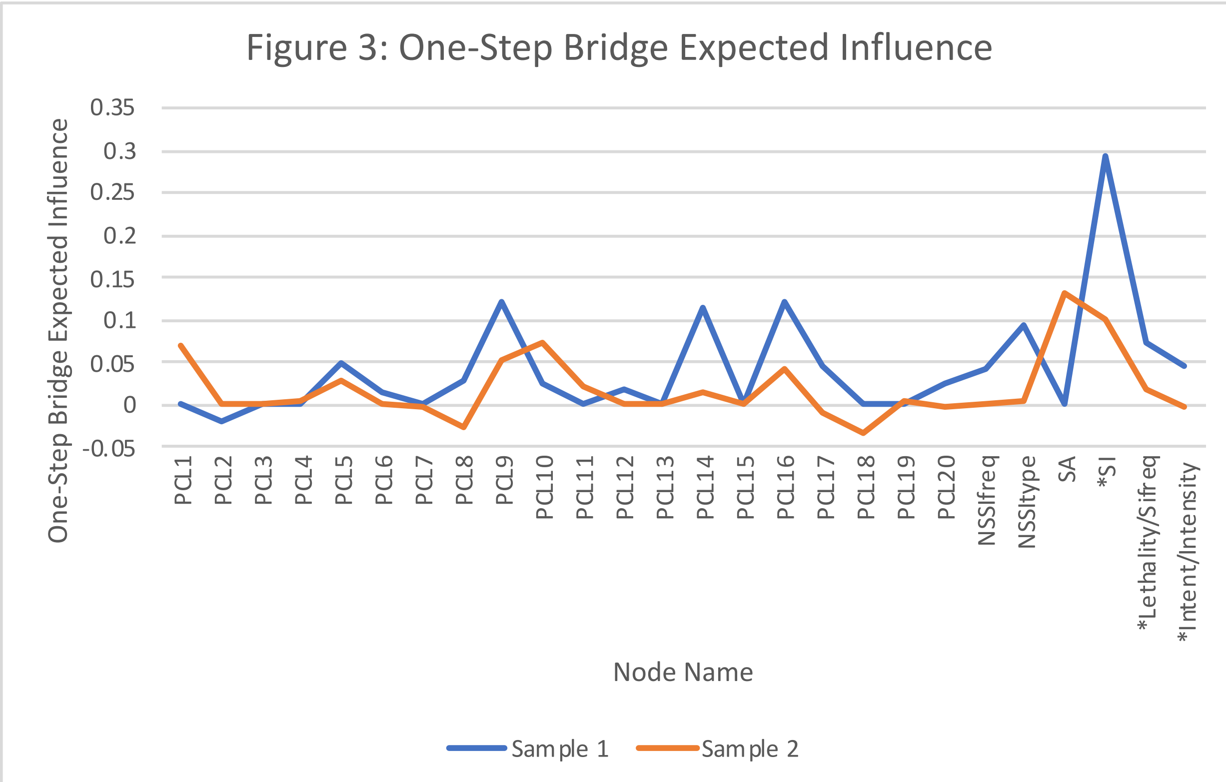
Figure 1: Visual Networks for Sample 1 and Sample 2



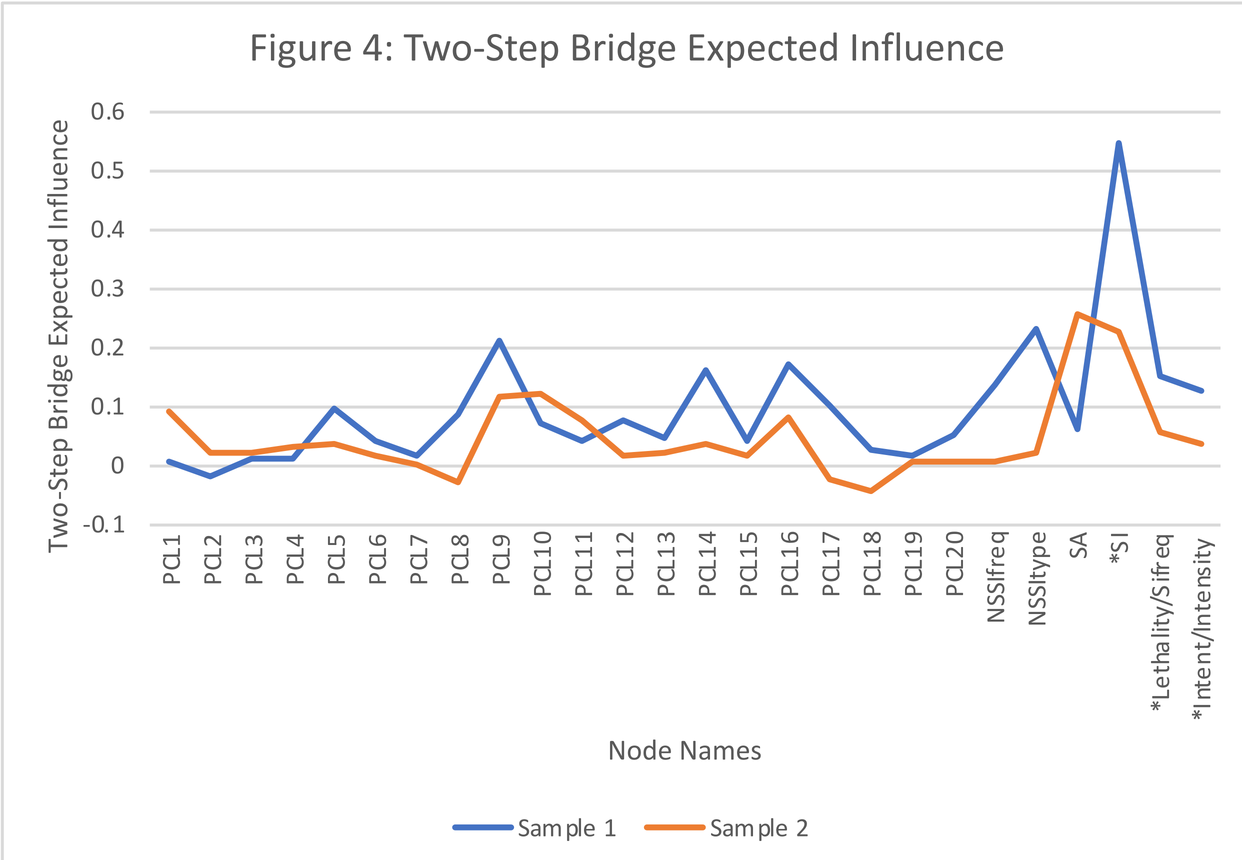
Regularized partial correlation network for Sample 1 (N=349) and Sample 2 (N=1,307). Thicker lines are indicative of stronger associations. Green lines represent positive associations and red lines represent negative associations. AverageLayout used to set nodes in same spatial position across networks. See Table 4 for a list of symptom names and description.



*indicates symptoms that vary between samples. See Table 4 for a list of symptom names and description.



*indicates symptoms that vary between samples. See Table 4 for a list of symptom names and description.



*indicates symptoms that vary between samples. See Table 4 for a list of symptom names and description.