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A Network Analysis of Posttraumatic Stress Disorder and Dissociation in Trauma-Exposed Adolescents

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Abstract

Posttraumatic stress disorder (PTSD) and dissociation have long been recognized to co-occur, leading the DSM-5 to introduce a dissociative subtype of PTSD into its nomenclature. Most research to date on the dissociative subtype has focused on adults. The current study aimed to extend this research to an adolescent sample and to examine symptom-level associations between PTSD and dissociation using network analysis. The analysis was conducted with 448 trauma-exposed detained US adolescents (24.55% female; mean age 15.98±1.25 years). A network consisting of 20 DSM-5 PTSD symptoms was constructed, followed by a network consisting of 20 PTSD symptoms and five dissociative items. Expected influence bridge centrality was estimated to examine items with the most/strongest cross-construct connections (i.e. between PTSD and dissociation). The PTSD symptoms *concentration problems*, *amnesia* and *recurrent memories* and the dissociative items *depersonalization*, *derealisation* and *can't remember things that happened* had the highest bridge centrality values. These symptom-level associations extend our understanding of the PTSD-dissociation relationship by pointing to specific symptoms of PTSD and dissociation that may drive the co-morbidity between the two constructs. These findings may inform future intervention efforts.

Keywords: PTSD, dissociation, dissociative subtype, network analysis, adolescents, youth

Highlights

- *Recurrent memories* was the most central PTSD symptom
- *Concentration problems* was the PTSD symptom with highest bridge centrality
- *Amnesia* and *Recurrent memories* also had high bridge centrality
- *Can't remember things* was dissociative symptom with highest bridge centrality
- Memory problems were bridge symptoms between PTSD and dissociation

1. Introduction

The associations among trauma, posttraumatic stress disorder (PTSD), and dissociation have long been recognized in the scientific literature (van der Hart & Horst, 1989). In 2013, the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5, American Psychiatric Association [APA], 2013) included within its nosology the dissociative subtype of PTSD. To meet criteria for the subtype, trauma survivors must first meet the criteria for PTSD (i.e., symptoms of intrusions, avoidance, negative alterations in cognitions and mood [NACM], alterations in arousal and reactivity [AAR]) and then additionally must report symptoms of depersonalization and/or derealization. Depersonalization refers to “out of body experiences” and derealization represents “experiences of unreality of surroundings” (APA, 2013). Whereas previous research has supported the existence of the dissociative PTSD subtype (for a review see Hansen, Ross, & Armour, 2017), the vast majority of these studies have focused on adults. Accordingly, less is known about the relationship between PTSD and dissociation in adolescents.

The lack of research on the dissociative subtype during the adolescent period is a major impediment to both empirical and clinical advances. Findings from studies conducted with adult samples may not be directly applicable to adolescents, given that posttraumatic reactions may manifest differently across different age groups, due to the different developmental milestones that these groups have achieved (e.g., the development of coping mechanisms and emotion regulation strategies; Brown, Becker-Weidman, & Saxe, 2014). Because of these differences, studies on dissociative PTSD conducted with adults should only be used with great caution when drawing conclusions regarding the phenomenology of dissociation and PTSD among adolescents. For accurate diagnosis and appropriate treatment of posttraumatic reactions in adolescents, it is important to build a solid database of research studies that focus specifically on this age group.

The relevance of dissociation for understanding posttraumatic stress reactions in adolescence is evident in the small body of research that has emerged to date. For example, in one study conducted with a clinical sample of 3081 traumatized adolescents, Choi et al. (2019) found that 53.7% of those with PTSD also met criteria for the dissociative PTSD subtype, characterized by depersonalization/derealization. Furthermore, Kadak, Nasiroglu, Boysan, and Aydin (2013) found that, following a severe earthquake, Turkish adolescents (*n* = 759) who scored higher on a measure of dissociation were also more likely to report higher levels of PTSD symptoms. Prevalence of the dissociative subtype is particularly pronounced among certain samples of high-risk and multiply trauma-exposed youth, such as those involved in the juvenile justice system (Bennett, Modrowski, Kerig, & Chaplo, 2015; Kerig et al., 2016; Modrowski & Kerig, 2017). Samples of detained youth have historically reported a high prevalence of dissociative symptoms; for example, Koopman and colleagues (2004) found that 56% of their sample were “mild to moderately” affected by dissociative symptoms and 27% were “severely affected”. By contrast, recent studies among adults examining latent profiles of PTSD symptoms to provide support for a dissociative subtype have reported substantially lower rates of individuals who fall into a dissociative symptom class, ranging between 12 – 32% (e.g., Steuwe, Lanius, & Frewen, 2012; Waelde, Silvern, & Fairbank, 2005; Wolf et al., 2012a; Wolf et al., 2012b).

Theoretical explanations have been posited to offer insight into why the dissociative subtype may be more prevalent among youth than adults. Carlson, Yates and Sroufe (2009) characterized dissociative experiences as lying along a continuum spanning normative to disordered behavior. As such, some passive, normative fractionation of experience (i.e., dissociative processes) may serve as a developmentally appropriate approach to organizing or understanding complex, contradictory experiences in the early years of life. Further, youth may be more prone than adults to engaging in active, pathological dissociation in response to a traumatic experience when affective and cognitive dysregulation overwhelm their capacity to respond in an organized fashion (Kerig & Bennett, 2013; Carlson et al., 2009; Putnam, 1997). Moreover, the literature has historically demonstrated a strong association between childhood-onset interpersonal trauma and pathological dissociative experiences (e.g., Irwin, 1999; Sanders & Giolas, 1991); accordingly, youth may also be at elevated risk for exhibiting dissociative symptoms due to the developmentally-specific forms of trauma to which they are exposed, such as parental maltreatment (e.g., Collin-Vézina & Hébert, 2005; Hulette, Freyd, & Fisher, 2011; Kearney, Wechsler, Kaur, & Lemos-Miller, 2010; Plattner et al., 2003).

Developmental theorists have additionally proposed that dissociative phenomena may play a different role in posttraumatic stress in adolescence as compared to adulthood (Carlson et al., 2009). Consistent with this proposition, Choi, Seng et al. (2017) found that, although depersonalization and derealization were important for characterizing the dissociative PTSD subtype in youth, there are more prominent dissociative symptoms that one should focus on in adolescents, including dissociative amnesia and dissociative avoidance. These findings mimic the results from studies conducted with adult samples, in which other facets of dissociation were more prominent in the dissociative PTSD subtype than the two included in the DSM-5 definition - depersonalization and derealization (Műllerová, Hansen, Contractor, Elhai, & Armour, 2016; Ross, Baník, Dědová, Mikulášková, Armour, 2018). Similarly, in a college sample, Armour, Contractor, Palmieri, and Elhai (2014) found that the dissociative symptoms of absorption and amnesia were as strongly associated with all PTSD symptom clusters as depersonalization and derealization. In line with these findings, Dorahy and van der Hart (2015) argued that depersonalization and derealisation are not sufficient to describe the range of dissociative symptoms that often occur in those with PTSD.

Efforts to better understand the interrelations among dissociative symptoms and posttraumatic symptom clusters, as well as those among PTSD symptom presentations in general, have led to some important methodological advances. In particular, in recent years, the field of psychotraumatology has seen a growing number of studies being conducted from the network perspective on mental disorders (for example, see a recent special issue on the topic; Frewen, O'Donnell, & D'Andrea [in press]). The network theory of mental disorders postulates that mental disorders are networks of symptoms that affect each other through causal interactions (Borsboom, 2017). Symptoms in the network are called nodes and the relationships between them are called edges. Existing network analysis studies have examined the relationship between PTSD and a range of related constructs, including major depressive disorder (Afzali, Sunderland, Teesson et al., 2017), alcohol use (Afzali, Sunderland, Batterham et al., 2017), risky sexual behaviour (Choi, Batchelder, Ehlinger, Safren, & O'Cleirigh, 2017), functional impairment (Ross, Murphy, & Armour, 2018), or even multiple covariates at the same time (Armour, Fried, Deserno, Tsai, & Pietrzak, 2017; Birkeland & Heir, 2017).

Two known studies so far have examined the network structure of DSM-5 PTSD and dissociative symptoms (Cramer, Leertouwer, Lanius, & Frewen, in press; McBride, Hyland, Murphy, & Elklit, 2019) in adults. First, using a sample of 473 Danish adults seeking psychological treatment for childhood sexual abuse, McBride et al. (2019) found that depersonalization was connected primarily to the PTSD symptoms of nightmares and flashbacks and derealization had connections primarily with the NACM and AAR symptoms. Second, using data from 557 adults with probable PTSD diagnosis gathered via Amazon Mechanical Turk, Cramer and colleagues (in press) found that although both depersonalization and derealization were related to the PTSD symptom of trauma-related amnesia, depersonalization also had a strong connection with self-destructive/reckless behaviour and flashbacks, whereas derealization only had a weak connection with these symptoms. Additionally, the authors found that, out of all PTSD and dissociation symptoms, depersonalization was the most central symptom in the network, i.e. it had the strongest connections with the other symptoms in the network (Cramer et al., in press). The differences in findings of these two studies could be due to the different measures used or different trauma types experienced by participants (Kelley, Weathers, McDevitt-Murphy, Eakin, & Flood, 2009).

We are aware of only six network analysis studies on PTSD to date that have been conducted with child and adolescent samples. Among these, Cao et al. (2019) investigated sex differences in DSM-IV PTSD symptoms in a sample of 868 disaster-exposed adolescents and found that the most central symptoms in girls were detachment, flashbacks, avoiding activities and people, and intrusive recollections, whereas in boys, these were flashbacks, physiological reactivity, diminished interest and foreshortened future. In another DSM-IV network study conducted with 786 children and adolescents exposed to natural disasters, Russell, Neill, Carrión and Weems (2017) found the most central symptoms to be physiological reactivity and avoiding activities in children, and physiological reactivity, and numbness related to happiness/love in adolescents. In a DSM-5 network study of PTSD, Bartels et al. (2019) analysed self-reports of PTSD symptoms from 475 traumatized children and adolescents and 424 caregiver reports on their children and found that the NACM symptoms featured prominently as the most central symptoms. Psychological distress, negative trauma-related cognitions and persistent negative emotional state were identified amongst the most central symptoms in both the children/adolescent and caregiver reports. Additionally, looking at the direction of the associations between symptoms, the authors reported that negative trauma-related cognitions and persistent negative emotional state were the driving forces in the PTSD networks, predicting many other symptoms.

In another network study, using a sample of 419 refugee minors in Germany, Pfeiffer et al. (2019) found that the most central symptoms were nightmares, physiological and psychological reactivity and concentration problems. Similarly, Ge, Yuan, Li, Zhang, and Zhang (2019) found that, in a sample of 1623 youth earthquake survivors, re-experiencing symptoms (i.e., intrusive memories, flashbacks, being upset by trauma reminders) displayed the greatest centrality across three time points; although the connectivity between these and other PTSD symptoms showed some variability over time with the arousal cluster and particularly irritability/anger increasing in centrality at six months post-trauma. Finally, de Haan et al. (2020) used a sample of 2313 trauma-exposed children and adolescents to examine the network structure of posttraumatic cognitions, several PTSD symptoms (not all DSM-5 symptoms) and depression. Strong physical sensations were amongst the most central symptoms in the network.

The current study aimed to contribute to this area of research by applying network analysis to the examination of symptom level connections in PTSD and of the relationship between PTSD and dissociation in trauma-exposed adolescents. More specifically, we were interested in the symptom level-associations 1) between the individual PTSD symptoms, and 2) between the PTSD and dissociation symptoms. For the latter, we utilized a bridge centrality metric which can identify symptoms that are most involved in the close relationship between the two constructs. To the best of our knowledge, this is the first network study of PTSD symptom clusters and dissociation in trauma-exposed adolescents. Based on previous adolescent network studies, we hypothesized that physiological reactivity would be amongst the most central PTSD symptoms. Additionally, we expected to find strong connections between the dissociative symptoms and the PTSD symptoms of flashbacks and amnesia, both of which are described as “dissociative” in the DSM-5 (APA, 2013) criteria for the PTSD diagnosis.

2. Method

2.1 Participants and Procedure

Youth included in the present study were recruited from two detention centers in the Mountain West region of the US. Legal guardians were informed about the nature of the study during visiting hours at the detention centre, and following provision of their informed consent, youth were invited to provide their own assent to participate. All self-report measures were administered on a laptop by trained research assistants in private visitation rooms within the detention facility. Youth were not offered compensation for their participation. All study procedures were approved by the institutional review boards of the University of Utah and the Utah Department of Human Services.

The original sample consisted of 500 youth. Of these, 22 did not complete the trauma history screen and/or the PTSD measure (see Section 2.2) and were excluded from the study. A further 24 were excluded as they indicated no trauma exposure. Finally, six participants were excluded due to missing more than 20% of data on the relevant measures, yielding an effective sample of *N*=448. Of the remaining 448 participants, 110 (24.55%) were female, 334 (74.55%) were male, two (0.45%) identified as transgender and two others did not report their sex. Participants were aged between 12 and 19 years, with the mean age of 15.98 years (*SD*=1.25). The majority (*n*=196, 43.75%) identified as Caucasian/White, followed by Latino(a)/Hispanic American (*n*=155, 34.60%).

2.2 Measures

2.2.1 Trauma history and PTSD

UCLA PTSD Reaction Index for DSM-5 (PTSD-RI; Pynoos & Steinberg, 2014) was used to assess both the trauma history and the PTSD symptoms. The scale enquires about 14 potentially traumatic events and participants indicate (yes/no) whether each event happened to them. PTSD symptoms are assessed with 27 items. Participants were asked how much of the time during the past month each item applied to them, with response options *0=None*, *1=Little*, *2=Some*, *3=Much*, *4=Most*. Sixteen out of the 27 items map directly onto the DSM-

5 criteria for PTSD (APA, 2013) and the remaining four DSM-5 symptoms are assessed by multiple items. In the current study, we used the item with the highest score. Questions were keyed to the most bothersome traumatic event. Cronbach's alpha for all 27 items was .93 in the current study.

2.2.2 Dissociation

Dissociation was assessed with four items from the PTSD-RI, which assess depersonalization and derealization (two each). The item with the highest score was used in the analysis. To capture other important aspects of dissociation, three items from the Overt Dissociation subscale of the *Trauma Symptom Checklist for Children* (Briere, 1996) were also included. These measured the symptoms of dissociative avoidance (*"I go away in my mind and try not to think*), dissociative amnesia (*"I can't remember things that happened,")* and dissociative disconnection (*"My mind goes empty or blank"*). The items were answered on the same scale as the PTSD symptom items.

2.3 Data Analysis

The data were prepared in IBM SPSS 25 and analysed in R version 3.6.0 (R code is available in Supplementary material). Two networks were estimated; one consisting of 20 PTSD items, and one consisting of 20 PTSD and five dissociation items. Missing data in the effective sample was minimal (0.47% of values missing on the 25 items included in the analysis). The networks were estimated using complete pairwise observations.

2.3.1 Network estimation

Both networks were estimated using the R package *bootnet* (Epskamp, Borsboom, & Fried, 2018). Polychoric correlations were computed between each pair of nodes and a Gaussian Graphical Model (GGM) was estimated. The GGM consists of nodes that represent variables and edges between the nodes that can be interpreted as partial correlations with values ranging from -1 to +1. To avoid computation of spurious edges, the network was regularized using the graphical lasso regularization technique, which shrinks all edges and constrains the very small ones to zero. This results in a more parsimonious network (Friedman, Hastie, & Tibshirani, 2008). In the visualization of the networks, blue solid lines were used to represent positive edges and red dashed lines were used to represent negative edges. The thicker and more saturated the line, the stronger the connection.

The R package *bootnet* was also used to examine the accuracy of the networks; we bootstrapped (2000 iterations) the 95% confidence intervals around the edge weight estimates. Smaller confidence intervals indicate greater accuracy. Finally, we computed tests of significant differences between all pairs of edge weights.

2.3.2 Centrality estimation

Centrality measures node interconnectedness and in the current study, we computed expected influence centrality (R package *qgraph*; Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012) for the PTSD network. Expected influence centrality for a specific node is the sum of all edges this node is directly connected to (Robinaugh, Millner, & McNally, 2016).

We then conducted the case-dropping subset bootstrap (2000 iterations, R package *bootnet*) which indicates whether the order of the centrality values (here expected influence centrality) remains unchanged if the network is re-estimated with smaller sub-samples. If the correlation between the original order of centrality values and the order derived from the sub-samples remains high, the centrality values are considered stable. A correlation stability coefficient (CS coefficient) was calculated to quantify the results of the subset bootstrap. Values of at least 0.25, and preferably above 0.5 are needed for the centrality values to be interpretable (Epskamp et al., 2018).

For the PTSD with dissociation network, we computed the one-step bridge expected influence centrality, using the R package *networktools* (Jones, 2018). Bridge centrality is useful when examining the co-morbidity between two disorders. The one-step bridge expected influence centrality is the sum of all direct edges (not absolute) between a specific node from one construct and all other nodes in the second construct (Jones, Ma, & McNally, 2019).

3. Results

3.1 Descriptive Statistics

Participants in the effective sample reported having experienced between one and 13 different trauma types, with a mean number of 5.08 (*SD*=2.59) different trauma types. The most commonly reported traumas were 'having known someone who died unnaturally' (68.53%), 'having been beaten up/shot at/threatened to be hurt' (67.19%), 'having seen someone being beaten up/shot at/killed' (64.3%), 'being hit/pushed/choked/shaken/bit/ burned/punished' (46.65%), and 'having seen/heard grownups in family physically fighting' (45.09%). In terms of the total number of traumatic experiences (i.e., including repeated traumas), the vast majority of the sample (96.0%) experienced more than one traumatic event; 27.9% reported between 2–10 traumas, 21.0% reported between 11-20 traumas, 12.3% reported between 21-30 traumas, and the remaining 34.8% reported more than 30 traumas. The total PTSD scores in the effective sample ranged from 0 to 74, with a mean score of 29.03 (*SD*=17.51). A total of 197 (43.97%) participants met the DSM-5 criteria for PTSD and of these, 119 reported symptoms of depersonalization and/or derealization, in line with the dissociative PTSD subtype. The means and standard deviations of the PTSD and dissociation items are presented in Appendix A in Supplementary material.

3.2 PTSD network

As shown in Figure 1, which depicts the PTSD network, the vast majority of the edges were positive, with the strongest edges identified between *diminished interest* and *detachment* symptoms (regularized partial correlation: 0.33), between *physiological reactions* and *avoidance of external reminders* (0.31), *detachment* and *no positive emotions* (0.30), *irritability and anger* and *reckless behaviour* (0.26), and between *recurrent memories* and *psychological distress* (0.25). The edge weight bootstrap (Appendix B in Supplementary material) showed overlapping 95% confidence intervals for the vast majority of the edge weights, but some of the strongest edges had non-overlapping intervals with many others in the network, suggesting that they are significantly stronger. This was supported by tests of significant differences (Appendix B in Supplementary material); the above edges were significantly stronger than many others in the network, but they were not significantly different from each other.

Standardized expected influence centrality is depicted in Figure 2. The case-dropping bootstrap (Appendix B in Supplementary material) showed that expected influence was relatively stable and this was supported by the CS coefficient of 0.59. Nodes with the highest expected influence centrality were the PTSD symptoms *recurrent memories* (standardized expected influence centrality: 2.07), *physiological reactions* (1.82) and *detachment* (1.32). The least central node was *hypervigilance* (-1.82). Tests of significant differences (Appendix B in Supplementary material) revealed that the three most central symptoms did not differ from each other, but they were significantly more central than most other symptoms in the network. On the other hand, *hypervigilance* was significantly less central than the majority of the other symptoms in the network.

3.3 PTSD and Dissociation Network

The combined PTSD and dissociation network is depicted in Figure 3 and again shows that the vast majority of the estimated edges were positive. As would be expected, the strongest edges were identified within the two constructs (i.e. within PTSD, and within dissociation) as opposed to between them. They included the associations between the PTSD symptoms *diminished interest* and *detachment* (regularized partial correlation: 0.32), *physiological reactions* and *avoidance of external reminders* (0.31), *detachment* and *no positive emotions* (0.29), *irritability and anger* and *reckless behaviour* (0.25), *recurrent memories* and *psychological distress* (0.24) and the associations between the dissociation items of *depersonalization* and *derealization* (0.40), *mind goes blank* and *go away in mind* (0.37), *mind goes blank* and *can't remember things* (0.28), and *go away in mind* and *can't remember things* (0.27). The strongest edges identified in the PTSD only network were also the strongest ones in the combined PTSD with dissociation network.

Of particular interest to the current study are the associations between PTSD and dissociation. The strongest "cross-construct" edges were identified between the dissociation item *can't remember things* with the PTSD symptom *concentration problems* (regularized partial correlation: 0.21) and with the PTSD symptom *amnesia* (0.19). The edge weight bootstrap and associated significance tests are presented in Appendix C (Supplementary material). As before, there was a lot of overlap in the 95% confidence intervals of the edge weights, but some of the strongest edges were significantly stronger than many others in the network.

In terms of bridge centrality, the highest bridge expected influence values among the PTSD items were found for *concentration problem*s (standardized: 1.03), *amnesia* (0.97) and *recurrent memories* (0.38). For dissociation, the highest relative values of bridge centrality were identified for the items *can't remember things that happened* (2.37), *depersonalization* (2.17) and *derealisation* (2.03). These items had the most/strongest associations with the items from the other construct.

4. Discussion

The results of the current study help to clarify the relationship between PTSD and dissociative symptoms in trauma-exposed adolescents. Most of the relationships between the symptoms in the PTSD network were positive, with the strongest edges identified primarily between the symptoms *within* PTSD symptom clusters, rather than *between* them, which is in line with the DSM-5 conceptualization of PTSD. As hypothesized, *physiological reactions* (B5) was one of the most central symptoms, together with *recurrent memories* and *detachment*. In the combined PTSD and dissociation network, the strongest edges between the PTSD symptoms were the same as those identified in the PTSD only network, suggesting that the addition of dissociative symptoms did not markedly change the structure of the network. The symptoms contributing most to the co-occurrence of PTSD and dissociation in our sample were the PTSD symptoms *concentration problems*, *amnesia* and *recurrent memories*, and the dissociative items *can't remember things that happened*, *depersonalization* and *derealization*. The relationships of the dissociative item *can't remember things that happened* with the PTSD symptoms *concentration problems* and *amnesia* were the strongest cross-construct connections in the network. The PTSD symptom *flashbacks* did not feature dominantly in the relationship between PTSD and dissociation. Our second hypothesis was therefore only partially supported. These results extend our understanding of the ways in which PTSD and dissociation co-occur in trauma-exposed adolescents by highlighting specific symptom-level associations.

The high centrality of the *physiological reactions* symptom in the PTSD network is noteworthy, as it supports the findings of the four previous network studies conducted with adolescents that have included this construct (Cao et al., 2019; de Haan et al., 2020; Pfeiffer et al., 2019; Russell et al., 2017). Most research to date examining patterns of physiological reactivity following exposure to trauma has been conducted among adult samples (e.g., Pole, 2007), with only a limited literature examining the role of physiological reactivity among developing adolescents (for a review see Kirsch, Wilhelm, & Goldbeck, 2011) with variable, inconsistent results that often do not replicate the findings among adults (Grasso & Simons, 2012; Kirsch, Wilhelm, & Goldbeck, 2015). In addition to biological differences between youth and adults (e.g., Quigley & Stifter, 2006), developmental differences may make physiological reactivity a more salient symptom for youth exposed to traumatic events. For example, youth may be more likely to appraise an ambiguous situation as a threat, leading to more frequent activation of physiological response systems, and youth may have greater variability in their ability to subsequently regulate and recover from heightened arousal (Obradović, 2012). Recurrent exposure to perceived threats with limited capacity for effective emotion regulation may lead youth to develop physiological sensitivity, which may place them at greater risk for internalizing and externalizing symptoms (Obradović, 2012). The current study provides further evidence that perceived physiological reactivity among youth may be differentially associated with the development of posttraumatic stress symptoms.

Of particular interest is the strong connection between *physiological reactions* and *avoidance of external reminders* – again a finding reported previously (Russell et al., 2017). This association could be seen as a learned response and it can be explained by conditioning theories of PTSD, where certain stimuli become associated with the traumatic event and cause physiological reactions, such as fear and anxiety, which subsequently leads to the avoidance of these stimuli in future (Gillihan, Cahill, & Foa, 2014).

In the adult network studies of PTSD, the most consistent finding so far has been the high centrality of the *negative emotional state* symptom (Armour et al., 2017; Benfer et al., 2018; Mitchell et al., 2017; Moshier et al., 2018; Spiller et al., 2017; Ross et al., 2018; von Stockert, Fried, Armour, & Pietrzak, 2018), although at least three studies also found the *physiological reactions* symptom to have high centrality (Armour et al., 2017; Benfer et al., 2018; Moshier et al., 2018; Spiller et al., 2018). In the current study, *negative emotional state* also had a relatively high centrality value, being the fourth most central symptom, suggesting some similarity with the adult samples.

Looking at the combined PTSD and dissociation network, the strongest cross-construct connections were identified between the dissociative item *can't remember things that happened* and the PTSD symptoms *amnesia* and *concentration problems*. Together with the PTSD symptom *recurrent memories* and the dissociative items *depersonalization* and *derealization,* these items had the highest bridge centrality values, suggesting that relative to the other items in the network, these items contribute the most to the PTSD – dissociation relationship in our sample.

These findings are interesting in that, apart from *amnesia*, the only other symptom of PTSD explicitly defined in the DSM-5 PTSD symptom criteria as "dissociative", is *flashbacks* (APA, 2013) and one would therefore expect these two symptoms to be most closely related to other dissociative symptoms. Having said that, Dorahy and van der Hart (2015) argued that other PTSD symptoms that are currently thought to reflect "non-dissociative PTSD" could actually be considered dissociative in nature. *Recurrent memories of trauma* fall into the category of positive dissociative experiences, defined by Cardeña and Carlson (2011) as *"a loss of continuity in subjective experience with accompanying involuntary and unwanted intrusions into awareness and behaviour"* (p.251). *Amnesia*, on the other hand, is a negative dissociative symptom, defined as *"an inability to access information or control mental functions or behaviors"* (p.251), whereas *depersonalization* and *derealization* are dissociative symptoms reflecting experiential disconnectedness (Cardeña & Carlson, 2011; Dorahy & van der Hart, 2015). Defined this way, the high relative bridge centrality values of PTSD symptoms *recurrent memories* and *amnesia* in our study make sense. As for *concentration problems,* the high relative bridge centrality value of this symptom could possibly be explained in terms of this symptom being a consequence of dissociation; the literature seems to agree that, speaking broadly, the essential feature of dissociation is disruption, discontinuity or a failure to integrate information and experiences in a way that would be expected (Putnam, 1997). Consequently, whilst dissociating, an individual may fail to concentrate on their immediate surroundings, because their ability to integrate the relevant information is impaired.

The dissociative item *Can't remember things that happened* and the PTSD item *amnesia*, worded in this study as '*I have trouble remembering important parts of what happened*', could be thought of as bridge symptoms (Cramer, Waldorp, van der Maas, & Borsboom, 2010). Bridge symptoms are symptoms that are part of two disorders in the sense that they interact with symptoms of both disorders and are thus responsible for the comorbidity between disorders (Cramer et al., 2010). Notably, although both of these symptoms are marked by memory problems, they differ in that posttraumatic memory loss as captured by the DSM-5 is specifically related to details of the traumatic event, whereas dissociative memory loss may be associated with events unrelated to and occurring after the trauma (APA, 2013; Dorahy & Van der Hart, 2015). In line with this conceptual difference, studies with adults have demonstrated that posttraumatic and dissociative amnesia are related yet distinct facets of their respective latent constructs (Armour et al., 2014). Given the similar connection found in the current study, it is possible that once memory problems associated with the traumatic event develop, the comorbidity between PTSD and dissociation is more likely. On the other hand, these findings also raise the question of whether amnesia is best thought of as a prominent feature of dissociation, or if it should continue to be listed as a symptom of the *negative alterations in cognition and mood* cluster of PTSD. With the current dearth of research into dissociation in adolescents, both of these areas are ripe for further investigation.

Since the inclusion of the dissociative PTSD subtype in DSM-5 (APA, 2013), research utilising the mixture modelling approach has supported the existence of this subtype in a proportion of individuals who meet the criteria for PTSD (see Hansen et al., 2017). As seen in the current study, network analysis can extend the mixture modelling approach by pointing to specific symptoms from the two constructs that contribute the most to the co-occurrence between PTSD and dissociation. By doing so, network analysis progresses our understanding of the dissociative PTSD subtype.

The results of this study may be useful for both researchers and clinicians working with trauma-exposed adolescents. Supporting the results of previous studies conducted with adolescents, we found that the *physiological reactions* symptom plays an important role in the PTSD network in the sense that it has many/strong connections with other symptoms. The cross-sectional nature of our study does not allow us to make conclusions about the cause-effect relationships between the individual symptoms; in other words, we cannot say whether *physiological reactions* is a highly central symptom because it causes other symptoms or because it is caused by other symptoms itself. A recent study conducted with 96 Israeli adult civilians exposed to rocket fire during the Israel-Gaza conflict, who provided twice-daily reports of their PTSD symptoms for a period of 30 days, found that *physiological reactions* reported at a given time had virtually no effect on the reporting of other symptoms at the next time reporting period (Greene, Gelkopf, Epskamp, & Fried, 2018). The authors, however, did not find *physiological reactions* to be amongst the most central symptoms. In their study, the symptom only had five significant edge weights, whereas in our adolescent sample, the symptom was connected with 12 other PTSD symptoms. It would be useful to extend the current study by using a longitudinal design in order to better understand the role (if any) that *physiological reactions* play in the development of other symptoms.

Also useful to clinicians may be the finding that PTSD and dissociation in adolescents seem to be associated primarily through the *recurrent memories*, *amnesia* and *concentration problems* symptoms. If replicated with other adolescent samples, these findings would suggest that if adolescents endorse any of these three symptoms, they may be more likely to also endorse symptoms of dissociation. This may be due to *amnesia* (and possibly also *recurrent memories* and *concentration problems*) being the so-called bridge symptoms that are part of both PTSD and dissociation, and may thus contribute to the comorbidity between the two disorders. In future studies, time-series data may be useful to determine whether this comorbidity indeed develops through these bridge symptoms and whether PTSD symptoms precede dissociation or the other way around.

The current study had several limitations that warrant future research in this area. Firstly, as mentioned above, the data was cross-sectional, thus precluding us from establishing the direction of the causal effects that the individual symptoms have upon each other. Moreover, temporal networks would be better able to point to symptoms that would be appropriate targets for interventions, thus leading to more targeted interventions and speedier recoveries. It is also important to note that cross-sectional networks cannot differentiate the between-participants and within-participants edges/relationships (Epskamp, Waldorp, Mõttus, & Borsboom, 2018). Secondly, our data were based on self-reports and clinical interviews could provide potentially useful corroborating information. Thirdly, using a larger sample and a measure of dissociation that provides a more comprehensive coverage of the different dissociative symptoms would extend the current study and, as suggested by prior research (Armour et al., 2014; Choi et al., 2017; (Műllerová, Hansen, Contractor, Elhai, & Armour, 2016; Ross, Baník, Dědová, Mikulášková, Armour, 2018), might identify other dissociative symptoms that play an even more important role in traumatized adolescents than the ones included in the present study. Fourthly, the small number of females in our sample did not allow us to look at potential gender differences in PTSD and dissociation. Previous research has shown that there are differences in PTSD network structure between adolescent males and females (Cao et al., 2019). Fifthly, the mean age of our sample was 15.98 years (ranging from 12 to 19) and it is possible that the results are more reflective of older adolescents than of youth in early adolescence or childhood. It would be useful to replicate the study with samples stratified by smaller age groups. Finally, our sample was homogeneous in the sense that all participants were involved with the justice system. Research has shown that compared to the general population of adolescents, trauma exposure and rates of PTSD are higher in justice-involved youth (Wood, Foy, Layne, Pynoos, & James, 2002) and multiple traumatization is the norm rather than an exception (Dierkhising et al., 2013). Generalizations of the current findings to other samples of adolescents should therefore only be made with caution.

5. Conclusion

The current study is the first known to apply network analysis to extend our understanding of the symptom-level associations between PTSD and dissociation in adolescents. The results suggest that concerning trauma-exposed detained adolescents, dissociation and PTSD are related primarily through the PTSD symptoms *recurrent memories, amnesia* and *concentration problems*. Of the five dissociative symptoms examined in this study, the item *can't remember things that happened* had the most/strongest associations with the PTSD symptoms. Future studies should use a more comprehensive measure of dissociation to determine whether the same or different PTSD symptoms are implicated in the relationship between the two constructs. Due to the relatively small and specific nature of our sample, the results should be replicated with larger and more diverse samples.

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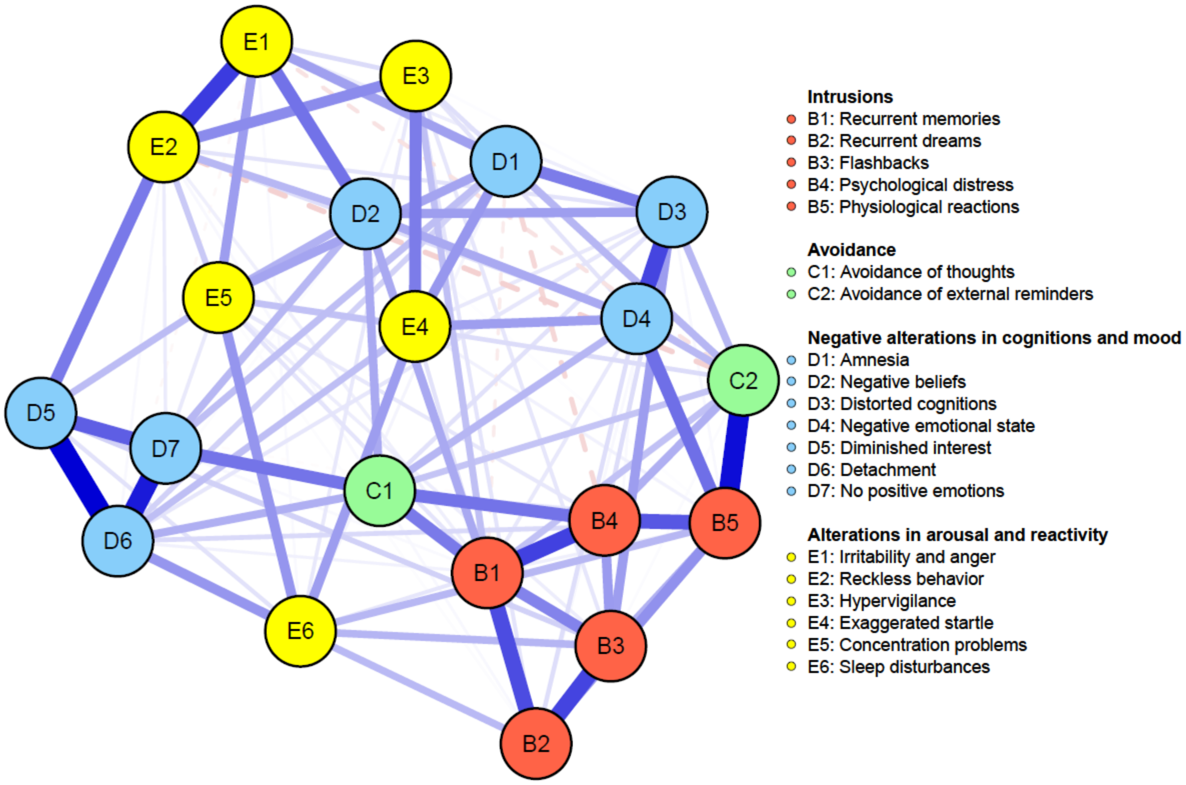

Figure 1. Regularized partial correlation network of 20 PTSD symptoms.

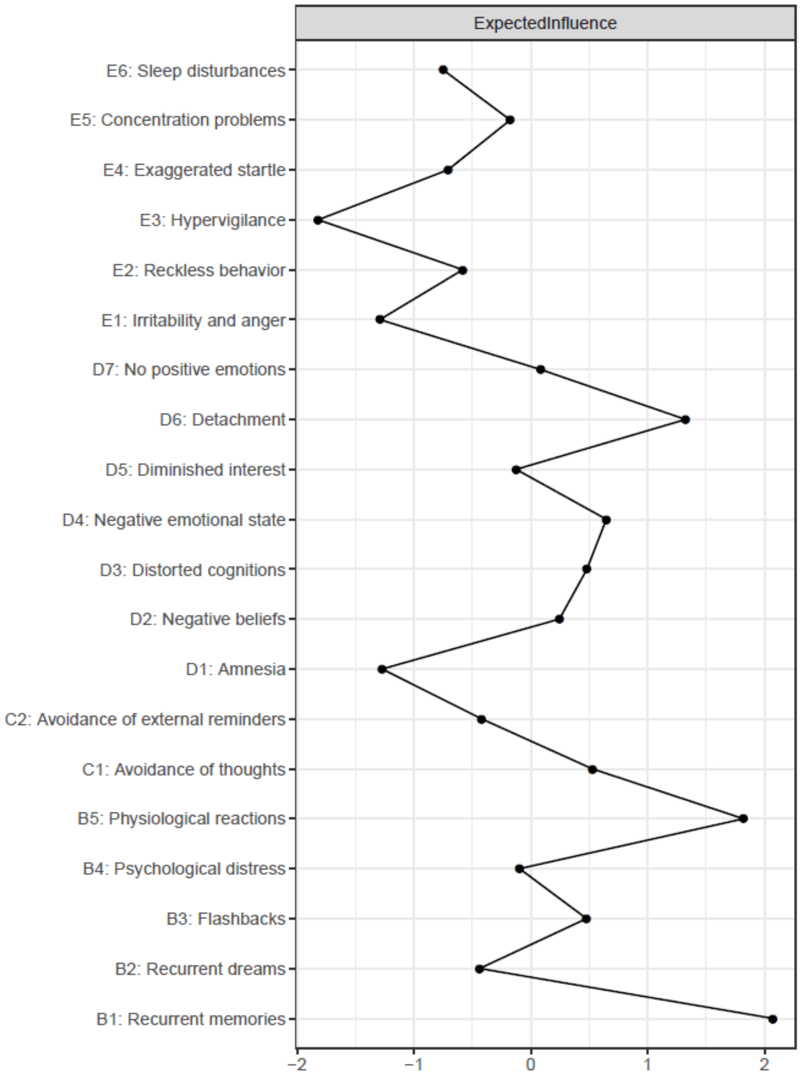

Figure 2. Standardized expected influence centrality for the PTSD network.

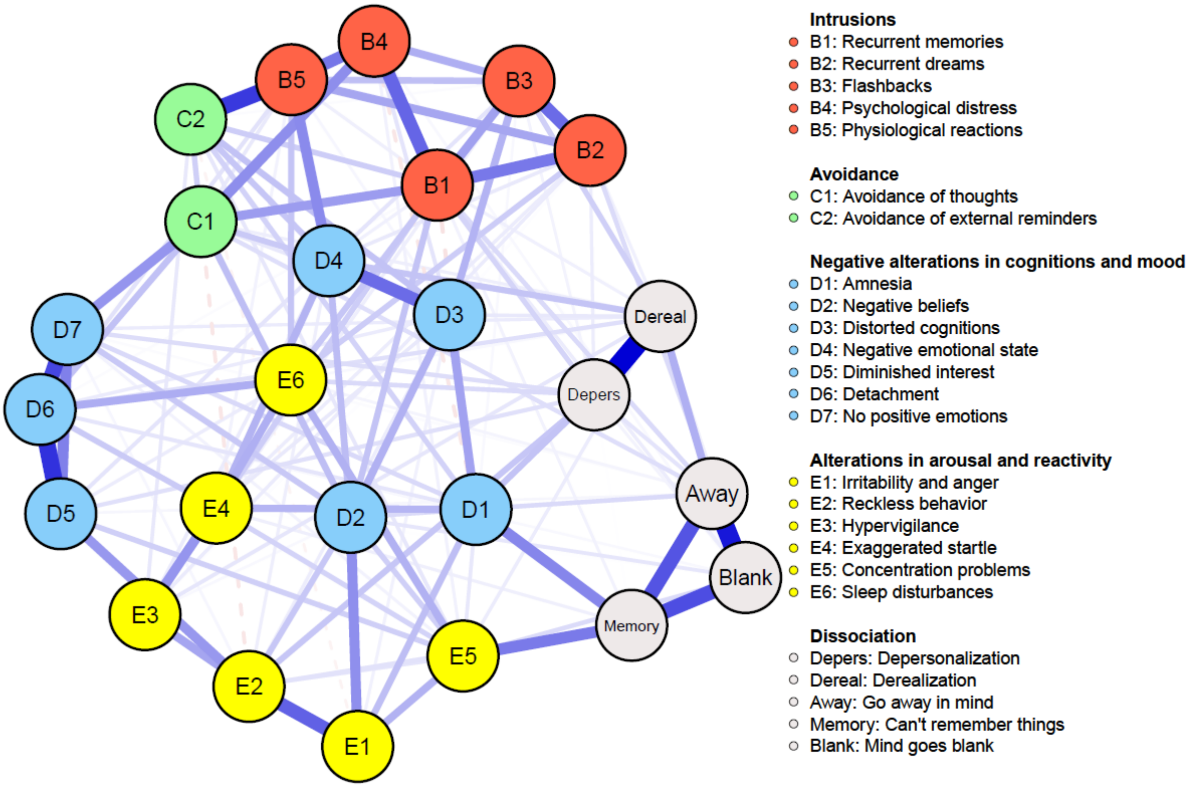

Figure 3. Regularized partial correlation network of 20 PTSD symptoms and five dissociation items.

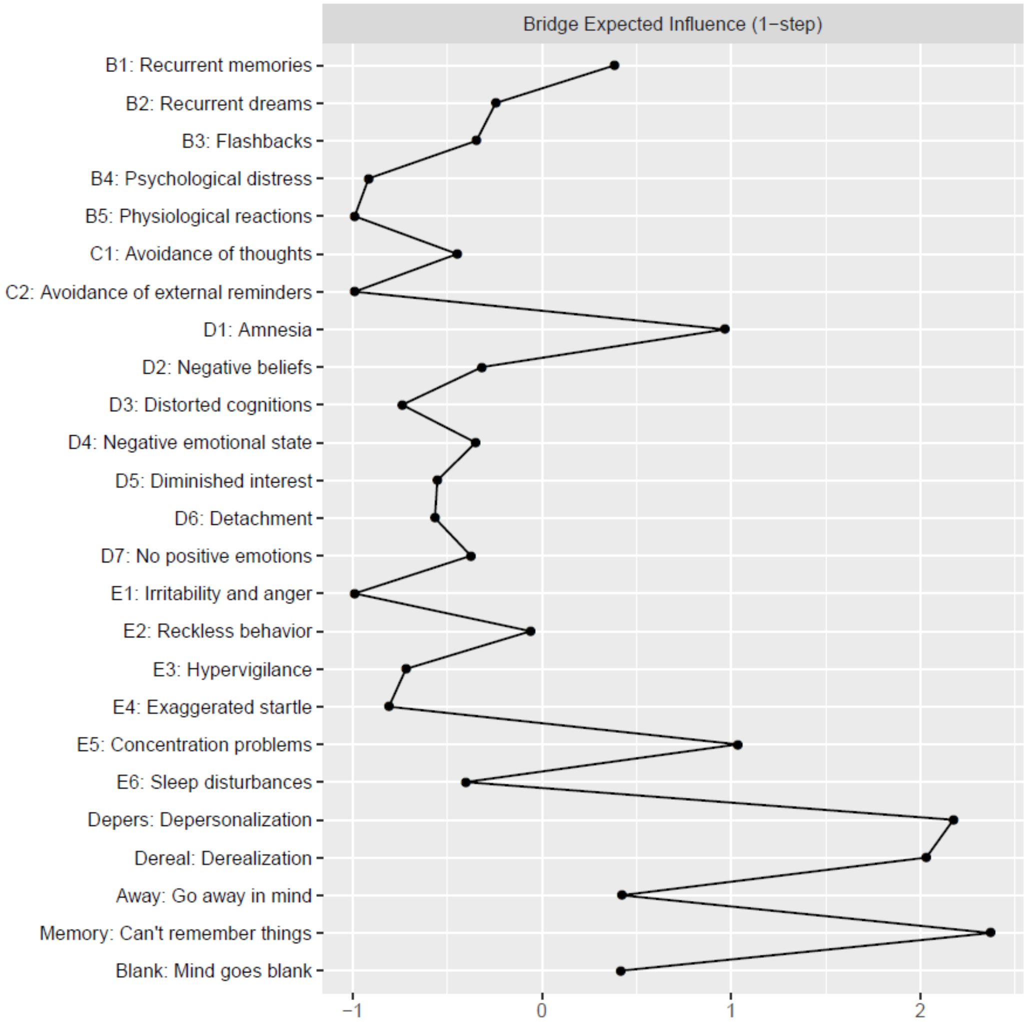

Figure 4. Bridge expected influence centrality for the combined PTSD and dissociation network.

A Network Analysis of Posttraumatic Stress Disorder and Dissociation in Trauma-Exposed Adolescents

Supplementary material

Appendix A

Table 1

Means and Standard Deviations and Response Frequencies on the PTSD and Dissociation Items (N = 448)

			Responses				
Symptom			*None*	*Little*	*Some*	*Much*	*Most*
	Mean	SD	*n* (%)				
PTSD							
B1: Recurrent memories	1.34	1.39	178 (39.91)	91 (20.40)	69 (15.47)	62 (13.90)	46 (10.31)
B2: Recurrent dreams	1.40	1.37	165 (36.91)	91 (20.36)	83 (18.57)	63 (14.09)	45 (10.07)
B3: Flashbacks	0.99	1.30	244 (54.59)	66 (14.77)	67 (14.99)	37 (8.28)	33 (7.38)
B4: Psychological distress	1.54	1.37	140 (31.25)	102 (22.77)	84 (18.75)	70 (15.63)	52 (11.61)
B5: Physiological reactions	1.41	1.40	168 (37.75)	93 (20.90)	64 (14.38)	73 (16.40)	47 (10.56)
C1: Avoidance of thoughts	1.65	1.44	139 (31.10)	89 (19.91)	72 (16.11)	85 (19.02)	62 (13.87)
C2: Avoidance of external reminders	1.30	1.39	185 (41.48)	87 (19.51)	76 (17.04)	49 (10.99)	49 (10.99)
D1: Amnesia	0.96	1.21	229 (51.35)	90 (20.18)	67 (15.02)	37 (8.30)	23 (5.16)
D2: Negative beliefs	2.18	1.37	64 (14.29)	90 (20.09)	96 (21.43)	96 (21.43)	102 (22.77)
D3: Distorted cognitions	1.90	1.48	115 (25.67)	77 (17.19)	87 (19.42)	78 (17.41)	91 (20.31)
D4: Negative emotional state	1.98	1.47	102 (22.82)	84 (18.79)	83 (18.57)	78 (17.45)	100 (22.37)
D5: Diminished interest	0.87	1.20	248 (55.48)	84 (18.79)	66 (14.77)	21 (4.70)	28 (6.26)
D6: Detachment	1.10	1.31	214 (47.77)	90 (20.09)	60 (13.39)	51 (11.38)	33 (7.37)
D7: No positive emotions	0.90	1.15	238 (53.36)	80 (17.94)	81 (18.16)	29 (6.50)	18 (4.04)
E1: Irritability and anger	1.54	1.36	134 (30.04)	108 (24.22)	86 (19.28)	66 (14.80)	52 (11.66)
E2: Reckless behaviour	1.24	1.34	189 (42.28)	92 (20.58)	73 (16.33)	55 (12.30)	38 (8.50)
E3: Hypervigilance	1.44	1.41	165 (36.83)	92 (20.54)	73 (16.29)	65 (14.51)	53 (11.83)
E4: Exaggerated startle	1.50	1.35	135 (30.20)	117 (26.17)	83 (18.57)	60 (13.42)	52 (11.63)
E5: Concentration problems	1.75	1.42	118 (26.40)	96 (21.48)	82 (18.34)	82 (18.34)	69 (15.44)
E6: Sleep disturbances	2.08	1.50	100 (22.42)	72 (16.14)	81 (18.16)	78 (17.49)	115 (25.78)

Dissociation							
Depers: Depersonalization	0.80	1.15	260 (58.04)	88 (19.64)	50 (11.16)	30 (6.70)	20 (4.46)
Dereal: Derealization	1.10	1.26	202 (45.09)	101 (22.54)	71 (15.85)	46 (10.27)	28 (6.25)
Away: Go away in mind	1.46	1.31	141 (32.27)	93 (21.28)	102 (23.34)	61 (13.96)	40 (9.15)
Memory: Can’t remember things	1.42	1.27	142 (32.27)	97 (22.05)	108 (24.55)	60 (13.64)	33 (7.50)
Blank: Mind goes blank	1.28	1.11	133 (30.43)	129 (29.52)	106 (24.26)	58 (13.27)	11 (2.52)

Note. Presented are valid percentages to account for the missing data

Supplementary

PTSD network

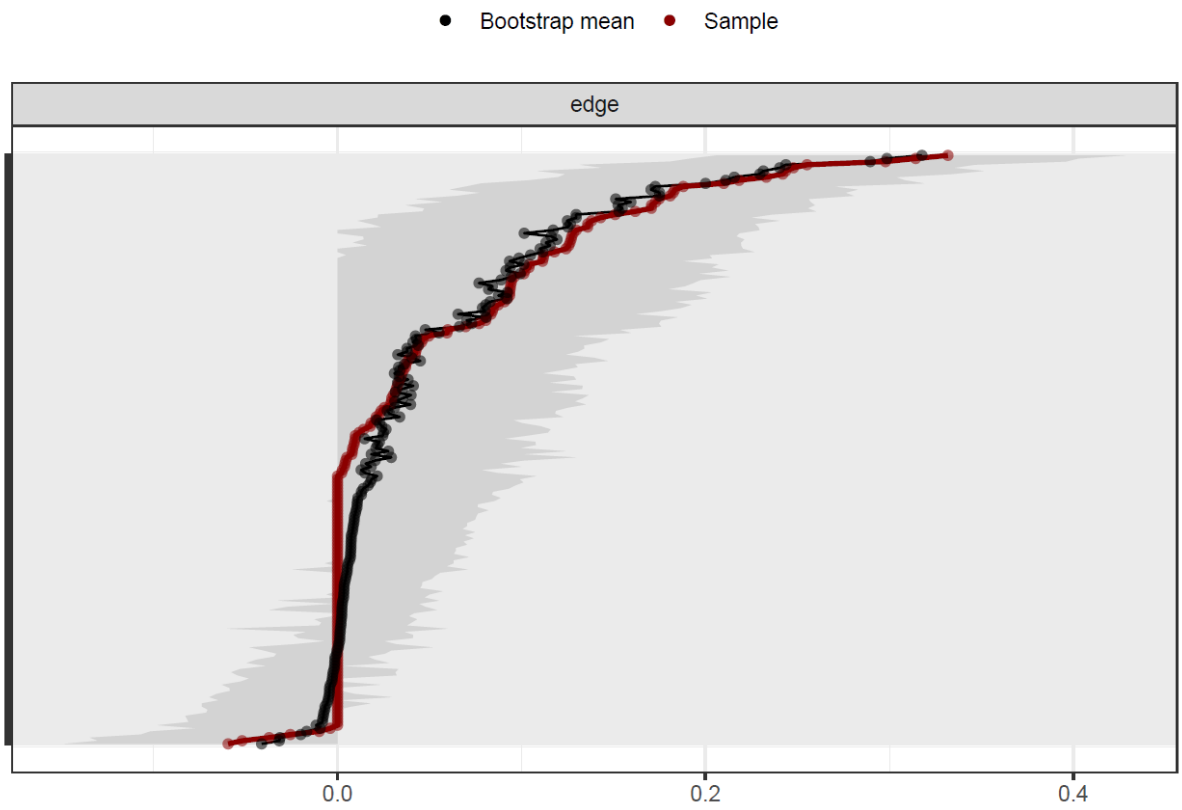

Figure A.1. Edge weight bootstrap for the PTSD network. The y-axis contains all 190 edges. The x-axis shows the strength of these edges. The red dots represent point estimates of the edges. The grey area is the associated 95% confidence interval.

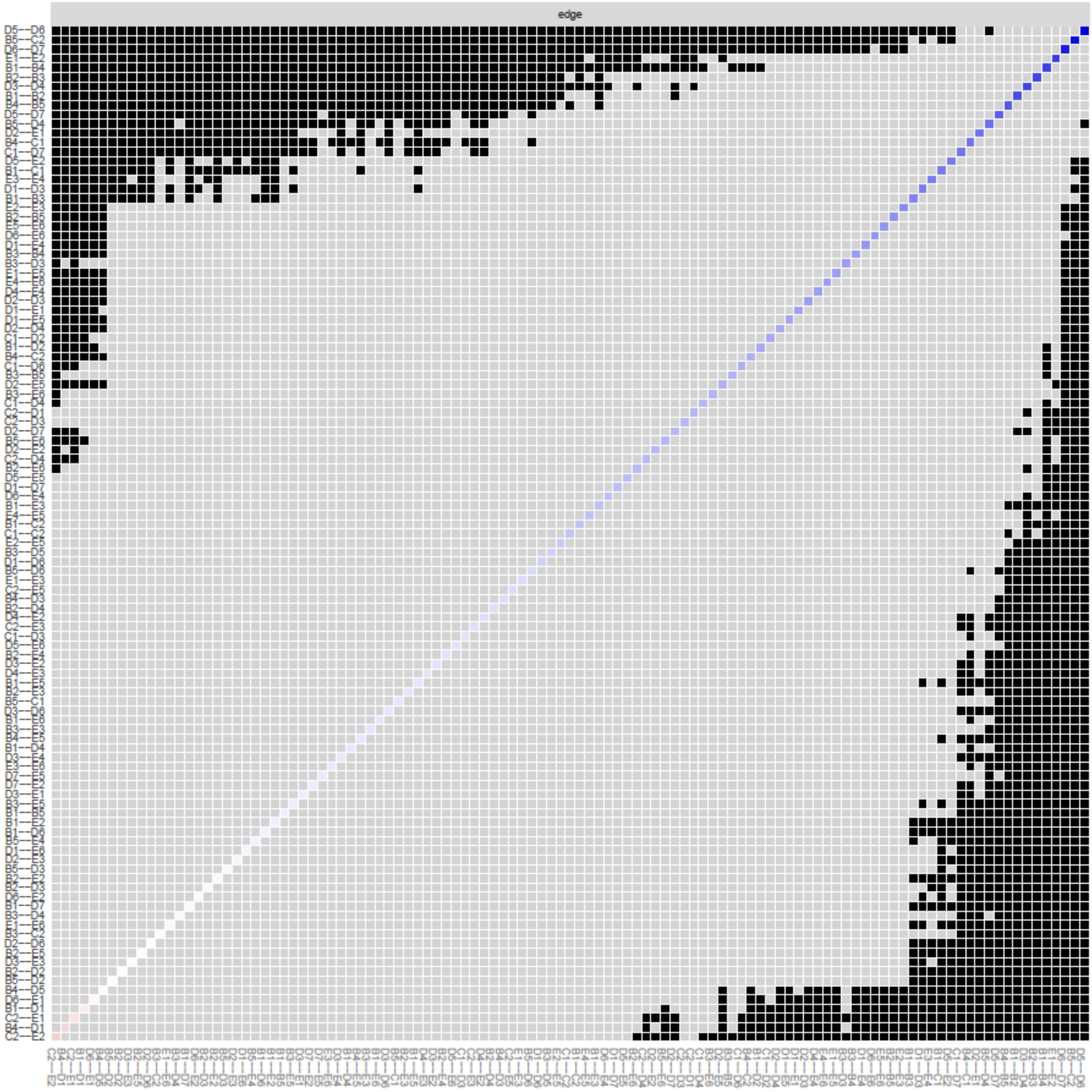

Figure A.2. Tests of significant differences between edge weights in the PTSD network. Black boxes indicate a significant difference between edge weights, grey boxes indicate no significant difference.

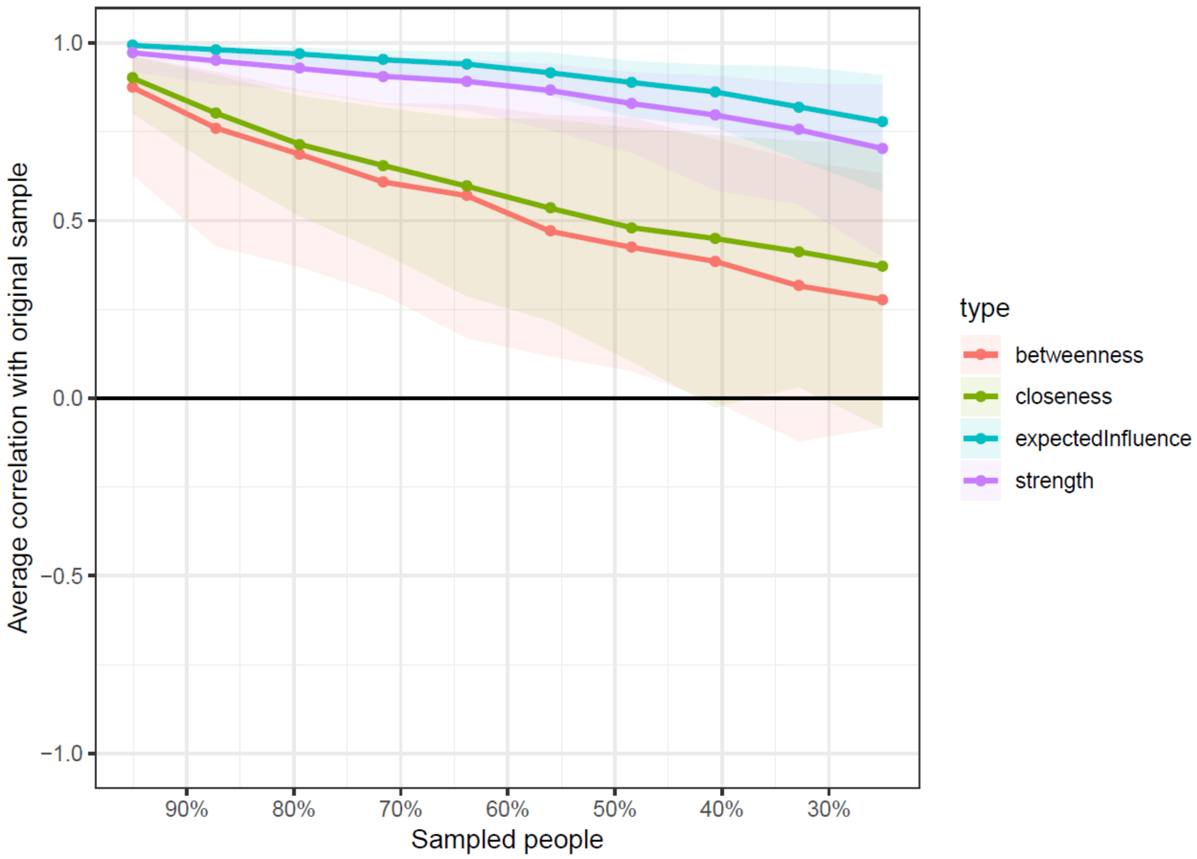

Figure A.3. Case-dropping bootstrap for the PTSD network. Average correlations between the centrality measures estimated with the full sample and the centrality measures estimated with different proportions of the sample (i.e., 90%, 80%, 70%, etc.).

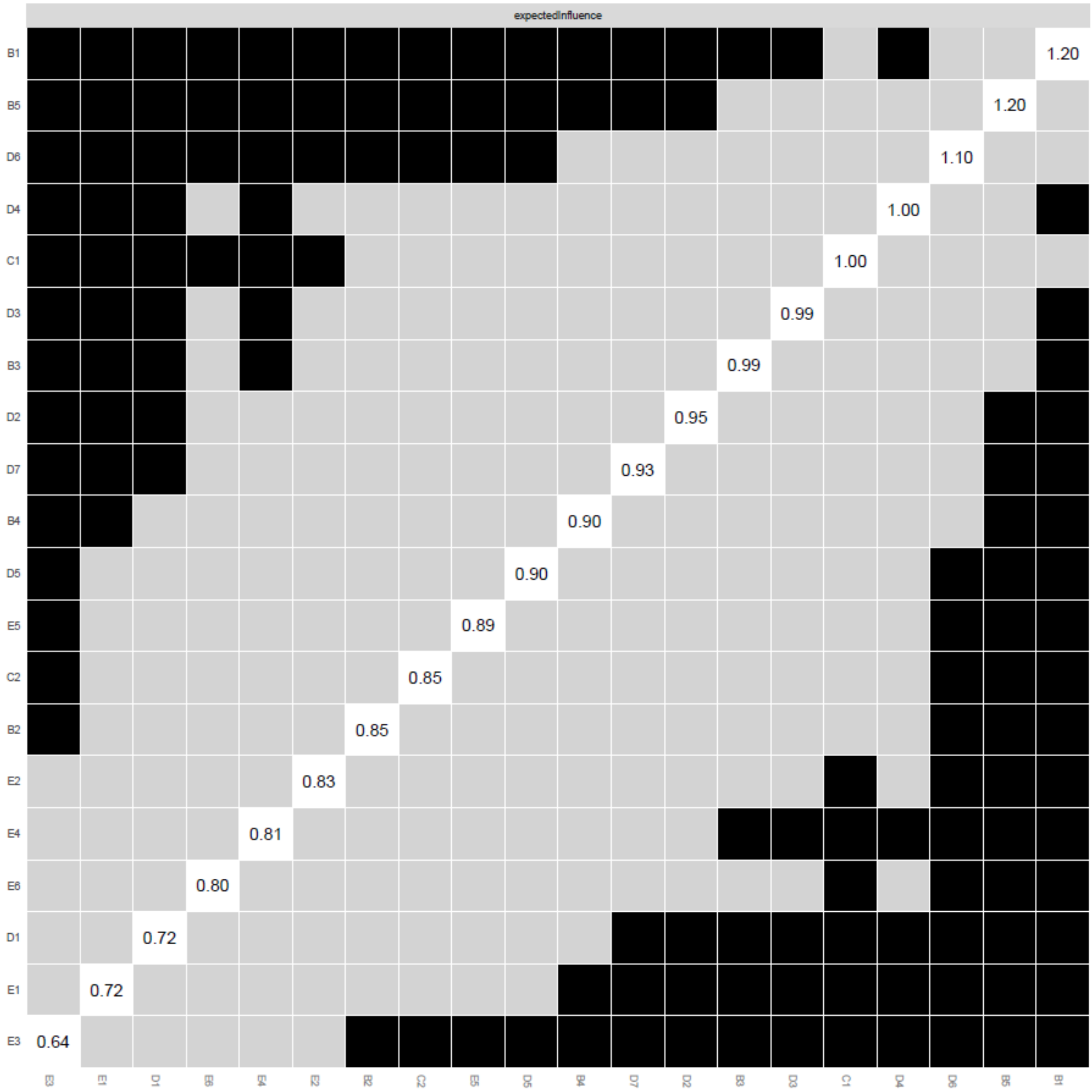

Figure A.4. Tests of significant differences between expected influence centrality values of the nodes in the PTSD network. Black boxes indicate a significant difference between centrality values of the individual nodes, grey boxes indicate no significant difference.

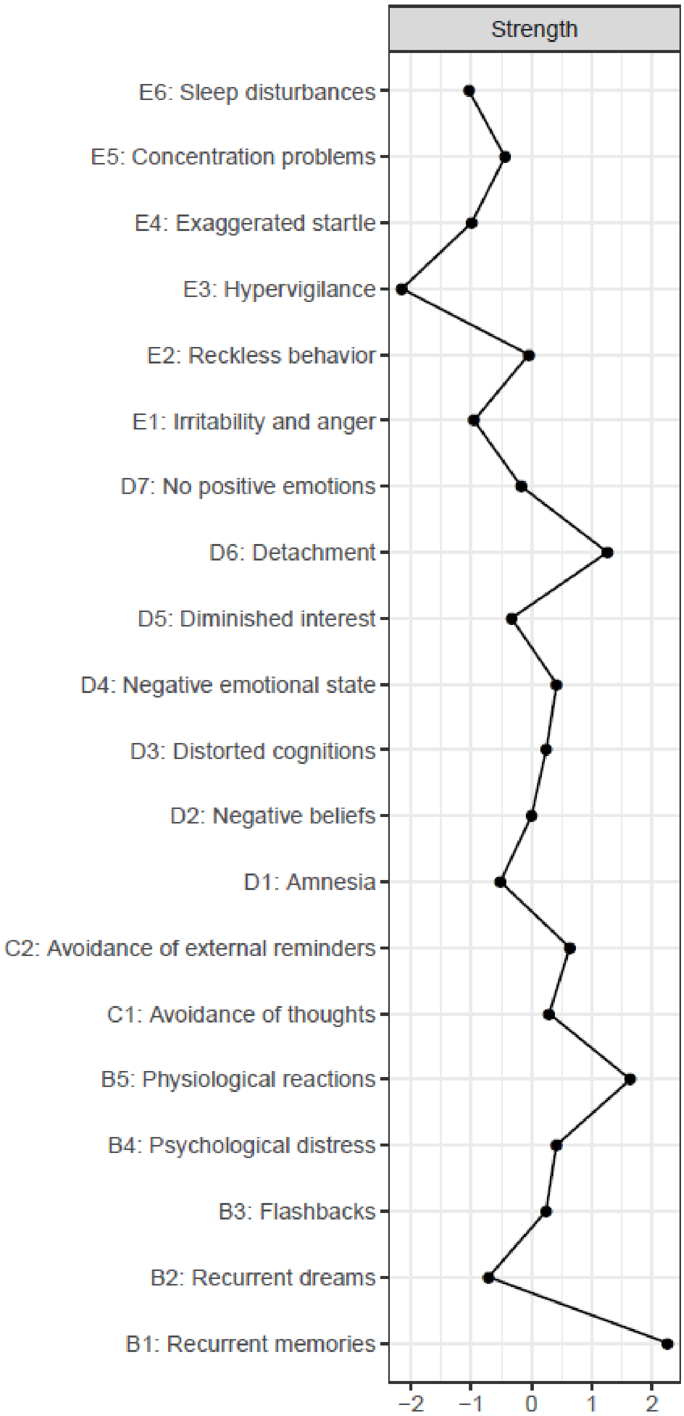

Figure A.5. Standardized strength centrality for the PTSD network (CS-coefficient = 0.51).

Note. Closeness centrality and Betweenness centrality are not presented, as their CS-coefficients were less than 0.25.

Appendix C

PTSD and dissociation network

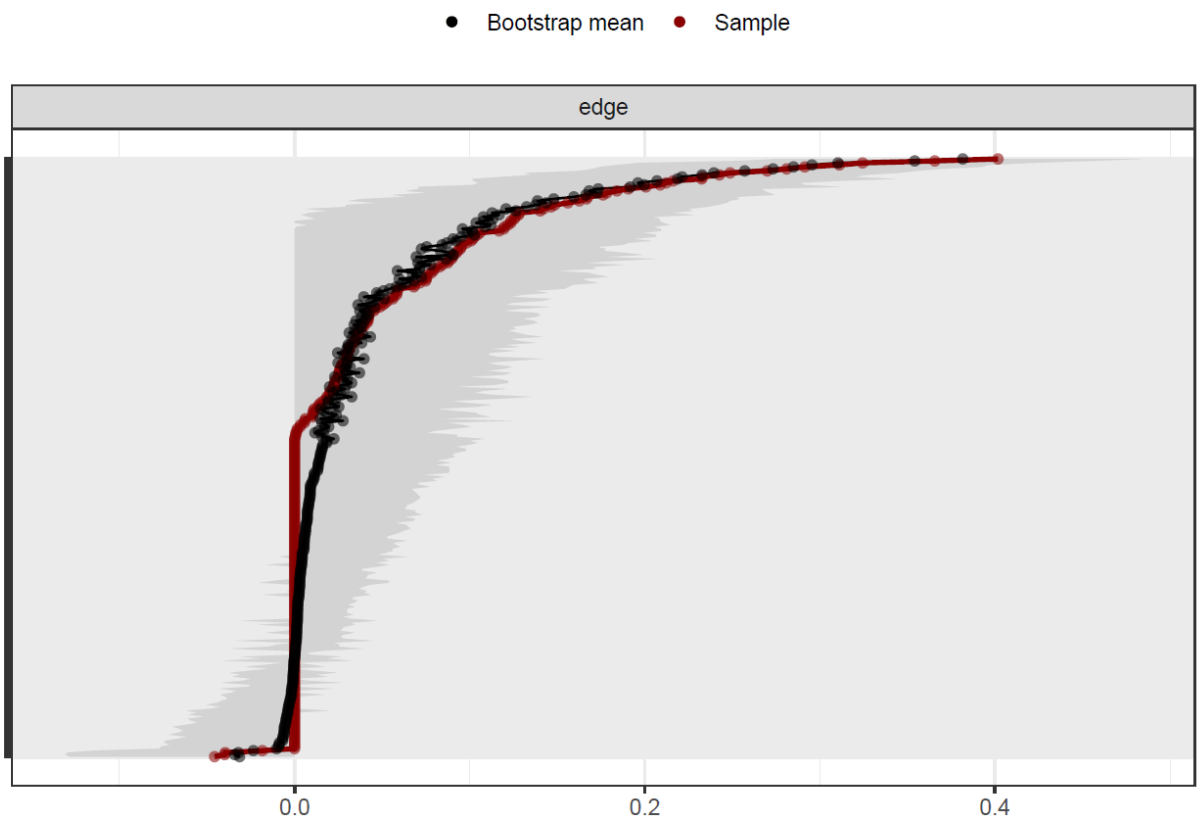

Figure B.1. Edge weight bootstrap for the combined PTSD and dissociation network. The y-axis contains all 300 edges. The x-axis shows the strength of these edges. The red dots represent point estimates of the edges. The grey area is the associated 95% confidence interval.

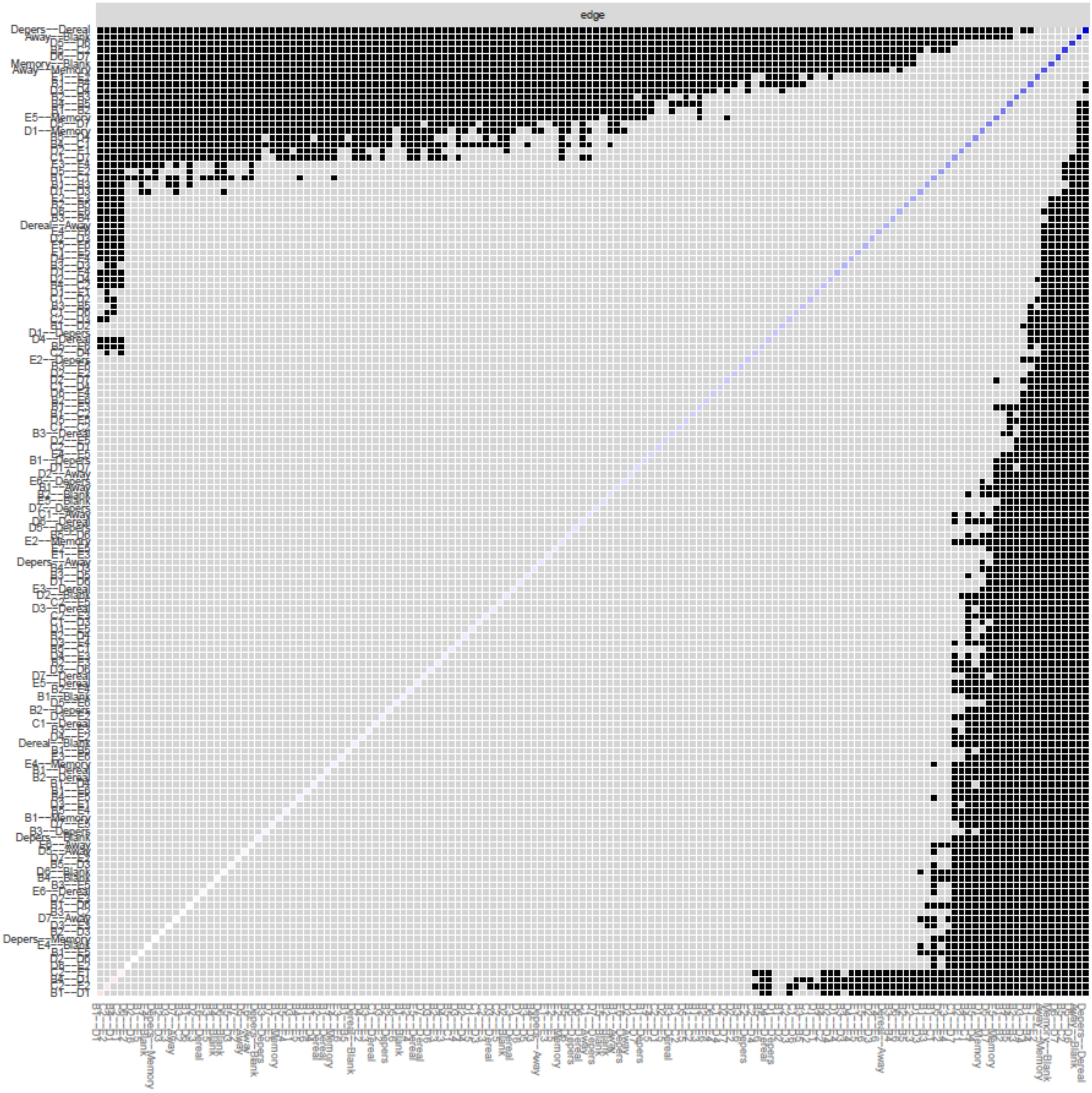

Figure B.2. Significant differences between edge weights in the combined PTSD and dissociation network. Black boxes indicate a significant difference between edge weights, grey boxes indicate no significant difference.

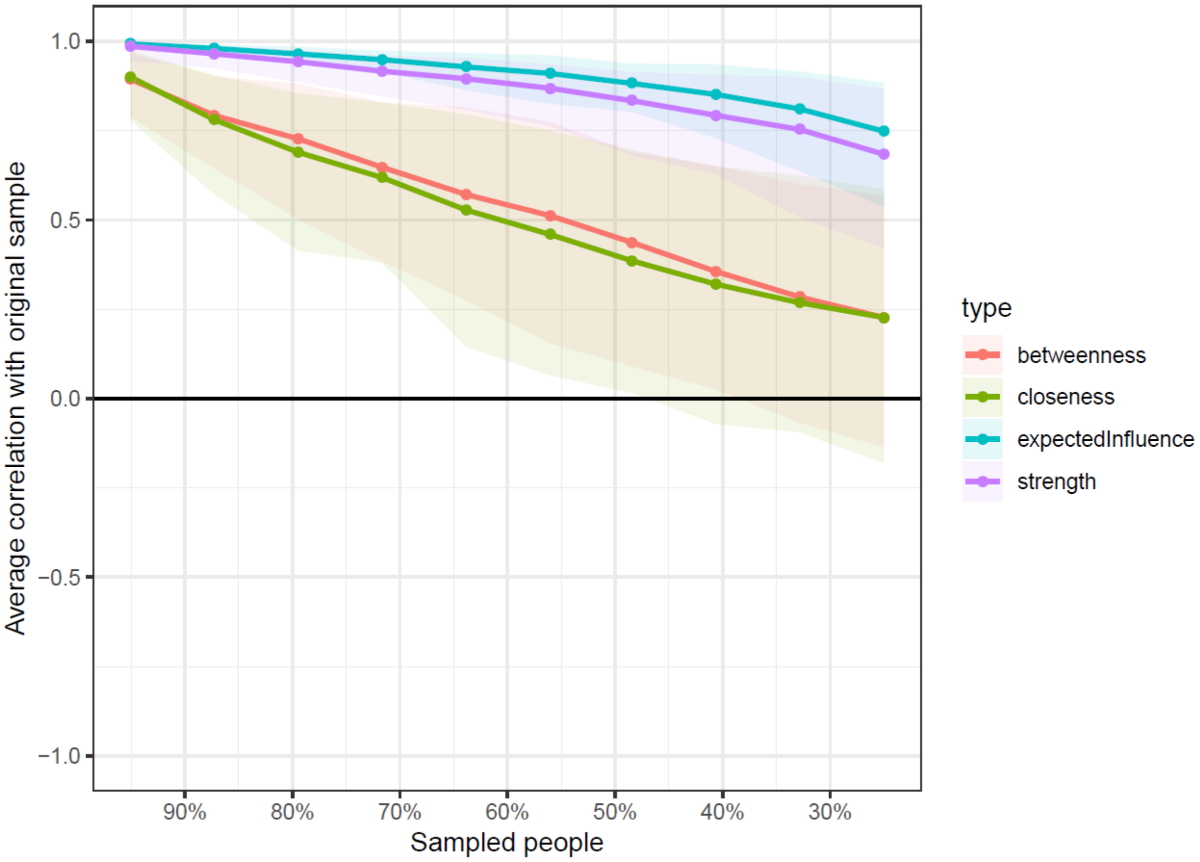

Figure B.3. Case-dropping bootstrap for the combined PTSD and dissociation network. Average correlations between the centrality measures estimated with the full sample and the centrality measures estimated with different proportions of the sample (i.e., 90%, 80%, 70%, etc.).

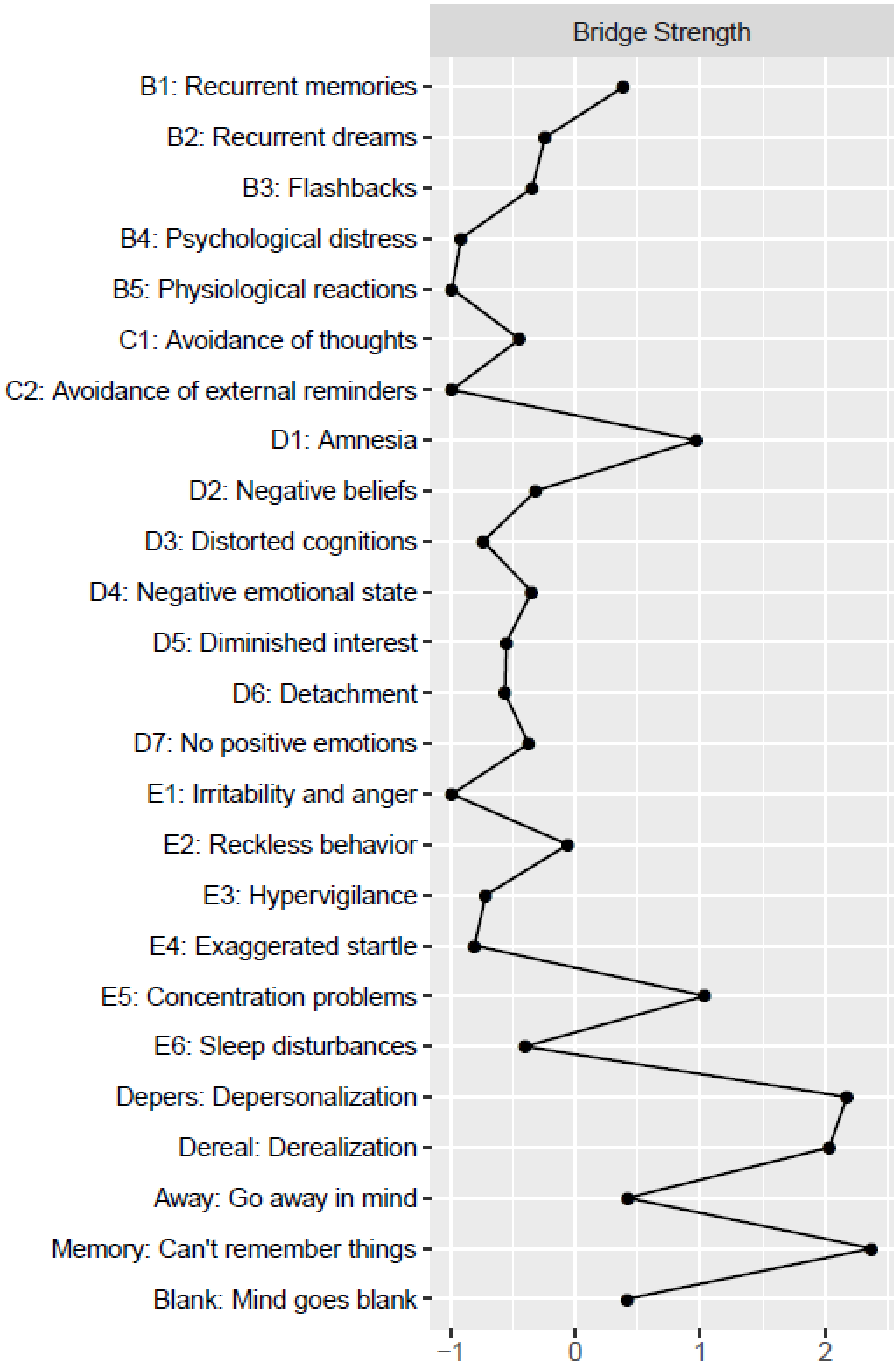

Figure B.4. Bridge strength centrality for the combined PTSD and dissociation network.

Appendix D

R code

```
###############
#
#   PTSD Network
#
###############

library(qgraph)                 # version 1.6.2
library(bootnet)                # version 1.2.2

sessionInfo()     # R version 3.6.0
setwd("…")


# Read data into R
data<-read.csv("Final with 448.csv")
View(data)

# Recode missing values
data[data=="999"]<-NA
data[data=="888"]<-NA
data[data=="777"]<-NA
View(data)

# Select items for analysis (20 PTSD items)
DataPTSD<-data[,c(92:111)]
View(DataPTSD)

# Variable names and colours
names<-c("B1", "B2", "B3", "B4", "B5", "C1", "C2", "D1", "D2", "D3", "D4", "D5", "D6",
         "D7", "E1", "E2", "E3", "E4", "E5", "E6")
longnames<-c("Recurrent memories", "Recurrent dreams", "Flashbacks", "Psychological
             distress", "Physiological reactions", "Avoidance of thoughts", "Avoidance of
             external reminders", "Amnesia", "Negative beliefs", "Distorted cognitions",
             "Negative emotional state", "Diminished interest", "Detachment", "No positive
             emotions", "Irritability and anger", "Reckless behavior", "Hypervigilance",
             "Exaggerated startle", "Concentration problems", "Sleep disturbances")
clusters<-list("Intrusions"=c(1:5), "Avoidance"=c(6,7), "Negative alterations in cognitions
            and mood"=c(8:14), "Alterations in arousal and reactivity"=c(15:20))

# Regularized partial correlation network
ptsd_Network<-estimateNetwork(DataPTSD, default="EBICglasso", corMethod="cor_auto",
              tuning=0.5)

# Weights matrix
ptsd_Network$graph
```

```
write.csv(ptsd_Network$graph, "ptsd_Network_WeightsMatrix.csv")

# Plot the network
ptsd_Network_Plot<-plot(ptsd_Network, layout="spring", labels=names, vsize=6, cut=0,
                        border.width=1.5, border.color="black", groups=clusters,
                        color=c("#ff6347", "#98fb98", "#87cefa", "#ffff00"),
                        nodeNames=longnames, legend.cex=.6, negDashed=T)

pdf("ptsd_Network.pdf",width=14, height=10)
ptsd_Network_Plot<-plot(ptsd_Network, layout="spring", labels=names, vsize=6, cut=0,
                      border.width=1.5, border.color="black", groups=clusters,
                      color=c("#ff6347", "#98fb98", "#87cefa", "#ffff00"),
                      nodeNames=longnames, legend.cex=.6, negDashed=T)
dev.off()

# Centrality values
cen<-centrality(ptsd_Network)
cen$InExpectedInfluence
write.csv(as.matrix(cen$InExpectedInfluence), "ptsd_Network_EI_Centrality.csv")

# Standardized centrality values
yyy<-cen$InExpectedInfluence
scale(yyy)
#mean(scale(yyy))
write.csv(as.matrix(scale(yyy)), "ptsd_Network_standardized_EI_Centrality.csv")

xxx<-cen$InDegree
scale(xxx)
mean(scale(xxx))
write.csv(as.matrix(scale(xxx)), "standardized_Strength_Centrality.csv")

ccc<-cen$Closeness
scale(ccc)
mean(scale(ccc))
write.csv(as.matrix(scale(ccc)), "standardized_Closeness_Centrality.csv")

zzz<-cen$Betweenness
scale(zzz)
mean(scale(zzz))
write.csv(as.matrix(scale(zzz)), "standardized_Betweenness_Centrality.csv")

# Centrality plots
centralityPlot(ptsd_Network,include="ExpectedInfluence")

centralityPlot(ptsd_Network,include="Strength")

pdf("ptsd_Network_EIcentrality.pdf", width=4, height=8)
centralityPlot(ptsd_Network, include="ExpectedInfluence")
dev.off()
```

```
pdf("ptsd_Network_STRENGTHcentrality.pdf", width=4, height=8)
centralityPlot(ptsd_Network, include="Strength")
dev.off()

# Edgeweight bootstrap
ptsd_Network_bootEDGE<-bootnet(ptsd_Network, nCores = 8, nBoots = 2000, type =
                               "nonparametric", statistics =
                               c("edge","strength","ExpectedInfluence", "betweenness",
                               "closeness"))

# Save edge weight bootstrap
save(ptsd_Network_bootEDGE, file = "ptsd_Network_bootEDGE.Rdata")

# Plot edge weight bootstrap
plot(ptsd_Network_bootEDGE, labels = FALSE, order = "sample")

pdf("ptsd_Network_bootstrappedEdges.pdf", width=7, height=5)
plot(ptsd_Network_bootEDGE, labels = FALSE, order = "sample")
dev.off()

# Case-dropping bootstrap
ptsd_Network_bootCASE<-bootnet(ptsd_Network, nCores = 8, nBoots = 2000,
                               statistics=c("ExpectedInfluence","strength","closeness","between
                               ness"), type = "case")

# Save case dropping bootstrap
save(ptsd_Network_bootCASE, file = "ptsd_Network_bootCASE.Rdata")

# Plot case-dropping bootstrap
plot(ptsd_Network_bootCASE,statistics=c("ExpectedInfluence","Strength","Closeness","Bet
weenness"))

pdf("ptsd_Network_bootCases.pdf", width=7, height=5)
plot(ptsd_Network_bootCASE,statistics=c("ExpectedInfluence","Strength","Closeness","Bet
    weenness"))
dev.off()

pdf("ptsd_Network_bootCases_EIonly.pdf", width=7, height=5)
plot(ptsd_Network_bootCASE,statistics="ExpectedInfluence")
dev.off()

# CS-coefficents
corStability(ptsd_Network_bootCASE, statistics=c("strength", "expectedInfluence",
            "closeness", "betweenness"))
# CS: betweenness = 0.049; closeness = 0.049; strength = 0.516; EI = 0.594

# Plot significant differences of edge weights (alpha = .05) ##
plot(ptsd_Network_bootEDGE, "edge", plot = "difference", onlyNonZero = TRUE, order =
    "sample")
```

```
pdf("ptsd_Network_SignificantEdgeWeights.pdf", width=10, height=10)
plot(ptsd_Network_bootEDGE, "edge", plot = "difference", onlyNonZero = TRUE, cex.axis
      = 0.3, order = "sample")
dev.off()

# Difference tests for EI centrality
plot(ptsd_Network_bootEDGE, "ExpectedInfluence", order="sample")

pdf("ptsd_Network_EI_differenceTests.pdf", width=10, height=10)
plot(ptsd_Network_bootEDGE, "ExpectedInfluence", order="sample")
dev.off()
```

```
############################
#
#   PTSD and dissociation network
#
############################


library(qgraph)              # version 1.6.2
library(bootnet)             # version 1.2.2
library(networktools)       # version 1.2.0

sessionInfo()     # R version 3.6.0
setwd("…")

# Read data into R
data<-read.csv("Final with 448.csv")
View(data)

# Recode missing values
data[data=="999"]<-NA
data[data=="888"]<-NA
data[data=="777"]<-NA
View(data)

# Select items for analysis (20 PTSD items and 5 dissociation items)
DataPTSDdis<-data[,c(92:116)]
View(DataPTSDdis)

# Variable names and colours
names<-c("B1", "B2", "B3", "B4", "B5", "C1", "C2", "D1", "D2", "D3", "D4", "D5", "D6",
         "D7", "E1", "E2", "E3", "E4", "E5", "E6", "Depers", "Dereal", "Away", "Memory",
         "Blank")
longnames<-c("Recurrent memories", "Recurrent dreams", "Flashbacks", "Psychological
             distress", "Physiological reactions", "Avoidance of thoughts", "Avoidance of
             external reminders", "Amnesia", "Negative beliefs", Distorted cognitions",
             "Negative emotional state", "Diminished interest", "Detachment", "No positive
             emotions", "Irritability and anger", "Reckless behavior", "Hypervigilance",
             "Exaggerated startle", "Concentration problems", "Sleep disturbances",
             "Depersonalization", "Derealization", "Go away in mind", "Can't remember
             things", "Mind goes blank")
clusters<-list("Intrusions"=c(1:5), "Avoidance"=c(6,7), "Negative alterations in cognitions
            and mood"=c(8:14), "Alterations in arousal and reactivity"=c(15:20),
            "Dissociation"=c(21:25))

# Regularized partial correlation network
ptsd_dis_Net<-estimateNetwork(DataPTSDdis, default="EBICglasso", corMethod =
             "cor_auto", tuning=0.5)

# Weights matrix
ptsd_dis_Net$graph
```

```
write.csv(ptsd_dis_Net$graph, "ptsd_dis_Net_WeightsMatrix.csv")

# Plot the network
ptsd_dis_Net_Plot<-plot(ptsd_dis_Net, layout="spring", labels=names, vsize=6, cut=0,
                  border.width=1.5, border.color="black", groups=clusters,
                  color=c("#ff6347", "#98fb98", "#87cefa", "#ffff00", "#eee9e9"),
                  nodeNames=longnames, legend.cex=.6, negDashed=T)

pdf("ptsd_dis_Net.pdf",width=14, height=10)
ptsd_dis_Net_Plot<-plot(ptsd_dis_Net, layout="spring", labels=names, vsize=6, cut=0,
                border.width=1.5, border.color="black", groups=clusters,
                color=c("#ff6347", "#98fb98", "#87cefa", "#ffff00", "#eee9e9"),
                nodeNames=longnames, legend.cex=.6, negDashed=T)
dev.off()

# Centrality values
cen<-centrality(ptsd_dis_Net)
cen$InExpectedInfluence
write.csv(as.matrix(cen$InExpectedInfluence), "ptsd_dis_Net_EI_Centrality.csv")

# Standardized centrality values
yyy<-cen$InExpectedInfluence
scale(yyy)
#mean(scale(yyy))
write.csv(as.matrix(scale(yyy)), "ptsd_dis_Net_standardized_EI_Centrality.csv")

centralityPlot(ptsd_dis_Net,include="ExpectedInfluence")

pdf("ptsd_dis_Net_EIcentrality.pdf", width=4, height=8)
centralityPlot(ptsd_dis_Net, include="ExpectedInfluence")
dev.off()

# Edgeweight bootstrap
ptsd_dis_Net_bootEDGE<-bootnet(ptsd_dis_Net, nCores = 8, nBoots = 2000, type =
"nonparametric")

# Save edge weight bootstrap
save(ptsd_dis_Net_bootEDGE, file = "ptsd_dis_Net_bootEDGE.Rdata")

# Plot edge weight bootstrap
plot(ptsd_dis_Net_bootEDGE, labels = FALSE, order = "sample")

pdf("ptsd_dis_Net_bootstrappedEdges.pdf", width=7, height=5)
plot(ptsd_dis_Net_bootEDGE, labels = FALSE, order = "sample")
dev.off()

# Case-dropping bootstrap
ptsd_dis_Net_bootCASE<-bootnet(ptsd_dis_Net, nCores = 8, nBoots = 2000,
                           statistics=c("ExpectedInfluence", "Strength", "Closeness",
                           "Betweenness"), type = "case")
```

```
# Save case dropping bootstrap
save(ptsd_dis_Net_bootCASE, file = "ptsd_dis_Net_bootCASE.Rdata")

# Plot case-dropping bootstrap
plot(ptsd_dis_Net_bootCASE,statistics=c("ExpectedInfluence","Strength","Closeness","Bet
      weenness"))

pdf("ptsd_dis_Net_bootCases.pdf", width=7, height=5)
plot(ptsd_dis_Net_bootCASE,statistics=c("ExpectedInfluence","Strength","Closeness","Bet
      weenness"))
dev.off()

pdf("ptsd_dis_Net_bootCases_EIonly.pdf", width=7, height=5)
plot(ptsd_dis_Net_bootCASE,statistics="ExpectedInfluence")
dev.off()

# CS-coefficents
corStability(ptsd_dis_Net_bootCASE, statistics=c("strength", "expectedInfluence",
              "closeness", "betweenness"))
# CS: betweenness = 0.049; closeness = 0.049; strength = 0.516; EI = 0.594

# Plot significant differences of edge weights (alpha = .05) ##
plot(ptsd_dis_Net_bootEDGE, "edge", plot = "difference", onlyNonZero = TRUE, order =
"sample")

pdf("ptsd_dis_Net_SignificantEdgeWeights.pdf", width=10, height=10)
plot(ptsd_dis_Net_bootEDGE, "edge", plot = "difference", onlyNonZero = TRUE, cex.axis =
      0.2, order = "sample")
dev.off()


# Bridge centrality for EI
# Names for the plot
longnamesX<-c("B1: Recurrent memories", "B2: Recurrent dreams", "B3: Flashbacks", "B4:
                    Psychological distress", "B5: Physiological reactions", "C1: Avoidance of
                    thoughts", "C2: Avoidance of external reminders","D1: Amnesia", "D2:
                    Negative beliefs", "D3: Distorted cognitions", "D4: Negative emotional
                    state", "D5: Diminished interest", "D6: Detachment", "D7: No positive
                    emotions", "E1: Irritability and anger", "E2: Reckless behavior", "E3:
                    Hypervigilance", "E4: Exaggerated startle", "E5: Concentration problems",
                    "E6: Sleep disturbances", "Depers: Depersonalization", "Dereal:
                    Derealization", "Away: Go away in mind", "Memory: Can't remember
                    things", "Blank: Mind goes blank")

A<-qgraph(ptsd_dis_Net$graph, layout="spring", labels=names, vsize=6, cut=0,
        border.width=1.5, border.color="black", groups=clusters,
        color=c("#ff6347", "#98fb98", "#87cefa", "#ffff00", "#eee9e9"),
        nodeNames=longnames, legend.cex=.6, negDashed=T)
B<-bridge(A, communities = c(rep("1",20),rep("2",5)), directed=F)
```

```
# Bridge centrality values
B
write.csv(as.matrix(B), "ptsd_dis_Network_BridgeCentralityValues.csv")

# standardize the bridge centrality values
yx<-B$`Bridge Expected Influence (1-step)`
scale(yx)
#mean(scale(yx))
write.csv(as.matrix(scale(yx)), "standardized_EI_bridgeExpectedInfluence(1-step).csv")

# Bridge centrality plot
plot(B,zscore=T)

pdf("ptsd_dis_Net_bridge.pdf", width=14, height=7)
plot(B,zscore=T)
dev.off()

pdf("ptsd_dis_Net_bridge_EI.pdf", width=7, height=7)
plot(B,zscore=T, include="Bridge Expected Influence (1-step)")
dev.off()
```