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The importance of the *DSM-5* posttraumatic stress disorder symptoms of cognitions and mood in traumatized children and adolescents: two network approaches

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Background: The aim of this study is to provide a better understanding of the central symptoms of *DSM-5* posttraumatic stress disorder (PTSD) in children and adolescents from the perspective of the child and its caregiver. Identifying core symptoms of PTSD can help clinicians to understand what may be relevant targets for treatment. PTSD may present itself differently in children and adolescents compared to adults, and no study so far has investigated the *DSM-5* PTSD conceptualization using network analysis. **Methods:** The network structure of *DSM-5* PTSD was investigated in a clinical sample of n = 475 self-reports of children and adolescents and n = 424 caregiver-reports using (a) regularized partial correlation models and (b) a Bayesian approach computing directed acyclic graphs (DAGs). **Results:** (a) The 20 *DSM-5* PTSD symptoms were positively connected within the self-report and the caregiver-report sample. The most central symptoms were *negative trauma-related cognitions* and *persistent negative emotional state* for the self-report and *negative trauma-related cognitions*, *intrusive thoughts or memories* and *exaggerated startle response* for the caregiver-report. (b) Similarly, symptoms in the negative alterations in cognitions and mood cluster (NACM) have emerged as key drivers of other symptoms in traumatized children and adolescents. **Conclusions:** As the symptoms in the *DSM-5* NACM cluster were central in our regularized partial correlation networks and also appeared to be the driving forces in the DAGs, these might represent important symptoms within PTSD symptomatology and may offer key targets in PTSD treatment for children and adolescents. **Keywords:** Posttraumatic stress symptoms; *DSM-5*; children and adolescents; network analysis.

Background

Originally intended to capture ongoing stress reactions observed in Vietnam Veterans after combat, posttraumatic stress disorder (PTSD) was soon also recognized to be prevalent in children and adolescents (Terr, 1983). For several decades, research has shown that posttraumatic stress symptoms (PTSS) are very common in children and adolescents exposed to various traumatic events (Copeland, Keeler, Angold, & Costello, 2007).

Since its introduction as a psychiatric disorder in the third edition of the Diagnostic and Statistical Manual of Mental Disorders (*DSM-III,* American Psychiatric Association) in 1980, PTSD has evoked an ongoing controversy regarding its nosology and conceptualization (North, Surís, Smith, & King, 2016). Even though each revision incorporated substantial change into the PTSD criteria, these criteria have been subject to much criticism over the years. Critics have targeted the definition of a traumatic event, the number of symptoms included in the PTSD criteria (Brewin, Lanius, Novac, Schnyder, & Galea, 2009) and the validity of the PTSD diagnosis (Summerfield, 2001). Even though the *DSM* and *ICD* (International Classification of Diseases; World Health Organization, 1992) suggest some developmental considerations over the age spectrum, it is questionable whether the PTSD criteria can be applied directly to children and adolescents without further adaption (Scheeringa, Zeanah, & Cohen, 2011).

With the introduction of the fifth version of the *DSM* (American Psychiatric Association, 2013), the number of PTSS was expanded from 17 to 20 and organized in four instead of three clusters: intrusions, avoidance, negative alterations in cognition and mood (NACM), and alterations in arousal and reactivity. As PTSD in its *DSM-IV* conceptualization was previously criticized for the symptom overlap with other mental disorders such as depression and anxiety (Brewin et al., 2009; Rosen & Lilienfeld, 2008), it is not surprising that the addition of the three new symptoms (distorted blaming of oneself or others, persistent negative emotional state, and self-destructive/

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reckless behavior) in the *DSM-5* again raised concerns about the extent to which the symptoms of the PTSD criteria overlap with other mental disorders (Brewin, 2013). In sharp contrast, the PTSD criteria for the 11th edition of the International Classification of Diseases (*ICD-11*) narrows the diagnostic entity of PTSD, aiming to eliminate overlapping and nonspecific symptoms (Cloitre, Garvert, Brewin, Bryant, & Maercker, 2013). The *ICD-11* workgroup for stress disorders reduced the number of PTSD symptoms to a restricted set of six 'core' symptoms (nightmares, flashbacks, avoidance of thoughts or memories, avoidance of external reminders, hypervigilance, and exaggerated startle response). The purpose of this restrictive approach was to improve diagnostic utility and decrease psychiatric comorbidity (Maercker et al., 2013). With regard to children and adolescents, one study found similar rates for *DSM-5* and *ICD-11* PTSD in traumatized children and adolescents (Danzi & La Greca, 2016). In contrast, two other recent studies have found that the restricted *ICD-11* PTSD criteria resulted in lower prevalence rates compared with *DSM-5* or *DSM-IV* in clinical samples of children and adolescents (Sachser & Goldbeck, 2016; Sachser et al., 2018) and it has been recognized that children and adolescents express disorders in different ways (House, 2002). Regarding PTSD, children and adolescents appear to demonstrate different symptoms and a wider range of associated symptoms compared to adults after being exposed to traumatic events (Scheeringa, Zeanah, Drell, & Larrieu, 1995). Therefore, it is unclear whether the narrowed *ICD-11* criteria will adequately capture the trauma-related symptomatology experienced by children and adolescents.

The prevailing lens through which psychopathology is currently viewed proposes a higher level latent construct, for example PTSD, that exclusively causes symptoms to occur. To uphold this perspective, this approach must presume that no causal connections between symptoms exist. However, a dynamic interplay between symptoms is highly plausible given the direct relations psychopathological symptoms have to one another. For example, nightmares cause sleep disturbance which leads to fatigue, which in turn leads to concentration problems. Network analysis has emerged as a promising alternative analytical method for conceptualizing mental disorders (Borsboom, 2017). Rather than conceptualize psychopathological syndromes as reflective indicators of an underlying, latent disease entity, for example PTSD, network analysis assumes that syndromes are the result of sets of associations between symptoms that mutually cause and reinforce each other. If these causal relations are sufficiently strong, symptoms can generate a level of feedback that renders them self-sustaining and can get stuck in a disorder state, such as PTSD (Borsboom, 2017).

Given the ability to identify the most influential symptoms in a potentially causal system, which are potentially accountable for the emergence and perpetuation of PTSD, network analysis has important implications. It may help to identify which symptoms constitute the central symptoms of PTSD and those most relevant to target in treatment. Central symptoms have strong connections to many other symptoms in the PTSS network and in theory, when activated, they are more likely than other symptoms to trigger other symptoms and thus establish and strengthen the network. With regard to children and adolescents, it may help to answer the question whether the six 'core' symptoms included in the *ICD-11* PTSD criteria adequately describe the symptomatic reactions in children after trauma and therefore have strong predictive value for diagnostic caseness (Mitchell et al., 2017). To date, network analysis of PTSS has been mainly employed with samples of adults (Armour, Fried, Deserno, Tsai, & Pietrzak, 2017; McNally, Heeren, & Robinaugh, 2017; Mitchell et al., 2017). Only one network analytic investigation of PTSS has been conducted to date with children and adolescents. Russell, Neill, Carrión, and Weems (2017) evaluated the underlying network structure of *DSM-IV* PTSS in a cross-sectional sample of children and adolescents exposed to Hurricanes Katrina and Gustav based on self-reports. Examining the influence of each node within the networks, they found that physiological reactivity and avoiding activities were central in the child network and numbness, nightmares, foreshortened future, physiological reactivity, and avoiding activities were central in the adolescent network.

To our knowledge, network analysis has not been applied to *DSM-5* PTSS in a heterogeneous traumatized sample of children and adolescents. To uncover the underlying network structure of PTSS in children and adolescents, we used two distinct network approaches. First, based on conditional independent relationships, we estimated a regularized partial correlation network, to uncover potential causal associations between symptoms. Because a regularized partial correlation network displays undirected edges (associations between symptom pairs), it is not possible to derive whether an edge between symptom A and symptom B indicates that symptom A, when active, activates symptom B or vice versa. Therefore, to further evaluate potential causal pathways among PTSS in children and adolescents, we used a Bayesian approach, resulting in directed acyclic graphs (DAGs). This approach uncovers direct associations between symptoms and provides an estimation of the direction of the association and thus displays potential causal symptom connections. As the caregiver-report is relevant to the diagnostic process of children and adolescents, it is of crucial importance to investigate the symptom network of child and adolescent PTSS from the caregivers' perspective as well. Therefore, our study addresses these gaps in the literature and aims to (a) estimate the network structure of the 20 *DSM-5* PTSS in a sample of children and adolescents using two different approaches (regularized partial correlation networks vs. directed acyclic graph), (b) analyze the accuracy and stability of the networks and (c) identify the most central symptoms of *DSM-5* PTSD in children and adolescents from the perspective of self- and caregiver-report to identify 'core' symptoms in the PTSD conceptualization as well as relevant targets for treatment.

Method

Participants and procedure

Participants were recruited from two mental health clinics in the USA, two mental health clinics in Germany, and six mental health clinics in Norway. The inclusion criteria for children and adolescents were being exposed to at least one potentially traumatic event (PTE) following the *DSM-5* definition, sufficient language skills and age 7–17. The sample comprised 475 self-reports from children and adolescents (M_{age} = 13.19, SD_{age} = 3.18; 66.4% female) and 424 caregiver-reports on their children (M_{age} = 11.81, SD_{age} = 3.46; 58.6% female). The number of PTEs ranged from 1 to 15 in the current sample. Data on the index event were available for 295 self-reports with children and adolescents reporting sexual abuse (34.2%), experiencing or witnessing physical violence or abuse (21.3%), accidental trauma including natural disaster, accidents or medical procedures (12.5%), traumatic loss (8.5%), war (2.4%), and other not specified stressful or scary event (20.8%). Data on the index event were available for 290 caregiver-reports with caregivers reporting sexual abuse (38.6%), experiencing or witnessing physical violence or abuse (17.6%), accidental trauma including natural disaster, accidents, or medical procedures (8.3%), traumatic loss (9.0%), war (1%), and other not specified stressful or scary event (22.1%). A detailed description of the samples can be seen elsewhere (Sachser et al., 2017). The study was approved by ethics committees at all participating sites. Prior to the assessment at the German and Norwegian sites, informed assent of the children and adolescents and informed consent of the legal guardians were obtained. The US sample was drawn from a retrospective collection of de-identified clinical data and therefore no full IRB review was required by the respective ethics committees. The mean total symptom score for the self-report sample (CATS M_{US} = 25.98, CATS M_{Germany} = 22.98, CATS M_{Norway} = 20.68) and the caregiver-report sample (CATS M_{US} = 24.88, CATS M_{Germany} = 20.76, CATS M_{Norway} = 15.84) reflects that traumatized children and adolescents in this study had a high mean severity of PTSS. Applying the *DSM-5* algorithm (itemscore $\geq$ 2) about 38% of children and adolescents could have been diagnosed with possible PTSD (Sachser et al., 2018).

Measures

Children and adolescents and caregivers were administered the Child and Adolescent Trauma Screen (CATS; Sachser et al., 2017), which was used to screen for PTEs and PTSS following the *DSM-5* conceptualization. When they endorsed at least one PTE, children, adolescents, and caregivers were presented with the symptom list and asked to rate how often the problem had bothered them in the last 2 weeks on a 4-point Likert scale with 0 = 'Never', 1 = 'Once in a while', 2 = 'Half of the time' and 3 = 'Almost always'. The CATS showed high internal consistency with Cronbach's α = .92 for the self-reports, and Cronbach's α = .93 for the caregiver-reports.

Statistical analyses

Regularized partial correlation network. We estimated the underlying network structure of relations among PTSS as reported in the CATS in the self-report and caregiver samples by using a *Graphical Gaussian Model* (GGM; Costantini et al., 2015; Lauritzen, 1996), which are based on pairwise associations between all symptoms (i.e. edges are the network term for associations and in this analyses represent regularized partial correlations between a pair of nodes (symptoms)). To estimate the partial correlations between the *DSM-5* PTSS, we applied a regularization technique to the data by using the graphical Least Absolute Shrinkage Operator (LASSO; Friedman, Hastie, & Tibshirani, 2008; Tibshirani, 1996) algorithm in combination with an Extended Bayesian Information Criterion (EBIC) via the R package *qgraph* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012) and *glasso* (Tibshirani, 1996). Data used for these analyses did not contain any missing values.

Centrality. To quantify the importance of each node in the network, previous studies computed the centrality indices *strength* (i.e. the absolute value of the weights of the edges connected to a node), *closeness* (i.e. the inverse of mean length of all shortest weighted paths from a node to all other nodes in the network), and *betweenness* (i.e. how often a given node lies on the shortest path between any pair of nodes) (Opsahl, Agneessens, & Skvoretz, 2010) by using the R package *bootnet* (Epskamp, Borsboom, & Fried, 2018) and plotted the normalized (*z*-scored) values for each node. These three common node centrality measures, calculated based on the absolute values of edge-weights, indicate how connected a node is within the network and therefore emphasize its potential clinical relevance (Opsahl et al., 2010). For all three centrality indices, higher scores indicate greater centrality. Recent network analysis revealed an unreliable estimation of betweenness and closeness (Epskamp et al., 2018). As this was also the case with our analyses, which means that the magnitude of these centrality indices was not stable when reestimate the indices after persons have been dropped from the sample and thus interpretation of the order should be done with caution (See Table S1 & Figures S1 and S2) we subsequently focused on node strength. Based on our accuracy and stability analyses, the sample appears to be sufficient to interpret the results of node strength. Analyses on node betweenness and closeness are additionally reported in Figures S3–S7. Additionally, indicators of the robustness and accuracy regarding edge-weights and centrality indices are reported (Epskamp et al., 2018).

Visualization. The outputs *qgraph* produces include a visual model of the estimated graphical LASSO network structures of the self-report and caregiver-report data sets (Figure 1). The layout of the nodes was specified by using the Fruchtermann-Reingold algorithm (Fruchterman & Reingold, 1991). Nodes possessing numerous strong connections are located near the center of the network. Also, strongly associated nodes appear closer together within the network, allowing for visual inspection of clustering among the symptoms. The edges vary in color saturation and thickness to reflect the strength of partial correlations. To produce these visual effects, we set the maximum edge value at .55 (the strongest partial correlation observed across both networks) and the minimum edge value at .01 (the weakest partial correlation observed across both networks). In doing so, we facilitate visual interpretation and comparison of color saturation and thickness of the edges across both networks.

Network comparison. Using the Network Comparison Test (NCT), a permutation-based test, via the R package *NetworkComparisonTest* (Van Borkulo, 2015) we tested for

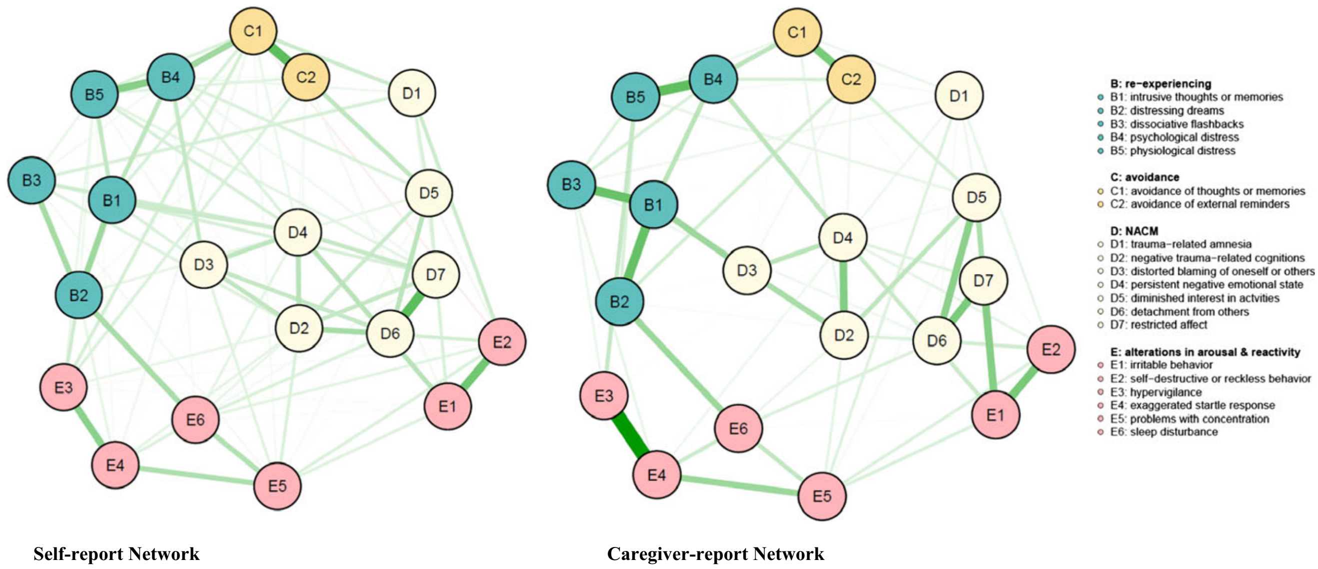


Figure 1 Estimated regularized partial correlation networks from the self-report (left) and caregiver-report (right) data set, containing the 20 *DSM-5* posttraumatic stress disorder (PTSD) symptoms. Positive partial correlations are represented by green lines, negative ones by red lines. The thickness and saturation of an edge are an indicator for the correlation strength. Maximum edge value = .55, minimum edge value = .01

differences in the network structure and the network connectivity (global strength) between the self-report and caregiver network.

Bayesian network. For the estimation of the Bayesian networks, we followed the advice of McNally et al. (2017) and ran the *hill-climbing* algorithm included in the R package *bnlearn* (Scutari, 2010). The network was visualized as a DAG. In a first step, to determine the existence of a directed edge between symptoms, the algorithm computes different network structures while adding edges, subtracting edges, and reversing their direction. For each new network with a possible edge addition, deletion or reversal, the algorithm computes a new BIC score. If the BIC of the network structure fits better compared to the network computed before, the addition, deletion, or reversal will be maintained. The algorithm continues until an optimized BIC score is reached. Second, we determined the weights of an edge by repeating this process with 50 random restarts with various candidate edges with 100 perturbations for each restart. This iterative procedure unveils the underlying potentially causal network structure. We demonstrated the stability of the network by bootstrapping 10,000 samples and computing a network for each sample and averaging them to one final network. This procedure included two steps. First, we determined the frequency of the presence of an edge in the 10,000 bootstrapped networks. In doing so, we retained an averaged network structure by using an 85% threshold frequency for the presence of an edge (Scutari & Nagarajan, 2013). In a second step, we determined the probability of the direction for each edge in the 10,000 bootstrapped networks. If the same edge direction appeared in 51% of the bootstrapped networks, then the edge direction was retained in the final, averaged network (McNally et al., 2017).

Visualization of the DAGs

In a first visualization of the final averaged DAG, the edges are indicators of the BIC value of an edge. The higher the absolute BIC value is, the more important the edge is to the model that best captures the potential causal associations. High BIC values for an edge hereby indicate higher magnitude of the connection between two symptoms. Thus, removing thick edges would be damaging to the model fit. In a second visualization of the final averaged network, edge thickness indicates the probability that an edge points in the direction displayed in the graph. The more often the same edge direction between pairs of symptoms appeared in the bootstrapped networks, the thicker the edge was depicted in the network (McNally et al., 2017).

Results

Regularized partial correlation network of DSM-5 PTSS

Self-reports. An overview of the symptom means, standard deviations, and the normalized (*z*-scored) strength values is shown in Table S2. Associations within the estimated network of the self-report data set were generally positive (Figure 1). Only one small negative edge was apparent between *avoidance of thoughts or memories* (C1) and *self-destructive/reckless behavior* (E2). Strong edges emerged between *avoidance of thoughts or memories* (C1) and *avoidance of external reminders* (C2); *restricted affect* (D7) and *detachment from others* (D6); and *irritable behavior* (E1), and *self-destructive/reckless behavior* (E2). Symptoms in the graph had the tendency to cluster closely with other symptoms in their *DSM-5* cluster except for *trauma-related amnesia* (D1), *irritable behavior* (E1), and *self-destructive/reckless behavior* (E2). Figure 2 shows the strength indices for all *DSM-5* PTSS. *Psychological distress* (B4), *avoidance of thoughts or memories* (C1), *negative trauma-related cognitions* (D2), *persistent negative emotional state* (D4), *detachment from others* (D6), and *restricted affect* (D7) had the highest scores on the strength index, indicating they were the most involved symptoms in the network. Strength (*CS* (cor = .7) = .67) exceeded the recommended cut-off of .5 and thus the stability analysis of the strength indices suggested a reliable estimation. By using nonparametric bootstrapping to calculate CIs around the edge-weights, we provided an estimation of the accuracy of edge-strength values. Figure S8 reveals that most of the bootstrapped CIs around the estimated edge-weights overlapped, indicating no significant difference between most of the edge-weights and therefore their order should be interpreted with caution. Further, we tested whether edges differ significantly from one another in their strength (Figure S9), and whether symptoms differ in their node strength (Figure S10). The results indicate that many of the symptoms did not differ significantly in strength.

Caregiver-reports. Associations within the network structure of the caregiver-report data set were solely positive (Figure 1). The network estimated based on the caregiver report data included the strongest edge (between *hypervigilance* (E3) and *exaggerated startle response* (E4)) across both networks. In addition, the analysis revealed strong edges between *intrusive thoughts or memories* (B1) and *distressing dreams* (B2); *intrusive thoughts or memories* (B1) and *dissociative flashbacks* (B3); and *psychological distress* (B4) and *physiological distress* (B5). Like the arrangement of symptoms in the self-report data set, caregiver-reported symptoms tended to cluster closely with other symptoms in their *DSM-5* cluster except for *trauma-related amnesia* (D1), *irritable behavior* (E1), and *self-destructive/reckless behavior* (E2).

Intrusive thoughts or memories (B1), *psychological distress* (B4), *negative trauma-related cognitions* (D2), *persistent negative emotional state* (D4), *detachment from others* (D6), and *exaggerated startle response* (E4) had the highest scores on the strength index, suggesting they were the most involved symptoms in the network. Strength (*CS*(cor = .7) = .52) exceeded the recommended cut-off of .5 and thus indicated a stable estimation. By using nonparametric bootstrapping to calculate CIs around the edge-weights, we provided an estimation of the accuracy of edge-strength values. Figure S11 reveals that most of the bootstrapped CIs around the estimated edge-weights overlapped, indicating no significant difference between most of the edge-weights and therefore their order should be interpreted with caution. Further, we tested whether edges differ significantly from one another in their strength (Figure S12), and whether symptoms differ in their node strength (Figure S13). The results indicate that many of the symptoms did not differ significantly in strength.

Network comparison

A comparison of the network structure revealed that the structure between the self-report and caregiver

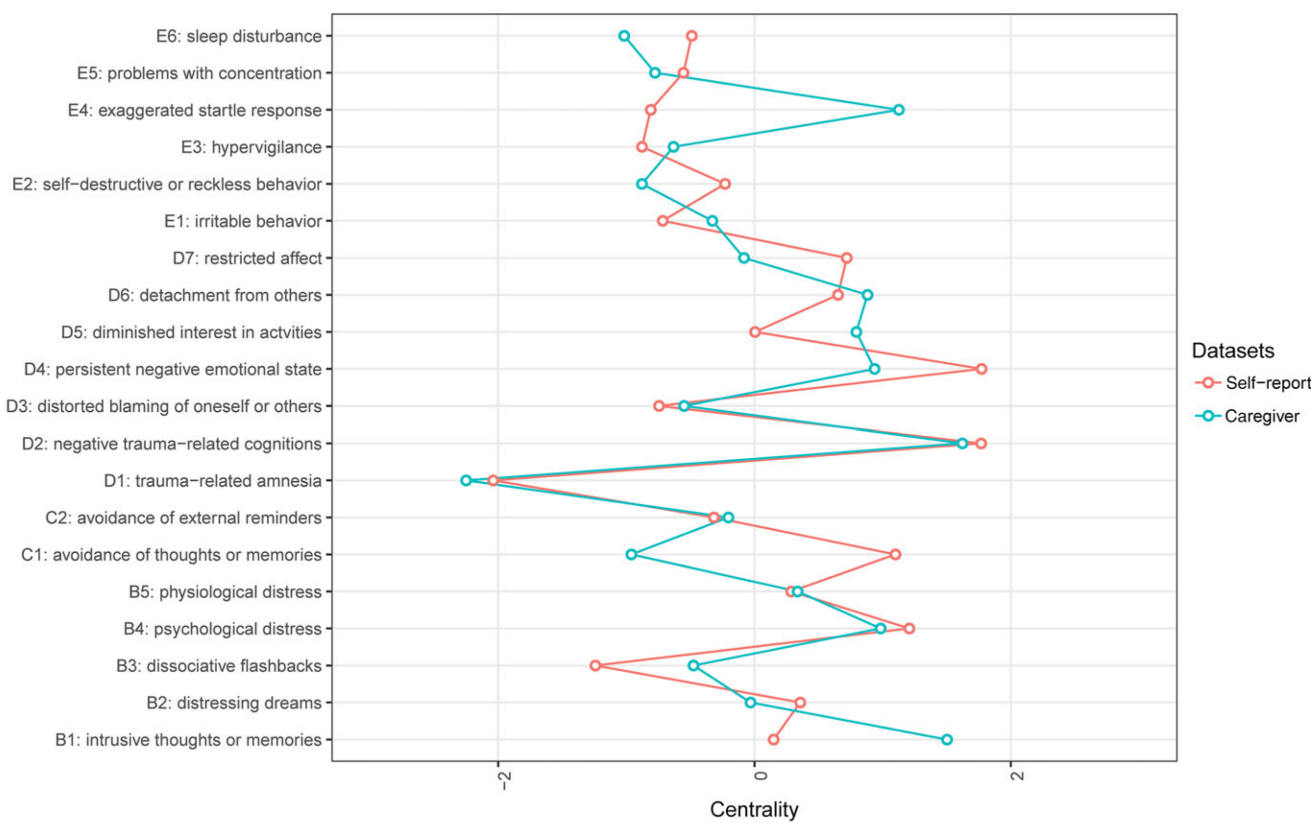


Figure 2 Estimated node strength centrality metrics (*z*-scored values) of the 20 *DSM-5* posttraumatic stress disorder (PTSD) symptoms (self-report = orange; caregiver-report = blue)

report network differed significantly ($M = .28$, $p < .000$). The results of the NCT further indicated that the network connectivity was significantly stronger in the self-report data ($S = .62$; $p = .001$; based on 1,000 permutations).

DAG self-reports

The DAG for the self-report data after the 10,000 bootstrap procedure is shown in Figure 3. Edge thickness indicates confidence that the predicted direction of an edge points in the direction displayed in the graph. Notable is that *persistent negative emotional state* (D4) figures at the top of the DAG directly predicting *negative trauma-related cognitions* (D2), *restricted affect* (D7), *diminished interest in activities* (D5), *irritable behavior* (E1), *psychological distress* (B4), *intrusive thoughts or memories* (B1), *distressing dreams* (B2), *dissociative flashbacks* (B3), *distorted blaming of oneself or others* (D3), *physiological distress* (B5), and *avoidance of thoughts or memorie*s (C1). Further, the findings suggest that *having problems with concentration* (E5), *exaggerated startle response* (E4), *being unable to recall important aspects of the traumatic event* (D1), *engage in self-destructive behavior* (E2), and *avoidance of external reminders* (C2) are downstream symptoms and seem to occur because of other symptoms. Figure S14 displays the same DAG where the thickness of an edge in the network captures the importance of an edge to the model.

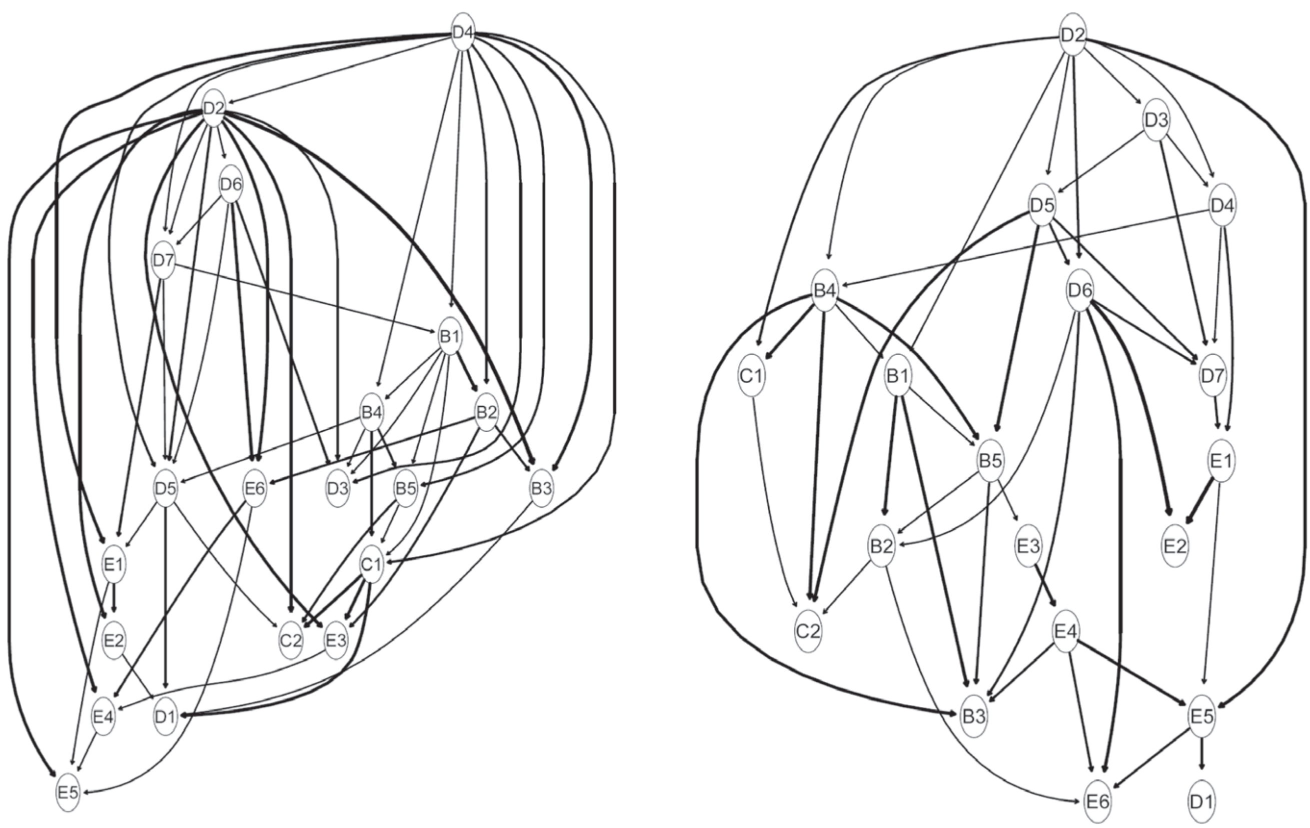
DAG caregiver-reports

The DAG for the caregiver-report data after the 10,000 bootstrap procedure is shown in Figure 3. Edge thickness indicates confidence that the predicted direction of an edge points in the direction displayed in the graph. Notable is that *negative trauma-related cognitions* (D2) figures at the top of the DAG directly predicting *avoidance of thoughts/memories* (C1), *intrusive thoughts or memories* (B1), *diminished interest in activities* (D5), *psychological distress* (B4), *detachment from others* (D6), *distorted blaming of oneself or others* (D3), *persistent negative emotional state* (D4), and *problems with concentration* (E5). Further, the findings suggest that *avoiding external reminders* (C2), *flashbacks* (B3), *being unable to recall important aspects of the traumatic event* (D1), *problems with concentration* (E5), and *difficulties in sleeping* (E6) are downstream symptoms and seem to occur because of other symptoms. Figure S15 displays the same DAG where the thickness of an edge in the network captures the importance of an edge to the model.

Discussion

To the best of our knowledge, our study represents the first network analytic investigation of *DSM-5* PTSS in children and adolescents based on self-report and caregiver-report data sets. We used a regularized partial correlation approach and a Bayesian network approach to evaluate the underlying network structure of the *DSM-5* PTSS and provide novel insights in the interrelations between PTSS in children and adolescents. Generally, connections between symptoms in the self-report and the caregiver data sets were positive. The NCT revealed that the PTSD symptom structure is not completely identical across both networks. Moreover, the overall level of connectivity was significantly higher in the child network. This difference in the symptom structure may be explained by the fact that many PTSS (e.g. *intrusive thoughts*) are not directly observable by caregivers and thus might influence the symptom severity ratings, resulting in lower overall connectivity.

Summarizing the results of the regularized partial correlation networks, *negative trauma-related cognitions*, *persistent negative emotional state*, and *psychological distress* were symptoms with high strength centrality in both the self and the caregiver-report sample. Likewise, both DAGs implicate that symptoms of the NACM cluster, especially *negative trauma-related cognitions* and *persistent negative emotional state* appear to act as driving forces among the PTSS networks. Symptoms of the cluster alterations in arousal and reactivity, especially having *problems concentrating*, appeared to result directly or indirectly because of those symptoms. Overall the symptoms in the NACM cluster, which was newly introduced in the *DSM-5,* were the most central symptoms in the network. Although most of the symptoms in the NACM cluster can be described as nonspecific symptoms that overlap with other mental disorders, they might in fact be driving forces (symptoms, which cause or trigger other symptoms top down in the DAG) in the symptomatology of PTSD in children and adolescents. More importantly, they might interact with symptoms of frequent comorbid disorders like depression and anxiety, functioning as bridging symptoms (symptoms, which feature in and connect both disorders). Compared with the most central symptoms of our study, Russell et al. (2017) found the highest centrality for physiological distress and numbness in their *DSM-IV* PTSS networks of children and adolescents exposed to hurricanes. These diverging results might be explained by the fact that the *DSM-IV* conceptualization did not include the symptoms *negative trauma-related cognitions* and *persistent negative emotional state* of the newly introduced NACM cluster in the *DSM-5*. Our results can be compared with two studies which found *persistent negative emotional state* as their most central symptom in their *DSM-5* PTSD networks of US military veterans (Armour et al., 2017; Mitchell et al., 2017). Contrary to our findings, negative trauma-related cognitions were not as central to their symptom



Self-report network **Caregiver-report network**

Figure 3 Directed acyclic graphs (DAGs) of the 20 *DSM-5* posttraumatic stress disorder (PTSD) symptoms based on the self-report and caregiver-report data sets. Edge thickness indicates confidence that the predicted direction of an edge points in the direction displayed in the graph. The 20 *DSM-5* PTSD symptoms are: B1 (intrusive thoughts or memories), B2 (distressing dreams), B3 (dissociative flashbacks), B4 (psychological distress), B5 (physiological distress), C1 (avoidance of thoughts or memories), C2 (avoidance of external reminders), D1 (trauma-related amnesia), D2 (negative trauma-related cognitions), D3 (distorted blaming of oneself or others), D4 (persistent negative emotional state), D5 (diminished interest in activities), D6 (detachment from others), D7 (restricted affect), E1 (irritable behavior), E2 (self-destructive or reckless behavior), E3 (hypervigilance), E4 (exaggerated startle response), E5 (problems with concentration), and E6 (sleep disturbance)

networks as they were within our network models. Regarding the DAGs, there is only one other study which has explored the network structure of *DSM-5* PTSD, specifically in adults reporting childhood sexual abuse. McNally et al. (2017) found that becoming physiologically reactive and upset in response to reminders of the trauma may represent key drivers in the symptom network. These divergent results may be partially explained by differing adult symptomatology, where reexperiencing symptoms may play a more central role (Sachser et al., 2018), and by the use of the *DSM-IV* conceptualization of PTSD, which lacks our most central symptoms in the regularized partial correlation networks and the driving forces in the DAGs: *negative trauma-related cognitions* and *persistent negative emotional state*.

Considering the restricted set of symptoms for PTSD in the upcoming *ICD-11*, the high centrality of the symptoms of the NACM cluster is noteworthy. A first investigation has revealed that *ICD-11* PTSD leads to a major reduction in PTSD prevalence in children and adolescents compared to diagnosis rates assessed with the *DSM-5* PTSD criteria set (Sachser et al., 2018). Given the assumed importance of the symptoms of the NACM cluster in the PTSD network of children and adolescents, future research should include these symptoms to avoid the loss of potential critical information.

Our study had several strengths and limitations. Major strengths of the study were that two distinct network approaches were used: an undirected approach (regularized partial correlation network) and a directed approach (DAGs), which were applied to the most recent PTSD conceptualization (*DSM-5*). Consistent with the recommendation for diagnosing PTSD in children and adolescents, we present PTSS networks based on the perspective of the children and adolescents as well as from the caregivers' perspective. The major weakness of our study was that our sample was too small to check for age-, trauma- or gender-specific changes during different developmental phases through childhood and adolescence. Further, we could not control for clinical covariates such as comorbidity or psychotropic medication. Our sample was severely traumatized as the major inclusion criterion was a *DSM-5* PTSD – A criterion traumatic event. However, only about 38% would have been diagnosed with PTSD according to *DSM-5* algorithm. This weakness can also be interpreted as a strength in the way that following the Research Domain Criteria (RDoC) approach participants for studies should not always be preselected by current diagnostic symptoms which could impede future research on etiology, symptomology, pathophysiology, and development of new treatments (Cuthbert & Insel, 2013). By including a broader range of severity, our sample also offered greater variability in symptom severity, allowing for a more robust examination of how variance in the severity of any given symptom might relate to severity in another. At the same time, our networks reflect the dimensional nature of mental disorders by including participants with almost no PTSS up to severely PTSS after experiencing a traumatic event. However, as a result of the specific study sample the results of this study might not be directly generalizable to other samples. Therefore, future research should focus on replications of network analyses across different populations of traumatized children and adolescents regarding age, sex, trauma type, and PTSS severity. The estimated networks are based on cross-sectional data, thus causal interpretation should be done with caution. PTSS may play different roles at different stages in the development of PTSD (e.g. intrusion of thoughts or memories or flashbacks may cause behavioral avoidance or disengagement at first, but later on, mood-related symptoms may influence avoidance or disengagement more). Future network analysis on *DSM-5* PTSS in children and adolescents should conduct dynamic network analysis and control for the time since the traumatic event.

Altogether our results add relevant information to the symptomatology, development, persistence, and treatment of PTSS in children and adolescents from a network perspective. In line with our results, the cognitive model of PTSD (Ehlers & Clark, 2000) suggests that trauma-related dysfunctional cognitions are central to the development and persistence of PTSD after experiencing traumatic events. With regard to PTSD treatment, the most evidence has been gathered for TF-CBT to be effective for children and adolescents with PTSS (Morina, Koerssen, & Pollet, 2016). Indeed, recent treatment studies suggest that the change in trauma-related cognitions might be an important mediator of the treatment response in TF-CBT (McLean, Yeh, Rosenfield, & Foa, 2015). Given the presumed importance of the symptoms of the NACM cluster in the PTSS network of children and adolescents, future research on PTSS in children and adolescents using the *ICD-11* classification system should additionally include items on trauma-related cognitions and mood. As the NACM symptoms could have a high chance of functioning as bridging symptoms to depression and anxiety, which are common comorbid conditions in children and adolescents with PTSD, future research should integrate symptoms of depression and anxiety together with PTSS and investigate longitudinal data to gather dynamic interpretations of symptom networks.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Table S1. Correlation-stability coefficients (CS) for the centrality indices betweenness, closeness, and strength.
Table S2. Item means, standard deviations, and strength indices for all items/symptoms.
Figure S1. Subset bootstrap test.
Figure S2. Subset bootstrap test.
Figure S3. Node Centrality.
Figure S4. Bootstrap differences test for closeness.
Figure S5. Bootstrap differences test for closeness.
Figure S6. Bootstrap differences test for betweenness.
Figure S7. Bootstrap differences test for betweenness.
Figure S8. Edge-weight accuracy test.
Figure S9. Edge-weight difference test.
Figure S10. Bootstrap differences test for strength.
Figure S11. Edge-weight accuracy test.
Figure S12. Edge-weight difference test.
Figure S13. Bootstrap differences test for strength.
Figure S14. Directed acyclic graph.
Figure S15. Directed acyclic graph.

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Key points

- Often the clinical presentation of PTSS includes a broad range of internalizing and externalizing symptoms, which overlap with symptoms of many other psychiatric disorders in children and adolescents.
- Network analysis seems to be an interesting approach to investigate the importance of different symptoms within the broad *DSM-5* PTSD conceptualization.
- Symptoms of the NACM cluster were the most central symptoms in the undirected networks and appeared to be the driving forces in the directed networks.
- Symptoms of the NACM cluster are overall very connected to many other symptoms and therefore may be clinically relevant targets in the treatment of PTSD in children and adolescents.

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