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Dysfunctional posttraumatic cognitions, posttraumatic stress and depression in children and adolescents exposed to trauma: a network analysis

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Background: The latest version of the International Classification of Diseases (ICD-11) proposes a posttraumatic stress disorder (PTSD) diagnosis reduced to its core symptoms within the symptom clusters re-experiencing, avoidance and hyperarousal. Since children and adolescents often show a variety of internalizing and externalizing symptoms in the aftermath of traumatic events, the question arises whether such a conceptualization of the PTSD diagnosis is supported in children and adolescents. Furthermore, although dysfunctional posttraumatic cognitions (PTCs) appear to play an important role in the development and persistence of PTSD in children and adolescents, their function within diagnostic frameworks requires clarification. **Methods:** We compiled a large international data set of 2,313 children and adolescents aged 6 to 18 years exposed to trauma and calculated a network model including dysfunctional PTCs, PTSD core symptoms and depression symptoms. Central items and relations between constructs were investigated. **Results:** The PTSD re-experiencing symptoms *strong or overwhelming emotions* and *strong physical sensations* and the depression symptom *difficulty concentrating* emerged as most central. Items from the same construct were more strongly connected with each other than with items from the other constructs. Dysfunctional PTCs were not more strongly connected to core PTSD symptoms than to depression symptoms. **Conclusions:** Our findings provide support that a PTSD diagnosis reduced to its core symptoms could help to disentangle PTSD, depression and dysfunctional PTCs. Using longitudinal data and complementing between-subject with within-subject analyses might provide further insight into the relationship between dysfunctional PTCs, PTSD and depression. **Keywords:** Children; adolescents; depression; DSM-5; ICD-11; network analysis; posttraumatic cognitions; posttraumatic stress disorder; trauma.

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Introduction

The current versions of the *International Classification of Diseases* (ICD-11; WHO, 2018) and the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5, APA, 2013) have recently been updated, leading to differences in the posttraumatic stress disorder (PTSD) diagnosis. The DSM-5 added a new criterion *negative alterations in cognitions and mood* to the DSM-IV criteria of re-experiencing, avoidance and hyperarousal. An advantage of this broad PTSD construct is its more comprehensive description of the disorder's symptomatology (Brewin et al., 2017). The disadvantage is that the disorder becomes very heterogeneous, with over half a million possible combinations of symptoms (Galatzer-Levy & Bryant, 2013). In contrast, the ICD-11 proposes a PTSD diagnosis reduced to its core symptoms (Brewin et al., 2017; WHO, 2018).

Each diagnostic algorithm has its strengths and weaknesses for children and adolescents. Especially after multiple adverse experiences, children and adolescents often show a variety of internalizing and externalizing symptoms (Goldbeck & Jensen, 2017; Schmid, Petermann, & Fegert, 2013). The question thus arises whether a PTSD diagnosis reduced to its core symptoms as proposed in ICD-11 is supported in children and adolescents or whether such a PTSD diagnosis excludes important (i.e. common and interconnected) symptoms – particularly low mood – which is part of the DSM-5 PTSD diagnosis. In support of the ICD-11 approach, Sachser et al. (2018) found a PTSD diagnosis reduced to its core symptoms to be appropriate for children and adolescents. Furthermore, studies that investigated the PTSD factor structure in children and adolescents showed that treating the core PTSD symptoms as a specific entity distinct from depression and generic emotional distress provided the best model fit (Kassam-Adams, Marsac, & Cirilli, 2010) and reduced PTSD-depression comorbidity (Ford, Elhai, Ruggiero, & Frueh, 2009). Related to this topic is the different handling of the PTSD re-experiencing cluster between DSM-5 and ICD-11. While the DSM-5 incorporates a broader variety on symptoms including intrusive memories, psychological distress and physiological reactions to trauma-related cues (APA, 2013), the ICD-11 only includes re-experiencing symptoms that are specific to PTSD (flashbacks and posttraumatic nightmares; Brewin, Lanius, Novac, Schnyder, & Galea, 2009; Maercker et al., 2013). This is based on an emerging literature suggesting that intrusive memories are also a common experience in depression (Payne, Kralj, Young, & Meiser-Stedman, 2019). However, Sachser et al. (2018) argue that including intrusive memories might be important to account for developmentally different presentations of re-experiencing symptoms in children and adolescents.

Another question that arises from the differences in PTSD definitions in DSM-5 and ICD-11 is how to conceptualize dysfunctional posttraumatic cognitions (PTCs) in the diagnostic framework for PTSD in children and adolescents. Dysfunctional PTCs are considered to emerge as a reaction to trauma exposure. The traumatic event itself and its consequences can be appraised in an extremely negative way that according to a cognitive model of PTSD (Ehlers & Clark, 2000) can play a powerful role in the development and maintenance of this disorder. In particular, Ehlers and Clark argue that PTCs can lead to a feeling of current threat, alongside the triggering of affect-laden memories of the trauma. Moreover, dysfunctional PTCs may motivate the use of short-term coping behaviours that in the long term might prevent cognitive change (in terms of either their appraisals or their trauma memories) and cause the symptoms to persist. Research has mainly focused on dysfunctional PTCs regarding the self (I am an incompetent person, I will never be the same again), the world (the world is a scary place where I am highly vulnerable) and self-blame/guilt. Numerous studies have found a strong relationship between dysfunctional PTCs and PTSD in children and adolescents (for a recent review see Mitchell, Brennan, Curran, Hanna, & Dyer, 2017). While DSM-5 views these dysfunctional PTCs as PTSD *symptoms*, they have also been viewed by some theorists (e.g. Ehlers & Clark, 2000) as a powerful *mechanism* in the development and persistence of PTSD. A further complicating factor is that dysfunctional PTCs have been reported to correlate moderately to strongly with disorders such as depression, anxiety and externalizing problems in children and adolescents (e.g. de Haan, Ganser, Münzer, Witt, & Goldbeck, 2017; Hiller et al., 2018; Liu & Chen, 2015).

Considering the differences in the recently proposed ICD-11 and DSM-5 PTSD criteria, the current paper aims to address the following three research questions in children and adolescents. (a) What items are central in a network of dysfunctional PTCs, PTSD (based on the ICD-11 but using a broad approach on re-experiencing symptoms) and depression? (b) Is a PTSD approach reduced to its core symptoms supported in this age group or does this approach exclude relevant symptoms of low and depressed mood, that is do low mood and PTSD symptoms belong to one broader but unitary construct? (c) How do dysfunctional PTCs relate to core PTSD symptoms and to depression symptoms?

Methods

Procedure

The *CPTCI International Data Set* is a worldwide collaboration of research groups investigating the role of PTCs in children and adolescents. It is the first international collaboration on posttraumatic cognitions and one of the largest international data sets on child trauma and PTSD. It includes 17 data sets

from eight different countries with 2,313 children and adolescents in total. Inclusion criteria for the participants were (a) an age between 6 and 18 years, (b) their traumatic experience met the definitions of PTSD criterion A according to either the DSM-IV or the DSM-5 (depending on the time at which the data were collected), (c) their traumatic experience was more than one month before data collection, and (d) they provided information on the original or short form of the *Child Posttraumatic Cognitions Inventory* (McKinnon et al., 2016; Meiser-Stedman et al., 2009). Each study from which data were drawn was approved by the Institutional Review Board at the recruiting study site. Informed consent was obtained from all participants included in each study. See Table S1 in the Supporting Information for a detailed description of the data sets.

Measures

Dysfunctional posttraumatic cognitions. The Child Posttraumatic Cognitions Inventory (CPTCI; Meiser-Stedman et al., 2009) is a self-report measure for children and adolescents assessing dysfunctional PTCs derived from Ehlers and Clark's model (2000). The questionnaire consists of two subscales, a permanent and disturbing change subscale (CPTCI-PC) and a fragile person in a scary world subscale (CPTCI-SW). Examples are 'My reactions since the frightening event mean I have changed for the worse' (CPTCI-PC) and 'I can't stop bad things from happening to me' (CPTCI-SW). In the current study, we used the items of the short form of the CPTCI (CPTCI-S), consisting of 10 of the original 25 items (McKinnon et al., 2016). Items are rated on a 4-point scale from *Don't agree at all* to *Agree a lot*. The total score of the CPTCI-S demonstrated good internal consistency in our study sample (Cronbach's α = .88).

Symptoms of posttraumatic stress disorder and depression. The included studies used a variety of validated DSM-IV and DSM-5 self-report measures to assess symptoms of PTSD and depression. Thirteen of the 17 data sets provided information regarding depression symptoms (indicated on the Table S1).

In line with ICD-11 (WHO, 2018), nine symptoms of PTSD were considered: (a) re-experiencing the traumatic event or events in the present in the form of (1) vivid intrusive memories, (2) flashbacks or (3) nightmares, which are typically accompanied by (4) strong and overwhelming emotions such as fear or horror and (5) strong physical sensations; (b) (6) avoidance of thoughts and memories of the event or events, or (7) avoidance of activities, situations or people reminiscent of the event or events; (c) persistent perceptions of heightened current threat, for example as indicated by (8) hypervigilance or (9) an enhanced startle reaction to stimuli such as unexpected noises. Notably, DSM-IV and DSM-5 PTSD measures were used to create the PTSD ICD-11 symptoms. The re-experiencing symptoms therefore reflect a mixture of DSM-5 and ICD-11 symptoms of PTSD.

For depression, 10 symptoms were taken into consideration: (a) depressed mood or (b) diminished interest in activities lasting at least 2 weeks accompanied by other symptoms such as (c) difficulty concentrating, (d) feelings of worthlessness or excessive or inappropriate guilt, (e) hopelessness, (f) recurrent thoughts of death or suicide, changes in (g) appetite or (h) sleep, (i) psychomotor agitation or retardation and (j) reduced energy or fatigue.

For each PTSD and depression symptom (see Table S2), three investigators in the CPTCI International Data Set (A.d.H., M.A.L and R.M.-S.) identified items that (a) adequately represented the specific symptom construct and (b) were sufficiently congruent in wording to be combined (cf. Kassam-Adams et al., 2012). If a measure assessed a symptom with different items, then the highest score of these potential items was used. This procedure is in line with the well-established UCLA PTSD Reaction Index (Steinberg, Brymer, Decker, & Pynoos, 2004). The depression symptom *beliefs of low self-worth or excessive or inappropriate guilt* was assessed in most depression measures only by *low self-worth*; we therefore exclusively used the worthlessness items to represent this depression symptom. Internal consistencies for the PTSD and depression symptoms were good (reduced samples due to list-wise deletion: PTSD Cronbach's α = .87, n = 1,429; depression Cronbach's α = .84, n = 713).

Missing data

Pooling international data to such a large data set presented some challenges. We did not have information from all participants for every PTSD and depression symptom. Some symptoms were not a part of the questionnaire or interview used, so participants could not give information regarding those symptoms. We considered our situation comparable to planned missingness or missing by design. Data that were missing because they were never intended to be collected in the first place, such as the use of multiple questionnaires containing different subsets of items, are assumed to be missing completely at random or at least missing at random (Schafer & Graham, 2002). Additionally, a negligible number of values were missing because participants left items unanswered (e.g. dysfunctional PTCs items between 0.1% and 0.8% missing data). Since the literature provides no consensus (Kleinke, 2017; Schafer & Graham, 2002) how much missing data are tolerable, we included all items in the final analysis if at least half the participants had answered it. This approach to missing data required two ICD-11 depression items to be excluded: *change in activity: psychomotor agitation or retardation* and *hopelessness* (answered in only 34.5% and 27.0% of the cases, respectively). Table S2 describes the symptoms included in the network analysis and the percentage of missing data. For the statistical analyses, we followed prior network papers; we did not impute missing data but estimated correlations among cognitions and symptoms based on pairwise complete observations (cf. Fried et al., 2018; Santos, Fried, Asafu-Adjei, & Ruiz, 2017). Therefore, all 2,313 participants were included in the network analysis.

Data analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, version 22.0; IBM-Corp., 2013) and R (R Core Team, 2019); see Appendix S1 for information on the R-packages and versions used. The R-script is further available as supporting information (see Appendix S2). The network was based on 10 cognition items, nine symptoms of PTSD and eight symptoms of depression (N = 27 items). Mean and standard deviation for all items in the network are reported in Table S2. We further provided the percentage of how many participants reported having the respective cognition or fulfilled the PTSD or depression symptom. Out of 1,429 participants with full data (61.8% of the total sample), 23.9% met a core PTSD diagnosis (including all five re-experiencing symptoms (1) vivid intrusive memories, (2) flashbacks or (3) nightmares, which are typically accompanied by (4) strong and overwhelming emotions such as fear or horror and (5) strong physical sensations). Reducing the re-experiencing cluster to vivid intrusive memories, flashbacks and nightmares led to a PTSD prevalence of 20.8% (out of 1,432 participants with full data, equal to 61.9% of the total sample).

Network estimation. The network analysis and its description below followed Epskamp and colleagues' recommendations (Epskamp, Borsboom, & Fried, 2018; Epskamp & Fried, 2018). In summary, we estimated regularized partial

correlation networks: nodes are items, and edges reflect the unique pairwise association between two nodes after controlling for all other nodes in the network. Regularization removes edges that are likely to be spurious, for instance due to multiple testing, leading to a sparse network. We used the *least absolute shrinkage and selection operator* (LASSO; Tibshirani, 1996) as the regularization method. Since the LASSO method estimates a collection of networks, the *extended Bayesian information criterion* (EBIC; Chen & Chen, 2008) was used to retrieve the network with the best fit to the data by applying the thresholded regularized *Gaussian graphical model* (Epskamp, 2018). Our data were ordinal and not normally distributed. In line with Epskamp and Fried (2018), we compared networks based on polychoric correlations with Spearman correlations. The correlation matrices showed less overlap than expected (r = .82). Given the large quantity of missing data (see Table S2), we used the Spearman correlations. Polychoric correlations can show problems in small cells in cross-tables (Epskamp & Fried, 2018). To visualize the network structures, we used the *Fruchterman–Reingold algorithm* (Fruchterman & Reingold, 1991). This algorithm positions strongly connected nodes closer to each other and puts the most connected nodes at the centre of the graph. In the resulting figure, thicker edges represent stronger associations between nodes; blue edges indicate positive associations, red edges negative ones.

Node centrality. To identify central cognitions and symptoms in our network model of dysfunctional PTCs, PTSD and depression (cf. aim 1), we estimated *expected influence* (EI; Robinaugh, Millner, & McNally, 2016) rather than *strength centrality*, in line with Fonseca-Pedrero et al. (2018). EI includes the sum of all edges of a node considering the presence of negative edges. In contrast, strength centrality uses the sum of absolute weights, whether positive or negative, which might distort interpretation. Higher values in EI indicate that nodes are more central in the network. Furthermore, the network approach can be used to detect symptoms that bridge different constructs (see Cramer, Waldorp, van der Maas, & Borsboom, 2010). To identify bridging symptoms, we calculated the bridge EI (Payton, 2018): for example, the sum of all edges that exist between a PTSD symptom and all depression or cognition items.

Network stability and accuracy. Bootstrapping can be used to estimate the accuracy and stability of networks (for details see Epskamp et al., 2018). First, we assessed the accuracy of network estimation. To estimate the accuracy of edge weights, we constructed confidence intervals (CI). Furthermore, we estimated whether differences between edge weights were significantly different using the bootstrap difference test. Then, a case-dropping subset bootstrap was used to evaluate the maximum proportion of cases that can be dropped such that with 95% probability the correlation between the original EI index and the EI of the network based on subsets is 0.7 or higher. This correlation stability coefficient (CS coefficient; how much data can be dropped) should not be below 25% and preferably above 50%. Again, we additionally estimated whether differences in EI were significantly different using the bootstrap difference test. Notably, the difference tests do not account for multiple testing and have to be considered exploratory. Both bootstrapping procedures were also used to estimate the accuracy and stability of the bridge EI.

Relations between constructs. To investigate whether using a PTSD diagnosis reduced to its core symptoms would actually lead to rather distinct constructs (cf. aim 2), the interconnectivity was analysed between the three constructs PTCs, PTSD and depression. We investigated whether items from the same construct (e.g. PTCs) were more closely associated with each other than with items from the other two constructs (e.g. PTSD and depression symptoms). We also analysed whether PTCs were significantly more closely connected to either PTSD or depression (cf. aim 3). Due to the lack of a standard procedure, we used both a permutation difference test and a bootstrap difference test to examine whether the observed difference was above what would be expected under chance conditions.

Results

Sample characteristics

The CPTCI international data set consists of 2,313 children and adolescents aged 6–18 years (M = 12.49, SD = 2.6) at assessment. Table 1 gives further information on demographics (sex, geographical background and sample type) and trauma-related data. For specific information per data set, see Table S1.

Network structure

No node was unconnected (see Figure 1). Of 351 potential edges, 87 (24.8%) nonzero edges emerged, with a mean weight of .028. Most edges were positive (n = 82, 94.3%; highlighted in blue); few edges were negative (n = 5, 5.7%; highlighted in red).

Bootstrapped confidence intervals for the edge weights showed that most edge weights did not differ significantly from each other (see Figure S1). This means that the order of edge weights should be

Table 1 Characteristics of the total sample

Total sample N = 2313	n	%
Sex		
Male	1179	51.0
Country/Territory		
United Kingdom	805	34.8
Netherlands	224	9.7
Switzerland	59	2.6
Gaza Strip	419	18.1
Taiwan	285	12.3
Australia	210	9.1
U.S.A.	87	3.8
Brazil	224	9.7
Sample		
Clinical	380	16.4
Emergency department/hospital	742	32.1
School	1127	48.7
Child protection	54	2.3
Nongovernmental organization	3	0.1
Not determined[a]	7	0.3
Trauma type index-event		
Interpersonal	437	18.9
War trauma	419	18.1
Accidental	766	33.1
Natural disaster	192	8.3
Other	141	6.1
Not determined[a]	358	15.5

[a]'Not determined' means that these participants could not be reliably classified in any category due to insufficient information.

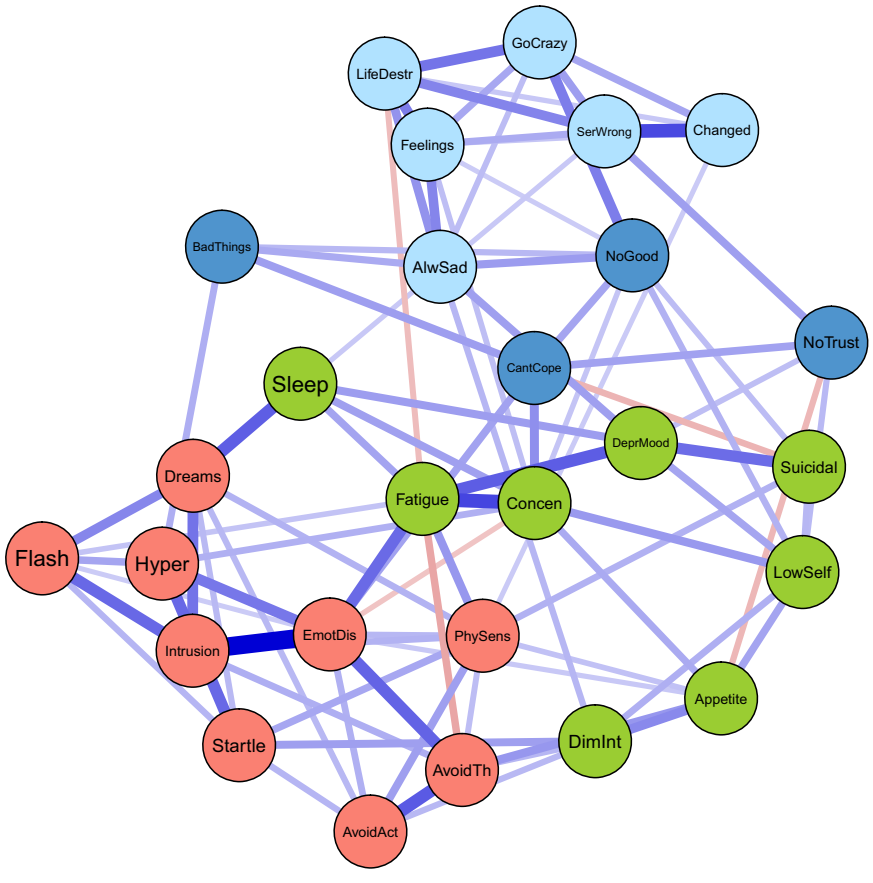

Figure 1 Network model of dysfunctional PTCs, PTSD, and depression symptoms. Red nodes = PTSD symptoms; green nodes = depression symptoms; blue nodes = dysfunctional PTCs of being a fragile person in a scary world (subscale CPTCI-SW); light blue nodes = dysfunctional PTCs of a permanent and disturbing change (subscale CPTCI-PC). Blue edges indicate positive associations and red edges indicate negative ones. Changed: Reactions since event mean I have changed for the worse; SerWrong: Reactions since event mean something is seriously wrong; AlwSad: I used to be a happy person but now I am always sad; Feelings: I will never be able to have normal feelings again; LifeDestr: My life has been destroyed by the frightening event; GoCrazy: Reactions since the event mean I must be going crazy; NoTrust: I don't trust people; NoGood: I am no good; CantCope: I can't cope when things get tough; BadThings: Bad things always happen

interpreted with care; a strong edge is stronger than a weaker edge, but is not necessarily statistically significantly so. Only the connection of the PTSD re-experiencing symptoms *strong or overwhelming emotions* and *vivid intrusive images or memories* differed significantly from all other edges.

Centrality

The CS coefficient for EI was 0.44, which means the order of centrality estimates has to be interpreted with some caution. Regarding the first research question, what items are central in a network of dysfunctional PTCs, PTSD and depression in children and adolescents, the PTSD re-experiencing symptoms *strong or overwhelming emotions* and *strong physical sensations* showed the highest EI, followed by the depression symptom *reduced ability to concentrate and sustain attention to tasks, or marked indecisiveness* (see Figure 2): these items were most connected to the other cognitions and symptoms. Notably, the pattern of connections varied across these most central items (see Figure 1). The PTSD symptom *strong or overwhelming emotions* had both a moderate connection with PTSD symptom *intrusive memories* (.32) and many smaller edges with items from all three constructs (<.20). Conversely, the PTSD symptom *strong physical sensations* had many small edges, predominantly within the PTSD construct (<.13). The depression symptom *difficulty concentrating* had the strongest connection with the depression symptom *fatigue* (.24) and many smaller edges with items from all three constructs (<.15).

In contrast, the cognition items *I don't trust people* and *Bad things always happen*, and the depression symptom *suicidality* had the weakest EI values (see Figure 2); they had few and weaker connections to other cognitions and symptoms (see Figure 1). Notably, the bootstrap significance test showed that most EI values did not differ significantly from each other (see Figure S2). Only the EI for *strong or overwhelming emotions* differed significantly from almost all other EI values, implying that it can be statistically interpreted as the most central item in the network. The EI values for *strong physical sensations* and *difficulty concentrating* differed significantly from up to half of the other items.

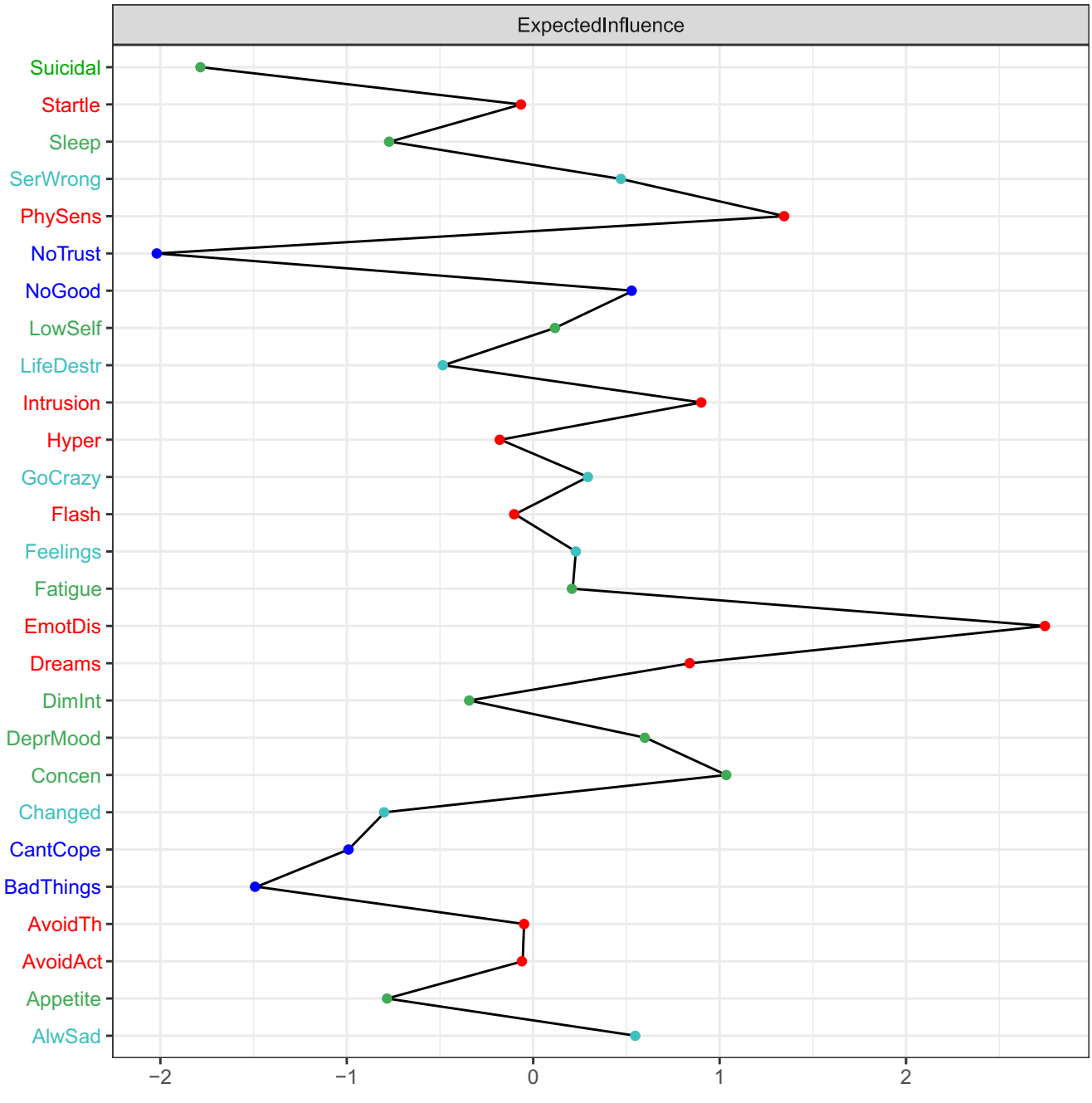

Figure 2 Expected influence for dysfunctional PTCs, PTSD, and depression symptoms. Red = PTSD symptoms; green = depression symptoms; blue = dysfunctional PTCs of being a fragile person in a scary world (subscale CPTCI-SW); light blue = dysfunctional PTCs of a permanent and disturbing change (subscale CPTCI-PC)

Bridging symptoms

The CS coefficient for bridge EI was 0.21 and did not meet the minimum threshold of 0.25. To avoid introducing selection or publication bias, we report all bridge EI values in Figure S3 but refrain from further interpreting them.

Relation between constructs

To investigate the relations of items within and between constructs, we examined whether the difference observed between associations of items within the same construct (e.g. PTCs items) and associations with items from the other two constructs (e.g. PTCs item with PTSD and depression symptoms) differed from zero using the permutation difference test and the bootstrap difference test. Results of both tests overlapped, except for one case. In this case, we report the more conservative, non-significant finding. Regarding the second research question whether a PTSD diagnosis reduced to its core symptoms is supported in children and adolescents, we found that edges within the same construct were significantly stronger than connections with items in the other two constructs (see Table 2). The same finding emerged for the comparison of specific constructs; for example, PTSD symptoms

Table 2 Comparison of edge weights within and between constructs

	Edge weights				
	Within[a]	Between	With cognitions	With PTSD	With depression
Cognitions	.061	.006	—	.004	.007
CPTCI-PC	.114	.003	.024	.003	.004
CPTCI-SW	.074	.009		.006	.012
PTSD	.083	.010	.004	—	.017
Depression	.064	.012	.007	.017	—

CPTCI-PC, CPTCI permanent and disturbing change subscale; CPTCI-SW, CPTCI fragile person in a scary world subscale; PTSD, posttraumatic stress disorder.
[a]Edges within the same construct were significantly stronger than connections with items in the other two constructs.

correlated significantly more strongly with other PTSD symptoms than with either depression or PTCs items (.083 vs. .017; .083 vs. .004). Lastly, we focused on the role of dysfunctional PTCs in line with the third research question regarding how dysfunctional PTCs relate to core PTSD symptoms and to depression symptoms in children and adolescents. Dysfunctional PTCs were not more strongly connected to PTSD than to depression (see Table 2).

Divided into the two subscales of the CPTCI, items within each subscale were again significantly more strongly interconnected than they were associated with PTSD or depression symptoms. In line with the findings of the dysfunctional PTCs' total score, the subscales were not more strongly connected to core PTSD symptoms than to depression symptoms. No significant differences between dysfunctional PTCs about a permanent and disturbing change (subscale CPTCI-PC) and dysfunctional PTCs of being a fragile person in a scary world (subscale CPTCI-SW) emerged (see Table 2).

Discussion

We conducted a network analysis including dysfunctional PTCs and core symptoms of PTSD and depression in an international sample of 2,313 children and adolescents exposed to trauma. The PTSD re-experiencing symptoms *strong or overwhelming emotions* and *strong physical sensations* and the depression symptom *difficulty concentrating* (which is a PTSD symptom in DSM-5 and previous versions of the DSM) emerged as the most central: these items were most connected to the other cognitions and symptoms (cf. aim 1). Items from the same construct were more strongly connected with each other than with items from other constructs (cf. aim 2). Dysfunctional PTCs were not more strongly connected to core PTSD symptoms than to depression symptoms (cf. aim 3).

Our findings in regard to aim 1 are in contrast to another recent network analysis in trauma-exposed children and adolescents. Using DSM-5 PTSD symptoms, Bartels et al. (2019) found that symptoms of the negative alterations in cognitions and mood cluster emerged as central in their network. However, also *psychological distress* (B4, DSM-5) and *avoidance of thoughts or memories* (C1, DSM-5) emerged as central. Both studies had similar sample characteristics regarding age and sex, but the distribution of the index-trauma differed. Most of the participants in Bartels et al.'s study (2019) reported interpersonal trauma (55.5%) compared with 18.9% in our sample. Furthermore, in line with our findings, *strong physical sensations* had previously emerged as a central symptom in another network analysis of PTSD symptoms in children and adolescents exposed to disasters (Russell, Neill, Carrion, & Weems, 2017). In a sample of disaster-exposed adolescents, Cao et al. (2018) found that, inter alia, PTSD re-experiencing symptoms such as *intrusive memories*, *flashbacks* and *strong physical sensations* were the most central. Primarily *flashbacks* had been included in other studies using the PTSD ICD-11 criteria before (e.g. Hansen, Hyland, Armour, Shevlin, & Elklit, 2015; Sachser et al., 2018). However, the central position of *strong or overwhelming emotions*, *strong physical sensations* and *intrusive memories* implies they should also be included in clinical assessments so as to monitor and address them.

Notably, centrality is merely a statistical parameter and does not automatically indicate that the most central nodes cause or influence other nodes; many alternative explanations exist. Drawing inferences from centrality analyses in cross-sectional data, for instance regarding intervention targets, requires researchers to make assumptions, as summarized in Fried et al. (2018). First, a central item might be a causal end point rather than a starting point. Therefore, targeting this symptom in treatment might not be successful, because the cause of the symptom has not been addressed. These and related questions can be answered much more easily in temporal data. Second, although symptoms such as suicidal ideation might not be central to the network, they may still be of high clinical relevance, so the argument that high centrality equals high importance does not necessarily hold. Third, symptoms may vary in their response to psychological or medical interventions. Finally, symptoms might be statistically central solely due to statistical effects.

For instance, many very similarly phrased items included in the same network structure will lead to strong connectivity among these items and hence high centrality (Fried & Cramer, 2017).

In addition to centrality metrics, we investigated for aim 2 whether using PTSD core symptoms would actually lead to a rather distinct pattern of dysfunctional PTCs, PTSD and depression in children and adolescents. Importantly, all three constructs had a similar number of items in the network (dysfunctional PTCs 10 items, PTSD nine items and depression eight items). The connections within each construct were indeed significantly stronger than to items in the other constructs. However, a methodological confounding factor could be that answering certain items in a given scale might increase their relations within the respective construct. Nevertheless, the results align with previous findings that using PTSD core symptoms might help to distinguish PTSD from depression (Ford et al., 2009; Kassam-Adams et al., 2010).

Whichever diagnostic classification system is used, PTSD and depression are often comorbid. Investigating bridge symptoms might provide further insights. Unfortunately, our results on bridging items were not stable enough to be interpreted; the parameters could not be estimated with the level of precision required for further inferences. This is likely due to the number of nodes in the network model and the considerable quantity of missing data for many items. However, considering the role of dysfunctional PTCs might shed light on the frequent comorbidity of PTSD and depression (aim 3). Connections emerged between dysfunctional PTCs and symptoms of PTSD and depression; dysfunctional PTCs were not more strongly connected to core PTSD symptoms than to depression symptoms. This was also true for both subscales of the dysfunctional PTCs (permanent and disturbing change; fragile person in a scary world).

Longitudinal data are needed to clarify how dysfunctional PTCs relate to core PTSD symptoms and to depression symptoms and the role their might be playing in the frequent comorbidity of PTSD and depression.

Limitations

A strength of our study is the use of diverse international trauma samples with a variety in age, trauma type and cultural background. Nevertheless, it is important to keep in mind that between-subject results might not generalize to within-subject levels (see Fisher, Medaglia, & Jeronimus, 2018).

The various PTSD and depression measures used at the study sites meant we had to pool different items across measures to create the symptoms and to deal with a considerable quantity of missing values. To date, no procedures have been established to impute missing values in network analyses. In the absence of such a technique, it has been suggested that using the completely observed part of the data set might be safer (Kleinke, Reinecke, Salfrán, & Spiess, 2019). We, therefore, estimated the correlations among cognitions and symptoms based on pairwise complete observations (after excluding two items, *psychomotor agitation or retardation* and *hopelessnes*s, due to more than 50% missing data), in line with recent publications (Fried et al., 2018; Santos et al., 2017). As a result, the network model does not control for both items when estimating relations among other items.

We used DSM-IV and DSM-5 PTSD measures to create the PTSD ICD-11 symptoms. This has been common practice so far (Brewin et al., 2017). Brewin et al. (2017) argue that symptoms of the avoidance and hyperarousal clusters can be assessed using DSM-based measures, but that there are differences between DSM and ICD-11 in defining and assessing *nightmares* and *flashbacks* from the re-experiencing cluster. We furthermore used a broader PTSD definition of the re-experiencing cluster than most previous ICD-11 studies by including *strong or overwhelming emotions*, *strong physical sensations* and *vivid intrusive images or memories*. The use of DSM measures and the broader PTSD definition of the re-experiencing cluster need to be considered when comparing our results to current or future ICD-11 research studies. Additionally, although we used PTSD core symptoms, there was still overlap between items of the three constructs, such as similar items (e.g. PTSD symptom *repetitive dreams or nightmares* and depression symptom *significantly disrupted sleep or excessive sleep*) or the rather unspecific role of the depression item *difficulty concentrating* (which is a PTSD symptom in DSM-5 and previous versions of the DSM).

We did not attempt to include externalizing difficulties in our network model as too few data sets had included a useful measure, though we recognize that this might have given a more comprehensive view on the relationship of dysfunctional PTCs, PTSS and further related psychological symptoms.

Furthermore, we did not control for possible confounding factors such as time since trauma, because only half of the sample provided data on this issue. A few negative edges emerged in our network that were unexpected, since the pairwise correlation matrix did not have any negative associations. These unexpected negative relationships might indicate common effect structures: due to their independent connection to the same variable, two unrelated items may display an artificial negative partial correlation (Epskamp & Fried, 2018).

Implications

Our findings add relevant information to the study and clinical management of PTSD in children. On the

one hand, the PTSD symptom *emotional distress to internal or external trauma-related cues* – which is not specifically captured within the new ICD-11 approach – seem to be very important. Including it in clinical assessments to monitor and address it might be of high clinical relevance. On the other hand, in regard to the new DSM-5 cluster negative alterations in cognitions and mood, our findings might indicate that – although PTSD symptoms, depression symptoms, and dysfunctional PTCs are highly associated – they are still part of distinct constructs. Treating them as such, in line with the ICD-11 approach, could help to distinguish PTSD, depression and dysfunctional PTCs. However, the new DSM-5 cluster is nevertheless a meaningful addition, because – by including symptoms of negative alterations in cognitions and mood – it helps to keep the close interplay of PTSD symptoms, depression symptoms and dysfunctional PTCs in mind. Consequently, trauma diagnostic and treatment need to address core PTSD symptoms as well as depression symptoms and dysfunctional PTCs. Those three might drive each other or might be driven by one construct. The relationship of these three constructs could be further investigated taking characteristics of the individual, of the social environment and of the trauma (history) itself into account (de Haan, Tutus, Goldbeck, Rosner, & Landolt, 2019). Cross- and longitudinal relationships of PTSD, depression and dysfunctional PTCs might differ in regard to variables such as age, sex or trauma history. Longitudinal studies are needed to gain more insight into these associations to be able to derive further clinical implications.

Conclusions

Strong or overwhelming emotions, *strong physical sensations* and *difficulty concentrating* stood out in several analyses as highly connected symptoms in children and adolescents exposed to trauma. They therefore should not be neglected in assessment and treatment. A PTSD diagnosis reduced to its core symptoms might help to disentangle PTSD, depression and dysfunctional PTCs. Using longitudinal data and complementing between-subject with within-subject analyses might provide further insight into the relationship between dysfunctional PTCs, PTSD and depression.

Supporting information

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

Appendix S1. Information about the specific R-packages used.
Appendix S2. R-script.
Figure S1. Bootstrapped difference test for edge weights.
Figure S2. Bootstrapped difference test for expected influence.
Figure S3. Bridge expected influence.
Table S1. Study characteristics: data sets included in analyses.
Table S2. Means and standard deviations of the cognitions and symptoms used in the network model.

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Key points

- ICD-11 proposes a PTSD diagnosis reduced to its core symptoms within the symptom clusters re-experiencing, avoidance and hyperarousal, while DSM-5 PTSD includes symptoms related to negative alterations in cognitions and mood.
- The PTSD re-experiencing symptoms *strong or overwhelming emotions* and *strong physical sensations* and the depression symptom *difficulty concentrating* emerged as most central in a network consisting of dysfunctional posttraumatic cognitions (PTCs), core PTSD symptoms and depression symptoms in children and adolescents.
- Dysfunctional PTCs and PTSD and depression symptoms were more strongly related to each other than to items from the other constructs.

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