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CLINICAL RESEARCH ARTICLE

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Age-related similarities and differences in networks of acute trauma-related stress symptoms in younger and older preschool children

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ABSTRACT

Background: Prior research on trauma-exposed preschool children has found various levels of trauma-related stress symptoms depending on age, which might be explained by developmental factors.

Objective: This study uses network analysis to extend prior research and compare symptom presentation in younger and older preschoolers in the acute phase (first 4 weeks) following a potentially traumatic event.

Method: Parent-reported trauma-related acute stress symptoms were assessed using the Pediatric Emotional Distress Scale – Early Screener via www.kidtrauma.com. First, the overall symptom severity and symptom levels were compared between younger (1–3 years) and older (4–6 years) preschoolers. Further, two Gaussian graphical models of stress symptoms in younger (n = 242; M_{age} = 2.3 years; SD_{age} = 0.6 years) and older preschoolers (n = 299; M_{age} = 4.8 years; SD_{age} = 0.7 years) were modelled and compared.

Results: Overall symptom severity did not differ between the groups. Symptom levels for developmental regression and avoidance of talking about the event were higher in older preschoolers. The network structures of the younger and the older preschoolers were largely similar. Highly central symptoms in both networks were trauma-unrelated fear and anger. The connections between fear of reminders and clinginess and trauma-unrelated fear and clinginess were stronger in the older preschoolers' network. The connections between worry and sadness and withdrawal; fear of reminders and creation of games, stories, and pictures; and whininess and clinginess were all stronger in the younger preschoolers' network.

Conclusions: Trauma-related stress symptomatology of younger and older preschoolers may not differ greatly in the acute phase. Trauma-unrelated fear and anger seem to be central symptoms in both groups. However, examining symptom-level associations across age groups revealed differential connections that might arise from developmental differences. If replicated in longitudinal and within-subject studies, these findings could help tailor interventions for trauma-exposed preschoolers in the acute phase.

Similitudes y diferencias relacionadas con la edad en redes de síntomas de estrés relacionados con trauma agudo en niños preescolares mayores y menores

Antecedentes: Investigaciones previas sobre niños preescolares expuestos al trauma han encontrado varios niveles de síntomas de estrés relacionados al trauma dependiendo de la edad, los cuales pueden ser explicados por factores del desarrollo.

Objetivo: Este estudio usa análisis en red para ampliar las investigaciones anteriores y comparar la presentación de síntomas en preescolares mayores y menores en la fase aguda (primeras 4 semanas).

Método: Se evaluaron los síntomas de estrés agudo relacionados a trauma reportados por los padres a través de la escala de *Sufrimiento Emocional Pediátrico – Early Screener* www.kidtrauma.com. Primero, se comparó la severidad general de los síntomas y el nivel de los síntomas entre niños preescolares menores (1-3 años) y mayores (4-6 años). Luego, se modelaron y compararon dos modelos gráficos gaussianos de síntomas de estrés en preescolares menores (n = 242; M_{edad} = 2.3 años; DE_{edad} = 0.6 años) y mayores (n = 299; M_{edad} = 4.8 años; DE_{edad} = 0.7 años).

Resultados: No hubo diferencias en la severidad general de los síntomas entre los grupos. Los niveles de síntomas para regresión del desarrollo y evasión de conversaciones sobre el tema, fueron más altos en los preescolares mayores. Las estructuras en red de los preescolares menores y mayores fueron mayormente similares. Los síntomas altamente centrales en ambas redes fueron el miedo y la ira no relacionados con el trauma. Las conexiones entre el

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关键词
创伤; 创伤后应激症状; 急性症状; 情绪困扰; 学龄前儿童; 网络分析

HIGHLIGHTS

- Symptom-specific differences in frequency between younger and older preschoolers emerged for developmental regression (younger < older) and avoidance of talking about the event (younger < older).
- Highly central symptoms in both age groups were trauma-unrelated fear and anger.

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Supplemental data for this article can be accessed here.

miedo de recordatorios y apego excesivo fueron más fuertes en la red de los preescolares mayores. Las conexiones entre preocupación y tristeza y retraimiento; miedo de recordatorios y creación de juegos, historias y dibujos; y quejumbrosidad y apego excesivo, fueron todas más fuertes en la red de los preescolares menores.
Conclusiones: Este estudio indica que la sintomatología de estrés relacionado a trauma en los preescolares menores y mayores no variaría de manera importante en la fase aguda. El miedo y la ira no relacionados al trauma parecen ser síntomas centrales en ambos grupos. Sin embargo, tras examinar asociaciones en los niveles de síntomas entre los grupos etarios, se revelaron conexiones diferenciales que podrían emerger a raíz de diferencias en el desarrollo. Si estos hallazgos se replicaran en estudios longitudinales y estudios controlados, podrían ayudar a adaptar las intervenciones para niños preescolares expuestos a trauma en la fase aguda.

年幼和年长的学龄前儿童急性创伤相关应激症状网络年龄相关的异同

背景: 先前对创伤暴露的学龄前儿童的研究发现, 不同的创伤相关应激症状水平取决于年龄, 可能由发育因素解释的。
目的: 本研究使用网络分析来扩展先前的研究, 比较年幼和年长学龄前儿童急性期 (前 4 周) 的症状表现。
方法: 使用儿科情绪困扰量表– 早期筛查 (www.kidtrauma.com) 评估父母报告的创伤相关急性应激症状。首先, 比较年幼 (1-3 岁) 和年长 (4-6 岁) 学龄前儿童的总体症状严重程度和症状水平。此外, 对年幼 (n = 242; M_{age} = 2.3 岁; SD_{age} = 0.6 岁) 和年长 (n = 299; M_{age} = 4.8 岁; SD_{age} = 0.7 岁) 的学龄前儿童应激症状的两个高斯图形模型进行了建模和比较。
结果: 组间的总体症状严重程度没有差异。年长的学龄前儿童的发育倒退和回避谈论该事件症状水平更高。年幼和年长的学龄前儿童的网络结构基本相似。两个网络中的核心症状都是与创伤无关的恐惧和愤怒。在年长学龄前儿童的网络中, 对提示物的恐惧, 粘人以及与创伤无关的恐惧和粘人之间的关联更强。在年幼学龄前儿童的网络中, 担心, 悲伤和退缩之间, 对提示物的恐惧和创造游戏, 故事和图片之间, 抱怨和粘人之间的关联更强。
结论: 本研究表明, 年幼和年长学龄前儿童的创伤相关应激症状在急性期可能没有很大不同。与创伤无关的恐惧和愤怒似乎是两人群的核心症状。然而, 对跨年龄人群症状水平关联的考查揭示了可能由发育差异引起的不同关联。如果能在纵向和被试内研究中重复, 这些发现可能有助于为急性期创伤暴露的学龄前儿童量身定制干预措施。

1. Introduction

Infants, toddlers, and kindergarteners (age 0–6 years, collectively referred to as preschoolers) are at particularly high risk of exposure to potentially traumatic events (PTEs) such as abuse, neglect, violence, and accidents, with many preschoolers experiencing more than one PTE (Lieberman, Chu, Van Horn, & Harris, 2011). Trauma-related stress symptoms are commonly exhibited by trauma-exposed preschoolers and include symptoms of posttraumatic stress disorder (PTSD), anxiety, depression, and oppositional defiant disorder (e.g. Briggs-Gowan et al., 2010; De Young, Kenardy, Cobham, & Kimble, 2012). Scheeringa, Zeanah, Drell, and Larrieu (1995) demonstrated that the PTSD criteria in the 4th edition of the *Diagnostic and Statistical Manual for Disorders* (American Psychiatric Association (APA), 1994) did not adequately capture the clinical symptoms manifested in preschoolers. Consequently, diagnostic algorithms such as the PTSD-AA (Scheeringa et al., 1995) and the DSM-5 PTSD preschool subtype (APA, 2013) include age-sensitive trauma-related stress symptoms that are more objective, behaviourally anchored, and developmentally sensitive.

However, preschoolers' symptom presentation after exposure to a PTE can vary depending on age due to rapid changes in cognitive, emotional, and self-regulatory development. Because memory is predominantly implicit prior to 18 months, it is argued that infants have no retrievable memories of experienced events (Scheeringa, 2009). Further, at 18 months, children have mastered only a few single words and usually speak only in two- to four-word sentences by 24 months (Hoff, 2013). As a result, children at this age are not able to express complex internal feelings such as loss of interest or persistent negative emotional states, both symptoms of PTSD according to DSM. Consequently, such symptoms, if displayed at all, are difficult for caregivers to detect. Around 36 months, it is argued that children's autobiographical memory allows a coherent narrative. Such memory allows the expression of experienced events through verbal recall, which is necessary to demonstrate key signs of posttraumatic stress such as intrusive thoughts and memories, distress when exposed to reminders, and avoidance behaviour (Scheeringa, 2009). However, research indicates that only at about age 4, children start to develop a temporal sense of self, which is a requirement for autobiographical memories (Povinelli, Landry, Theall, Clark, & Castille, 1999). Moreover, the ability to make a temporal connection is closely linked to the ability to tell a detailed personal narrative (Welch-Ross, 2001). Further, 4- to 5-year old children are more consistent in making connections between past mental states and how these influence current behaviours than 3-year-old children (Lagattuta & Wellman, 2001). Because many stress symptoms require the ability to connect the present to the past, it

might be only at the age of 4 that preschoolers display symptoms such as distress when exposed to reminders or avoidance behaviour.

A few studies have investigated age differences in symptom presentation among preschoolers. Scheeringa, Zeanah, Myers, and Putnam (2003) found that traumatized 1–3-year-old children manifested more intrusions, separation anxiety, and major depression disorder symptoms than 4–6-year-old children. Another study by Scheeringa and Zeanah (1995) found that traumatized toddlers between 19 and 48 months showed more re-experiencing symptoms than infants between 3 and 18 months. In a sample of preschoolers exposed to intimate partner violence, Levendosky, Bogat, and Martinez-Torteya (2013) found that arousal symptoms were the symptoms most frequently reported across all ages from 1 to 7 years. However, the authors found significant age differences with other symptoms: Intrusion symptoms peaked at age 4, symptoms of avoidance increased during the first 3 years of life before stabilizing, and the development of new fears increased until age 3 but were no longer observed in older preschoolers. Laor et al. (1996) examined differences in general stress symptoms among 3-, 4-, and 5-year-old preschoolers after missile attacks and found no differences in symptom prevalence across the three age groups.

Because these studies focused on differences in symptom prevalence or symptom frequency, we applied the network approach to mental disorders (Borsboom & Cramer, 2013) in the present study to investigate possible differences in symptom-level associations in trauma-related stress symptom presentations between younger and older preschoolers. The network approach characterizes mental disorders as being caused by interactions between observable psychopathological phenomena such as symptoms. Thus, a dynamic interplay of symptoms is responsible for the emergence and maintenance of a mental disorder. In the case of posttraumatic stress disorder for instance, a typical example of a causal interaction between symptoms is that in the aftermath of a traumatic event one might experience intrusive memories of the trauma that may give rise to physiological arousal, which may, in turn, cause sleeping problems. Symptom networks allow the analysis of the interactions among individual symptoms and to assess their centrality, or relative importance, within the network structure. Symptoms with high centrality may have a stronger influence on other symptoms and thus might be of clinical importance (Borsboom & Cramer, 2013). Although recent research has argued that the concept of centrality is not straightforward in its application to clinical practice (e.g. Rodebaugh et al., 2018), salient central symptoms in individual subgroups have also been argued to potentially lead to a better understanding of relevant treatment targets (Isvoranu, Epskamp, & Cheung, 2020).

Because questions about the development of PTSD in preschoolers and treatment components of early interventions remain unanswered (De Young & Kenardy, 2017), a better understanding of symptoms in the first 4 weeks after exposure to a PTE will help to optimize age-sensitive assessment and refinement of age-specific evidence-based early interventions. A study by De Young et al. (2012) found high prevalence of clinginess, avoidance of trauma reminders, irritability, and temper tantrums in 130 burned children, particularly within the first month after the event. If left untreated, the trajectory of trauma-related stress reactions can be chronic and debilitating in up to 13% of children (De Young et al., 2012). Therefore, if the acute symptomatology is severe and might result in impaired functioning, treatment ought to begin immediately (Scheeringa, 2009).

In light of these considerations, the current study followed an exploratory approach and aimed 1) to compare overall trauma-related stress symptom severity, 2) to examine differences in symptom specific severity levels, and 3) to estimate network models and compare their network structures and characteristics in younger and older preschoolers.

2. Method

2.1. Procedure and participants

The present study used anonymized caregiver data on children's trauma-related stress symptoms collected via a German- and English-language website and mobile app called Kidtrauma (https://www.kidtrauma.org) within the first 4 weeks after exposure to a PTE. Kidtrauma offers traumatized adolescents and caregivers of traumatized children support in coping with acute and chronic stress symptoms following a PTE. In addition, adolescents as well as caregivers can complete a Trauma-Check, a scientifically validated short questionnaire, within 4 weeks after trauma exposure to clarify whether professional advice is recommended. Nearby counselling centres and trauma therapists are displayed on the website and app. The website was launched in December 2014. Parents could have learned about KidTrauma through reports in newspapers, magazines, newsletters, social media, and brochures that were distributed in children's hospitals. Data for the present study was collected from 29 January 2015 to 30 March 2020. The overall sample from this time period included 1386 caregiver-reports on trauma-related stress symptoms in preschoolers. In total, 807 cases were excluded because the time since trauma exceeded 4 weeks

and 42 cases because the child was older than 6 years. Additionally, we checked data quality by testing for multivariate outliers, which led to the exclusion of additional 15 cases (please see supplementary material [SM] 1 for a description of the multivariate outlier analysis). The final sample in the present study comprised 541 caregiver reports for preschoolers (M_{age}: 3.7 years; SD_{age}: 1.4 years; range: 1–6 years) who had been exposed to a PTE within the previous 4 weeks. In comparison with the final sample, the outliers excluded showed significant differences in the proportion of children exposed to natural disasters (included > excluded) and overall symptom severity (excluded > included). Both samples were gender balanced. Also, most children in both samples had experienced an accident. Data on type of caregiver, country of origin, type of trauma, and time since trauma exposure was available for all 541 young children (Table 1). The Office of Data Protection of the State of Zurich approved data collection via Trauma-Check before the website and app went online. Further, because all data from Kidtrauma are completely anonymized, no further ethics approval was necessary according to Swiss law. Additionally, all parents explicitly gave consent for their data to be used for research purposes.

Table 1. Sample description.

Variable	Overall sample (1–6 years) (*N* = 541)	Younger preschoolers (1–3 years) (*n* = 242)	Older preschoolers (4–6 years) (*n* = 299)
Child Sex			
Female	227 (42.0%)	98 (40.5%)	129 (43.1%)
Male	314 (58.0%)	144 (59.5%)	170 (56.9%)
Age *M/SD*	3.7/1.4	2.3/0.6	4.8/0.7
1 year	20 (3.7%)	20 (8.3%)	
2 years	134 24.8%)	134 (55.4%)	
3 years	88 (16.3%)	88 (36.4%)	
4 years	101 (18.7%)		101 (33.8%)
5 years	146 (27.0%)		146 (48.8%)
6 years	52 (9.6%)		52 (17.4%)
Parent-report			
Mother	295 (54.5%)	136 (56.2%)	159 (53.2%)
Father	127 (23.5%)	54 (22.3%)	73 (24.4%)
Both parents	119 (22.0%)	52 (22.3%)	67 (22.4%)
Country			
Germany	256 (47.3%)	134 (55.4%)	122 (40.8%)
Switzerland	190 (35.1%)	54 (22.3%)	136 (45.5%)
Austria	28 (5.2%)	15 (6.2%)	13 (4.3%)
UK	26 (4.8%)	24 (9.9%)	2 (0.7%)
United States	18 (3.3%)	5 (2.1%)	13 (4.3%)
Canada	2 (0.4%)	2 (0.8%)	
Australia/ New Zealand	3 (0.6%)	1 (0.4%)	2 (0.7%)
Other country	18 (3.3%)	7 (2.9%)	11 (3.7%)
Types of Trauma Exposure			
Accident	233 (43.1%)	101 (41.7%)	132 (44.1%)
Violence	128 (23.7%)	57 (23.6%)	71 (23.7%)
Natural disaster	11 (2.0%)	5 (2.1%)	6 (2.0%)
Other type of trauma exposure	169 (31.2%)	79 (41.7%)	90 (30.1%)
Time since trauma exposure			
Less than 1 week	202 (37.3%)	103 (42.6%)	99 (33.1%)
1–2 weeks	198 (36.6%)	82 (33.9%)	116 (38.8%)
3–4 weeks	141 (26.1%)	57 (23.6%)	84 (28.1%)

Multiple exposure to different trauma types was not assessed. Reported here is index trauma, for which parents completed the Trauma-Check.

2.2. Outcome measures

The Trauma-Check at Kidtrauma comprises two parts. First, parents are asked about sociodemographic information (child sex and age, informant, and country of residence) and trauma characteristics (type of PTE, time since PTE). Second, trauma-related stress symptoms are assessed using the Pediatric Emotional Distress Scale – Early Screener (PEDS-ES; Kramer, Hertli, & Landolt, 2013). The 21-item PEDS-ES is a modified version of the Pediatric Emotional Distress Scale (PEDS) by Saylor, Swenson, Reynolds, and Taylor (1999) and assesses parent-rated changes in child behaviour after a PTE in preschoolers. The 21 items are rated on a 4-point Likert scale (0 = 'equal or less often,' 1 = 'a little more often,' 2 = 'much more often,' and 3 = 'very much more often'). The PEDS-ES demonstrated good psychometric properties (Cronbach's α = .76; sensitivity: 85%, specificity: 63%) in a sample of 87 children (age 2 to 6 years) who sustained a road traffic or burn accident (Kramer et al., 2013) and has recently been successfully used for screening purposes in a large international multisite randomized controlled trial (RCT) (Haag et al., 2020). A cut-off score of ≥ 8 identifies preschoolers at risk of developing PTSD (Kramer et al., 2013). Notably, the symptoms assessed by the PEDS-ES (and the PEDS) are not based on a specific diagnostic PTSD algorithm. Instead, the items cover a variety of symptoms that most likely develop in young children after exposure to a PTE. Cronbach's α for the overall sample in our study was = .92 (Cronbach's $\alpha_{younger\ preschoolers}$ = .92, Cronbach's $\alpha_{older\ preschoolers}$ = .93). Please see SM2 for an overview of the items, their labels, and their paraphrasing in the present study.

2.3. Statistical analyses

Data cleaning and preparation and multivariate outlier analysis were done with SPSS (version 24.0.0.0 for Windows, IBM Inc.). All main analyses were performed using R (version 3.6.1). The overall statistical approach included three steps and followed Burger et al.'s (2020) procedures.

2.3.1. Samples for comparison

Taking the developmental considerations and empirical findings outlined in the introduction into consideration, we decided to subdivide our sample into younger (1–3 years; n = 242; M_{age} = 2.3 years; SD_{age} = 0.6 years) and older (4–6 years, n = 299; M_{age} = 4.8 years; SD_{age} = 0.7 years) preschoolers and used these groups for further analyses. Additionally, the age groups defined for this

study align with the age groups used in prior research (Scheeringa et al., 2003) and therefore allow better comparability.

2.3.2. Handling of items measuring the same underlying construct

Items measuring the same underlying construct pose a major challenge in the network analysis of psychopathology (Fried & Cramer, 2017), because the interpretation of edges as putative causal associations between symptoms is inadmissible if the nodes represent indistinct entities. We followed Burger et al.'s (2020) statistical procedure, which incorporates both statistical and theoretical considerations. Items were combined if they were correlated ≥ .50 and could be understood as measuring the same construct from a theoretical point of view as rated by all three authors. Both tantrums and aggressiveness can be understood as externalizing expressions of anger, so these items were combined as anger by computing their average (Kerr & Schneider, 2008). As a result, the symptom-level comparison and the network-related analyses comprised 20 items instead of 21. See SM3 for item pairs that showed a correlation ≥ .50 but were understood as theoretically distinctive constructs by the authors and were therefore not combined.

2.3.3. Comparison of trauma-related symptoms levels between younger and older preschoolers

The PEDS-ES sum scores and differences in specific symptom severity of younger and older preschoolers were compared using a Welch two-sample *t* test for independent samples and a MANOVA. The PEDS-ES sum score was computed with the original scale, consisting of 21 items. In cases of significant differences (Bonferroni corrected) in specific symptom severity, Cohen's *d* (Cohen, 1988) was calculated as an effect size to measure the magnitude of these differences (0.2 = small effect, 0.5 = medium effect; 0.8 = large effect).

2.3.4. Network estimation

Network models were estimated separately for the two groups. Because the data set consisted of continuous variables, Gaussian graphical models (Lauritzen, 1996) were used to estimate unique associations among the 20 trauma-related stress symptoms as network models. In network models, variables are displayed as nodes, and edges between them represent conditional dependent relationships. In the present study, edges reflect partial correlations. The estimation of the edges was based on polychoric correlations considering psychopathological symptoms can be considered to be ordered categorically. The network models were regularized by applying the graphical least absolute shrinkage operator algorithm (LASSO; Tibshirani, 1996) in combination with the extended Bayesian information criterion (EBIC) via the *qgraph* package in R (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012) to avoid false-positive associations. The LASSO shrinks all edge-weights towards zero. Subsequently, small, spurious edge-weights are set to exactly zero, resulting in a parsimonious, better interpretable network model. The level of sparsity is controlled by the tuning parameter λ, which is selected empirically using the EBIC.

2.3.5. Node centrality

To quantify the centrality or importance of each node in the network models, expected influence (EI; Robinaugh, Millner, & McNally, 2016) and predictability (Haslbeck & Waldorp, 2018) were estimated. EI is quantified as the sum of all edge values extending from a node, where the sign of each edge is maintained. Higher EI values indicate higher node centrality in the networks. Second, predictability was estimated, which quantifies how well a node can be predicted by all the other nodes it shares an edge with within the network model. Statistically, predictability is quantified as shared variance (akin to R^2) (Haslbeck & Waldorp, 2018). Predictability can be understood as an absolute measure of interconnectedness and indicates how clinically relevant certain edges are in the network model. We further determined the accuracy and stability of the networks and EI indices. See SM4–SM7 for method descriptions and results.

2.3.6. Network comparison

Differences in the network structures (global invariance test) were examined with the NetworkComparisonTest (Van Borkulo et al., 2015). Additionally, we correlated the weight matrices and examined the five largest absolute differences in edge weight between the same node pairs in both networks.

3. Results

The average PEDS-ES sum score was M = 18.79 (SD = 12.84) for the younger preschoolers and M = 20.83 (SD = 13.73) for the older preschoolers. Among the younger preschoolers, 193 (80%) of 244 cases had a PEDS-ES sum score of ≥ 8. Of the older preschoolers, 243 (81%) scored ≥ 8 on the PEDS-ES. Means, standard deviations, EI indices, and predictability for the 20 trauma-related stress symptoms are presented in SM8.

3.1. Sum-score and symptom specific differences between age groups

Younger and older preschoolers did not differ significantly in their overall PEDS-ES sum score ($t(527.94)$ = −1.78, p = .075, Cohen's d = −0.15, 95% CI [−4.29, .21]). For the specific PEDS-ES items, MANOVA results showed overall group differences (T^2 (20, 520) = 3.21, p < .000). Please see Figure 1 for symptom-specific differences. Multiple testing (Bonferroni

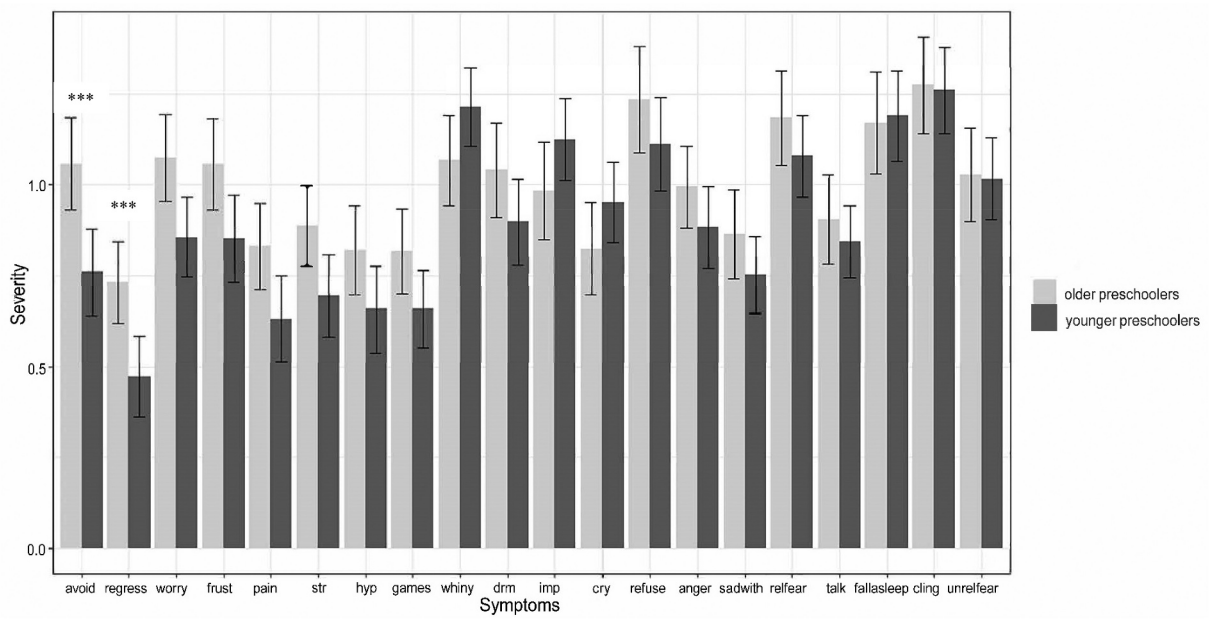

Figure 1. Post-hoc comparison (sorted by decreasing means) for the 20 trauma-related stress symptoms between the younger and older preschoolers; 95% confidence intervals are included; significance levels for items are only indicated when they were still significant after using the Bonferroni method for multiple testing. ***p = .001. Whiny = whininess, imp = impatience, refuse = refusal to sleep alone, fallasleep = trouble falling asleep, drm = bad dreams, unrelfear = trauma-unrelated fear, worry = worry, cry = crying, sadwith = sadness and withdrawal, cling = clinginess, hyp = hyperactivity, frust = frustration, pain = aches/pain, regress = developmental regression, str = exaggerated startle response, games = creation of games/stories/pictures about PTE, talk = talk about PTE, avoid = avoidance of talking about PTE, relfear = fear of reminders, and anger = anger.

correction) indicated that younger preschoolers' levels of regression (t(532.74) = −3.20, p = .001, Cohen's d = −0.27, 95% CI [−.42, −.10]) and avoidance of talking about PTE (t(522.47) = −3.34, p = .001, Cohen's d = −0.29, 95% CI [−.47, −.12]) were lower than the older preschoolers.

3.2. Network analyses

3.2.1. Trauma-related stress symptom network models

Figure 2 shows the estimated networks of the 20 trauma-related stress symptoms for the two age groups.

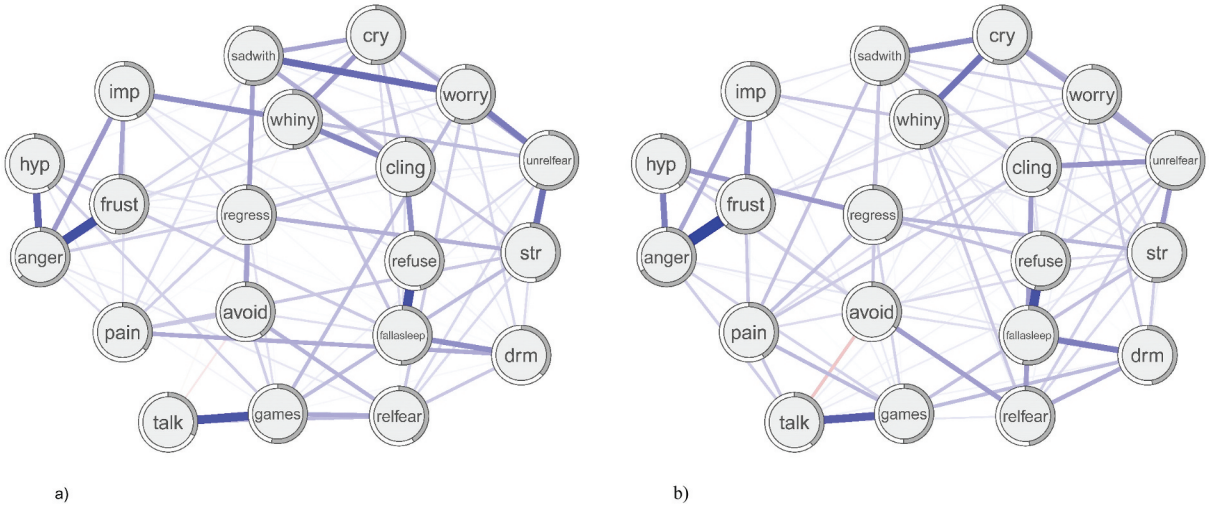

Figure 2. Regularized partial correlation network of the 20 trauma-related stress symptoms from the younger preschoolers (a) and older preschoolers (b) samples. Blue lines represent positive edges, red lines represent negative edges. The grey pie chart around each node equals the percentage of variance explained by the neighbouring nodes. Whiny = whininess, imp = impatience, refuse = refusal to sleep alone, fallasleep = trouble falling asleep, drm = bad dreams, unrelfear = trauma-unrelated fear, worry = worry, cry = crying, sadwith = sadness and withdrawal, cling = clinginess, hyp = hyperactivity, frust = frustration, pain = aches/pain, regress = developmental regression, str = exaggerated startle response, games = creation of games/stories/pictures about PTE, talk = talk about PTE, avoid = avoidance of talking about PTE, relfear = fear of reminders, and anger = anger.

3.2.1.1. Younger preschoolers. Of 190 possible edges, 99 (52.11%) emerged, indicating a moderate interconnectedness between the symptoms. Mean edge weight was $r = .05$. All but the connections between whininess and talk about PTE (−.02), crying and talk about PTE (−.01), and talk about PTE and avoidance of talking about PTE ($r = -.05$) were positive. The strongest edges emerged between frustration and anger ($r = .38$), trouble falling asleep and refusal to sleep alone ($r = .38$), and talking about the PTE and creation of games, stories, and pictures ($r = .35$). Among the 20 symptoms, creation of games, stories, pictures, trauma-unrelated fear and anger showed the highest EI indices (Figure 3). Talk about PTE showed the weakest EI value. Overall predictability was .47, indicating that each node shares moderate variance with all other nodes in the network. The symptoms trauma-unrelated fear (.57), worry (0.57), and anger (.62) showed the highest predictability (SM8).

3.2.1.2. Older preschoolers. Of 190 possible edges, 111 (58.42%) emerged, indicating a moderate interconnectedness between the symptoms. Mean edge weight was $r = .05$. All but the connection between talk about PTE and avoidance of talking about the PTE ($r = -.12$) were positive. The strongest edges emerged between frustration and anger ($r = .49$) and trouble falling asleep and refusing to sleep alone ($r = .38$). Among the 20 symptoms, trauma-unrelated fear and anger showed the highest EI indices (Figure 3). Avoidance of talking about PTE and talk about PTE showed the weakest EI values. Overall predictability was .49, indicating that each node shares moderate variance with all other nodes in the network. The symptoms frustration (.62), trauma-unrelated fear (.60), and anger (.67) showed the highest predictability (SM8).

3.2.2. Comparison of networks

The correlation between the adjacency matrices of $r = .72$ indicated that the network structures were highly similar. The global invariance test revealed a nonsignificant result ($p = .181$), indicating no differences in the overall network structure between the two age groups. Following an

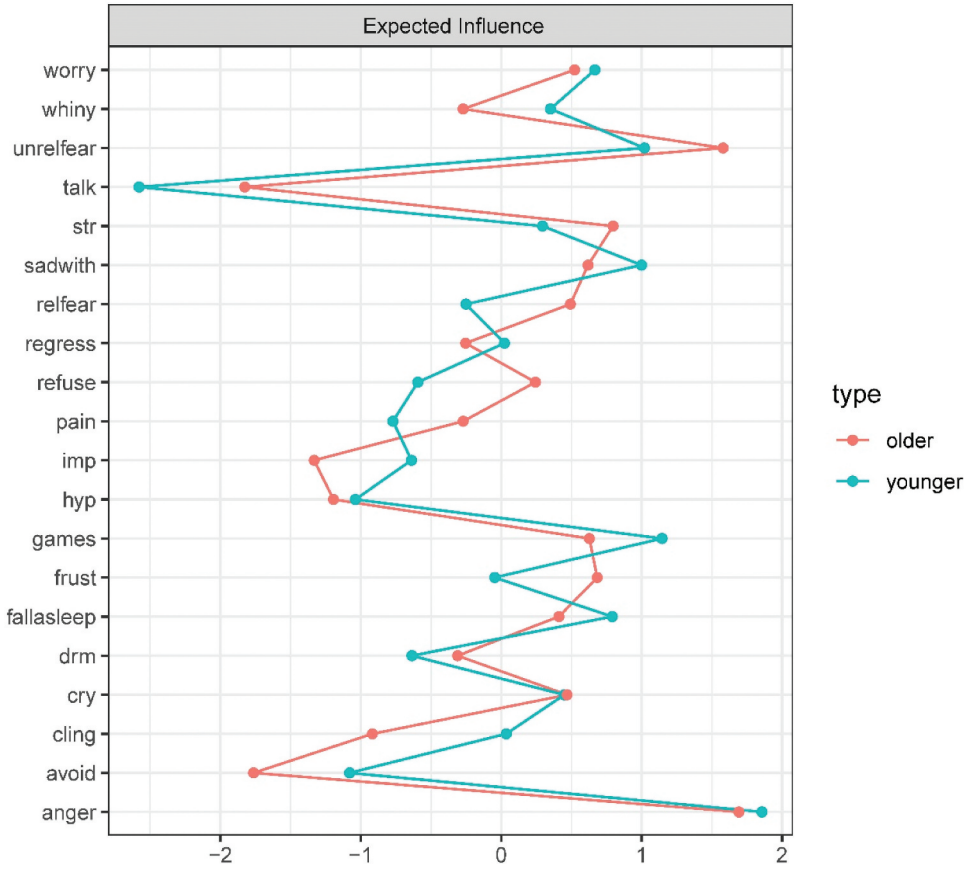

Figure 3. Estimated node expected influence (z-scored values) of the 20 trauma-related stress symptoms (younger preschoolers = turquoise; older preschoolers = orange). Whiny = whininess, imp = impatience, refuse = refusal to sleep alone, fallasleep = trouble falling asleep, drm = bad dreams, unrelfear = trauma-unrelated fear, worry = worry, cry = crying, sadwith = sadness and withdrawal, cling = clinginess, hyp = hyperactivity, frust = frustration, pain = aches/pain, regress = developmental regression, str = exaggerated startle response, games = creation of games/stories/pictures about PTE, talk = talk about PTE, avoid = avoidance of talking about PTE, relfear = fear of reminders, and anger = anger.

exploratory approach, we examined which edge weights between the same node pairs in the two networks showed the largest differences (Figure 4). The largest absolute differences in edge weight were obtained for the following node pairs: worry and sadness and withdrawal (Δ_r = 0.19), younger > older; fear of reminders and creation of games, stories, and pictures (Δ_r = 0.16), younger > older; fear of reminders and clinginess (Δ_r = 0.18), older > younger; trauma-unrelated fear and clinginess (Δ_r = 0.20), older > younger; and whininess and clinginess (Δ_r = 0.18), younger > older.

4. Discussion

To our knowledge, this study is the first to apply network analysis to investigate potential age-dependent differences in the interconnectedness and centrality of trauma-related stress symptoms in preschoolers in the acute phase after trauma exposure. The high percentage of preschoolers exceeding the PEDS-ES cut-off score (younger: 80%, older: 81%) indicates that our sample was severely affected. Other studies that used the PEDS-ES in the acute phase reported equivalent percentages of only 6.34% (Kramer et al., 2013) and 27.21% (Haag et al., 2020). In contrast to the studies by Kramer et al. (2013) and Haag et al. (2020), which included only accidental trauma cases, trauma types in our sample were more diverse and included interpersonal trauma. Research indicates that interpersonal trauma might lead to higher overall symptom severity (Scheeringa & Zeanah, 1995; Vasileva & Petermann, 2017). Thus, our sample might be expected to display a larger overall symptom severity.

4.1. Overall symptom severity and symptom levels

Investigating the overall PEDS-ES symptom severity (aim 1), we found no differences between the age groups.

Examining symptom-specific severity levels (aim 2), we found differences only in developmental regression and avoidance of talking about the PTE between the age groups. In contrast to Scheeringa et al. (2003), we found no differences between the manifestation of intrusion symptoms, separation anxiety (clinginess, trauma-unrelated fear), symptoms of depression (sadness and withdrawal, crying), and hyperarousal symptoms. In line with Levendosky et al. (2013), we found no differences in the frequency of arousal symptoms. In the cases of developmental regression and avoidance of talking about PTE, the difference could be explained as a development-dependent artefact. Behaviour such as thumb-sucking and bed-wetting is more common in children age 1–3 than in older children and thus might not be perceived more often or perceived as unusual by caregivers after their child was exposed to a PTE. Moreover, younger preschoolers might not be able to speak at all or not with such sufficient complexity for caregivers to perceive that their child is avoiding to talk about the event. Also, avoidance as a coping

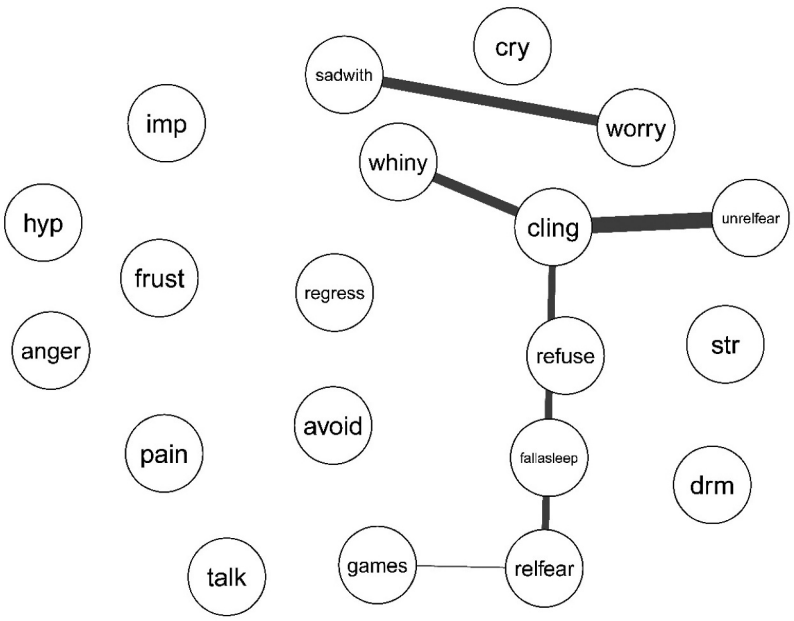

Figure 4. Network displaying the five edges with the largest edge weight difference (based on the difference scores of the respective weight matrices) between the two networks. Whiny = whininess, imp = impatience, refuse = refusal to sleep alone, fallasleep = trouble falling asleep, drm = bad dreams, unrelfear = trauma-unrelated fear, worry = worry, cry = crying, sadwith = sadness and withdrawal, cling = clinginess, hyp = hyperactivity, frust = frustration, pain = aches/pain, regress = developmental regression, str = exaggerated startle response, games = creation of games/stories/pictures about PTE, talk = talk about PTE, avoid = avoidance of talking about PTE, relfear = fear of reminders, and anger = anger.

strategy might require a certain level of cognitive development, such as the ability to explicitly remember past events, to establish a connection between trauma and trauma-related stimuli. Consequently, it is questionable whether regression and avoidance of talking about the PTE are suitable for the inclusion in an assessment of trauma-related stress symptoms in young preschoolers in general.

4.2. Network models

Comparing the networks (aim 3), we found no difference in their global network structure. The connections in both networks were generally positive. The average predictability across all nodes was 0.47 in the younger preschooler network and 0.49 in the older preschooler network, indicating that 47% and 49%, respectively, of the variation of a symptom not predicted by the intercept model can be explained by the symptoms it shares an edge with. In comparison to other predictability results (Haslbeck & Fried, 2017), the symptoms in our network were moderately determined by each other. Trauma-unrelated fear, worry, and anger showed the highest predictability in the younger preschooler network, and frustration, trauma-unrelated fear, and anger exhibited the highest predictability in the older preschooler network. Therefore, intervening on their neighbouring nodes may have considerable impact on these symptoms; for instance, hyperactivity, impatience, and frustration are connected to anger. However, to assume that all edges are directed towards the symptom exhibiting high predictability could be misleading in cross-sectional data, because edges could also be bidirectional or point away from these symptoms (Haslbeck & Waldorp, 2018). Trauma-unrelated fear and anger stood out as highly connected symptoms in both the younger and older preschooler networks. Studies have documented an increased risk of anxiety in preschoolers exposed to a PTE (e.g. Briggs-Gowan et al., 2010; Levendosky et al., 2013). Moreover, trauma-exposed preschoolers show an attention bias towards mild threats (e.g. angry faces) following exposure to a PTE (Briggs-Gowan et al., 2016) and might therefore be constantly in a state of fear, which in turn potentially leads to symptoms such as exaggerated startle response and sadness and withdrawal, as the network structure implies. Furthermore, Pollak (2008) showed that emotion processing is disrupted in traumatized young children, and therefore they might tend to exhibit angry behaviour, which could lead to heightened frustration and impatience.

Exploring the largest differences in connection strength between the networks revealed a stronger connection between fear of reminders and clinginess and between trauma-unrelated fear and clinginess in older preschoolers than for younger ones. Because children at the ages of 1 to 3 are constantly under adult supervision, the results indicate that caregivers might not be able to differentiate between normal and stress-related behaviours in situations of fear and distress (De Young & Landolt, 2018). However, it might also be that parents expect more autonomy from older preschoolers than younger preschoolers and thus are more sensitive in perceiving clinginess.

Conversely, the stronger connection between whininess and clinginess found in younger preschoolers than in older preschoolers might indicate that older preschoolers might be capable of regulating their emotions in a more differentiated way. Research indicates that children between 3 and 7 years shift from a reactive and more caregiver-regulated behaviour towards more advanced, cognitive behavioural forms (Diamond, 2002). The weaker connection in the older preschooler network between fear of reminders and creation of games, stories, and pictures may be explained by the fact that older preschoolers possess more language skills and thus might express trauma-related fear less through play and more through talking. However, symptom severity in talking about the PTE did not differ significantly between the two groups, and the connection between talking about the PTE and fear of reminders were also less strong in the older group, which contradicts this hypothesis. A possible explanation for the stronger connection between worry and sadness and withdrawal in the younger preschooler network might be that younger preschoolers are less independent, so their caregivers might be more perceptive of withdrawal as a reaction to worrying compared to older preschoolers.

4.3. Implications for clinical practice

Our study indicates that trauma-unrelated fear and anger are highly central symptoms across both age groups. Therefore, targeting trauma-unrelated fear and anger in early, secondary preventive interventions might be crucial to preventing the development of longer-lasting trauma-related disorders. Acutely traumatized preschoolers and their parents might benefit especially from learning relaxation strategies such as breathing techniques and imagination (Pollio & Deblinger, 2017). Parents might benefit from being educated about how parenting behaviours and the parent–child relationship can relieve their child's distress. Parents who might act overprotectively or anxiously around their child might exacerbate the child's symptomatology by providing a negative model for behaviour, especially shortly after their child has been exposed to a PTE. Therefore, educating the parents about helpful behaviours could help reduce trauma-unrelated fear and symptoms connected to trauma-unrelated fear, such as exaggerated startle response or sadness and withdrawal (De Young, Haag, Kenardy, Kimble, &

Landolt, 2016). Interestingly, a recently published RCT study in preschoolers examined a parent-directed secondary intervention that also targeted exactly these symptoms and was shown to lead to faster recovery in acutely traumatized preschoolers (Haag et al., 2020).

When assessing trauma-related stress symptoms, clinicians could give parents more guidance about what age-appropriate behaviour is and what might be key signs of posttraumatic stress. For instance, secondary enuresis and thumb-sucking might be signs of distress in older preschoolers after trauma-exposure, whereas the same behaviour could be age typical in younger preschoolers and have no clinical significance. Further, the high centrality of anger potentially emphasizes its importance for the diagnosis of PTSD in preschool children. As previously suggested (Scheeringa et al., 1995), the low centrality of avoidance behaviour and its low symptom frequency further underlines the possible limited value of these symptoms in younger children. Although our study did not examine the validity of the DSM-5 preschool subtype, our results still raise the question whether the PTSD criteria should be further adapted for the youngest age group.

4.4. Strengths and limitations

A strength of our study is the two samples investigated, which are drawn from a population that is difficult to recruit. Further, we used advanced statistical methods to paint a fine-grained picture of possible differences in symptom-specific levels and the interconnectedness between trauma-related stress symptoms in different age groups.

Despite these strengths, the results of this study have to be discussed in light of several limitations. First, although limited to a specific short post-trauma time period, the analyses were based on cross-sectional data. Therefore, conclusions about causal interaction cannot be drawn from results provided by the network approach. The sampling was based on developmental psychological considerations. However, developmental gaps, especially in the younger preschoolers, still might have been relatively large, potentially impacting which trauma-related stress symptoms were predominantly shown by children and perceived by their caregivers. Therefore, different age groups (<12 months, 1–2 years vs. 3–6 years; De Young & Landolt, 2018) should be further investigated. Third, research suggests that the distribution of some trauma-related stress symptoms might not be linear over the first 6 years of life (Levendosky et al., 2013). Consequently, grouping age ranges did not enable us to detect possible nonlinear associations between age and symptoms.

Lastly, the assessment of the trauma-related stress symptoms was based on parent reports, which are known to present a limitation to all studies of trauma-related stress symptoms in preschoolers, especially those concerning internalizing and cognitive symptoms (De Young & Landolt, 2018). In our case, this could mean that the networks reflect how parents perceive trauma-related symptom presentation rather than the true structure of these symptoms.

4.5. Implications for future research

Future research needs to replicate these findings with other sets of symptoms and controlling for possible confounding variables, such as type of PTE. For instance, a study conducted by Scheeringa and Zeanah (2001) revealed that PTEs that involve threats to caregivers may produce higher overall symptom severity, more symptoms of hyperarousal, fear, and aggression, and fewer symptoms of numbing than PTEs that do not involve such threats. Additionally, the temporal development of trauma-related stress symptoms within the first 4 weeks after exposure to a PTE and the stability in preschoolers should be investigated with a longitudinal, within-subject network approach. Intervention research may well benefit from testing whether targeting the symptoms trauma-unrelated fear and anger is predictive of a better treatment response. This seems crucial as a recent study of social anxiety with cross-sectional networks revealed limited transfer of the results to actual treatment data (Rodebaugh et al., 2018). Furthermore, research should examine whether central symptoms in the acute phase, such as trauma-unrelated fear and anger, are predictive of PTSD beyond the first 4 weeks to identify children in need of immediate preventive treatment in early interventions.

5. Conclusion

This study uses network analysis to shed light on the age-dependent similarities and differences in the trauma-related stress symptom presentation in acutely traumatized preschoolers. Overall, our results indicated that the trauma-related stress symptomatology of younger and older preschoolers might not differ substantially in the acute phase following trauma exposure. Trauma-unrelated fear and anger stood out as highly central symptoms in both age groups. However, examining symptom-level associations across age groups revealed differential connections between clinginess; fear of reminders; trauma-unrelated fear; creation of games, stories, and pictures; worry; whininess; and sadness and withdrawal that might occur due to developmental differences. Future research should focus on replicating these findings in longitudinal studies to validate these symptoms

as important treatment targets and to help tailor early interventions for better outcomes.

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Data availability statement

Given that the ethical committees agree, the datasets used and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Disclosure statement

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