Executive functions in trauma-exposed youth: a meta-analysis

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ABSTRACT
An earlier meta-analysis and review indicated that trauma exposure may be related to lower levels of executive functioning in youth. Since different developmental trajectories were found for three core executive functions, the present study focused on working memory, inhibition, and cognitive flexibility specifically. We conducted a multi-level meta-analysis on 55 studies and 322 effect sizes published between 2001 and 2017. These studies used low-quality measurements; the effect size was significantly stronger when compared to single trauma-exposed youth, exposedviolence-abused youth, and foster care/adopted youth. The present study focused on three core executive functions: working memory in trauma-exposed youth; inhibition; and cognitive flexibility. Our findings imply that trauma-exposed youth have lower levels of executive functions. Clinical practice should incorporate problems in executive functioning, especially working memory, inhibition, and cognitive flexibility, in assessment and treatment guidelines.

FUNCTIONES EJECUTIVAS EN JÓVENES EXPUESTOS AL TRAUMA: UN METANÁLISIS

Planteamiento: Un metanálisis y una revisión previas indicaron que la exposición al trauma estaría relacionada con niveles más bajos de funcionamiento ejecutivo en los jóvenes. Objetivo: El objetivo de esta revisión fue investigar las diferentes trayectorias de desarrollo para tres funciones ejecutivas centrales, las cuales enfocamos específicamente en la memoria de trabajo, la inhibición y la flexibilidad cognitiva. Método: Realizamos un metanálisis multinivel con 55 estudios y 322 tamaños de efecto publicados entre 2001 y 2017, obtenidos de MEDLINE, Embase, y PsycINFO. Los 8070 participantes en los estudios seleccionados tenían entre 2 y 25 años. Investigamos si la asociación entre los constructos seria moderada por los moderadores específicos del trauma (edad, género, etnia, status socioeconómico) y características de medición (calidad). Resultados: Encontramos tamaños de efecto de pequeño a mediano para la memoria de trabajo (d = −0.49), la inhibición (d = −0.46) y la flexibilidad cognitiva (d = −0.44). Análisis de moderadores mostraron que, para la memoria de trabajo, cuando los estudios utilizaron mediciones de baja calidad, el tamaño del efecto fue significativamente más fuerte que cuando los estudios utilizaron mediciones de alta calidad. Comparado con los jóvenes expuestos a un solo trauma, los jóvenes expuestos a trauma/sobrecarga y los jóvenes que viven en condiciones de acogida o han sido adoptados mostraron más problemas en la inhibición y los jóvenes que viven en condiciones de acogida o han sido adoptados mostraron más problemas de flexibilidad cognitiva. Conclusión: Nuestros hallazgos implican que los jóvenes expuestos a trauma tienen niveles más bajos de funciones ejecutivas. En sus guías de evaluación y tratamiento, la práctica clínica debe incorporar problemas en el funcionamiento ejecutivo, especialmente la memoria de trabajo, la inhibición y la flexibilidad cognitiva.

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HIGHLIGHTS
• Abusedviolence-exposedadopted and foster care youth have lower levels of inhibition.
• Adopted and foster care youth have lower levels of cognitive flexibility.
• Low-quality measurement studies show lower levels of working memory in trauma-exposed youth.
• Executive functioning should be a focus in treatment of trauma-exposed youth.
Executive functions cover multiple skills, such as inhibition, organization, cognitive flexibility, self-monitoring, regulation of emotions, working memory, and attention. These are essential in preparing and executing goal-directed behaviour (Diamond, 2013; Goldstein, Naglieri, Princiotta, & Otero, 2014). Most studies indicate that executive function processes in youth are distinct, albeit moderately associated with each other (Best, Miller, & Jones, 2009; Miyake et al., 2000). Some debate exists on whether separate executive functions can be subsumed in a single, central executive function. However, impairment in global executive functioning is rare. Different regions of the prefrontal cortex are activated in different executive function tasks, and distinct developmental pathways have been identified for different executive processes (Anderson, 2002; Best et al., 2009). Most empirical neuropsychological research differentiates between three core executive functions: inhibition, working memory, and cognitive flexibility. These three domains are considered core executive functions from which higher order functions such as reasoning, problem solving, and planning arise (e.g. Diamond, 2013; Miyake et al., 2000). Therefore, in this study we focus on working memory, inhibition, and cognitive flexibility.

The first core executive function, working memory, is a cognitive process of temporarily storing and manipulating information. Working memory is distinct from short-term memory, because short-term memory only stores information, without manipulating it (Baddeley, 2012; Goldstein et al., 2014). Verbal working memory (which ‘works’ with words, numbers, and letters) and visuospatial working memory (which ‘works’ with figures and spatial information) are commonly distinguished. Inhibition or inhibitory control, the second core executive function, refers to the ability to control attention, thoughts, and emotions, thereby suppressing dominant, automatic, or prepotent responses when necessary (Diamond, 2013; Miyake et al., 2000). Prepotent response inhibition and interference control are commonly distinguished aspects of inhibition (Friedman & Miyake, 2004; Miyake & Friedman, 2012). Prepotent response inhibition enables us to suppress a dominant motor response (Aron, 2011; Miyake et al., 2000), whereas interference control is the ability to ignore irrelevant information by resisting distractor interference (Friedman & Miyake, 2004; Nigg, 2000). The third core executive function, cognitive flexibility, refers to the ability to switch between tasks, demands, priorities, rules, and perspectives. It helps in thinking ‘outside the box’ and forming creative solutions (Best et al., 2009; Diamond, 2013). Being cognitively
flexible enables learning from mistakes and generating alternative solutions. Inflexible individuals fail to adapt to new situations or demands; they continue making the same mistakes, showing rigid and ritualistic behaviour (Anderson, 2002).

A previous meta-analysis and a review showed that trauma-exposed and maltreated youth performed worse on executive functions than controls (Kavanaugh et al., 2017; Malarbi et al., 2017). Trauma exposure is thought to influence executive functions by impacting underlying neurobiological mechanisms. As brain development continues into adulthood, trauma exposure may impact the development of executive functions in youth. Empirical research in humans showed that early life stress such as maltreatment affects the hypothalamic–pituitary–adrenocortical axis, but also structures of the corticolimbic networks (De Bellis, 2001; De Bellis et al., 1999; Gunnar & Quevedo, 2007). Most affected brain regions in maltreated youth are the prefrontal cortex, orbitofrontal cortex, anterior cingulate cortex, and amygdala (Cowell, Cicchetti, Rogosch, & Toth, 2015; De Bellis & Thomas, 2003; Teicher & Samson, 2016). Atypicities in structural connectivity between the anterior cingulate cortex and dorsolateral, orbitofrontal, and ventromedial prefrontal cortices are shown by brain imaging studies (Hart & Rubia, 2012). These brain networks are activated during response inhibition, working memory, and emotion processing tasks, which suggest that the neural networks for executive functioning are affected by trauma exposure in youth (Teicher & Samson, 2016).

Development of executive functions continues until young adulthood, with the most rapid development taking place during preschool and the early school years (Best & Miller, 2010; Friedman et al., 2015; Miyake & Friedman, 2012). However, the separate executive functions show slightly different developmental trajectories (Best & Miller, 2010; Huizinga, Dolan, & van der Molen, 2006). Working memory seems to follow a linear development from preschool to adolescence. Inhibition, on the other hand, improves most rapidly during the preschool years, followed by a modest linear improvement through adolescence. For cognitive flexibility, preschoolers are able to handle shifts of simple tasks and this increases during childhood to more unexpected shifts between complex tasks. Switching of complex tasks seems to mature by middle adolescence. All executive function skills show a developmental pattern of ‘rises and falls’, which is related to brain development (Best & Miller, 2010; Johnson & De Haan, 2011). These different developmental trajectories may suggest different effects of both timing and the duration of trauma exposure (Teicher & Samson, 2016) on executive functions.

1.2. Moderators

By performing moderator analyses, we can examine the influence of trauma-specific moderators, sample characteristics, and executive function task characteristics on the strength of the association between trauma exposure and executive functions. First, we tested whether trauma characteristics (i.e. type, onset, duration, and post-traumatic stress complaints) influenced the strength of the association between exposure and executive functions. Specifically, interpersonal, repeated trauma has more severe effects on the brain than single trauma. The earlier and the more prolonged the trauma exposure has been, the stronger the impact of trauma exposure is (e.g. Cook et al., 2005; Bruce et al., 2014; Cowell et al., 2015; Teicher & Samson, 2016).

Consequently, we tested whether earlier onset and longer duration of trauma, trauma subtype (single trauma, violence/abuse, adoption/foster care), and post-traumatic stress disorder (PTSD) would be associated with significantly lower executive functions.

Sample characteristics (age, socio-economic status, gender, and ethnicity) could influence the strength of the association between trauma exposure and executive function in youth. Differential effects of trauma exposure have been established for gender (Alisic et al., 2014), age (e.g. Lupien, McEwen, Gunnar, & Heim, 2009; Weems et al., 2010), and ethnicity (López et al., 2017), with stronger effects of trauma exposure for girls, younger children, and Hispanic and black adolescents.

The strength of the association between trauma exposure and executive functions could also be influenced by the quality of the executive function measure. Working memory, inhibition, and cognitive flexibility are moderately associated (Best et al., 2009; Miyake & Friedman, 2012), complicating the clear assessment of executive functions (Diamond, 2013). For example, tasks such as the Digit Span, go/no-go tasks, and the Wisconsin Card Sorting Task have various outcome measures. These outcome measures vary in how purely they assess the different executive functions (Huizinga et al., 2006). Therefore, we tested whether the quality of the outcome measurement influences the strength of the association of trauma exposure with executive functions in youth.

In sum, we investigated whether trauma-specific characteristics (onset, duration, type, and PTSD complaints), sample characteristics (gender, age, and ethnicity), and executive function task characteristics (executive function measure) influenced the relationship between trauma exposure and executive functions in youth.
1.3. The present study

As our understanding of the mental health consequences of trauma exposure in youth has increased considerably (e.g. Alsic, Jongmans, van Wesel, & Kleber, 2011; Jonkman, Verlinden, Bolle, Boer, & Lindauer, 2013; Lamers-Winkelman, Willemen, & Visser, 2012), treatments for youth have been developed to treat these (Morina, Koerssen, & Pollet, 2016). However, the link between executive functions and trauma exposure in youth is less well understood. Only the Attachment, Regulation, and Competence model includes executive functions in its guidelines (Blaustein & Kinniburgh, 2015). Our aim is to inform clinical practice to allow for integration of executive functions in therapy protocols for traumatized youth. Therefore, we investigated the extent to which youth exposed to trauma suffer from problems with their executive functions. In addition, we investigated whether different moderators influence the strength of the relationship between trauma exposure and executive functions. To answer these questions, we conducted what is, to our knowledge, the first multi-level meta-analysis to investigate working memory, inhibition, and cognitive flexibility in trauma-exposed children and adolescents.

2. Methods

2.1. Selection of studies

This analysis included: (1) studies comparing working memory, inhibition, and/or cognitive flexibility between trauma exposed and non-exposed individuals, and studies that reported a correlation coefficient to assess the relationship between trauma exposure and these executive functions; (2) studies reported in English; and (4) studies with samples aged between 0 and 25 years old. We focused on this specific age range because of strong indications that the development of the prefrontal cortex is largely accomplished by around the age of 25 years (e.g. Arain et al., 2013). Exclusion criteria were: studies including participants with traumatic brain injury and current drug abuse, as these factors are known to influence executive functioning (Fernández-Serrano, Pérez-García, Schmidt Río-Valle, & Verdejo-García, 2010; Gioia, Isquith, Kenworthy, & Barton, 2002); studies that examined foster care or adopted youth but had no control group, as traumatic exposure varies widely in these samples and drawing conclusions is problematic without a reference group. Primary outcome measures pertained to working memory, cognitive flexibility, and inhibitory control. Trauma exposure was defined as exposure to events that, according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (American Psychiatric Association, 2013), are considered potentially traumatic. For example, a traffic accident, witnessing domestic violence or a shooting, living in a war environment, and neglect are considered traumatic events (American Psychiatric Association, 2013).

2.2. Information sources

The search covered PsycINFO, Embase, and MEDLINE (until August 2017), and was based on the Meta-Analysis Reporting Standards. Appendix A shows the full electronic search strategy.

2.3. Study selection

The eligibility assessment is displayed in Figure 1, and was performed by two independent reviewers in a standardized manner (see Appendix B). In the title and abstract screening phase, 1000 of the 10,605 papers were screened by two reviewers (first author and screeners 1 and 2), and disagreements were resolved by consensus. In the second screening phase, full text screening, 1162 papers were screened by two reviewers (screeners 1 and 2). Disagreements were resolved by consultation with the first author. Finally, we included 32, 32, and 30 papers on working memory, inhibition, and cognitive flexibility, respectively.

2.4. Data collection process

We developed a data-extraction sheet (Appendix C). The first author coded all studies, and the second author coded 15%, and disagreements were resolved by discussion. Interrater agreement was 1.00 for Cohen’s kappa and intraclass correlation ranged between 0.96 and 1.00. Of 64 authors contacted for further information, 15 responded and 12 provided data that were requested. We could not retrieve the full text for 262 papers. After further enquiries with authors we retrieved an additional 13 full text papers. However, none of these papers was eligible for inclusion. References for the included papers are listed in Appendix E.

2.5. Data items

Information was extracted from each included study on: (1) characteristics of participants (i.e. age, gender, socio-economic status, years of schooling, ethnicity); (2) study characteristics (i.e. research design, publication status, and overall study quality); (3) type of trauma exposure (i.e. trauma type, onset, and duration); (4) post-traumatic stress (post-traumatic stress complaints, PTSD diagnosis); and (5) type of outcome measure (e.g. Wechsler Intelligence Scale for Children Digit Span backwards, Trail Making Test-B).

For the participant characteristics, overall study quality (at study level) was assessed by two independent research assistants. We used the Quality Assessment Tool for Quantitative Studies of the Effective Public Health Practice Project (Thomas,
Ciliska, Dobbins, & Micucci, 2004). This is an assessment tool for the quality of both randomized and case–control studies. A global quality rating of weak, moderate, or strong was assigned by both reviewers. There was 97.8% consensus between the two reviewers. Furthermore, discrepancies were at subscale level, not at the global rating level.

For trauma characteristics, type of trauma exposure was divided into three categories: single trauma exposure; exposure to violence, abuse, or neglect; and adopted or foster care youth. Onset and duration of trauma exposure were measured using reported information about the mean age of the start of trauma exposure and the mean duration (in years). See Appendix C for more detailed information about data extraction.

For studies reporting on working memory, inhibition, and/or cognitive flexibility, we coded type of outcome measure for each effect size in all data sets. With regard to the outcome measure used, we coded quality of the measurement instrument, based on the extent to which measurement of cognitive flexibility, inhibition, and working memory were confounded with the assessment of speed or other executive function elements and the level of cognitive load of the measures. These decision rules were based on the executive function research expertise of the third author and conform to recent literature specifications about quality of outcome measures of executive function (e.g., Tamminga, Reneman, Huizenga, & Geurts, 2016). The codes are described in Appendix D.

2.6. Strategy of analysis

In 65.5%, 68.8%, and 73.3% of the papers about respectively working memory, inhibition, and
cognitive flexibility, more than one relevant effect size was reported. Papers reported on multiple effect sizes for the following reasons: (1) different outcome measures were used to assess executive functions; (2) different aspects of executive functions were measured (e.g. verbal versus non-verbal working memory); (3) various assessments of the association between trauma exposure and executive functions in time were included; and (4) different groups were investigated to assess the association between trauma exposure and executive functions (e.g. comparisons between maltreated children with PTSD and a control group, and comparisons between maltreated children without PTSD and a control group). Cohen’s \( d \) was calculated using reported means and standard deviations, and reported correlations were transformed to Cohen’s \( d \). The SPSS syntax for effect size calculation was double-checked by the second author.

We used a three-level meta-analytic random effects model as it increases power (Assink & Wibbelink, 2016). It gives us more information because effect sizes are not eliminated or averaged (Assink & Wibbelink, 2016; Cheung, 2014). We modelled three levels of variance: (1) variance in effect sizes due to random sampling; (2) variance in effect size due to differences within studies; and (3) variance in effect sizes between studies (Borenstein, Hedges, Higgins, & Rothstein, 2010). This multi-level approach allows dependency of effect sizes within studies. As a result, we can include multiple effect sizes per study and test whether there are between- or within-study differences in effect sizes when heterogeneity is assumed (Assink & Wibbelink, 2016). Moderator analyses can explain within- or between-study differences in effect sizes when there is heterogeneity (Borenstein et al., 2010). We used an expert tutorial (Assink & Wibbelink, 2016) for the software R to perform statistical analyses for our three-level meta-analyses with a random model using the Metafor package (Viechtbauer, 2006).

### 2.7. Publication bias

Publication selection bias is a common issue in meta-analyses (Borenstein et al., 2010). We used the PET-PEESE approach to investigate publication selection bias, as this approach has been shown to outperform the Fail Safe \( N \) analysis and Trim & Fill strategy (Stanley & Doucouliagos, 2014). The PET-PEESE approach consists of two steps. The first step, the precision-effect-test (PET), is based on results on the Egger test, an analysis in which the standard error is used as a moderator. When the intercept in this model is not significantly different from zero, a significant moderator implicates possible publication bias. When the intercept is significantly different from zero, we take the next step: PEESE (precision-effect estimate with standard error). However, instead of the standard error, the variance is included as a moderator. When the effect size varies significantly with the standard error, the analysis gives an implication for publication bias. However, it should be noted that all publication bias analyses have a low power to detect bias (Borenstein et al., 2010; Stanley & Doucouliagos, 2014). Furthermore, we used the PET-PEESE approach in a random model but, as in all other publication bias assessments, it is designed for a fixed effects model.

### 3. Results

#### 3.1. Associations between trauma exposure and executive functions

We performed three separate multi-level meta-analyses. Overall effect sizes are displayed in Table 1. For working memory, we examined 26 samples and 102 effect sizes, reporting data on 5172 participants aged between 3 and 24 years. Figure 2 displays a forest plot showing the effect sizes and their confidence intervals. The analysis yielded a significant, small to medium effect size of \( d = -0.49 \) in a random model. This indicated that trauma-exposed youth perform worse on working memory than non-exposed youth. For inhibition, we examined 29 samples with 119 effect sizes, reporting data on 3391 participants aged between 5 and 20 years. In Figure 3, effect sizes and their confidence intervals are displayed. The analysis yielded a significant, small to medium effect size of \( d = -0.46 \) in a random model. Thus, trauma-exposed youth also perform worse on inhibition tasks than non-exposed youth. For cognitive flexibility, we examined 27 samples with 101 effect sizes, reporting data on 2959 participants aged between 2 and 24 years. In Figure 4, the forest plot displays the effect sizes and confidence intervals. This analysis yielded also a significant, small to medium effect size of \( d = -0.44 \) in a random model. When investigating outliers for the variables of interest, we found four outliers in the effect sizes: working memory (one outlier), inhibition (two outliers), and cognitive flexibility (one outlier). After trimming these outliers to the value of the highest/lowest effect size plus/minus one unit, we found that the mean effect size, although still significant, decreased to \(-0.37\) for inhibition, but remained the same for working memory and cognitive flexibility.

### Table 1. Effect sizes (ES) and confidence intervals (CI) for meta-analyses on the association between trauma exposure and working memory, inhibition, and cognitive flexibility.

| Variable          | \( K \) | \( n \) | \( d \) | 95% CI         | \( p \) |
|-------------------|--------|--------|--------|----------------|--------|
| Working memory    | 26     | 102    | -0.49  | -0.67; -0.31   | < 0.001|
| Inhibition        | 29     | 119    | -0.46  | -0.66; -0.26   | < 0.001|
| Cognitive flexibility | 27    | 101    | -0.44  | -0.63; -0.26   | < 0.001|

\( K \) = number of samples.
3.2. Variation in effect sizes

To investigate whether moderator analyses were necessary, we analysed whether variation in effect sizes could be attributed to random sampling error, within-study variance (level 2), or between-study variance (level 3). For working memory, effect sizes were heterogeneous as both within-study variance ($\sigma^2_v = 0.05$), $X^2 (1) = 105.64, p < 0.001$), and between-study variance were significant ($\sigma^2_v = 0.16, X^2 (1) = 69.00, p < 0.001$). Of the total variance, 20.4% was attributable to within-study differences and 72.0% to between-study differences. For inhibition, both within-study variance ($\sigma^2_v = 0.04$), $X^2 (1) = 17.11, p < 0.001$) and between-study variance were significant ($\sigma^2_v = 0.23, X^2 (1) = 45.32, p < 0.001$). Of the total variance, 13.3% was attributable to within-study differences and 76.4% to between-study differences. When we analysed the

Figure 2. Forest plot of the meta-analysis on the association between trauma exposure and working memory. RE, random effects.
heterogeneity of effect sizes for cognitive flexibility, we found significant within-study variance ($\sigma^2 = 0.02$), $X^2 (1) = 7.20$, $p = 0.007$) and between-study variance ($\sigma^2 = 0.19$, $X^2 (1) = 54.02$, $p < 0.001$). Of the total variance, 7.2% was attributable to within-study differences and 75.6% to between-study differences. In sum, significant heterogeneity was found between and within studies for working memory, inhibition, and cognitive flexibility. To explain the variation in effect sizes on the second and third levels, we added moderators to the random effects model.

### 3.3. Moderator analyses

We examined the extent to which moderators influenced the association between trauma exposure and executive functions by adding moderators as covariates (separately) to the random effect models. Table 2
displays the results of these analyses for working memory. We found that the quality of the measurement instrument ($F(2,99) = 6.50, p = 0.002$) influenced the association between trauma exposure and working memory significantly. The mean effect size for low-quality measurements was significantly stronger than the effect size that was found for high-quality measurements. We found that study quality was not an overall significant moderator ($F(2,99) = 2.43, p = 0.093$). However, we found that

Figure 4. Forest plot of the meta-analysis on the association between trauma exposure and cognitive flexibility. RE, random effects.
studies with a weak quality had a mean effect size that was significantly stronger than studies with a strong quality.

For inhibition, only type of trauma exposure was a significant moderator ($F(2,116) = 5.21$, $p = 0.007$). The mean effect size for single trauma exposure did not differ significantly from zero. No significant differences were found between violence-exposed/abused and adopted/foster care youth, but the

| Variable | Study quality | ES | $\beta$ (SE) | $t_0$ | $\beta_1$ (SE) | $t_1$ | $F$ (df,df) |
|----------|---------------|----|--------------|------|---------------|------|-------------|
| **Age (mean centred)** | 24 | 94 | $-0.47$ (0.82) | $-5.74$*** | 0.04 (0.02) | 1.85 | 3.42 (1,92) |
| | 25 | 90 | $-0.45$ (0.09) | $-5.23$*** | 0.00 (0.00) | 0.74 | 0.55 (1,88) |
| | 11 | 53 | $-0.32$ (0.09) | $-3.41$** | 0.00 (0.00) | 1.02 | 1.03 (1,51) |
| | 26 | 102 | | | | | 0.05 (1,100) |
| **Not controlled for SES (RC)** | 15 | 65 | $-0.51$ (0.12) | $-4.18$*** | | | |
| **Controlled for SES** | 11 | 37 | 0.04 (0.19) | | 0.218 | | |
| **Study quality** | 26 | 102 | | | | | 2.43 (2,99) |
| **Strong (RC)** | 9 | 25 | $-0.34$ (0.14) | $-2.49$* | | | |
| **Moderate** | 14 | 47 | $-0.52$ (0.12) | $-4.38$*** | $-0.18$ (0.16) | $-1.15$ | |
| **Weak** | 7 | 30 | $-0.67$ (0.14) | $-4.98$*** | $-0.34$ (0.15) | $-2.20$* | |
| **Trauma characteristics** | | | | | | | |
| **Onset** | 6 | 11 | $-0.72$ (0.29) | $-2.48$* | $-0.01$ (0.07) | 0.17 | 0.03 (1,9) |
| **Duration** | 6 | 17 | $-0.74$ (0.27) | $-2.78$* | $-0.01$ (0.08) | $-0.17$ | 0.03 (1,15) |
| | 25 | 101 | | | 1.73 (2,98) | | |
| **Single (RC)** | 4 | 10 | $-0.28$ (0.16) | $-1.71$ | | | |
| | 16 | 59 | $-0.41$ (0.11) | $-3.79$*** | $-0.14$ (0.14) | $-0.95$ | |
| | 7 | 32 | $-0.71$ (0.17) | $-4.11$*** | $-0.44$ (0.24) | $-1.86$ | |
| **PTSD diagnoses** | 7 | 26 | | | 3.47 (1,24) | | |
| **No diagnoses in sample (RC)** | 4 | 13 | $-0.38$ (0.18) | $-2.10$* | | | |
| | 7 | 13 | | | $-0.24$ (0.13) | | $-1.86$ |
| **Measurement characteristics** | 26 | 102 | | | 6.50 (2,99)* | | |
| **Quality** | | | | | | | |
| **High (RC)** | 8 | 28 | $-0.27$ (0.12) | $-2.32$* | | | |
| | 11 | 43 | $-0.44$ (0.12) | $-3.75$*** | $-0.17$ (0.11) | $-1.62$ | |
| **Low** | 14 | 31 | $-0.65$ (0.12) | $-5.64$*** | $-0.38$ (0.11) | $-3.54$*** | |
| **Diagnoses in sample** | 7 | 13 | | | 3.47 (1,24) | | |
| **Weak** | 7 | 13 | | | | | |

**Table 3.** Moderator analyses for the association between trauma exposure and inhibition.

| Variable | K | ES | $\beta$ (SE) | $t_0$ | $\beta_1$ (SE) | $t_1$ | $F$ (df,df) |
|----------|----|----|--------------|------|---------------|------|-------------|
| **Age (mean centred)** | 27 | 85 | $-0.49$ (0.11) | $-4.66$*** | 0.02 (0.03) | $-0.62$ | 0.38 (1,83) |
| | 28 | 109 | $-0.46$ (0.10) | $-4.47$*** | 0.00 (0.00) | 0.43 | 0.19 (1,107) |
| **Gender (% female, mean centred)** | 14 | 48 | $-0.25$ (0.08) | $-3.20$*** | 0.00 (0.00) | 0.27 | 0.07 (1,46) |
| | 29 | 119 | | | | | 0.14 (1,117) |
| | 17 | 83 | $-0.43$ (0.13) | $-3.26$** | | | |
| **Controlled for SES (RC)** | 12 | 36 | | | $-0.08$ (0.21) | | $-0.37$ |
| | 29 | 119 | | | | | 2.43 (2,116) |
| | 11 | 37 | $-0.42$ (0.15) | $-2.85$** | | | |
| **Onset** | 11 | 41 | $-0.64$ (0.14) | $-4.48$*** | $-0.22$ (0.20) | $-1.10$ | |
| | 10 | 41 | $-0.29$ (0.14) | $-2.07$* | 0.14 (0.17) | 0.83 | |
| **Type** | 29 | 119 | | | 5.21 (2,116)** | | |
| **Violence/abuse** | 3 | 6 | 0.04 (0.19) | 0.21 | | | |
| | 22 | 90 | $-0.43$ (0.12) | $-3.58$*** | $-0.47$ (0.16) | $-2.85$** | |
| | 6 | 23 | $-0.79$ (0.24) | $-3.31$*** | $-0.83$ (0.31) | $-2.72$** | |
| **PTSD diagnoses** | 14 | 55 | | | | 0.47 (1,53) | |
| | 6 | 13 | $-0.48$ (0.18) | $-2.63$* | | | |
| **Diagnoses in sample (RC)** | 13 | 42 | | | $-0.09$ (0.13) | | $-0.69$ |
| **Quality** | 29 | 119 | | | 0.04 (2,116) | | |
| **High (RC)** | 15 | 43 | $-0.45$ (0.11) | $-4.04$*** | | | |
| | 14 | 38 | $-0.46$ (0.12) | $-4.03$*** | 0.01 (0.09) | | |
| | 11 | 38 | $-0.48$ (0.12) | $-3.87$*** | 0.03 (0.11) | | $-0.27$ |

K = number of samples; ES = number of effect sizes; $\beta_0$ = mean effect size (Cohen’s $d$); $t_0$ = test statistic for difference mean effect with zero; $\beta_1$ = regression coefficient; $t_1$ = test statistic for difference mean effect with the reference category (RC); $F$ (df,df) = test statistic for testing significance of moderator; violence/abuse includes physical and emotional abuse, neglect, sexual abuse, and violence exposure; values with the same subscripts do not differ significantly from each other at $p < 0.05$. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. 

For inhibition, only type of trauma exposure was a significant moderator ($F(2,116) = 5.21$,
average effect sizes for these groups differed significantly from zero and from single trauma-exposed youth. Study quality was, overall, not a significant moderator \((F (2,116) = 2.42, p = 0.092)\). However, studies with a moderate quality had a significantly stronger effect size than weak-quality studies. Results of moderator analyses are displayed in Table 3.

For cognitive flexibility, although the overall moderator of trauma type was not significant \((F(2,101) = 2.62, p = 0.078)\), we found that the average effect size for single trauma exposure did not differ significantly from zero, but the mean effect sizes for violence-exposed/abused and adopted/foster care youth did, such that adopted/foster care youth performed significantly lower on cognitive flexibility than children who experienced single traumatic events, but not compared to abused youth. Results of moderator analyses for cognitive flexibility are displayed in Table 4.

### 3.4. Publication bias

We applied the PET-PEESE approach to examine publication bias in our meta-analyses. For all analyses, the PET was sufficient for assessment. The effect sizes varied significantly with the standard error for working memory \((p < 0.001)\), inhibition \((p < 0.001)\), and cognitive flexibility \((p = 0.001)\), which makes publication selection bias likely. After assessment of the funnel plots, it seemed that there were few ‘small’ studies that reported positive effects sizes and relatively few ‘large’ studies that reported negative effect sizes. This indicates the presence of a file-drawer problem in research on trauma exposure and executive functioning in youth (Franco, Malhotra, & Simonovits, 2014).

### 4. Discussion

In the present study, we analysed the association between trauma exposure and executive functions in youth using multi-level meta-analyses. The results demonstrate small to moderate effect sizes for the association between trauma exposure and working memory \((d = –0.49)\), inhibition \((d = –0.46)\), and cognitive flexibility \((d = –0.44)\). These small to medium effect sizes indicate that approximately 68% of trauma-exposed youth will have a lower score on executive function tasks than youth in the control group. It is important to keep in mind, however, that we cannot draw strong conclusions about the clinical significance of the effect sizes. This is because not all outcome measures used standardized scores, and because the level of daily life impairments cannot readily be inferred from their executive functions. Executive functions work in complex ways to ultimately influence behaviour in daily life, with many factors (e.g. individual motivation, environmental support, compensatory strategies) potentially affecting this link. At the same time, because executive
functions play a role in so many aspects of daily life, small to medium effect sizes can be expected to represent clinically relevant problems in trauma-exposed youth. Thus, our findings support the hypothesis that trauma exposure affects executive functions in youth.

We found that studies that used low-quality measurements showed a significantly larger effect size for the association between trauma-exposure and working memory than studies that used high-quality measurements. Researchers should be aware of the role of possible confounds when drawing conclusions based on low-quality outcome measures. Furthermore, we found that violence-exposed/abused and adopted/foster care youth demonstrated lower levels of inhibition and adopted/foster care youth showed lower levels of cognitive flexibility. Based on knowledge about early brain development and developmental trajectories of executive functions, we expected that early and prolonged exposure to traumatic events would result in problems in executive functioning compared to single trauma exposure. It is probable that adopted/foster care youth have spent these early years in an atypical, mostly emotionally unsafe environment (Merz, Harlé, Noble, & McCall, 2016), which explains why they experience more difficulties in inhibition and cognitive flexibility than single trauma-exposed youth.

Although our results suggest that trauma types influence the impact on inhibition and cognitive flexibility, we did not find that onset and duration of trauma exposure influence this relationship, and this gives us no direct indications for critical periods in the development of executive functions. This unexpected finding may be explained by the high amount of missing data (between 75% and 90%) on these moderator variables. As moderator analyses already have a lower power than the main effects analyses, this could have led to a failure to detect a meaningful difference in effect sizes across subgroups. In light of the debate about the existence of critical periods, it is interesting to note that age at testing was not a significant moderator. This goes against the widely held notion that the moderating effect of age would be stronger for younger children, as it is assumed that earlier trauma exposure has a more severe impact on cognitive function. Although at first sight perhaps counterintuitive, our findings could be explained by the fact that we did not have enough information about onset, duration, and time between cessation of trauma exposure and executive function assessment. An important suggestion for future research is, then, to clearly assess (and report) these aspects of trauma exposure to allow for further investigation of how they determine the degree of executive functioning impairments. In sum, our findings, that were based on a small amount of effect sizes should be interpreted very carefully. Based on our moderator variable for trauma type and previous neuroimaging studies, we still expect that timing and duration of trauma exposure may affect the impact of trauma exposure on executive functions (Teicher & Samson, 2016).

4.1. Strengths and limitations

Our study was the first meta-analysis to examine the relationship between trauma exposure and executive functions in youth with a three-level meta-analysis approach. Therefore, we could take into account the dependency among effect sizes. Our results give a systematic overview of available empirical research on this topic, and our focus on the three core executive functions (working memory, inhibition, and cognitive flexibility) added scientific and clinical value. Despite these strengths, our meta-analysis has several limitations. First, although we specifically attempted to decrease the presence of publication bias by searching for unpublished papers and dissertations, our contact attempts were mostly not answered. As our analyses indicated the presence of publication bias, our results should be interpreted carefully and 'real' effects may be smaller than the effects we found. Secondly, our meta-analysis was limited by missing data on theoretically important moderators such as trauma onset and duration. As there are strong indications from neuroimaging studies that the timing and duration of trauma exposure impact youth, we suggest that future research addresses these factors whenever possible. Thirdly, as both a strength and a limitation, we used various instruments that measured executive functions. This makes drawing conclusions on executive functioning in trauma-exposed youth more difficult. We handled this limitation by using a quality code on the measurement instrument, which makes us more confident about reliable outcomes. As we found that studies that used low-quality measurements showed a significantly larger effect size than studies that used high-quality measurements, future research that focuses on working memory should take this into account. As determining the quality of a task is difficult and can lead to discussion, one could, for example, combine a series of valid and reliable working memory measures in order to draw reliable conclusions instead of focusing on a sole outcome measure. Fourthly, 30–40% of studies were coded as low quality, which signals the importance for researchers to further increase the quality of their research by systematically reporting selection bias, study design, confounders, blinding, data collection methods, and withdrawal and dropouts. Fifthly, it should be noted that, as described in the introduction section, there are different types of working memory (verbal versus non-verbal) and inhibition (response inhibition and interference control). Although we aimed to investigate these differences, this was not possible because many studies used tasks that did not adequately distinguish between these different forms of working memory or inhibition. For example, many non-verbal working
memory tasks do not exclude verbal working memory strategies, and there is little consensus about the categorization of Stroop-like tasks in response inhibition or interference control (e.g. Geurts, Van den Bergh, & Ruzzano, 2014). Finally, it is also important to note that we could not test causal pathways or investigate underlying neurobiological mechanisms in our meta-analysis. While exposure to trauma may impact executive functioning, it could also be that deficits in executive functions may make individuals more at risk for exposure to traumatic events (Aupperle, Melrose, Stein, & Paulus, 2012). Therefore, future research should investigate this possibility to prevent trauma exposure and, in turn, its severe consequences such as PTSD, and internalizing and externalizing problems.

4.2. Future research

The dissociative subtype of PTSD was recently added to DSM-5 (American Psychiatric Association, 2013). Furthermore, empirical evidence indicates a link between dissociative symptoms and executive functions (McKinnon et al., 2016; Parlar, Frewen, Oremus, Lanius, & McKinnon, 2016). The overlap between dissociation and cognitive problems such as attention and inhibition is not yet clearly established, however. This makes it highly (clinically) relevant to assess dissociative symptoms when investigating the link between trauma exposure and executive functioning. However, there were only three studies that assessed dissociative symptoms in participants and therefore we could not include this variable. As a result, we would like to point out this important limitation of existing work and therefore strongly suggest that future research addresses dissociation when investigating the link between trauma exposure and executive functioning.

In recent literature, ‘hot’ executive functions have gained increasing attention. These functions are used for motivationally or emotionally salient goal-directed behaviour (Prencipe et al., 2011; Zelazo & Carlson, 2012). Although this was beyond the scope of our meta-analysis, which focused on the three core executive functions, it would be very interesting for future studies to look at emotionally valent tasks as specifically trauma-exposed youth may suffer from chronic activation of the stress response in the brain and attention bias towards threatening stimuli (e.g. Gunnar & Quevedo, 2007; Pine et al., 2005).

The clear linkages between trauma exposure and executive functions indicate that it is pivotal for future intervention research to address executive functions as a possible moderator of intervention effects. For example, as working memory is assumed to be fully loaded in Eye Movement Desensitization and Reprocessing (EMDR), it could be that youth with lower working memory capacities may not be able to perform two tasks simultaneously and therefore would benefit less from treatment. Another possibility could be that techniques in trauma-focused cognitive behaviour therapy make an appeal to the basic capacity to inhibit emotions, thoughts, and action to regulate intrusive thoughts.

4.3. Conclusions

The results of our meta-analyses highlight the relationship between trauma exposure and working memory, inhibition, and cognitive flexibility in youth, especially for adopted and foster care youth. Future research on executive function in trauma-exposed youth should take into account the differential developmental pathways of executive functions and should investigate the onset and duration of trauma exposure. To draw reliable conclusions about the impact of trauma exposure in youth, researchers should use high-quality measurements. Our findings imply that clinical practice should use transdiagnostic models to incorporate problems with executive functions in their assessment and treatment guidelines for traumatized youth. Care in which trauma-exposed youth could benefit more from treatments that also focus on a broader spectrum of problems, such as executive functions, should be the next step in both research and clinical practice.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Table A1. Search strategy for the Embase database.

1. Aircraft accident/ or destruction/ or falling/ or structure collapse/ or traffic accident/ or exp victim/ or fire/ or explosion/ or mass disaster/ or natural disaster/ or hurricane/ or tornado/ or threat/ or assault/ or battering/ or child abuse/ or family violence/ or exp partner violence/ or battered woman/ or ethnic conflict/ or genocide/ or homicide/ or human trafficking/ or infanticide/ or physical violence/ or torture/ or sexual aggression/ or exp female genital mutilation/ or sex trafficking/ or sexual coercion/ or sexual exploitation/ or exp sexual abuse/ or exp rape/ or exp sexual abuse/ or exp sexual harassment/ or exp child abuse/ or emotional abuse/ or physical abuse/ or war crime/ or war/ or kidnapping/ or abduction/ or hostage/ or stalking/ or detention/ or suicide/ or suicide attempt/ or exp child death/ or early life stress/ or orphanage/ or foster care/ or earthquake/ or incest/

2. (psychiatr* or psychol* or neurocogn* or cognit* or neuropsych* or psycho or psychosocial).ab,ti.

3. 1 and 2

4. 2 and (mass fatality* or catastrophe or disaster* or accident* or aircraft crash or destruction or annihilation or falling or fall? or collapse or automobile collision or flood* or inundation or hurricane* or tornado* or cyclone* or typhoon* or twister or earthquake* or tsunami* or fire or wildfire* or blast* or threat or harassment or assault or battering or ethnic conflict or racial conflict or genocide or ethnic cleansing or ethnic or homicide or assassination or murder or trafficking or infanticide or torture or sexual aggression or female genital mutilation or circumcision wom*n or partner abuse or spouse abuse or wife beating or battered wife or shooting or armed attack or war or warfare or child soldier or unwanted child or abandoned child or kidnap* or abduct* or hostage or stalk* or detention or police custody or arrested or accidental death or ((suicide or self killing or suicide attempt or violence/ [sexual or [sexualised or [sexualised against women] or [death adj3 (male or female)] or unnatural death or death bod* or corpse? or psychotrauma or emotional trauma or mental trauma or psychical trauma or psychological trauma or psychic trauma or early life stress or orphan or orphanage or institutional care or rejected child or foster care or foster family or foster home or drowning or volcano eruption or child maltreatment or child mistreatment or killing* or wrongful death* or sex offense* or physical maltreatment or parental death or maternal death or shell shock or corporal punishment or punishment or psychological abuse or battered females or incest* or acute stress or traumatic stress or Victim* or violent or violence or traumatic or trauma or psychotrauma* or maltreatment or abuse or neglect or deprivation or bullying or bullied).ab,kw,ti.

5. posttraumatic stress disorder/ or acute stress disorder/ or exp psychotrauma/ or exp psychotrauma assessment/ or bullying/

6. (ptsd or pts or posttraumatic stress or post traumatic stress or posttraumatic symptom? or post traumatic symptom? or bullying or bullied or cyberbullying).ab,kw,ti.

7. (life change event? and trauma*).ab,kw,sh,ti.

8. or/5–7 [traumatic events]

9. adolescents/ or child/ or minors/ or child, abandoned/ or exp child, exceptional/ or child, orphaned/ or child, unwanted/

10. (young adult? or childhood or youth* or boy? or girl? or sibling* or child or children or adolescents or adolescence or juvenile or minors or teen or teens or teenagers? or young people or toddler? or pre school* or preschool? or infant? or school age?).ab,kw,ti.

11. (pe/distr* or child*).jw.

12. or/9–11 [0–25 yrs]

13. ((school or campus or universiti* or bus) and (accident? or shoot* or massacre or violence or disaster?) or utopya).ab,kw,ti.

14. 8 and (12 or 13)

15. *executive function/ or exp *attention/ or exp *memory/ or *problem solving/ or *self control/ or *self evaluation/ or *creativity/ or *delay discounting/ or *attentional bias/ or *memory bias/ or exp *inhibition (psychology)/

16. (executive function? or executive dysfunction?) or dysexecutive syndrome or executive control or cognitive control or (inhibitory adj2 control) or self-control or selective attention or cognitive inhibition or interference control or focused attention or attentional inhibition or attentional control or endogenous attention or voluntary attention or top-down attention or active attention or goal driven attention or executive attention or delaying gratification or delayed gratification or Temporal Discounting or Intertemporal Preference* or Intertemporal Decision Making or Delayed Gratification or Response Inhibition or working memory or verbal working memory or nonverbal working memory or visuospatial working memory or cognitive flexibility or cognitive development or set shifting or mental flexibility or mental set shifting or creativity or verbal fluency or category fluency or semantic fluency or task switching or planning or reasoning or problem-solving or fluid intelligence or self regulation or effortful control).ab,kw,ti.

17. or/15–16

18. 14 and 17

19. exp executive function test/

20. ((Conners Continuous Performance TEST or (Stroop adj3 task? or Test)) or D-KEFS or Delis-Kaplan Executive Function System or Wisconsin Card Sorting Test or WCST or card sorting test or Porteus maze? or Rey-Osterrieth Complex Figure or RCFT or (brief adj3 (behavior or task? or test* or inventory)) or (behavior rating inventory of executive functions or BADS or behavioural assessment of the dysexecutive syndrome or Stop/go or stop/go or stop/go/ or Go/no go/ or Flanker or Dimensional card sorting task or Self-ordered pointing task or Conflict task or Gambling task or attention bias).ab,kw,ti. [specific tests]

21. 19 or 20

22. 14 and 21

23. Bender Gestalt Test/ or Kaufman assessment battery for children/ or test of everyday attention/ or Wechsler adult intelligence scale/ or Wechsler intelligence scale for children/ or Wechsler memory scale/ or exp maze test/

24. (NEPSY or neuropsychological assessment or KABC or kaufman assessment or WJ-III or woodcock johnson or Test of Everyday Attention or WISC or Wechsler Intelligence or WRAML2 or wide range of assessment and learning or Test of Problem Solving or differential ability scales or VMI or Visual Motor Integration or cognitive Assessment System or children memory scale or Cambridge Neuropsychological Test Automated Battery or CANTAB).ab,kw,ti. [generic relevant tests]

25. 23 or 24

26. 14 and 25

27. or/18,22,26

28. (ibi or traumatic brain or abi or acquired brain).kw,sh,ti.

29. 27 not 28

30. (animal/ or animal experiment/ or animal model/ or nonhuman/ or rat/ or mouse/ or (rat or rats or mouse or mice)).tl not human/

31. 29 not 30

32. remove duplicates from 31
Table A2. Search strategy for the MEDLINE database.

1. Accidental falls or accidents, Aviation or Accidents, home or accidents, traffic or drowning or mass casualty incidents or disaster victims or explosions or cyclonic storms or earthquakes or tornadoes or exp ethnic violence or exp child abuse or physical abuse or exp intimate partner violence or domestic violence or spouse abuse or torture or battered woman or exp genocide or homicide or exp sex offenses or infanticide or sexual harassment or circumcision, female or exp war crimes or stalking or parental death or maternal death or suicide, attempted or suicide, assisted or foster home care or orphans or incest
2. (psychiat* or psychol* or neurocogn* or cognit* or neuropsych* or psycho or psychosocial).ab,jw,kf,ti.
3. 1 and 2
4. 2 and (mass fatalit* or catastrophe or disaster? or accident? or aircraft crash or destruction or annihilation or falling or fall? or collapse or automobile collision or flood* or inundation or hurricane* or tornado* or cyclone* or typhoon* or twister or earthquake* or tsunami* or fire or wildfire* or blast* or threat or harassment or assault or battering or ethnic conflict or genocide or ethnic cleansing or ethnicicide or homicide or assassination or murder or trafficking or infanticide or torture or sexual aggression or female genital mutilation or circumcision wom?n or female circumcision or female genital circumcision or female genital cutting or FGM or ritual female genital surgery or sexual coercion or sexual exploitation or forced prostitution or rape or sexual abuse or molestation or sex abuse? or frottissement or child abuse or abused child or child negligence or neglected child or child neglect or emotional abuse or emotional neglect or physical neglect or physical abuse or battered wom?n or partner abuse or spouse abuse or wife beating or battered wife or shooting or armed attack or war or warfare or child soldier or unwanted child or abandoned child or kidnap* or hostage or stalk* or detention or police custody or arrest* or accidental death or (suicide or self-killed or suicidal) adj3 witness*) or (death adj3 (sibl* or brother or sister)) or unnatural death or death bod* or corpse? or psychotrauma or emotional trauma or mental trauma or psychical trauma or psychological trauma or psychic trauma or early life stress or orphan or orphanage or institutional care or rejected child or foster care or foster family or foster home or drowning or volcano eruption or child maltreatment or child mistreatment or killing* or wrongful death* or sex offense* or physical maltreatment or parental death or maternal death or parental death or shell shock or corporal punishment or punishment or psychological abuse or battered females or incest* or acute stress or traumatic stress or Victim? or violent or violence or traumatic or trauma or psychotrauma* or maltreatment or abuse or neglect or deprivation or bullying or bullied).ab,kf,ti.
5. exp 'Trauma and Stressor Related Disorders'/ or bullying/
6. (ptsd or pts or postrau or postraumatic stress or post traumatic stress or posttraumatic symptom? or post traumatic stress or bullying or bullied or cyberbullying).ab,kf,ti.
7. (life change event? and trauma*).ab,kf,sh,ti.
8. 3–7 [traumatic events]
9. adolescent or child? or minors? or child, abandoned? or exp child, exceptional? or child, orphaned? or child, unwanted/
10. (young adult? or childhood or youth* or boy? or girl? or sibling* or child or children or adolescents or adolescence or juvenile or minors or teen or teens or teenager? or young people or toddler? or pre school* or preschool* or infancy or infant? or school age).ab,kf,ti.
11. (pe?diatr* or child*).jw.
12. or/9–11 [0–25 yrs] or (school or campus or universit* or bus) and (accident? or shoot* or massacre or violence or disaster?) or (utoya).ab,kf,ti.
13. (school or campus or universit* or bus) and (accident? or shoot* or massacre or violence or disaster?) or (utoya).ab,kf,ti.
14. and (12 or 13)
15. executive function? or attention/ or Memory, Short-Term/ or exp problem solving/ or self control? or creativity? or delay discounting? or Inhibition (Psychology)/
16. (executive function? or executive dysfunction? or dysexecutive syndrome or executive control or cognitive control or (inhibitory adj2) control or self-control or selective attention or cognitive inhibition or interference control or focused attention or attentional inhibition or attentional control or endogenous attention or voluntary attention or top-down attention or active attention or goal driven attention or executive attention or delayed gratification or delay discounting or Temporal Discounting or Intertemporal Preference or Intertemporal Decision Making or Deferred Gratification or response inhibition or inhibition or verbal working memory or nonverbal working memory or visual spatial working memory or cognitive flexibility or cognitive development or set shifting or mental flexibility or mental set shifting or creativity or verbal fluency or category fluency or semantic fluency or task switching or planning or reasoning or problem-solving or fluid intelligence or self regulation or effortful control).ab,kf,ti.
17. or/15–16
18. 14 and 17
19. (Conners Continuous Performance TEST or (Stroop adj3 (task? or Test)) or D-KEFS or Delis-Kaplan Executive Function System or Wisconsin Card Sorting Test or WCST or card sorting test or Porteus maze? or Rey-Osterrieth Complex Figure or RCFT or (brief adj3 (behavior or task? or test* or inventory)) or 'behavior rating inventory of executive functions' or 'BEHAVIOURAL ASSESSMENT OF THE DYSEXECUTIVE SYNDROME' or 'Stop/go or stop/signal' or 'Go/no go' or Flanker or Dimensional card sorting task or Self-ordered pointing task or Conflict task or Gambling task or attention bias).ab,kf,ti. [specific tests]
20. 14 and 19
21. Wechsler Scales/
22. (NEPSY or neuropsychological assessment or KABC or Kaufman assessment or 'WJ-III' or woodcock johnson or 'Test of Everyday Attention' or WISC or wechsler intelligence or WRAML2 or 'wide range of assessment and learning' or 'Test of Problem Solving' or differential ability scales or VMI or Visual Motor Integration or cognitive Assessment System or children memory scale or Cambridge Neuropsychological Test Automated Battery or CANTAB).ab,kf,ti.
23. 21 or 22 [generic relevant tests]
24. 14 and 23
25. or/18,20,24
26. (tbi or traumatic brain or ab or acquired brain).kf,sh,ti.
27. 25 not 26
28. animals/ not humans/
29. 27 not 28
30. remove duplicates from 29
31. limit 30 to (dutch or english)
Table A3. Search strategy for the PsycINFO database.

1. Falls/ or home accidents/ or pedestrian accidents/ or exp transportation accidents/ or exp disasters/ or threat/ or coercion/ or punishment/ or school violence/ or physical abuse/ or emotional abuse/ or exp harassment/ or victimization/ or human trafficking/ or kidnapping/ or battered females/ or domestic violence/ or exposure to violence/ or exp partner abuse/ or exp sex offenses/ or circumcision/ or battered females/ or kidnapping/ or exp suicide/ or homicide/ or emotional trauma/ or foster children/ or foster care/ or orphans/ or orphanages/

2. (psychiatr* or psychol* or neurocogn* or cognit* or neuropys* or psycho or psychosocial).ab,id,ti.

3. 1 and 2

4. 2 and (mass fatality* or catastrophe or disaster? or accident? or aircraft crash or destruction or annihilation or falling or fall? or collapse or automobile collision or flood* or inundation or hurricane* or tornado* or cyclone* or typhoon* or twister or earthquake* or tsunami* or fire or wildfire* or blast* or threat or harassment or assault or battering or ethnic conflict or racial conflict or genocide or ethnic cleansing or ethnocide or homicide or homicide or assassination or murder or trafficking or infanticide or torture or sexual aggression or female genital mutilation or circumcised wom*n or female circumcision or female genital circumcision or female genital surgery or sexual coercion or sexual exploitation or forced prostitution or rape or sexual abuse or molestation or sex abuse? or prostitution or child abuse? or sexual or child neglect or neglected child or sexual abuse or emotional abuse or emotional neglect or psychological neglect or physical neglect or physical abuse or battered wom*n or child partner abuse or spouse abuse or wife beating or battered wife or shooting or armed attack or war or warfare or child soldier or unwanted child or abandoned child or kidnap* or abduct* or hostage or stalk* or hostage or police custody or arrested or accidental death or (suicide or self killing or suicidality adj3 witness* or (death adj3 (sibl* or brother or sister)) or unnatural death or death bod* or corpse* or psychotrauma or emotional trauma or mental trauma or psychological trauma or psychiatric trauma or early life stress or orphan or orphanage or institutional care or rejected child or foster child or foster family or foster home or drowning or volano explosion or child maltreatment or child mistreatment or killing? or wrongful death* or sex offenc* or physical maltreatment or parental death or maternal death or paternal death or shell shock or corporal punishment or punishment or psychological abuse or battered females or incest* or acute stress or traumatic stress or Victim? or violent or nonviolent or traumatic or trauma or psychotrauma* or maltreatment or abuse or neglect or deprivation or bullying or bullied).ab,id,ti.

5. posttraumatic stress disorder/ or acute stress disorder/ or exp bullying/

6. (ptsd or pts or posttraumatic stress or post traumatic stress or posttraumatic symptom? or post traumatic symptom? or bullying or bullied or cyberbullying).ab,ti.

7. (life change event? and trauma*).ab,ti,sh,ti.

8. or/3–7 [traumatic events]

9. (‘(140’ or ‘180’ or ‘200’ or ‘320’)ag.

10. (young adult? or childhood or youth* or boy or girl* or sibling* or child or children or adolescents or adolescence or juvenile or minors or teen or teens or teenage? or young people or toddler? or pre school? or preschool? or full school? or infant? or school age?).ab,ti.

11. (pe?diatr* or child*).jx.

12. (ptsd or ptss or posttraumatic stress or post traumatic stress or posttraumatic symptom? or post traumatic symptom? or bullying or bullied or cyberbullying).ab,ti.

13. (school or campus or campus*).ab,ti.

14. 8 and (12 or 13)

15. executive function? or attention/ or exp memory/ or exp problem solving/ or self control/ or creativity/ or delay discounting/ or dysexecutive syndrome/

16. (executive function? or executive dysfunction? or dysexecutive syndrome or executive control or cognitive control or (inhibitory adj2 control) or self-control or selective attention or cognitive inhibition or interference control or focused attention or attentional inhibition or attentional control or endogenous attention or voluntary attention or top-down attention or active attention or goal driven attention or executive attention or endogenous attention or voluntary attention or top-down attention or active attention or goal driven attention or executive attention or delay discounting or delayed gratification or Temporal Discounting or Intertemporal Preference* or Intertemporal Decision Making or Deferred Gratification or response inhibition or working memory or verbal working memory or nonverbal working memory or visual spatial working memory or cognitive flexibility or cognitive development or set shifting or mental flexibility or mental set shifting or creativity or verbal fluency or category fluency or semantic fluency or task switching or planning or reasoning or problem-solving or fluid intelligence or self regulation or effortful control).ab,id,ti.

17. or/15–16

18. 14 and 17

19. Stroop effect/ or Stroop Color Word Test/

20. (Conners Continuous Performance TEST or (Stroop adj3 (task? or Test)) or D-KEFS or Delis-Kaplan Executive Function System or Wisconsin Card Sorting Test or WCST or card sorting test or Porteus maze? or Rey-Osterreith Complex Figure or RCTF or (brief adj (behavior or task? or test* or inventory)) or (behavior rating inventory of executive functions? or BADS or ‘BEHAVIOURAL ASSESSMENT OF THE DYSEXECUTIVE SYNDROME’ or ‘Stop/go’ or ‘stop/signal’ or ‘Go/no’ or Flanker or Dimensional card sorting task or Self-ordered pointing task or Conflict task or Gambling task or attention bias).ab,ti,ti.[specific tests]

21. 17 or 20

22. 14 and 21

23. Bender Gestalt Test/ or Wechsler Intelligence Scale for Children/ or Woodcock Johnson Psychoeducational Battery/ or Digit span testing/ or Porteus Maze Test/ or Kaufman Assessment Battery for Children/ or Wechsler Adult Intelligence Scale/ or Wechsler Preschool Primary Scale/ or Kohn Block Design Test/

24. (NEPSY or neuropsychological assessment or KABC or Kaufman assessment or ‘WJ-III’ or woodcock johnson or ‘Test of Everyday Attention’ or WISC or wechsler intelligence or WMAT or ‘range of assessment and learning’ or ‘Test of Problem Solving’ or differential ability scales or VMI or Visual Motor Integration or cognitive Assessment System or children memory scale or Cambridge Neuropsychological Test Automated Battery or CANTAB).ab,ti.

25. 23 or 24

26. 14 and 25

27. or/18,22,26

28. (ibi or traumatic brain or abi or acquired brain).id,ti.

29. 27 not 28

30. cognitive control.ab,ti.

31. (executive function? or executive dysfunction? or dysexecutive syndrome or executive control or cognitive control or (inhibitory adj2 control)).ab,ti.

32. (self-control or selective attention or cognitive inhibition or interference control or focused attention or attentional inhibition or attentional control).ab,ti.

33. (task switching or planning or reasoning or problem-solving or fluid intelligence or self regulation or effortful control).ab,ti.

34. (cognitive development or set shifting or mental flexibility or mental set shifting or creativity or verbal fluency or category fluency or semantic fluency or executive inhibition or working memory or verbal working memory or nonverbal working memory or visual spatial working memory or cognitive flexibility).ab,ti.

35. (delayed gratification or delayed gratification or Temporal Discounting or Intertemporal Preference* or Intertemporal Decision Making or Deferred Gratification).ab,ti.

36. (endogenous attention or voluntary attention or top-down attention or active attention or goal driven attention or executive attention or delaying gratification).ab,ti.

37. 8 or 9

(Continued)
Table A3. (Continued).

39. 13 or 38
40. 39 and (17 or 21 or 25)
41. 40 not 28
42. limit 41 to (human and (dutch or english))
43. limit 42 to ('0100 journal' or '0110 peer-reviewed journal' or '0400 dissertation abstract')

Appendix B

Table B1. Eligibility assessment criteria.

Types of studies
We included studies that compared trauma-exposed youth with a control group in terms of inhibition, working memory, or cognitive flexibility.
We included studies that investigated the association between trauma exposure and inhibition, working memory, or cognitive flexibility in youth, with the exception of samples of orphans, institutionalized and adopted youth.
We included studies that compared orphans, institutionalized, and adopted youth with a control group in terms of inhibition, working memory, or cognitive flexibility.

Types of participants
We included samples with traumatized youth aged 0–25 years, in which the upper age limit could not exceed 25 years of age.
We excluded samples when participants were reported to have physical disabilities or illness: such as traumatic brain injury, poisoning, cancer, heart problems, epilepsy.

Trauma criteria
Population: orphans, foster children, adopted children.
Experiencing/witnessing/hearing about:
- Natural disaster (e.g. hurricane, earthquake)
- Fire/explosion
- Accident (traffic, school, home, neighbourhood)
- Bullying (extreme)
- Physical attack (beaten, kicked, etcetera)
- Shooting
- War/community violence
- Verbal abuse
- Domestic violence
- Rape, sexual abuse
- Stalking
- Police arrest
- Physical neglect
- Emotional neglect
- Abduction/kidnapping
- Severe illness
- Death by violence
- Death of a loved one

Outcome measures
Working memory:
- Visuospatial working memory
- Spatial working memory
- Verbal working memory

Inhibition:
- Response inhibition
- Inhibitory control
- Interference control
- Cognitive inhibition
- Selective attention
- Focused attention
- Effortful control

Cognitive flexibility:
- Set shifting
- Task switching
- Shifting

Correlations or means
We included studies that reported raw correlations between measures or means and standard deviations between two groups.
## Appendix C

### Table C1. Coding scheme.

| Variable              | Variable labels                                                                 |
|-----------------------|---------------------------------------------------------------------------------|
| **Study characteristics** |                                                                                  |
| PaperID               | Paper identification number (001, 002, 003, etc.)                               |
| SampleID              | Sample identification number (001, 002, 003, etc.)                              |
| ESID                  | Effect size identification number (001, 002, 003, etc.)                        |
| Authors               | Author names                                                                    |
| Year                  | Publication year                                                                 |
| Publication status     | 1 = published, 0 = not published                                                |
| N                     | Number of participants in total sample                                          |
| AgeMean               | Mean age, total sample                                                          |
| AgeSD                 | Standard deviation age, total sample                                            |
| Gender                | Percentage girls in total sample                                                |
| Ethnicity             | Percentage minority ethnicity in total sample                                    |
| SES                   | 1 = controlled for SES, 0 = not controlled for SES                              |
| N_control             | Number of participants in control group                                         |
| AgeMean_control       | Mean age, control group                                                         |
| AgeSD_control         | Standard deviation age, control group                                           |
| Gender_control        | Percentage girls in control group                                               |
| Ethnicity_control     | Percentage minority ethnicity in control group                                  |
| N_trauma              | Number of participants in trauma group                                          |
| AgeMean_trauma        | Mean age, trauma group                                                          |
| AgeSD_trauma          | Standard deviation age, trauma group                                            |
| Gender_trauma         | Percentage girls in trauma group                                                |
| Ethnicity_trauma      | Percentage minority ethnicity in trauma group                                   |
| **Trauma characteristics** |                                                                               |
| PTSD_measure          | PTSD measurement instrument: 1 = CRIES (child), 2 = CRIES (parent), 3 = TSCC, 4 = PDS, 5 = UCLA PTSD index, 6 = CAPS-CA, 7 = PCL, 8 = PCL-C, 9 = TSCYC, 10 = PSS, 11 = KSADS, 12 = observation, 13 = mini-KID, 14 = IES, 15 = psychiatric evaluation, 16 = SCID |
| PTSD_Diagnosis        | 1 = PTSD diagnoses in sample, 0 = no PTSD diagnoses in sample                  |
| Type_trauma           | 1 = disaster, 2 = fire or explosion, 3 = vehicle accident, 4 = accident, 5 = overall abuse, 6 = overall neglect, 7 = physical abuse/threat, 8 = verbal abuse/threat, 9 = emotional neglect, 10 = physical neglect, 11 = domestic violence, 12 = sexual abuse/rape, 13 = (witness) shooting, 14 = stalking, 15 = person in family arrested, 16 = severe bullying (with physical threat), 17 = abduction, 18 = witness of a violent death, 19 = death of a loved one, 20 = adoption/foster care with known history of abuse or neglect, 21 = adoption/foster care with unknown history, 22 = severe illness or medical condition in loved one, 23 = indirect victimization 24 = community violence (later subsumed into 1 = single trauma exposure, 2 = violence exposed/abused/neglect, 3 = adopted or foster care youth) |
| Onset                 | Mean age (years) of onset of trauma exposure                                    |
| Duration              | Mean age (years) of duration of trauma exposure                                 |
| **Measurement characteristics** |                                                                               |
| WM_Task               | Working memory outcome measure                                                  |
| WM_mean_control       | Mean score on working memory outcome measure for control group                  |
| WM_SD_control         | Standard deviation on working memory outcome measure for control group          |
| WM_mean_trauma        | Mean score on working memory outcome measure for trauma group                   |
| WM_SD_trauma          | Standard deviation on working memory outcome measure for trauma group           |
| WM_correlation        | Correlation between trauma exposure and working memory outcome measure          |
| WM_quality            | 1 = high, 2 = medium, 3 = low                                                   |
| INH_Task              | Inhibition outcome measure                                                      |
| INH_mean_control      | Mean score on inhibition outcome measure control group                          |
| INH_SD_control        | Standard deviation on inhibition outcome measure for control group              |
| INH_mean_trauma       | Mean score on inhibition outcome measure for trauma group                        |
| INH_SD_trauma         | Standard deviation on inhibition outcome measure for trauma group                |
| INH_correlation       | Correlation between trauma exposure and inhibition outcome measure              |
| INH_quality           | 1 = high, 2 = medium, 3 = low                                                   |
| FLEX_Task             | Cognitive flexibility outcome measure                                           |
| FLEX_mean_control     | Mean score on cognitive flexibility outcome measure for control group           |
| FLEX_SD_control       | Standard deviation on cognitive flexibility outcome measure for control group   |
| FLEX_mean_trauma      | Mean score on cognitive flexibility outcome measure for trauma group             |
| FLEX_SD_trauma        | Standard deviation on cognitive flexibility outcome measure for trauma group     |
| FLEX_correlation      | Correlation between trauma exposure and cognitive flexibility outcome measure    |
| FLEX_quality          | 1 = high, 2 = medium, 3 = low                                                   |
### Table D1. Quality coding of included working memory outcome measures.

| Task – outcome measure | Measures | Quality |
|------------------------|----------|---------|
| (WISC) Digit Span      |          |         |
| Overall                | Verbal working memory | Low    |
| Backwards–forwards     | Verbal working memory | High   |
| Backwards              | Verbal working memory | Medium |
| WISC WMI index         | Working memory    | Low    |
| CANTAB SWM             |          |         |
| SWM between errors 4–8 boxes | Spatial working memory | Medium |
| Within errors 4–8 boxes | Spatial working memory | Medium |
| Double errors          | Spatial working memory | Medium |
| Total errors 4–8 boxes (key outcome) | Spatial working memory | High   |
| Strategy (key outcome) | Spatial working memory | High   |
| Mean score             | Spatial working memory | Low    |
| CANTAB Spatial Span (SSP) |          |         |
| SSP errors             | Spatial working memory | High   |
| SSP length             | Spatial working memory | High   |
| SSP strategy           | Spatial working memory | High   |
| SSP latency            | Spatial working memory | Medium |
| WJ-II                  |          |         |
| Numbers reversed       | Verbal working memory | Medium |
| NEUROPSI               |          |         |
| Digit backwards span   | Verbal working memory | Medium |
| Spatial backwards span | Spatial working memory | Medium |
| CAT                    |          |         |
| Spatial working memory (overall) | Spatial working memory | Low    |
| Combined tasks         |          |         |
| Digit Span (WISC) + Corsi Block test | Working memory (spatial + verbal) | Medium |
| Listening recall task  | Verbal working memory | Medium |
| Odd-one-out            | Verbal working memory | Medium |
| Spin the pots (# stickers) | Working memory (spatial) | Medium |
| Six boxes (scrambled)  | Working memory (spatial) | Medium |
| BRIEF                  |          |         |
| Working memory subscale | Working memory    | Low    |

### Table D2. Quality coding of included inhibition outcome measures.

| Task – outcome measure | Measures | Quality |
|------------------------|----------|---------|
| Stroop                 |          |         |
| Errors card III        | Interference control | Medium |
| RT card III            | Interference control | Medium |
| Interference score (card III – II) | Interference control | High   |
| Delis Kaplan Color Word Interference | Mean score | Interference control | Medium |
| Errors card III        | Interference control | Medium |
| Contrast time/ errors (difference card III–II/I) | Interference control | High   |
| Go/no-go               |          |         |
| Percentage correct no-go responses | Response inhibition | High   |
| Percentage errors of commission | Response inhibition | High   |
| Reaction time errors of commission | Response inhibition | High   |
| Total percentage correct | Response inhibition | Low    |
| Total reaction time    | Response inhibition | Low    |
| Conners Performance Test II | Commission errors | Response inhibition | High   |
| Stop Signal Test       |          |         |
| SSRT                   | Inhibit prepotent response | High   |
| Proportion successful stops | Inhibit prepotent response | Medium |
| Stop signal delay      | Inhibit prepotent response | Medium |
| Mean probability of inhibition over all delay intervals corrected for omission errors | Inhibit prepotent response | High   |
| Flanker                |          |         |
| Accuracy incongruent   | Interference control | Medium |
| RT incongruent         | Interference control | Medium |
| Incongruent–congruent RT | Interference control | High   |
| Interference score     | Interference control | High   |
| Nepsy                  |          |         |
| Knock and tap: accuracy score | Motor inhibition | High   |
| Statue: accuracy score | Motor inhibition | High   |
| Gradual Onset Continuous Performance Task | Slope of commission errors | Interference control | High   |
| Logan Stop-Change      |          |         |
| % Correct responses for tone delay trials | Interference control | Medium |
| Mean reaction time for tone delay trials | Interference control | High   |
| Change task (McClure)  |          |         |
| CSRT                   | Interference control | High   |
| Three pegs task        | Prepotent response inhibition | Medium |

(Continued)
### Table D2. (Continued).

| Task – outcome measure | Measures | Quality |
|-------------------------|----------|---------|
| Tapping task            | Prepotent response inhibition | Medium |
| Day night               | Interference control          | Low     |
| Proportion correct test trials | Inhibition | Low     |
| NEUROPSI                | Motor functions (Go/no-go + Luria’s) | Inhibition | Low |
| BRIEF                   | Inhibition subscale            | Low     |
| Verbal Inhibition/Motor Inhibition Task | Inhibition | Low |
| Combined number of errors | Inhibition | Low |
| Luria’s hand game based task | Inhibition | Low |

Assignment of quality is partly based on the paper of Geurts et al. (2014).

### Table D3. Quality coding of included cognitive flexibility outcome measures.

| Task – outcome measure | Measures | Quality |
|-------------------------|----------|---------|
| Trail Making Test (TMT) | Cognitive flexibility | Medium |
| TMT-B                   | Cognitive flexibility | Low     |
| TMT-A + B               | Cognitive flexibility | High    |
| DKEFS Category switching | Average score CF – average score switching | Verbal flexibility | High |
| DCSS                    | Highest level achieved | Set shifting | Low |
| CANTAB IED              | Total errors/errors block 6/errors block 8 | Set shifting | Medium |
|                         | Total errors adjusted | Set shifting | Medium |
|                         | Stages completed       | Set shifting | Medium |
|                         | EDS errors             | Set shifting | High    |
|                         | PRE ED errors          | Set shifting | Medium |
|                         | Total trials           | Set shifting | Medium |
|                         | Total trials adjusted  | Set shifting | Medium |
|                         | Mean score             | Set shifting | Low     |
| WCST                    | Perseverative errors   | Set shifting | High    |
|                         | Perseverative responses| Set shifting | Medium |
|                         | Total errors           | Set shifting | Low     |
|                         | Categories completed   | Set shifting | Low     |
|                         | Failure to maintain set| Set shifting | High    |
| Flexible item task      | Proportion correct     | Set shifting | Medium |
| BRIEF                   | Cognitive flexibility subscale | Cognitive flexibility | Low |
| Cognitive Flexibility Inventory | Cognitive flexibility | Low |
| Combined tasks          | TMT-B + WCST perseverance | Cognitive flexibility | Medium |

Assignment of quality is partly based on the paper of Gueurs, Corbett, and Solomon (2009).

### Table D4. Excluded tasks and outcome measures.

| Tasks – outcome measures | Measures |
|--------------------------|----------|
| Go/no-go                | Selective attention |
| Correct Go responses (number of correct ‘go’ responses) | Selective attention |
| % Correct Go responses (percentage of ‘go’ trials correct) | Selective attention |
| Incorrect Go responses (number of incorrect ‘go’ responses) | Selective attention |
| Go trial non-responses (non-responses on ‘go’ trials) | Selective attention |
| Mean Go trial RT (mean reaction time of correct ‘go’ responses) | Selective attention |
| Conner’s Performance Test II | Selective attention |
| Correct detection | Selective attention |
| RT                     | Selective attention |
| Omission errors        | Selective attention |
| Variability            | Sustained attention |
| Stop Signal Test       | Time interval between go and stop signals |
| SSD                    | Selective attention |
| Go RT                  | Selective attention |
| Direction errors       | Selective attention |
| Flanker                | Selective attention |
| Accuracy congruent     | Selective attention |
| RT congruent           | Selective attention |
| Combined scores congruent | Selective attention |
| Logan Stop-Change      | Selective attention |
| Go RT                  | Selective attention |
Table D4. (Continued).

| Tasks – outcome measures | Measures |
|--------------------------|----------|
| SSD                      | Selective attention |
| WISC Digit Span Forwards | Attention/short-term memory |
| CANTAB SWM               | Speed |
| Mean time to first response | Short-term memory |
| Sentence repetition      | Psychomotor speed |
| TMT                      | Vigilance + alertness |
| TMT-A                    | Verbal fluency |
| Digital Vigilance Test   | Verbal learning |
| COWAT                    | Verbal learning |
| Animal naming            | Verbal learning |
| Total words              | Verbal learning |
| Grooved Pegboard         | Planning + psychomotor speed |
| California Verbal Learning Test | |
| List A                   | Visual–motor coordination |
| List B                   | Visual organizing/reasoning |
| Short delay free recall  | Visual short-term memories |
| Long delay free recall   | Reasoning |
| Discriminability         | Arithmetic abilities |
| WISC-III                 | Memory |
| Block design             | Visual–spatial ability |
| Object assembly          | Left–right discrimination |
| Coding                   | Visual–spatial ability |
| Similarities             | Planning |
| Arithmetic               | Short-term memory |
| Rey Osterrieth Complex Figure recall | Self-control |
| Rey Osterrieth Complex Figure copy | Conflict interference (emotional) |
| Money Road Map           | Selective attention |
| Judgement of Line Orientation | Verbal memory: |
| Tower of London          | Visual memory + new learning |
| Reading span of Daneman & Carpenter | Attention bias |
| Self-control scale       | Behavioural disinhibition (trait) |
| Conflict task (Egner 2008) | Short-term memory |
| Hayling sentence repetition | Overall cognitive function |
| Sentence repetition span  | Behavioural inhibition (trait) |
| Paired Associate Learning test CANTAB | Impulsivity |
| Dot-probe                | Temperament |
| Retrospective Self Report of Inhibition (RSRI) | Attention |
| Stanford Binet Sentence, Objects and Digits | Behavioural inhibition |
| Bayley scales            | Overall (executive) functioning |
| BIS/BAS scales           | |
| Barrat Impulsivity Scale | |
| Children’s Behavior Questionnaire (CBQ) | |
| FDI index WISC           | |
| Gift delay task          | |
| Composite score of DCCS, Day/Night/CBCL | |
| WCST                     | Random errors |

**Appendix E**

**References of papers used in meta-analyses for working memory, inhibition, and cognitive flexibility**

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Barrera, M., Calderon, L., Bell, V., Calderón, L., & Bell, V. (2013). The cognitive impact of sexual abuse and PTSD in children: A neuropsychological study. *Journal of Child Sexual Abuse, 22*(6), 625–638. doi:10.1080/10538712.2013.811141

Bauer, P. M., Hanson, J. L., Pierson, R. K., Davidson, R. J., & Pollak, S. D. (2009). Cerebellar volume and cognitive functioning in children who experienced early deprivation. *Biological Psychiatry, 66*(12), 1100–1106. doi:10.1016/j.biopsych.2009.06.014

Beers, S. R., & De Bellis, M. D. (2002). Neuropsychological function in children with maltreatment-related posttraumatic stress disorder. *The American Journal of Psychiatry, 159*, 483–486. doi:10.1176/appi.ajp.159.3.483

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Cecil, C. A. M., Viding, E., McCrorry, E. J., & Gregory, A. M. (2015). Distinct mechanisms underlie associations between forms of childhood maltreatment and disruptive nocturnal behaviors. *Developmental Neuropsychology, 40*(3), 181–199. doi:10.1080/87565641.2014.983636

Cowell, R. A., Cicchetti, D., Rogosch, F. A., & Toth, S. L. (2015). Childhood maltreatment and its effect on neurocognitive functioning: Timing and chronicity matter. *Development and Psychopathology, 27*, 521–533. doi:10.1017/S0954579415000139

De Bellis, M. D., Woolley, D. P., & Hooper, S. R. (2013). Neuropsychological findings in pediatric maltreatment. *Child Maltreatment, 18*(3), 171–183. doi:10.1177/1077559513497420

Dileo, J. F., Brewer, W., Northam, E., Yucel, M., Anderson, V., Brewer, W., & Anderson, V. (2017). Investigating the neurodevelopmental mediators of aggression in children: An exploratory field study. *Child Neuropsychology, 23*(6), 655–677. doi:10.1080/09297049.2016.1186159

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