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Inhibitory control in trauma-exposed youth: A systematic review

Jitske van der Bij[a,*], Rosanne Op den Kelder[c,d], Barbara Montagne[a], Muriel A. Hagenaars[b]

[a] Center for Psychiatry, GGZ-Centraal, Laan van Heelmeesters 2, 1211MS, Hilversum, The Netherlands
[b] Department of Clinical Psychology, Utrecht University, Heidelberglaan 1, 3584 CH, The Netherlands
[c] Research Institute of Child Development and Education, University of Amsterdam, Nieuwe Achtergracht 166, 1018 WV, Amsterdam, The Netherlands
[d] De Bascule, Academic center for Child and Adolescent Psychiatry, Rijksstraatweg 145, 1115 AP, Duivendrecht, The Netherlands

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ABSTRACT

The aim of this systematic review was to provide insight in inhibitory control (prepotent response inhibition and interference control) in trauma-exposed youth from a developmental perspective and exploring the effects of prolonged stress. A systematic search was conducted, resulting in 1722 abstracts. Of those, 33 studies met inclusion criteria. Twelve studies measured prepotent response inhibition (Go/no-go and Stop-signal task), 20 studies measured interference control (Flanker and Stroop task), and one measured both. Some studies indeed found evidence for prolonged trauma exposure impeding both subcomponents of inhibitory control, although others did not. At a later age, inhibitory control problems on task performance seem to disappear. However, distinct patterns of brain activity may suggest that those individuals employ compensation strategies. Together, the findings may suggest that non-specific inhibitory control problems occur after prolonged trauma exposure, with older youth possibly employing compensation strategies on the tasks. Future studies may provide a clearer picture of the compensation strategies and the circumstances in which they become visible.

1. Introduction

Epidemiological research on child traumatic stress has demonstrated that there is a high prevalence rate of exposure to traumatic events in childhood and adolescence; over 66 % children reported at least one traumatic event by the age of 16 (Copeland et al., 2007). According to the Diagnostic and Statistical Manual of Mental Disorders, a trauma is defined as an event in which somebody experiences or witnesses a threat or violation of a person's psychical or psychological integrity (American Psychiatric Association, 2013). Approximately 11.5–21.5 % of youth develop posttraumatic stress disorder (PTSD) after trauma exposure (Alisic et al., 2014). Apart from PTSD, exposure to traumatic life events during childhood puts youth more at risk for various negative consequences. Cognitive and affective development was found to be impeded after prolonged stress originating from childhood single or multiple trauma exposure (Pechtel and Pizzagalli, 2011). In line with this, trauma-exposed youth (with and without PTSD) demonstrated performance decrements in a wide range of cognitive domains such as general intelligence, memory and executive functioning including inhibitory control (Malarbi et al., 2016; Op den Kelder et al., 2018; Samuelson et al., 2010). Our review adds to this literature by investigating two subcomponents of inhibitory control separately (prepotent response inhibition and interference control). We also investigate developmental differences and prolonged stress in trauma-exposed youth regarding inhibitory control.

1.1. Trauma, neurodevelopment and executive functioning

Severe stress or deprivation during childhood seems to be associated with negative consequences at the neurodevelopmental level. Exposure to a traumatic life event results in a physiological stress response by activation of the hypothalamus-pituitary-adrenal (HPA) axis and subsequently, the production of glucocorticoids by the adrenal glands (Gunnar and Quevedo, 2007). In turn, long-term suppressed or elevated glucocorticoids levels (as a result of chronic stress) have been associated with impaired brain development and functioning (Lupien et al., 2009). For example, an increased density of glucocorticoids receptors due to long-term stress has been suggested to affect the maturation of the prefrontal cortex (PFC) with subsequently a negative impact on its associated capacities (Teicher et al., 2003). Relative to other brain areas, the PFC has a long developing-period i.e., its development ends around the age of 25 years (Arain et al., 2013). The PFC in interaction with other cortical and subcortical areas plays an important role in executive functioning (EF) (Garon et al., 2008). Reviews and a meta-

* Corresponding author.
E-mail addresses: j.vanderbij@ggzcentraal.nl (J. van der Bij), r.opdenkelder@uva.nl (R.O. den Kelder), b.montagne@ggzcentraal.nl (B. Montagne), m.a.hagenaars@uu.nl (M.A. Hagenaars).

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analysis repeatedly pointed out the negative effects of trauma exposure on EF (Aupperle et al., 2012; Malarbi et al., 2016; Op den Kelder et al., 2018). However, EF is not a heterogeneous construct and is often defined as an umbrella term that encompasses separate but related cognitive processes (Miller and Cohen, 2001). Most models propose that EF comprises three core concepts: inhibitory control, working memory, and cognitive flexibility (Lehto et al., 2003; Miyake et al., 2000). Executive functions models are different in their focus, but inhibitory control remains a major component for most authors (Dimond and Lee, 2011; Zelazo et al., 1997). According to Miyake and Friedman (2012), inhibitory control is the purest function of EF because it is highly correlated with unitary EF.

1.2. Trauma and inhibitory control

Inhibitory control refers to the ability to "control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external lure" (Diamond, 2014, p. 137). This ability seems to develop over time and increases with age (Carver et al., 2001). A good development of inhibitory control early in life appears to be quite predictive of outcomes throughout life, including adulthood. For example, Moffitt et al. (2011) found that better inhibitory control was highly correlated with better physical and mental health, feeling happier in life and with being less likely to make risky choices or using drugs. Conversely, inhibitory control problems have been linked to numerous (psychiatric) disorders, such as obsessive-compulsive disorder (e.g., Mancini et al., 2018; Menzies et al., 2007; Penadés et al., 2007), substance abuse disorders (e.g., Monterosso et al., 2005; Nigg et al., 2006), bipolar mood disorder (e.g., Murphy et al., 1999), and primary complex motor stereotypies (Mirabella et al., 2019). This marks the importance of a good development of inhibitory control and makes it of great interest to know how trauma exposure might disturb its normal developmental process. Therefore, in this review we focus entirely on inhibitory control and trauma exposure. Though inhibitory control is commonly referred to as being one construct, in behavioral and cognitive neuroscience perspective it is considered to be multifaceted (Friedman and Miyake, 2004; Nigg, 2000). A widely used distinction in inhibitory control is the difference between prepotent response inhibition and interference control (Diamond, 2014; Nigg, 2000). Those are both forms of reactive inhibition; i.e., cue-triggered process that stops an already initiated response (Aron, 2011). Another inhibition type that is sometimes distinguished is pro-active inhibition; i.e., a preparatory process that influences whether the response will be initiated in the first place (Friedman and Miyake, 2004; Miyake and Friedman, 2012). Here, we focus on prepotent response inhibition and interference control, as these types of inhibitory control are the most frequently studied in trauma-exposure literature. Prepotent response inhibition involves suppressing a dominant motor response (Casey et al., 2001; Nigg, 2000). Interferences control refers to the efficiency with which one is able to ignore distracting irrelevant information while processing a target (Stroop, 1935). Tasks such as the Go/no-go and Stop-signal are commonly used to measure prepotent response inhibition (Logan et al., 1984) whereas tasks such as the Flanker task (Eriksen, 1995), Simon task (Simon and Rudell, 1967) and Stroop task (Stroop, 1935) are commonly used to measure interference control.

1.3. The aim of the current review

The primary aim of this systematic review was to give a literature update and gain further insight in inhibitory control in trauma-exposed developing youth compared to their non-trauma-exposed peers. Compared to previous studies (Aupperle et al., 2012; Malarbi et al., 2016; Op den Kelder et al., 2018), we focused entirely on inhibitory control and looked at two subcomponents of inhibitory control that are delineated in theoretical models such as Diamond et al. (2015) and Nigg (2000): prepotent response inhibition and interference control. As the prefrontal cortex develops with age, we examined inhibitory control and trauma exposure from a developmental perspective. We also explored inhibitory control with regard to prolonged (i.e., prolonged trauma or PTSD) versus isolated stress. This was achieved by a descriptive overview based on a systematic review.

2. Methods

2.1. Study selection

A comprehensive search of computerized databases MEDLINE, EMBASE and PsycINFO was conducted in order to identify articles that reported about inhibitory control in trauma-exposed youth. We based our search on the search strategy of the most recent meta-analysis on trauma exposure and executive functioning (Op den Kelder et al., 2018). We included articles until July 2018. The same combination of Medical Subject Headings (MESH) and search terms was used across databases. The full electronic search strategy is described in Appendix A.

Screening of the relevance of the retrieved titles and abstracts was performed independently by two reviewers (first author and an independent screener). When at least one of them considered an abstract to be potentially relevant, the full article was in a second phase retrieved for evaluation independently by two authors (first and second author). Emerging discrepancies were resolved by discussion. Fig. 1 displays the study selection process.

2.2. Inclusion and exclusion criteria

In order to be included, studies had to meet the following criteria: (a) studies compared inhibitory control in individuals who were directly exposed to traumatic life events to non-trauma-exposed controls without comorbid psychiatric conditions; (b) studies measured inhibitory control using widely known experimental or neuropsychological inhibition tasks (Stop-signal task, Go/no-go task, Stroop task, DKEFS color word interference task, Simon task, or Flanker task); (c) studies published in a peer-reviewed journal before August 2018 and written in English; (d) studies contained 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 around the age of 25 years (Arain et al., 2013). Studies which included participants with a neurological or other medical disease (e.g. traumatic brain injury) and current drug abuse were excluded, as these factors are known to influence executive functioning (Fernández-Serrano et al., 2010; Gioia et al., 2002).

2.3. Measures of inhibitory control

2.3.1. Prepotent response inhibition

We selected studies that used the Go/no-go task and Stop-signal task to measure the effects of trauma-exposure on prepotent response inhibition. In these tasks, participants have to respond to the majority of stimuli (go trials) and then suddenly withhold a response when a no-go sign or stop-signal is presented (Logan et al., 1984). In a modified version, the stop change task, participants had to change their response instead of withholding a response (Nelson et al., 2007). The most commonly used measure of prepotent response inhibition in the Go/no-go task is the rate of errors produced in no-go trials (Chiu et al., 2014). For the Stop-signal task, the most commonly used measure of prepotent response inhibition is the Stop Signal Reaction Time (SSRT), i.e., the time required to stop a response that is already in process of being executed (Logan and Cowan, 1984). There are different ways to compute the SSRT, the most common being the mean method and the integration method (See Mirabella et al., 2006; Verbruggen et al., 2013). Although both tasks are considered to measure prepotent response inhibition (Nigg, 2000), the Go/no-go task measures the ability to

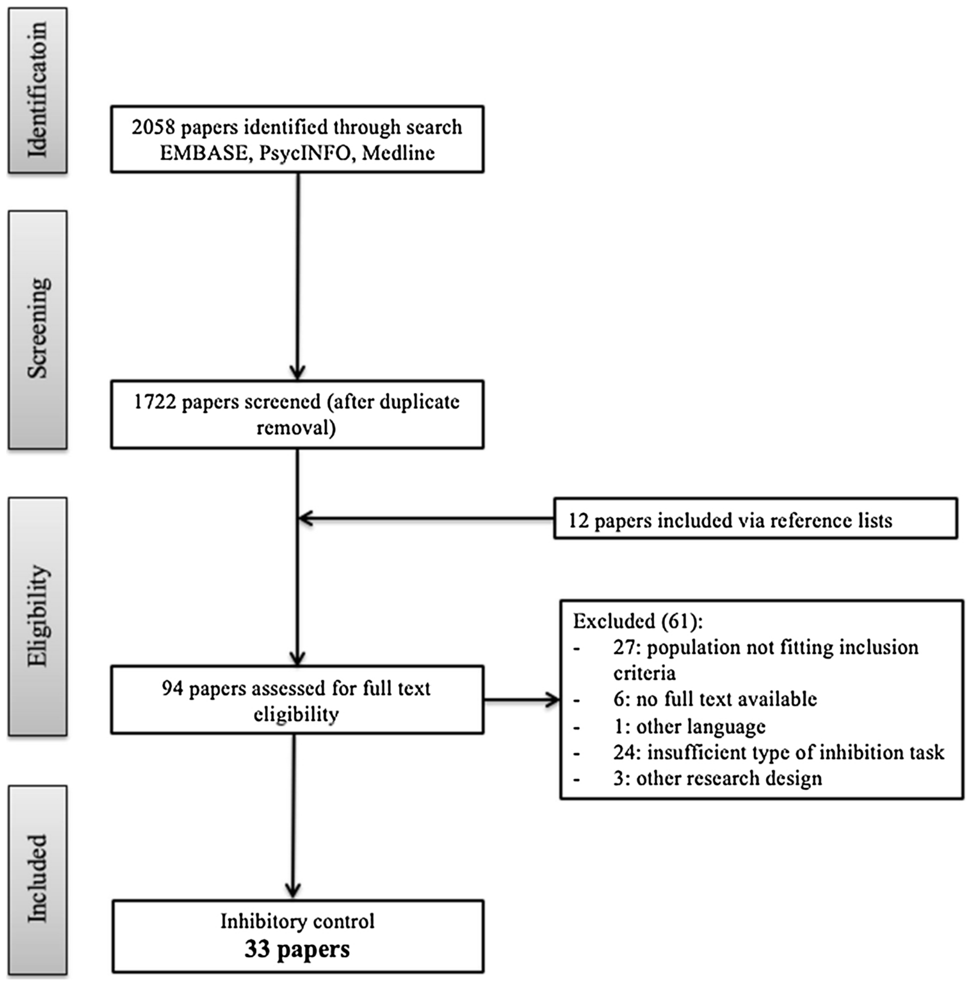

Fig. 1. PRISMA Flow Chart highlighting the number of articles found at each stage of the search and the final number of studies included in this review.

suppress a potential action ('action restraint') and the Stop-signal task measures the ability to inhibition an already initiated action ('action cancellation,' see Raud et al., 2020). We therefore investigated these tasks separately.

2.3.2. Interference control

We selected studies that used the Flanker task (Eriksen, 1995), Simon task (Simon and Rudell, 1967) and Stroop task (Stroop, 1935) to measure interference control. In these tasks, participants have to respond to a target stimulus while ignoring other distracting information. In the Flanker task, this is typically done by a presenting a centrally located stimulus (for example an arrow), which is flanked on both sides by either congruent (arrows pointing in the same way) or incongruent stimuli (arrows pointing in the opposite way) (Eriksen, 1995). Two main measures reflect interference control: 1) difference in reaction time between congruent and incongruent trials, also called the Flanker effect (Fan et al., 2002) and 2) the difference in response accuracy between congruent and incongruent trials (Eriksen, 1995). In the Simon task, participants are asked to press a left- or right-sided key for specific visual stimuli. The task requires inhibition of spatially incompatible responses (i.e., right-sided response for left-sided visual targets). Interference control is indicated by lower accuracy and/or longer reaction times for incongruent versus congruent trials (Simon and Rudell, 1967). In the Stroop task, interference control is typically measured by asking participants to inhibit the automatic response to read words and to name instead the color in which the words are printed. Three main measures reflect interference control: 1) number of errors, 2) the associated reaction time and 3) the contrast time score (the discrepancy between reading words and the inhibition of reading words) (Stroop, 1935). Studies mostly used the original Stroop task, but the Delis-Kaplan Executive Function System Color-Word Interference Test has also been used (D-KEFS; Delis, Kaplan, & Kramer, 2001) even as an emotional/trauma version of the Stroop (with emotional/trauma related words), a day and night version for young children or a subliminal trauma version (see Table 1). Although the Stroop is officially supposed to measure interference control (Nigg, 2000), it has also been proposed to measure prepotent response inhibition (Friedman and Miyake, 2004). Therefore, we decided to look at the effect of trauma exposure on the Flanker, the Simon and Stroop task separately.

2.4. Quality of included studies

We assessed all papers for study quality using the Assessment Tool for Quantitative Studies of the Effective Public Health Practice Project (Thomas et al., 2004). Two independent coders rated the studies with a global quality rating of weak, moderate, or strong. There was complete consensus between the two reviewers at global rating level. Eleven papers were coded as strong quality, thirteen as moderate quality, and nine as weak quality.

3. Results

The search identified 1722 potentially eligible articles. Thirty-three papers fulfilled the inclusion criteria. As our search strategy was based on the search strategy of the study of Op den Kelder et al. (2018), it is important to note that there was a 60% overlap of included studies. The

Table 1
Characteristics of the included studies, which assessed inhibitory control in trauma-exposed youth compared to non-traumatized controls.

Subjects		N (M/F)	Age M (SD)	IQ M (SD)	Task (Stimulus)	Measure(s)	fMRI/ERP
Asha, 1991	Orphanages	68 (35/33)	10-12**	–	Stroop (color/word)	RT incongruent	–
	Control group*	65 (33/32)	10-12**	–			
Augusti and Melinder, 2013	Maltreatment	21 (7/14)	9.48 (1.54)	> 70	D-KEFS color word interference	RT interference	–
	Control group*	22 (7/15)	9.50 (1.50)	> 70			
Barrera et al., 2013	Sexual abuse victims with PTSD symptoms	13 (5/8)	10.92 (2.63)	–	Stroop (color/word)	RT interference	–
	Sexual abuse victims without PTSD symptoms	26 (5/21)	9.88 (1.68)				
	Control group*	37 (9/28)	10.11 (2.17)	–			
Barrera-Valencia et al., 2017	PTSD	23 (14/9)	12 (2.00)	70 (22.00)	Stroop (color/word)	RT interference	–
	Control group*	24 (7/ 17)	12 (3.00)	84 (16.00)			
Beers and De Bellis, 2002	Maltreatment and PTSD	14 (8/6)	11.38 (2.60)	105.71 (11.89)	Stroop (color/word)	RT interference % errors	–
	Control group*	15 (8/7)	12.17 (1.75)	113.20 (11.69)			
Bruce et al., 2009	Foster children: MTFC-P	10 (unknown)	6.08 (0.57)		Flanker	RT incongruent	–
	Foster children: RFC	13 (unknown)	5.92 (0.68)				
	Control group*	11 (unknown)	5.99 (0.76)				
Bruce et al., 2013	Maltreated foster children	11 (6/5)	10.98 (0.86)	–	Go/No-Go (numbers)	Commission errors	Yes
	Control group*	11 (6/5)	10.91 (0.90)				
Cardona et al., 2012	Institutionalized children with an history of abandonment	18 (18/0)	11.50 (2.52)	> 85	Stroop (color/word)	RT interference	–
	Control group*	18 (18/0)	11.5 (2.52)	> 85			
Carrion et al., 2008	Early life trauma + PTSD	16 (7/9)	13.70 (-)	–	Go/No-go (letters)	Commission errors	Yes
	Control group*	14 (6/8)	13.30 (-)				
Daly et al., 2017	Maltreated college students	66 (17/49)	20.36 (1.38)	113.62 (9.70)	D-KEFS color word interference	RT interference	–
	Control group*	44 (14/30)	20.42 (1.28)	115.48 (9.45)			
De Bellis et al., 2009	Maltreated children without PTSD	38 (19/19)	11.87 (3.08)	> 70	Stroop (color/word)	RT interference	–
	Maltreated children with PTSD	60 (23/27)	11.74 (3.32)				
	Control group*	104 (45/59)	12.52 (3.04)				
Du et al., 2016	Survivor group earthquake	16 (7/8)	20.19 (1.1)	–	Stroop (subliminal trauma)	RT incongruent	yes
	Control group*	14 (8/7)	21.64 (0.63)				
Eigsti et al., 2011	Institutionalized children who are internationally adopted between:			Non-verbal IQ	Go/No-go (Pokémon)	Commission errors	–
	1-12 months	20 (9/11)		93.60 (26.20)			
	13-24 months	14 (5/9)		102.10 (23.30)			
	25-75 months	12 (9/3)		105.80 (28.90)			
	Control group*	24 (17/7)	11.6 (3.0)	107.00(33.80)			
Freeman and Gayle Beck, 2010	Abuse with PTSD	20 (0/20)	14.1 (1.7)	98 (12)	Stroop (trauma words)	RT interference	–
	Abuse without PTSD	13 (0/13)	13.8 (2.0)	101(8)			
	Control group*	20 (0/20)	14.6 (1.7)	105 (10)			
Hart et al., 2018	Maltreatment	22 (15/7)	17.2 (2.4)	91.7 (15.2)	Stop signal task	SSRT	yes
	Control group*	27 (21/6)	17.5 (1,6)	105.4 (10.1)			
Kirke-Smith et al., 2014	Maltreatment	40 (26/14)	15.16 (1.9)	87.37 (12.58)	D-KEFS color word interference	Errors interference	
					Day - night	Combined errors	
	Control group*	40 (23/17)	15.09 (1.9)	100.97 (8.08)			
Kirke-Smith et al., 2016	Maltreatment	40 (26/14)	11-18**	79.33 (-)	D-KEFS color word interference	RT interference	–
	Control group*	40 (23/17)	11-18**	100.97 (-)			
Lamm et al., 2018	Institutionalized children	68 (33/35)	12.63 (0.55)	–	Go/No-go (letters)	Commission errors	–
	Institutionalized foster care children	68 (34/34)	12.63 (0.55)				
	Control group*	52 (23/29)	12.68 (0.39)				

(continued on next page)

Table 1 (*continued*)

Subjects		N (M/F)	Age M (SD)	IQ M (SD)	Task (Stimulus)	Measure(s)	fMRI/ERP
Li et al., 2013	Poly-victimization with PTSD	26 (3/23)	19.62 (0.85)	Raven screening: 50.14 (5.19)	Stop-signal task	SSRT	–
	Poly-victimization without PTSD	38 (1/37)	19.66 (0.67)	49.9 (5.08)			
	non-poly victimization	31 (2/29)	19.65 (0.66)	49.37 (5.43)			
	Control group*	36 (2/34)	19.61 (0.84)	49.27 (5.10)			
Lim et al., 2015	Severe childhood abuse	23 (15/8)	17.2 (2.44)	91.7 (15.20)	Stop signal task	SSRT	yes
	Control group*	27 (21/6)	17.5 (1.63)	105.4 (10.10)			
Loman et al., 2013	Internationally adopted institutionalized children (12 months)	24 (11/13)	11.0 (0.6)	< 75	Go/No-go (letters)	RT no-go's Commission errors	yes
	Internationally adopted institutionalized children (2-8 months)	31 (25/16)	10.8 (0.6)		Flanker (arrows)	RT incongruent	
	Control group*	27 (13/14)	11.0 (0.7)				
McDermott et al., 2012	Institutionalized children with early adversity without foster care intervention.	33 (20/13)	8.53 (0.40)	< 70	Go/No-go (letters)	RT no-go's Commission errors	yes
	Institutionalized children with early adversity and foster care intervention	43 (22/21)					
	Control group*	41 (24/17)	–				
Merz et al., 2013	Children adopted with				Stop signal task	SSRT	–
	9 months	41 (16/25)	13.10 (2.53)	107.51 (10.01)		Commission	
	14 months	34 (13/21)	12.82 (3.57)	99.53 (12.44)		errors	
	Control group*	133 (65/78)	12.26 (2.75)	–			
Mezzacappa et al., 2001	Therapeutic school +abuse	25 (25/0)	10.4 (2.2)	99.9 (12.1)	Stop-signal task	Commission errors	–
	Therapeutic school + no abuse	52 (52/0)	11.2 (2.3)	105.7 (16.2)			
	Control group*	48 (48/0)	9.8 (1.6)	100.0 (13.1)			
Moradi et al., 1999	PTSD	23 (11/12)	12.90 (2.92)	–	Stroop (emotional)	RT interference	–
	Control group*	23 (10/13)	13.56 (1.89)				
Mueller et al., 2010	Adopted children with early life stress	12 (3/9)	13.16 (2.58)	105.67 (10.47)	Stop-signal Change task	CSRT	yes
	Control group*	21 (11/10)	13.85 (1.96)	109.62 (12.05)			
Nadeau and Nolin, 2013	Neglect	30 (18/12)	10.67 (1.55)	95.33 (13.09)	D-KEFS color word interference	RT interference	
	Control group*	30 (19/11)	10.22 (1.06)	105.17 (16.54)			
Navalta et al., 2006	Childhood sexual abused	26 (0/26)	20.0 (-)	–	Go/No-go task (figures)	Commission errors RT no-go-trials	–
	Control group*	19 (0/19)	194 (-)				
Park et al., 2014	Children witnessed single death with PTSD.	26 (6/20)	12.42 (0.30)	–	Flanker task (arrows)	RT incongruent	–
	Children witnessed single death without PTSD.	25 (9/16)	12.45 (0.44)				
	Control group*	30 (9/21)	12.56 (0.28)				
Patriquin et al., 2012	Childhood sexual abuse	28 (0/28)	18.84 (0.96)	–	Stroop (emotional)	RT interference	–
	Adult victimization Revictimization	35 (0/35)					
		31 (0/31)					
	Control group*	29 (0/29)	–				
Puetz et al., 2016	Maltreatment	21 (10/11)	12.47 (1.66)	WASI-IQ 105.24 (15.80)	Stroop (emotional)	RT interference	Yes
	Control group*	19 (8 /11)	12.91 (1.32)	106.21 (12.36)			
Quamma, 1997	Maltreatment	30 (14/16)	5.1 (0.48)	WPPSI-R. 6.93 (3.01)	Stroop (day and night)	% errors interference	
	Control group*	28 (12/16)	5.1 (0.41)	8.30 (3.37)			
Tibu et al., 2016	Institutionalized children	90 (43/47)	8.63 (-)	–	Flanker task (arrows)	RT incongruent	
	Control group*	56 (26/30)	8.44 (-)				

* Non-traumatized and non-psychiatric control group.
** Studies did not provide a mean and standard deviation, but only an age-range.

differences in included studies were due to: (1) a different search strategy and different inclusion criteria, (2) inclusion of more recent studies (2017–2018), and (3) inclusion of emotional versions of inhibitory tasks. The results of the selected studies are presented in three sections in order to answer our research questions: (1) Trauma exposure and inhibitory control subcomponents, (2) Trauma exposure and inhibitory control from a developing perspective, and (3) Prolonged stress and inhibitory control. Table 1 provides an overview of all included studies. Besides these three sections, we elaborate on secondary measures of task performance such as brain imaging results and ERP in studies that were included.

3.1. Trauma exposure and inhibitory control subcomponents

3.1.1. Prepotent response inhibition

Thirteen articles reported about prepotent response inhibition in trauma-exposed youth compared to a non-trauma-exposed group. Seven of them used the go/no-go task and six the stop signal task (one study used a modified version of the stop signal, the stop change task (Nelson et al., 2007)).

3.1.1.1. Go/no-go task. Two of the seven studies (28.6 %) found reduced prepotent response inhibition for trauma-exposed youth on the go/no-go task compared to the control group (Eigsti et al., 2011; Lamm et al., 2018). Five studies (71.4 %) reported that trauma-exposed youth did not perform worse on the go/no-go task compared to the control group (Bruce et al., 2013; Carrion et al., 2008; Loman et al., 2013; McDermott et al., 2012; Navalta et al., 2006). Interestingly, four of these studies did find group differences on other measures such as brain activity measured using fMRI or ERP during the go/no-go task (see Trauma exposure, inhibitory control and brain measures (Bruce et al., 2013; Carrion et al., 2008; Loman et al., 2013; McDermott et al., 2012)). The one study that did not found group differences included a relative old sample group of college woman (M = 20 years; Navalta et al., 2006).

3.1.1.2. Stop-signal task. Four of the six studies (66.7 %) found reduced prepotent response inhibition for trauma-exposed participants in the stop signal task (Li et al., 2013; Merz et al., 2013; Mezzacappa et al., 2001; Mueller et al., 2010). Two studies (33.3 %) showed no impeded prepotent response inhibition for trauma-exposed participants on the stop signal task (Hart et al., 2018; Lim et al., 2015). Interestingly, these studies (that used the same sample) found a different pattern of brain activity on fMRI for traumatized children during task-performance (see Trauma exposure, inhibitory control and brain measures; Hart et al., 2018; Lim et al., 2015).

In summary, taking the prepotent response inhibition tasks together, six studies found that trauma exposure was related to impeded prepotent response inhibition, another six studies found no group differences on behavioral tasks but on other measures (i.e., on brain activity in fMRI and ERP), and one study found no differences between trauma and non-trauma groups. This latter study contained relatively old participants (see Trauma exposure and inhibitory control from a developing perspective). Additionally, four out of six studies that found impeded prepotent response inhibition were rated as moderate or strong study quality. From the studies that found indirect or no effects, three out of seven were rated as moderate or strong study quality.

3.1.2. Interference control

Twenty-one articles examined interference control. Four of them used the Flanker task, seventeen used the Stroop task, and none used the Simon task.

3.1.2.1. Flanker task. Two of four studies (50 %) found poorer interference control in trauma-exposed youth on a Flanker task (Park et al., 2014; Tibu et al., 2016). The two studies (50 %) that didn't reveal group differences on flanker task performance, found a different pattern of brain activity on ERP for trauma-exposed children during task-performance (Loman et al., 2013; Bruce et al., 2009).

3.1.2.2. Stroop task. Nine of the seventeen studies (52.9 %; four using the original Stroop task, three the D-KEFS CWIT task, and two the emotional/trauma version) found reduced interference control in trauma-exposed participants on a Stroop task (Barrera et al., 2013; Beers and De Bellis, 2002; Cardona et al., 2012; De Bellis et al., 2009; Freeman and Gayle Beck, 2010; Kirke-Smith et al., 2016, 2014; Moradi et al., 1999; Nadeau and Nolin, 2013). Eight studies (47.1%; two using the original Stroop task, two the D-KEFS CWIT task, two the emotional/trauma, one the subliminal trauma, and one the day-night version) showed no impeded interference control for trauma-exposed participants (Asha, 1991; Barrera-Valencia et al., 2017; Patriquin et al., 2012; Quamma, 1997; Daly et al., 2017; Augusti and Melinder, 2013; Du et al., 2016; Puetz et al., 2016). Interestingly, three of these studies found group differences on other measures such as a different pattern of brain activity during the Stroop task (Du et al., 2016; Puetz et al., 2016) or an increase of self-reported executive function problems including inhibitory control, measured with the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2002) (Daly et al., 2017). Of the remaining five studies, two studies included a small sample (Augusti and Melinder, 2013) or a very young age group (M = 3.11; (Quamma, 1997)) possibly leading to problems with validity, power and a floor effect respectively.

In summary, taking the interference control tasks together, eleven studies found that trauma exposed youth showed impeded interference control, and another five studies found group differences on other measures (i.e., brain activity in fMRI or self-reported cognitive complains in daily life as measured by the BRIEF). Five studies did not find differences for trauma-exposed and non-trauma exposed groups, with two studies possibly suffering from a floor effect (see “Trauma exposure and inhibitory control from a developing perspective”) and one lacking power. Additionally, seven of the eleven studies that found impeded inhibitory control were rated as strong study quality, whereas only two of the ten studies that did not find direct effects was rated as strong study quality.

3.1.3. Overall conclusion inhibitory control

In conclusion, 46.2 % of the studies found differences for trauma-exposed and non-trauma-exposed group for primary measures of prepotent response inhibition, and an additional 46.2 % on other measures (fMRI and ERP) versus 52.3 % and 23.8 % (fMRI, ERP and BRIEF) respectively for interference control. Thus, both the results of behavioral performance and brain activity measures, most studies reported lower levels of inhibitory control in trauma-exposed youth compared to non-trauma-exposed youth. We found the same pattern for prepotent response inhibition and interference control.

3.2. Trauma exposure and inhibitory control from a developing perspective

The age of the participants in the 33 included studies ranged from 3 to 25 years old, which is a wide age-range including several developmental stages. Based on a commonly used developmental age subdivision (Berk, 2000), we examined effects of trauma on inhibitory control in four developmental stages; early childhood (2–5), middle childhood (6–11), adolescence (12–17) and young adulthood (18–25). Since the results for prepotent response inhibition and interference control were similar, we combined these two inhibition domains.

3.2.1. Early childhood

One study examined inhibitory control in this age group (Quamma, 1997) and found no impeded inhibitory control for trauma-exposed youth.

3.2.2. Middle childhood

The 10 studies in this age group mostly included children in the age range from 8 to 11 years (see Table 1 for exceptions). Five studies (50%) reported reduced inhibitory control for trauma-exposed participants (Eigsti et al., 2011; McDermott et al., 2012; Mezzacappa et al., 2001; Nadeau and Nolin, 2013; Tibu et al., 2016). Five studies (50 %) found no differences between trauma-exposed and non-trauma-exposed participants for inhibitory control in this age group (Asha, 1991; Augusti and Melinder, 2013; Bruce et al., 2013, 2009; Loman et al., 2013). Despite the fact that there was no effect on task performance, three studies revealed a different pattern of brain activity during the go/no-go and Flanker task (Bruce et al., 2013; Loman et al., 2013; McDermott et al., 2012). Of the two remaining studies, one included a small sample size (Augusti and Melinder, 2013).

3.2.3. Adolescence

Seventeen studies examined this age group. Most of them included children in the age range 12–15 (see Table 1 for exceptions). Twelve studies (70.6 %) found reduced inhibitory control after trauma exposure in this age group (Barrera et al., 2013; Beers and De Bellis, 2002; Cardona et al., 2012; De Bellis et al., 2013; Freeman and Gayle Beck, 2010; Kirke-Smith et al., 2016, 2014; Lamm et al., 2018; Merz et al., 2013; Moradi et al., 1999; Mueller et al., 2010; Park et al., 2014). Five studies (29.4 %) did not find a difference between trauma-exposed and non-trauma-exposed youth on a primary measure of task performance` (Carrion et al., 2008; Hart et al., 2018; Lim et al., 2015; Puetz et al., 2016; Barrera-Valencia et al., 2017). Interestingly, four of these studies found differences in brain activity during task performance (Carrion et al., 2008; Hart et al., 2018; Lim et al., 2015; Puetz et al., 2016; see “Trauma, inhbitory control and brain measures”) and one study did not (Barrera-Valencia et al., 2017).

3.2.4. Young adulthood

Five articles included participants in this oldest age group of interest in this review. Most studies included participants in the age range 18–21 years old (see Table 1 for exceptions). One of the five (16.7 %) studies found reduced inhibitory control in poly-victimized college students with PTSD (Li et al., 2013). Four studies (83.3 %) did not (Navalta et al., 2006; Patriquin et al., 2012), although two of these reported effects on other outcome measures (i.e. altered brain activity: Du et al., 2016; cognitive complains in daily life: Daly et al., 2017).

In conclusion, impeded inhibitory control was found mostly in the age categories 6–11 and 12–18, where effects of trauma on primary task measures were found in 50 % and 583 % of the studies (with an additional 30 % and 333 % of the studies reporting effects of other measures such as fMRI, ERP or BRIEF questionnaire). In contrast, none of the trauma-exposed participants from 0 to 5 and only 20 % from 18 to 25 (with an additional 33.3 % with effects on secondary measures) displayed impeded inhibitory control, measured by task performance. In the discussion the implications of these results are further discussed.

4. Prolonged stress and inhibitory control

4.1. Prolonged stress

Most of the selected studies (94 %) examined the effects of prolonged trauma-related stress on inhibitory control, such as childhood maltreatment. Only two of the included 33 papers (6 %) specifically examined single trauma victims (versus complex trauma victims or versus no-trauma controls), i.e., an earthquake (Du et al., 2016) and witnessing a deadly trap (Park et al., 2014). In only one of these studies (50 %) trauma-exposed children had poorer inhibitory control than non-trauma-exposed children (Park et al., 2014), but this was the case for those with PTSD only, suggesting an effect of PTSD rather than trauma. The other study (50 %) did not find a difference in inhibitory control between the single trauma-exposed and non-trauma-exposed participants. It has to be noted that this study contained an older age-group (M = 20.19) (Du et al., 2016).

4.2. PTSD

Only five of the 33 (15.2 %) articles compared a trauma-exposed group with PTSD to a trauma-exposed group without PTSD and a non-trauma-exposed control group (Barrera et al., 2013; De Bellis et al., 2013; Freeman and Gayle Beck, 2010; Li et al., 2013; Park et al., 2014), thereby providing information of the effects of trauma versus the effects of PTSD. Four of these five studies (80 %) found an effect of trauma on inhibitory control regardless of PTSD (Barrera et al., 2013; De Bellis et al., 2013; Freeman and Gayle Beck, 2010; Li et al., 2013). The only (20 %) study that found an effect of PTSD was Park et al. (2014), who compared children after a single trauma with and without PTSD to a non-trauma-exposed control group. They found that the children with PTSD performed significantly poorer on the inhibitory task.

In conclusion, the results of studies examining prolonged versus isolated stress suggest that chronicity is an import factor in the decline of inhibitory control, although just a few studies have examined this, and these are just preliminary conclusions. In the only study that found poorer inhibitory control after single trauma exposure, this effect was explained by PTSD. In the discussion the implications of these results are further discussed.

4.3. Trauma, inhibitory control and brain measures

As noticed before, several studies revealed a different pattern of brain activity in trauma-exposed youth during inhibitory tasks (Bruce et al., 2013; Carrion et al., 2008; Du et al., 2016; Hart et al., 2018; Lim et al., 2015; Mueller et al., 2010; Puetz et al., 2016). Of the total of 33 included studies, there were seven fMRI (22.6 %) and two ERP (6.5 %) studies assessing brain activity during task performance.

4.3.1. fMRI

All seven studies (100 %) found differences in brain activation between trauma-exposed and non-trauma-exposed youth during different inhibitory tasks (Bruce et al., 2013; Carrion et al., 2008; Du et al., 2016; Hart et al., 2018; Lim et al., 2015; Mueller et al., 2010; Puetz et al., 2016). Non-trauma-exposed controls exhibited a stronger activation during an inhibitory task in several brain regions such as the right anterior cingulate cortex, the middle frontal gyrus, and the right ligual gyrus (Bruce et al., 2013) and the middle frontal cortex (Carrion et al., 2008). Trauma-exposed participants exhibited a stronger activation in several other brain regions, such as the left inferior parietal lobule (Bruce et al., 2013), the inferior prefrontal cortex and striatum (Mueller et al., 2010), the dorsomedial frontal cortex and the middle frontal cortex (Hart et al., 2018; Lim et al., 2015), the left ventral anterior cingulate cortex and the bilateral parahippocampal gyrus (Du et al., 2016); left anterior insula, extending info left ventrolateral prefrontal cortex/ orbitofrontal cortex; left amygdala, left inferior parietal cortex and bilateral visual association cortex (Puetz et al., 2016).

4.3.2. ERP

Two ERP studies (100 %) found both deviating pattern of event-related potentials (ERP) in trauma-exposed youth compared to non-trauma-exposed controls (Loman et al., 2013; McDermott et al., 2012). They did not find group differences on task performance (Flanker or go/no-go task) but revealed a differential reactivity between correct and error responses via error-related negativity (ERN) in trauma-exposed participants compared to their non-trauma-exposed controls.

In conclusion, the results of studies using brain measurements all revealed (100 %) a different pattern of brain activity in trauma-exposed participants during an inhibitory task compared to their non-trauma-exposed controls. Based on the current fMRI and ERP studies it is hard to reveal one specific pattern of brain activity in trauma-exposed youth.

This might be due to the fact that the studies examined brain activity in different ways and during different kinds of inhibitory tasks, probably resulting in different brain activation patterns.

5. Discussion

The aim of this systematic review was to give a literature update and gain more insight in inhibitory control in trauma-exposed youth compared to their non-trauma-exposed peers. Specifically, we focused on two subcomponents of inhibitory control: prepotent response inhibition and interference control. We examined inhibitory control and trauma exposure from a developmental perspective and explored the effects of prolonged stress (i.e., prolonged trauma or PTSD). Our findings were in line with earlier research (Aupperle et al., 2012; Malarbi et al., 2016; Op den Kelder et al., 2018) and indicate that especially youth exposed to prolonged stress might be impeded in both subcomponents of inhibitory control and that this seems to become less pronounced by aging.

5.1. Trauma exposure and inhibitory control subcomponents

Our results suggest that trauma-exposed youth may encounter difficulties in inhibitory control. Compared to non-trauma-exposed controls, they often performed worse on an inhibitory task or showed a different pattern of brain activity during the task. This was the case for prepotent response inhibition as well as interference control without remarkable differences. This may be explained in three ways. First, trauma exposure may equally affect both subcomponents of inhibitory control. It is known that these subcomponents are closely related and share an underlying neural network which is known to be extremely vulnerable to prolonged stress (i.e. prefrontal cortex; Bari and Robbins, 2013) probably rendering them both fragile to trauma exposure. Some researchers indeed argue that the high correlation between prepotent response inhibition and interference control indicates that they can better be seen as one inhibitory control system (Friedman and Miyake, 2004). Second, we might not be able to reveal differences between the two subcomponents due to a problem with task validity, a well-known problem for all tasks in the EF domain. Because of specificity issues, executive function measurements virtually always assess several different components of EF as well as other nonexecutive functions (Suchy, 2009). Therefore, it might even be harder to measure two very closely related cognitive functions such as prepotent response inhibition and interference control. It has for example been debated whether the Stroop task should be classified as an interference control task (Nigg, 2000) or a prepotent response inhibition task (Friedman and Miyake, 2004). Third, studies used different outcome measurements which makes a good comparison difficult. The lack of agreement in inhibitory tasks, subdivisions and measurement outcomes make it complicated to gain a fruitful insight in the effect of trauma on subcomponents of inhibitory control. Future research may unravel specific facets of inhibitory control, thereby providing more insight in these elements and the way they are influenced by trauma exposure.

5.2. Trauma exposure and inhibitory control from a developing perspective

Our results revealed that inhibitory control was mostly impeded in trauma-exposed children from 6 to 11 and 12–17 years old, either directly on inhibitory task performance indirectly as reflected in distinct patterns of brain activation. Interestingly, we found no evidence that inhibitory control was impeded in very young trauma-exposed children (age < 6) and in those older than 17 years. Regarding the youngest group, developmental studies pointed out that inhibitory control is even quite a challenge for non-trauma-exposed children under the age of 6. Dowsett and Livesey (2000) for example, showed that although children under the age of 6 might be able to understand and verbalize when a response should be inhibited, they may often not succeed in inhibiting their response. Thus, there might be a floor effect in this group, masking the influence of trauma exposure. Another explanation might be that young children are easily distracted when performing a non-enjoyable inhibition task. Regarding the oldest age category (18–25 years old), a possible suggestion might be that youth employ alternative strategies by aging, which helps them to compensate and to perform well on the inhibitory task. Support for this notion comes from the fact that several studies who failed to report an effect of trauma exposure on task performance, showed an altered pattern of brain activity during the inhibitory task. If youth develop compensatory strategies, they might perform well on isolated laboratory tasks, but they may not be able to execute this compensation strategy well in complex and more demanding daily life situations. Supporting evidence for more problems in everyday life comes from one study in which trauma-exposed 18+ participants reported significant more cognitive problems in daily life than their non-trauma-exposed counterparts (on the BRIEF), while there were no differences on task performance (Daly et al., 2017). This may indicate that inhibitory control problems can be missed on neuropsychological assessment of trauma-exposed youth at an older age, while still having a negative impact on more complex daily functioning. Future studies using more complex or ecologically valid outcome measures and measures of proactive forms of inhibitory control are merited to investigate inhibitory control, and to get a clearer picture of specific deficits and (adaptive) coping strategies in trauma-exposed youth. One approach may be to measure ‘hot’ executive functions referred to as executive functions used for more complex motivationally and emotionally salient goal-directed behavior (Zelazo and Carlson, 2012). We included too few emotional valent tasks to draw conclusions about ‘hot’ EF, but future research focusing specifically on hot versus cold EF might help to increase detection of inhibitory control problems in trauma-exposed youth. Finally, other aspects of inhibitory control, such as proactive inhibition, should also be examined, as well as the effect of and interaction between task-relevance and stimulus salience (see for example Mirabella, 2018).

5.3. Prolonged stress and inhibitory control

Most of the studies examined prolonged stress (i.e., prolonged trauma or PTSD), while only a few examined isolated stress (i.e., single trauma). Careful conclusions based on these few studies suggest that prolonged exposure to stress may play an important role in the relationship between trauma exposure and inhibitory control. This is in line with the idea of Teicher et al. (2003) that an increased density of glucocorticoids receptors due to prolonged stress could affect the maturation of the PFC and subsequently negatively impact its associated capacities, such as inhibitory control. In our review the effect of prolonged trauma on inhibitory control seems to be independent of PTSD, although the effect of prolonged stress as a result of PTSD remains unclear. Note that the included studies operationalized trauma in many different ways with only a few using standardized measurements like the Childhood Trauma Questionnaire or the Impact of Event Scale. If indeed especially prolonged stress (i.e., prolonged trauma) impedes inhibitory control in youth, then (early) interventions may prevent or even reverse this process. Future research could help us to provide more insight in the reversibility of these effects. Research on trauma and inhibitory control would also profit from a consistent use of measurements across studies.

5.4. Trauma exposure, inhibitory control and brain measures

Although it was not the primary aim of this review, the additional neurobiological findings in this review suggested effects of trauma exposure on brain patterns during inhibitory tasks. All studies included in our review that used brain measures showed an altered pattern of brain activity of trauma-exposed versus non-trauma-exposed youth during the task, even when there was no difference in task performance. This might suggest that trauma-exposed youth activated other brain regions to compensate, helping them to show the same task performance. Based on the included fMRI studies, it remains unclear what these compensatory strategies exactly are. The lack of a consistent pattern of brain activity in trauma-exposed youth might be due to the fact that the fMRI studies examined brain activity in different ways for example whole brain versus region of interest analyses and they used different inhibitory tasks. It has been speculated that the different brain activation patterns in trauma-exposed youth might reflect that they rely more on working memory and sustained attention (Bruce et al., 2009). It has also been proposed that trauma-exposed youth rely more on networks of error-detection to compensated for their inhibitory problems (Hart et al., 2018; Lim et al., 2015). Future research may provide more insight in these alternate brain patterns and possible compensation strategies.

5.5. Strengths & limitations

The findings of the current study must be interpreted in the context of a number of limitations. First, the included studies used different trauma and inhibitory control outcome-measures and none of them conducted a pre-trauma and post-trauma comparison to evaluate the causal direction between trauma exposure and inhibitory control deficits. Thus, it is not clear whether impeded inhibitory control is a risk factor for trauma exposure or a plausible consequence (Aupperle et al., 2012). Second, to delineate our search we have limited the inclusion of task types that measure inhibitory control. We might have missed specific tasks that could provide relevant information. Third, the current study provides a descriptive overview of literature. The systematic description of the results of the included studies suggests that there is no difference regarding the two inhibitory subcomponents. However, this lack of difference should be tested using a meta-analytic approach. Using a meta-analytic approach, various effect sizes within and across studies could be taken into account and moderators such as developmental stage and prolonged stress could let us to investigate the relationship between trauma exposure and inhibitory control more in depth. Fourth, 27% of the studies were rated as a weak study quality. This means that we have to interpret our results with caution. Finally, as all systematic reviews, also our study is limited by the high possibility of publication bias.

5.6. Overall conclusion

Trauma, especially prolonged stress (i.e., prolonged trauma or PTSD), might impeded inhibitory control in developing youth. At a later age, these problems might become less prominent possibly by employing compensation strategies reflected in a different pattern of brain-activity during inhibitory task-performance. This compensation strategy may not be sustainable in daily life, though being more complex and demanding. Therefore, inhibitory control problems can easily be overlooked, despite culminating in major problems in life. We found no evidence for delineating prepotent response inhibition and interference control, which may have important methodological implications and possibly consequences for theories on inhibitory control. In any case, future studies using more complex or ecologically valid outcome measures and measures of proactive inhibitory control are merited to investigate inhibitory control, and to get a clearer picture of specific deficits and (adaptive) coping strategies in trauma-exposed youth. This might provide further insight in the effect of trauma on inhibitory control and the reversibility of these effects.

Appendix A

Full electronic search strategy performed on 27th July 2019.

EMBASE

Ovid, Embase Classic + Embase 1947 to present

#1 Child abuse and trauma

posttraumatic stress disorder/ OR exp child abuse/ OR physical abuse/ OR emotional abuse/ OR childhood trauma survivor/ OR exp violence/OR adoption/ OR adopted child/ OR foster care/ OR institutionalization/ OR institutionalized adolescent/ OR institutionalized child/ OR life event/ OR early life stress/ OR psychotrauma/ OR aircraft accident/ OR accident/ OR home accident/ OR traffic accident/ OR accident/ OR exp victim/ OR crime/ OR war crime/ OR sexual crime/ OR natural disaster/ OR mass disaster/ OR disaster/ OR emergency shelter/ OR refugee camp/ OR psychotrauma assessment/ OR exp human trafficking/ OR exp child welfare/ OR battered child syndrome/ OR abandoned child/ OR institutionalized child/ OR orphanage/ OR exp war/ OR exp refugee/ OR (ptsd* OR ptss* OR post-traumatic stress* OR posttraumatic stress* OR traumatic stress* OR psychotrauma* OR psycho-trauma* OR neglect* OR abuse OR maltreat* OR sexual abuse OR child mistreatment OR childhood trauma OR adopted OR adoption OR foster care OR institutionaliz* OR trauma exposure OR early adversity OR emotional trauma OR psychological trauma OR violence OR accident* OR crime* OR disaster* OR victim* OR war OR wars OR human traffic* OR stress disorder* OR ((stressor OR trauma) ADJ2 disorder*) OR traumatic experience* OR traumati#ed youth OR violen* OR armed conflict* OR civil disorder* OR ethnic cleansing OR genocid* OR political instability OR political violence OR political unrest OR postwar OR terrorism OR accompanied minor* OR asylum* OR displaced people OR refugee* OR unaccompanied minor*).ti,ab,kw.

Results: 789.278

#2 Children (0-25)

infant welfare/ OR toddler/ OR child/ OR child, preschool/ OR adolescence/ OR "minor (person)"/ OR young adult/ OR juvenile/ OR child, abandoned/ OR child, adopted/ OR child, foster/ OR child, orphaned/ OR child, unwanted/ OR disabled children/ OR homeless youth/ OR (infant* OR toddler* OR child* OR teen* OR adolesc* OR youth* OR minors* OR young adult* OR young people OR preschool* OR kid OR kids OR prepubescen* OR prepuberty* OR puberty OR pubescen* OR under ag* OR underag* OR juvenile* OR girl* OR boy* OR preadolesc* OR high school* student* OR highschool* student*).ti,ab,kw.

#3 cognition

neuropsychology/ OR neuropsychological test/ OR cognitive function test/ OR task performance/ OR cognitive defect/ OR mental task/ OR task performance/ OR cognition assessment/ OR cognition/ OR executive function/ OR (neurocogni* OR neuropsycholog* OR cognition OR cognitive processes OR executive function* OR executive dysfunction* OR executive control).ti,ab,kw.

#4 inhibition

self control/ OR selective attention/ OR continuous performance test/ OR exp "inhibition (psychology)"/ OR Stroop test/ OR simon task/ OR (inhibitory control* OR disinhibition OR response-inhibition OR selfcontrol OR interference control OR cognitive inhibition OR selective attention OR focused attention OR executive attention OR effortful control OR cognitive control OR self-regulation OR go-no-go OR stop signal OR flanker OR continuous performance test* OR continuous performance task* OR D-KEFS OR DKEFS OR delis-kaplan OR Stroop OR inhibition task* OR gonogo OR go-nogo OR signal task* OR SSRT* OR stop signal* OR stopsignal* OR stop task* OR day-night OR flanker* OR conflict task* OR inhibition task* OR inhibition test* or simon task* or simon effect*).ti,ab,kw.

1 AND 2 AND 3 AND 4 646 results

NOT Medline 489 results

PsycINFO

Ovid

#1 Child abuse and trauma

Exp Posttraumatic Stress Disorder/ OR emotional trauma/ OR posttraumatic stress/ OR exp child abuse/ OR abandonment/ OR child neglect/ Or emotional abuse/ or domestic violence/ OR battered females/ OR verbal abuse/ or exp sex offenses/ OR intimate partner violence/ OR school violence/ OR exp violent crime/ OR violence/ OR coercion/ OR exposure to violence/ OR survivors/ OR victimization/ OR crime victims/ OR human trafficking/ OR relational aggression/ OR exp harassment/ OR pedophilia/ OR falls/ or home accidents/ or pedestrian accidents/ or exp transportation accidents/ or accidents/ OR exp disasters/ OR foster care/ OR foster parents/ OR foster children/ OR "adoption (Child)"/ OR adopted children/ OR institutionalization/ OR orphanages/ OR orphans/ OR exp stimulus deprivation/ OR kidnapping/ or exp suicide/ or homicide/ OR political revolution/ OR terrorism/ OR war/ OR refugees/ OR asylum seeking/ OR political asylum/ OR (ptsd* OR ptss* OR post-traumatic stress* OR posttraumatic stress* OR traumatic stress* OR psychotrauma* OR psycho-trauma* OR neglect* OR abuse OR maltreat* OR sexual abuse OR child mistreatment OR childhood trauma OR adopted OR adoption OR foster care OR institutionaliz* OR trauma exposure OR early adversity OR emotional trauma OR psychological trauma OR violence OR accident* OR crime* OR disaster* OR victim* OR war OR wars OR human traffic* OR stress disorder* OR ((stressor OR trauma) ADJ2 disorder*) OR traumatic experience* OR traumati#ed youth OR violen* OR armed conflict* OR civil disorder* OR ethnic cleansing OR genocid* OR political instability OR political violence OR political unrest OR postwar OR terrorism OR accompanied minor* OR asylum* OR displaced people OR refugee* OR unaccompanied minor*).ti,ab,id.

#2 Children (0-25)

(neonatal birth 1 mo OR infancy 2 23 mo OR preschool age 2 5 yrs OR school age 6 12 yrs OR adolescence 13 17 yrs).ag. OR child welfare/ OR adopted children/ OR foster children/ OR orphans/ OR predelinquent youth/ OR juvenile delinquency/ OR (infant* OR toddler* OR child* OR teen* OR adolesc* OR youth* OR minors* OR young adult* OR young people OR preschool* OR kid OR kids OR prepubescen* OR prepuberty* OR puberty OR pubescen* OR under ag* OR underag* OR juvenile* OR girl* OR boy* OR preadolesc* OR high school* student* OR highschool* student*).ti,ab,id.

#3 cognition

neuropsychology/ OR neuropsychological assessment/ OR cognitive impairment/ OR cognition/ OR cognitive development/ OR cognitive processes/ OR cognitive science/ OR cognitive psychology/ OR cognitive neuroscience/ OR developmental neuroscience/ OR neuropsychiatry/ OR executive function/ OR cognitive control/ OR cognitive ability/ OR dysexecutive syndrome/ OR (neurocogni* OR neuropsycholog* OR cognition OR cognitive processes OR executive function* OR executive dysfunction* OR executive control).ti,ab,id.

#4 inhibition

Response inhibition/ OR self-control/ OR self-regulation/ OR focused attention/ OR selective attention/ OR "interference (learning)"/ OR stroop effect/ OR stroop color word test/ OR Simon effect/ OR (inhibitory control* OR disinhibition OR response-inhibition OR self-control OR interference control OR cognitive inhibition OR selective attention OR focused attention OR executive attention OR effortful control OR cognitive control OR self-regulation OR go-no-go OR stop signal OR flanker OR continuous performance test* OR continuous performance task* OR D-KEFS OR DKEFS OR delis-kaplan OR Stroop OR inhibition task* OR gonogo OR go-nogo OR signal task* OR SSRT* OR stop signal* OR stopsignal* OR stop task* OR day-night OR flanker* OR conflict task* OR inhibition task* OR inhibition test* or simon task* or simon effect*).ti,ab,id,tm.

1 AND 2 AND 3 AND 4549 results

Medline

Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, and Daily 1946 to July 19, 2018

#1 Child abuse and trauma

Exp Trauma and Stressor Related Disorders/ OR exp violence/ OR exp sex offenses/ OR exp homicide/ OR exp war crimes/ OR exp war exposure/ OR exp crime victims/ OR disaster victims/ OR refugees/ OR accidental falls/ OR accidents, aviation/ OR accidents, home/ OR accidents, occupational/ OR accidents, traffic/ OR exp armed conflicts/ OR adoption/ OR psychological deprivation/ OR (ptsd* OR ptss* OR post-traumatic stress* OR posttraumatic stress* OR traumatic stress* OR psychotrauma* OR psycho-trauma* OR neglect* OR abuse OR maltreat* OR sexual abuse OR child mistreatment OR childhood trauma OR adopted OR adoption OR foster care OR institutionaliz* OR trauma exposure OR early adversity OR emotional trauma OR psychological trauma OR violence OR accident* OR crime* OR disaster* OR victim* OR war OR wars OR human traffic* OR stress disorder* OR ((stressor OR trauma) ADJ2 disorder*) OR traumatic experience* OR traumati#ed youth OR violen* OR armed conflict* OR civil disorder* OR ethnic cleansing OR genocid* OR political instability OR political violence OR political unrest OR postwar OR terrorism OR accompanied minor* OR asylum* OR displaced people OR refugee* OR unaccompanied minor*).ti,ab,kf

#2 Children (0-25)

neonates/ OR infant, newborn/ OR infant/ OR child, preschool/ OR child/ OR adolescent/ OR young adult/ OR child, abandoned/ OR child, adopted/ OR child, foster/ OR child, orphaned/ OR child, unwanted/ OR disabled children/ OR homeless youth/ OR (infant* OR toddler* OR child* OR teen* OR adolesc* OR youth* OR minors* OR young adult* OR young people OR preschool* OR kid OR kids OR prepubescen* OR prepuberty* OR puberty OR pubescen* OR under ag* OR underag* OR juvenile* OR girl* OR boy* OR preadolesc* OR high school* student* OR highschool* student*).ti,ab,kf.

#3 cognition

Neuropsychology/ OR cognition/ OR cognitive dysfunction/ OR neurosciences/ OR cognitive neuroscience/ OR executive function/ OR (neurocogni* OR neuropsycholog* OR cognition OR cognitive processes OR executive function* OR executive dysfunction* OR executive control).ti,ab,kf.

#4 inhibition

neuropsychological tests/ OR stroop test/ OR self-control/ OR exp "inhibition (psychology) "/ OR (inhibitory control* OR disinhibition OR response-inhibition OR selfcontrol OR interference control OR cognitive inhibition OR selective attention OR focused attention OR executive attention OR effortful control OR cognitive control OR self-regulation OR go-no-go OR stop signal OR flanker OR continuous performance test* OR continuous performance task* OR D-KEFS OR DKEFS OR delis-kaplan OR Stroop OR inhibition task* OR gonogo OR go-nogo OR signal task* OR SSRT* OR stop signal* OR stopsignal* OR stop task* OR day-night OR flanker* OR conflict task* OR inhibition task* OR inhibition test* or simon task* or simon effect*).ti,ab,kf.

1 AND 2 AND 3 AND 41020 results

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.neubiorev.2020.06.001.

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