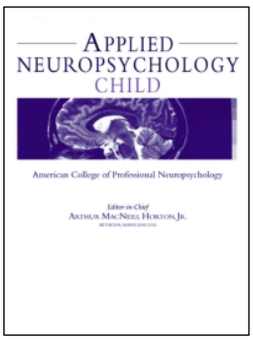

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Neurocognitive deficits in children and adolescents following maltreatment: Neurodevelopmental consequences and neuropsychological implications of traumatic stress

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ABSTRACT

Childhood maltreatment is a significant risk factor for a host of psychiatric, developmental, medical, and neurocognitive conditions, often resulting in debilitating and long-term consequences. However, there is no available neuropsychological resource reviewing the literature on the associated neurocognitive deficits in children and adolescents. This review comprehensively examines the 23 prior studies that evaluated the intellectual, language, visual-spatial, memory, motor, and/or attention/executive functions in children and adolescents following an experience of childhood abuse and/or neglect. Neurocognitive impairments were frequently reported. Impairments in executive functions were the most frequent and severe reported impairments, although intelligence, language, visual-spatial skills, and memory are also at serious risk for compromised development following maltreatment. However, specific factors such as abuse/neglect duration, severity, type, and timing during development were all associated with neurocognition. This indicates that these factors are of greater importance than just the presence of abuse/neglect in identifying risk for neurocognitive compromise. Such neurocognitive deficits appear to be a consequence to the known neurobiological and brain development abnormalities of this population, suggesting traumatic stress can be a potential cause of neurodevelopmental disorders. These findings have critical implications for the clinical practice and research involving children following childhood maltreatment and other types of traumatic stress.

KEYWORDS

Childhood maltreatment; cognition; executive; neuropsychology; traumatic stress

Childhood maltreatment is defined as a child's experience of sexual abuse, physical abuse, emotional abuse, or neglect (Crooks & Wolfe, 2007). Maltreatment occurs in one in eight U.S. children (12.5%) by 18 years of age (Wildeman et al., 2014). In 2012, U.S. state and local child protective services (CPS) estimated that 686,000 children experienced maltreatment, making it a national health concern (U.S. Department of Health and Human Services, Administration for Children, Youth, and Families, Children's Bureau, 2013). Despite positive outcomes for some children and adolescents (Agaibi & Wilson, 2005; Carpenter & Stacks, 2009; Howell, 2011; Skopp, McDonald, Jouriles, & Rosenfield, 2007), childhood maltreatment is a significant risk factor for a host of psychiatric, developmental, medical, and neurocognitive conditions, often resulting in debilitating and long-term consequences (Crooks & Wolfe, 2007; De Bellis, Spratt, & Hooper, 2011; De Young, Kenardy, & Cobham, 2011; Kendall-Tackett, 2010; Pechtel and Pizzagalli, 2011; Wilson, Hansen, & Li, 2011).

Given the high rates and the growing research on long-term consequences, it was deemed critical to the field to provide a detailed review of the literature regarding the reported neurocognitive deficits in children following the experience of childhood maltreatment (i.e., sexual abuse, physical abuse, emotional/verbal abuse, and neglect). Articles considered for inclusion in the current study were searched through the databases PubMed and PsycINFO. Inclusion criteria for this review: the study included only children and adolescents (ages 3–19 years), assessed 1 + neurocognitive domain (e.g., intelligence, memory, executive functions), and involved 1 + type of childhood maltreatment (i.e., physical abuse, sexual abuse, emotional/verbal abuse, and/or neglect). The final review included 23 studies conducted from 1995–2015. In order to provide a comprehensive review of neurocognitive functioning, this review describes the literature on intelligence, executive functions, language, visual-spatial, memory, and motor/psychomotor domains. Prior neurocognitive study results are provided in Table 1, describing the

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Table 1. Prior studies on the neurocognitive deficits following childhood maltreatment.

Study Authors	Sample	Exclusion	Maltreatment Group	Control Group	Maltreatment Type	Domains Assessed	Relevant Non-Significant Findings	Significant Findings	Diagnostic Factors
Augusti and Melinder (2013)	Recruited through CPS and domestic violence shelters	IQ < 70	21 children (mean age: 9.48 years; 8–12 years; 14 females)	22 children (mean age: 9.50 years; 8–12 years; 15 females) recruited through schools in same area as maltreatment group	Physical abuse, neglect, & witness domestic violence	IQ & executive functions	No IQ (89.05 vs. 95.68), set shifting, or inhibition group differences	Maltx group: Lower spatial working memory and working memory strategy. No correlations between executive measures and trauma symptoms	No mention of psychiatric diagnoses
Barrera et al. (2013)	Recruited from non-government organization specializing in sexual abuse; Spanish speaking	None reported	1. Sexual abuse with PTSD ($n = 13$; mean age: 10.92 years; 8 females) 2. Sexual abuse without PTSD ($n = 26$; mean age: 9.88 years; 21 females)	37 children (mean age: 10.11 years; 28 females) recruited from a local school	Sexual abuse	Executive, memory, & construction/ visual-motor skills	No group differences in memory, cognitive flexibility, problem solving, or visual-motor/ construction	Maltx groups: Lower inhibitory control (errors on inhibition task)	No effect of PTSD on neurocognition. No mention of psychiatric diagnoses (excluding PTSD)
Beers and De Bellis (2002)	Recruited through psychiatry outpatient program	Birth complications/ prenatal exposure, medical illness, head injury, obesity/growth failure, IQ < 80, psychotropic medications, anorexia nervosa, PDD, schizophrenia, & substance abuse	14 medication-naïve children with PTSD secondary to maltreatment (mean age: 11.38 years; 6 females)	15 children who were similar in age, race, SES, and IQ (mean age: 12.17 years; 7girls), without axis I diagnosis	Sexual abuse, physical abuse, & witness domestic violence	Language, attention, executive, memory, visual-spatial, & psychomotor functions	No language or psychomotor processing speed group differences	Maltx group: Lower attention/executive (response inhibition, interference control, sustained attention), visual-perception, construction, & delayed memory recall	Comorbid disorders: MDD, DD, SAD, ODD, ADHD-Inattentive Type
Carrey et al. (1995)	Recruited through child protection organizations and an outpatient & day treatment center	Intellectual disability, poor physical health, neurological disorder, serious childhood accidents, & 2 + foster home placements	18 children (7–13 years; 13 females)	18 children matched for age, sex, and level of parental income and education	Physical & sexual abuse	IQ	No non-verbal IQ group differences	Maltx group: Lower verbal IQ (81 vs. 96.4) and overall IQ (88.4 vs. 101.3). Verbal IQ correctly classified 81% of children by abuse status. Significant correlation between verbal and overall IQ and abuse severity (composite of frequency, duration, and severity)	No mention of psychiatric diagnoses

(*Continued*)

Table 1. Continued.

Study Authors	Sample	Exclusion	Maltreatment Group	Control Group	Maltreatment Type	Domains Assessed	Relevant Non-Significant Findings	Significant Findings	Diagnostic Factors
Cowell et al. (2015)	Selected from local department of human services as children with abuse/neglect history	None reported	228 children (89 females)	142 children (60 females) recruited from same neighborhoods as maltreated children, with comparable demographic factors	Physical, sexual, emotional abuse & neglect	Motor, memory, & executive functions	No executive differences between control group and those who experienced maltreatment during one developmental period. No motor or memory group differences	Maltx group: Lower working memory and inhibitory control. Maltreatment during infancy and chronic maltreatment history were associated with lower inhibitory control and working memory	No mention of psychiatric diagnoses
De Bellis et al. (2009)	Recruited through advertisements targeted at DSS agencies	IQ < 70, significant disability, significant medical/neurological disorder, head injury, autism spectrum disorder, low birth weight, & prenatal complications	1. Neglect with PTSD: 22 children (mean age: 8.30 years; 4–12 years; 38% female) 2. Neglect without PTSD: 39 children (mean age: 7.19 years; 3–12 years; 54% female)	45 children (mean age: 7.77 years; 4–11 years; 38% female) similar in age, gender, race, and SES, recruited from surrounding community	Neglect	IQ, fine motor, language, visuospatial, memory, attention, & executive functions	No fine motor group differences	Both maltx groups: Lower IQ (92.36 & 94.51 vs. 101.96), attention/executive (problem solving and visual attention), language (speeded naming, comprehension, and receptive vocabulary), visuospatial (visual-motor, perceptual, spatial), and memory (verbal and visual)	PTSD symptoms were correlated with attention/executive and visuospatial functioning. PTSD severity and emotional abuse severity were correlated with IQ. No mention of diagnoses (excluding PTSD)
De Bellis et al. (2013)	Recruited through statewide advertisements and recruitment presentations targeted at CPS agencies	IQ < 70, significant disability, significant medical/neurological disorder, head injury, schizophrenia/psychosis, anorexia nervosa, autism spectrum disorder, low birth weight, prenatal exposure/complications, & alcohol or substance use disorder	1. With PTSD: 60 children (mean age 11.74 years; 6–17 years; 37 females) 2. Without PTSD: 38 children (mean age: 11.87 years; 6–17 years; 19 females)	105 children (mean age: 12.52 years; 6–17 years; 59 females) without an axis 1 disorder, from schools and community settings in surrounding catchment area	Physical, sexual, emotional abuse, neglect, and witness domestic violence	IQ, fine motor, attention, language, visuospatial, memory, & executive functions	No fine motor differences	Both maltx groups: Lower IQ (94.12 & 95.05 vs. 108.55) attention/executive (sustained attention, problem solving, attention/working memory), language (receptive & comprehension), and delayed memory recall. PTSD group: lower visuospatial performance. Language and memory were associated with sexual abuse history	Lower construction performance found only in the PTSD group. PTSD diagnosis duration was negatively correlated with visuospatial functions. No mention of diagnoses (excluding PTSD)

DePrince et al. (2009)	Recruited through flyers in social service and mental health agencies, community centers, and local businesses	None reported	1. Familial-trauma group ($n = 44$; mean age: 10.70 years; 53% female) 2. Non-familial-trauma group ($n = 38$; mean age: 10.05 years; 57% female)	28 children (mean age: 10.36 years; 67% female) recruited through same methods as clinical groups	Physical abuse, sexual abuse, & witness domestic violence	Executive functions	None	Familial trauma was associated with lower executive functions (composite score of working memory, inhibition, auditory attention, and processing speed; medium effect size)	No mention of diagnoses (excluding PTSD). PTSD symptom severity was not associated with executive functions
Fishbein et al. (2009)	Randomly sampled in five public schools	Prior drug use, learning disability & special education services	553 children (10–12 years)	None	Physical abuse, emotional abuse, neglect (as well as school/parental stressors and community stressors)	IQ & executive functions	None	Self-reported personal stressors (including maltreatment) were associated with lower IQ. Neglect was specifically associated with lower IQ and physical abuse was associated with lower cognitive flexibility	Abuse history was associated with ADHD symptoms
Jaffee and Maikovich-Fong (2011)	Data from a nationally representative sample of children in the United States who have had contact with CPS	None reported	1,777 children (46% female; mean age in months: 35.74; 1–107 months)	None	Physical abuse, sexual abuse, emotional abuse, neglect, & other abuse	IQ	None	Children maltreated in multiple developmental periods had lower IQ than those who experienced abuse/neglect in only one developmental period. The dose of child abuse and neglect was associated with IQ, as chronic child abuse and neglect was associated with lower IQ	No mention of psychiatric diagnoses
Jones et al. (2004)	Recruited through clinical participation in a sexual abuse evaluation within a child protection unit	None reported	21 children (mean age: 7.7 years; 5 months-15 years; 86% female)	None	Sexual abuse	IQ	None	3/21 participants displayed evidence of intellectual impairment (IQ < 70). FSIQ mean for sample: 96.6	No mention of psychiatric diagnoses
Kavanaugh and Holler (2014b)	Chart review of adolescent psychiatric inpatient unit	Medical/neurological condition	1. Maltx with PTSD ($n = 17$; mean age: 15.61 years; 13–19 years; 60% female) 2. Maltx without PTSD ($n = 18$;	18 adolescents (mean age: 15.59 years; 13–19 years; 61% female) within inpatient unit	Physical, sexual, emotional abuse & neglect	Language & executive functions	No group differences in inhibitory control or receptive vocabulary	Language was associated with sexual abuse. Lower confrontational naming was found in the PTSD group. Both maltx groups:	No significant differences between groups in ADHD, mood, anxiety, psychotic, behavioral, and autism spectrum

(*Continued*)

Table 1. Continued.

Study Authors	Sample	Exclusion	Maltreatment Group	Control Group	Maltreatment Type	Domains Assessed	Relevant Non-Significant Findings	Significant Findings	Diagnostic Factors
			mean age: 15.19 years; 13–19 years; 61% female)					Lower overall executive functions, while those with PTSD displayed lower problem solving/planning than those without PTSD. Executive functions and language were associated with anxiety/depressive symptoms	disorders. Language was associated with PTSD status
Kavanaugh and Holler, (2014a)	Chart review of adolescent psychiatric inpatient unit	Medical/neurological condition	15 adolescents (mean age: 15.74 years; 13–19 years; 40% female)	24 adolescents (mean age: 15.29 years; 13–19 years; 37% female) within inpatient unit	Physical, sexual, emotional abuse & neglect	IQ, memory, language, visual-motor, attention/ executive, & processing speed	No group differences in processing speed and memory	Maltx group: Lower IQ, language, visual-motor, attention, cognitive flexibility, and visual-motor organization. When controlling for IQ, only visual-motor organization was lower in maltx group.	No significant differences between groups in ADHD, mood, anxiety, psychotic, behavioral, and autism spectrum disorders.
Kavanaugh et al. (2015)	Chart review of adolescent psychiatric inpatient unit	Medical/neurological condition, bipolar disorder, autism spectrum disorders, & psychotic disorder	49 adolescents (mean age: 15.48 years; 13–19 years; 51% female)	73 adolescents (mean age: 15.19 years; 13–19 years; 66% female) within the inpatient unit	Physical, sexual, emotional abuse & neglect	Language & executive functions	Neglect was not associated with language/ executive functioning. No language group differences	Physical and sexual abuse was specifically correlated with cognitive flexibility/ set shifting and problem solving/ planning, while emotional abuse was correlated with working memory/ attention	No group differences remained after controlling for PTSD; 77% of the total sample had multiple psychiatric disorders (84% in maltx group; 73% in control group)
Kirke-Smith et al. (2014)	Recruited from schools for children with emotional-behavioral difficulties	None reported	40 children (mean age: 181.92 months; ages 11–18 years; 14 females)	40 children (mean age: 181.10 months; 17 females) without medical diagnoses or learning difficulties	Emotional abuse, emotional abuse, sexual abuse, neglect, & witness domestic abuse	IQ & executive functions	No group differences in cognitive flexibility/ switching	Maltx group: Lower IQ (100.97 vs. 87.37), and after controlling for IQ, group had lower working memory, fluency, and inhibition	Psychiatric diagnoses in maltx group: ADHD, anxiety/ depressive disorders, CD/ODD, and other disorder
Mezzacappa et al. (2001)	Participants in a study of the psychometric properties of	None reported	Therapeutic (school environment), Abused group	1. Therapeutic, non-abused group (TN; $n = 52$; mean	Physical & sexual abuse	IQ & executive functions	No IQ group differences (TA IQ = 99.9; TN IQ = 105.7; PS	Within the abuse group (TA), greater difficulty on a task of passive avoidance	No mention of psychiatric diagnoses

	executive control measures		(TA; $n = 25$; mean age: 10.4 years)	age: 11.2 years) 2. Public school group (PS; $n = 48$; mean age: 9.8 years)			IQ = 100). No group differences on tasks of passive avoidance learning and inhibitory control	learning was associated with increased age	
Mills et al. (2011)	Longitudinal birth cohort	None reported	3,796 children with IQ testing completed at 14 year follow-up	None	Child abuse & neglect	IQ	None	Abuse and neglect was independently associated with lower IQ at age 14 years (-4.8 mean difference)	No mention of psychiatric diagnoses
Nolin and Ethier (2007)	Recruited through CPS agencies	Sexual abuse, intellectual disability, birth complications, & neurological disorders	1. Neglect with physical abuse ($n = 56$; mean age: 9.3 years; 39% female) 2. Neglect without physical abuse ($n = 28$; mean age: 8.7 years; 46% female)	53 children (mean age: 8.8 years; 49% female) in the same academic classes as clinical group participants, without significant age/gender/income differences to clinical groups	Neglect & physical abuse	Motor, attention, executive, memory, visual-motor integration, language, & IQ	No language or memory group differences	Neglect groups: Lower visual-motor integration, slowed fine motor speed, auditory attention and working memory. Neglect/physical abuse group had additionally lower performance in problem solving, abstraction, and planning/problem solving	No mention of psychiatric diagnoses
Noll et al. (2010)	Recruited through CPS agencies as part of longitudinal study (18 years)	None reported	84 females (ages 6–16 at start of study)	89 females recruited via advertisements in newspapers and posters in welfare, child care and community facilities in same neighborhoods	Sexual abuse	Receptive language	None	Both groups started with similar receptive language skills, yet abuse history was associated with a lower rate of receptive language development and an earlier age in peak language skills	No mention of psychiatric diagnoses
Perna and Kiefner (2013)	Review of clinical practice patients	Neurological history, major neurodevelopmental disorders, documented cyanotic episode, major medical conditions, & PTSD	18 children (mean age: 11.6 years; 31% female)	23 children (mean age: 11.3 years; 33% female) with similar/comparable SES to maltx group	Physical abuse, emotional abuse, & significant neglect	IQ, processing speed, memory, & executive functions	No group differences in IQ, memory, or processing speed	Maltx group: Lower executive functions (working memory, categories achieved, failure to maintain set, and perseverations) when controlling for IQ	Psychiatric diagnoses: DBD, ODD, CD, MDD, GAD, AD-NOS
Porter et al. (2005)	Recruited through outpatient	Prenatal substance exposure, traumatic brain injury and	24 children (mean age: 10.83 years; 19 females)	24 children (mean age: 10.83 years; 19 females)	Sexual abuse	IQ & memory	No memory differences when	Maltx group: lower verbal IQ (100.99 vs. 112.71) and	Psychiatric diagnoses: PTSD, GAD, MDD, ADHD, ODD,

(*Continued*)

Table 1. Continued.

Study Authors	Sample	Exclusion	Maltreatment Group	Control Group	Maltreatment Type	Domains Assessed	Relevant Non-Significant Findings	Significant Findings	Diagnostic Factors
	mental health agencies	prolonged loss of consciousness (>10 minutes), meningitis, neurological disorders, & IQ < 80		recruited through school district in surrounding area, matched for age, race, gender, handedness, grade, and estimated family income			controlling for IQ and SES	performance IQ (103.06 vs. 112.38). Low performance in attention/ concentration	Bipolar disorder, anxiety disorder, adjustment disorder, DD, reactive attachment disorder
Spann et al. (2012)	Recruited from local community	Axis 1 disorder, medical or neurological disorder, IQ < 70, & loss of consciousness >5 minutes	30 adolescents (mean age: 14.8 years; 12–17 years; 15 females)	None	Physical, sexual, emotional abuse; physical & emotional neglect	Executive functions	None	Perseverative errors on a problem-solving task were correlated with the overall score on a childhood trauma questionnaire. Perseverative errors additionally correlated with physical abuse and physical neglect.	None
Vasilevski and Tucker (2015)	Recruited through admittance to human services social welfare facility	IQ < 80, major language and reading deficits, major visual and auditory deficits, psychiatric or developmental disorders, organ/ systemic disorder or traumatic injury affecting central nervous system	39 adolescents (mean age: 14.6 years; 12–16 years)	43 adolescents (mean age: 14.52 years), matched for age, gender, IQ, and SES recruited from four government secondary schools		IQ, memory, processing speed, visuoperception, attention/ executive functions, &language	No language group differences	Maltx group: Lower inhibitory control, working memory, learning, visuospatial function, and processing speed. Length of child protection involvement correlated with memory	None

Note. CPS = Child Protective Services; IQ = Intelligence Quotient; Maltx = Maltreatment; PTSD = Post-Traumatic Stress Disorder; PDD = Pervasive Developmental Disorder; MDD = Major Depressive Disorder; DD = Dsythymic Disorder = SAD = Separation Anxiety Disorder; ODD = Oppositional Defiant Disorder; ADHD = Attention-Deficit/Hyperactivity Disorder; DSS = Department of Social Services; GAD = Generalized Anxiety Disorder; DBD = Disruptive Behavior Disorder; AD-NOS = Anxiety Disorder-Not Otherwise Specified.

utilized sample size, exclusion criteria, maltreatment/control group demographics, type of abuse/neglect examined, neurocognitive domains assessed, relevant findings, and influence of psychiatric disorder diagnoses. To provide support for a neurodevelopmental conceptualization of childhood stress, we first briefly describe the neurobiological and brain development in traumatic stress research findings, and then provide the review of the neurocognitive impairments in children and adolescents following childhood maltreatment. Treatment and conceptualization implications are described in later sections.

Neurobiological response and brain development

While a comprehensive review of prior neurobiological and neuroimaging studies is well beyond the scope of this article, a basic understanding of such trauma-related consequences provides a framework within which to interpret neurocognitive findings. It is known that stress and trauma during childhood can cause severe disruption or alteration to the child's ongoing neurodevelopmental process (Anda et al., 2006; Taber, Salpekar, Wong, & Hurley, 2011; Teicher, Tomoda, & Andersen, 2006). Within the developmental traumatology framework, originally proposed by De Bellis, a stressor such as childhood trauma activates the body's biological stress response systems for potentially harmful prolonged periods of time (e.g., limbic-hypothalamic-pituitary-adrenal axis, sympathetic nervous system, and serotonin system; De Bellis, 2001; Teicher et al., 2003, 2006). This stress response causes a shift to occur from a process of brain development and growth (required during neurodevelopment) to one of preservation and survival (De Bellis & Zisk, 2014; Teicher et al., 2003). The neurobiological consequences of childhood stress include the elevated presence of catecholamines, corticotropin-releasing hormones, cortisol, and serotonin in the circulatory system (De Bellis et al., 2011; De Bellis & Zisk, 2014; Lupien et al., 2005; Teicher et al., 2003; Twardosz & Lutzker, 2010). As reviewed by De Bellis and Zisk (2014), such elevated levels of stress hormones and neurotransmitters during neurodevelopment may contribute to abnormal apoptosis or pruning, delays in myelination, inhibition of neurogenesis, or decreases in brain growth factors. Thus, the neurobiological response to childhood maltreatment places these children at risk for abnormal brain development.

Hypothesized to be secondary to the neurobiological stress response, researchers have identified structural and functional brain abnormalities in children and adolescents following childhood maltreatment. The majority of studies examining the influence of childhood stress on brain functioning have come from Carrion and colleagues (Carrion, Garrett, Menon, Weems, & Reiss, 2008; Carrion, Haas, Garrett, Song, & Reiss, 2010; Carrion et al., 2001; Carrion, Weems, & Reiss, 2007; Carrion, Weems, Richert, Hoffman, & Reiss, 2010; Richert, Carrion, Karchemskiy, & Reiss, 2006). Following childhood stress and trauma, such structural imaging studies of children and adolescents have identified decreased total brain volume (Carrion, Weems et al., 2010; De Bellis et al., 2002), as well as more specific findings in reduced volume in the prefrontal cortex and hippocampus (Carrion & Wong, 2012; Hart & Rubia, 2012), as well as amygdala and corpus callosum (Hart & Rubia, 2012). Functional imaging studies have also identified reduced hippocampal activation during memory-based tasks and reduced prefrontal cortex activation in inhibitory control tasks (Carrion & Wong, 2012; Hart & Rubia, 2012), while additional imaging studies have identified structural interregional connectivity abnormalities following childhood maltreatment (Hart & Rubia, 2012). Prior studies on the post-event cascade of neurobiological dysregulation and brain abnormalities provide strong evidence of an alteration to nervous system development following childhood stress and trauma (Carrion & Wong, 2012; De Bellis & Zisk, 2014).

Neurocognitive functioning

Intelligence

While the majority of studies identify lowered intellectual functioning in children following maltreatment compared to healthy control groups, group mean IQ scores typically fell between the low average (standard score = 80–89; Carrey, Butter, Peringer, & Bialik, 1995; Kirke-Smith, Henry, & Messer, 2014; Perna & Kiefner, 2013) to average range (standard score = 90–109; De Bellis, Hooper, Spratt, & Woolley, 2009; De Bellis, Woolley, & Hooper, 2013; Jones, Trudinger, & Crawford, 2004; Mezzacappa, Kindlon, & Earls, 2001; Porter, Lawson, & Bigler, 2005). Only one study reported mean overall IQ in the abuse/neglect group to be within the borderline range (standard score = 70–79; Kavanaugh & Holler, 2014a). Results of this specific study are thought to reflect the severity of the sample, as this study is the only study on IQ to be conducted within an acute adolescent inpatient psychiatric setting. However, groups were not matched on important demographic variables, which also likely contributed to differences. In addition to finding group differences,

researchers have found specific correlations between intelligence and abuse severity (Carrey et al., 1995; De Bellis et al., 2009), developmental period of experienced abuse/neglect (Jaffee & Maikovich-Fong, 2011), type of abuse/neglect experienced (Fishbein et al., 2009; Mills et al., 2011), posttraumatic stress disorder (PTSD) severity (De Bellis et al., 2009), and duration of maltreatment (Jaffee & Maikovich-Fong, 2011). In sum, childhood maltreatment is potentially associated with lowered IQ compared to matched control groups, yet IQ frequently remains within the range of typical development. Furthermore, research indicates that the severity, type, timing, and duration of maltreatment have a significant influence on IQ, suggesting a continuum rather than categorical model may be more appropriate in clinical conceptualization.

Attention and executive functions

Second only to IQ, attention/executive functions (EF) are one of the most frequently studied aspects of neurocognition following childhood maltreatment. Only one identified study has not found lower executive performance in children and adolescents following maltreatment (Mezzacappa et al., 2001), although authors noted a greater difficulty on a task of passive avoidance learning was associated with increased age in the abuse group, suggesting a vulnerability to greater challenges during later childhood and adolescence. Alternatively, all other identified studies have found maltreatment-related executive weaknesses. Specific attention/executive weaknesses have been identified in inhibitory/interference control, cognitive flexibility, sustained attention, visual/auditory attention, working memory, fluency, planning/problem solving, and abstraction (Augusti & Melinder, 2013; Barrera, Calderon, & Bell, 2013; Beers & De Bellis, 2002; Cowell, Cicchetti, Rogosch, & Toth, 2015; De Bellis et al., 2009, 2013; DePrince, Weinzierl, & Combs, 2009; Kavanaugh & Holler, 2014a, 2014b; Kavanaugh, Holler, & Selke, 2015; Kirke-Smith et al., 2014; Nolin & Ethier, 2007; Perna & Kiefner, 2013; Spann et al., 2012; Vasilevski & Tucker, 2015).

Attention/executive functioning has been associated with specific types of maltreatment, as physical abuse has been associated with problem solving (Fishbein et al., 2009; Kavanaugh et al., 2015) and cognitive flexibility (Kavanaugh et al., 2015; Spann et al., 2012), sexual abuse with problem solving and cognitive flexibility (Kavanaugh et al., 2015), and emotional abuse with attention/working memory (Kavanaugh et al., 2015). Compared to those with a neglect history, children with a neglect and physical abuse history had additional weaknesses in problem solving, abstraction, and planning/problem solving (Nolin & Ethier, 2007). Attention/executive functioning has also been associated with the presence of PTSD (Kavanaugh & Holler, 2014b), total amount of PTSD symptoms (De Bellis et al., 2009), and self-reported anxious and depressive symptoms (Kavanaugh & Holler, 2014b). The overall trauma experience severity and presence of chronic maltreatment (Cowell et al., 2015; Spann et al., 2012) have additionally been associated with executive functioning. Further, Cowell et al. (2015) found that maltreatment during infancy was associated with lower inhibitory control and working memory, while there were no identified executive weaknesses (compared to healthy controls) in those children who only experienced maltreatment during one developmental period. In sum, significant attention/executive weaknesses have been identified in children and adolescents following childhood maltreatment. These impairments appear to be relatively nonspecific, as weaknesses across executive subdomains have been reported. Specific factors such as the type of maltreatment; amount of maltreatment types; presence of PTSD, PTSD, and anxious/depressive symptoms; duration or frequency; and timing during development all appear to have a role in the risk for subsequent attention/executive weaknesses.

Visual–spatial

One study has found no visual construction differences between children and adolescents following maltreatment compared to those without a maltreatment history (Barrera et al., 2013). Alternatively, remaining studies have identified lower visual–spatial performance in children and adolescents following maltreatment, specifically in aspects of visual perception, visual construction, and visual-motor integration (Beers & De Bellis, 2002; De Bellis et al., 2009, 2013; Kavanaugh & Holler, 2014a; Nolin & Ethier, 2007; Vasilevski & Tucker, 2015). Overall visual-spatial functioning has been associated with PTSD diagnosis duration (De Bellis et al., 2013) and severity (De Bellis et al., 2009). Furthermore, visual-construction group differences remained significant in one study after controlling for the effects of visual-motor integration and visual-perception, with authors hypothesizing such differences likely contains involvement of executive weaknesses such as planning and organization (Kavanaugh & Holler, 2014a). In summary, research has identified significant weaknesses in visual-perceptual, visual-motor, and visual-constructional skills in children and adolescents following maltreatment, with evidence that these weaknesses can be associated with the severity and duration of PTSD.

Language

Multiple studies have found no differences in language skills between children and adolescents following maltreatment compared to control groups (Beers & De Bellis, 2002; Nolin & Ethier, 2007; Vasilevski & Tucker, 2015). Alternatively, group-based differences have been identified in aspects of speeded naming, language comprehension, receptive vocabulary, and confrontational naming (De Bellis et al., 2009, 2013; Kavanaugh & Holler, 2014b). Such language weaknesses have been associated with sexual abuse (De Bellis et al., 2013; Kavanaugh & Holler, 2014b) as well as the presence of PTSD and anxious/depressive symptoms (Kavanaugh & Holler, 2014b). One longitudinal study also found that while children with an abuse history started with similar receptive language skills compared to non-abused peers, they acquired receptive language skills at a significantly lower rate and peaked in receptive language skills at an earlier age than healthy control children (Noll et al., 2010). Prior research has provided mixed results with regard to language abilities following childhood maltreatment, with inconsistent findings potentially due to the association of language abilities to sexual abuse, PTSD, and anxious/depressive symptoms. Furthermore, the delayed rate of acquisition and earlier peak in language development could provide further explanation for such inconsistent findings.

Memory

While memory functioning following stress and trauma has received extensive attention in the adult literature, there is relatively limited research on memory following childhood maltreatment. Five studies have found no differences in memory functioning between children and adolescents following maltreatment compared to control groups (Barrera et al., 2013; Cowell et al., 2015; Kavanaugh & Holler, 2014a; Nolin & Ethier, 2007; Perna & Kiefner, 2013; Porter et al., 2005). Alternatively, other group analyses have identified memory weaknesses in aspects of verbal/visual immediate and delayed recall (Beers & De Bellis, 2002; De Bellis et al., 2009, 2013; Vasilevski & Tucker, 2015). In one study, PTSD was associated with delayed visual recall (De Bellis et al., 2009) while in another study overall memory was associated with sexual abuse (De Bellis et al., 2013). Learning retention has also correlated with the length of child protection involvement (Vasilevski & Tucker, 2015). Results indicate that children and adolescents may experience maltreatment-related verbal and visual memory weaknesses, although findings are inconsistent and appear related to the presence of sexual abuse and length of child protection involvement.

Motor/psychomotor

Motor and psychomotor functions have also been studied in the childhood maltreatment field. Four of the five studies that have examined fine motor speed and dexterity have found no group differences between healthy control groups and children and adolescents with a history of maltreatment (Beers & De Bellis, 2002; Cowell et al., 2015; De Bellis et al., 2009; De Bellis et al., 2013). Alternatively, Nolin and Ethier (2007) found that groups of neglected children, with and without physical abuse, showed slower performance on one task of fine motor speed compared to a group of healthy control children. Further, three of four studies found no psychomotor processing speed differences between groups (Beers & De Bellis, 2002; Kavanaugh & Holler, 2014a; Perna & Kiefner, 2013), although one study did identify slowed psychomotor processing speed in a group of adolescents following childhood maltreatment (Vasilevski & Tucker, 2015). Although the majority of studies have found no influence of maltreatment on motor/psychomotor functioning, there still remains of dearth of literature and future studies are warranted.

Summary

The described studies have identified risk for neurocognitive weaknesses in children and adolescents following childhood maltreatment. Executive functions were the most frequently involved domain, although vulnerability was identified across the majority of neurocognitive domains. However, like any risk factor, sustaining an event of child abuse/neglect does not guarantee neurocognitive impairments. Rather, neurocognitive risk should likely be considered within a continuum and not within a binary or categorical model (i.e., yes or no). Fortunately, many studies also examined factors that can better predict individual patient risk. Specifically, neurocognitive weaknesses were associated with factors such as maltreatment type, severity, duration, and frequency, PTSD presence, duration, and severity, associated anxious/depressive symptom severity, and the developmental period in which maltreatment occurred (infancy associated with worse outcome). More than the basic presence or absence of maltreatment history, these are the critical factors (as well as genetic and environmental factors) involved in potential manifestation of neurocognitive deficits following childhood maltreatment.

Neuropsychological practice implications

Evaluation

Children with a history of maltreatment often present with severe emotional-behavioral, social, and academic

difficulties. In other childhood disorders, neurocognitive functions, such as executive functions, are consistently found to be associated with short and long-term social, emotional-behavioral, and adaptive functioning (Baum et al., 2010; Bornstein, Hahn, & Suwalsky, 2013; Gligorović & Buha Đurović, 2014; Lawson et al., 2014; Park, Yelland, Taffe, & Gray, 2012; Rinsky & Hinshaw, 2011). Thus, executive functions and other neurocognitive impairments are likely playing a significant role in the neurobehavioral difficulties of these children. It has been recently recommended that children should receive a developmental assessment following exposure to childhood maltreatment (National Scientific Council on the Developing Child, 2005/2014). The identification and understanding of neurocognitive impairments in a population such as this one is most appropriately conducted in clinical practice by a pediatric neuropsychologist. A neuropsychological evaluation following maltreatment would likely be most effective if attention/executive functions were areas of focus, along with evaluation of other neurobehavioral domains, such as emotional-behavioral, language, intellectual, visual-spatial, learning/memory, and motor-related skills. Given the potential for severe behavioral dysregulation during the evaluation, detailed behavioral observations, qualitative assessment of the task completion process, and adjustments to the standard session (e.g., frequent breaks, reinforcement protocol) are likely to be critical components of an effective interpretation and conceptualization. In a population characterized by brain development abnormalities and severe behavioral difficulties, a pediatric neuropsychologist is an ideal provider to make the connections between these areas of development, characterize neurocognitive and emotional-behavioral strengths and weaknesses, and guide the treatment of identified weaknesses. As such, the pediatric neuropsychologist can be a useful ally to psychiatrists, social workers, and clinical psychologists in the management of childhood maltreatment.

Treatment

Evidenced-based psychotherapeutic treatments, such as cognitive-behavioral therapy, are considered the first line of intervention for children following childhood trauma (following removal of the trauma-inducing stimulus; Carrion, Wong, & Kletter, 2013; De Bellis & Zisk, 2014). Psychopharmacologic treatment can also effectively treat psychiatric symptoms following childhood trauma (De Bellis & Zisk, 2014). While psychotherapeutic interventions have interestingly shown promise in improving neurocognitive functioning in adults with post-traumatic stress disorder (PTSD; Walter, Palmeiri, & Gunstad, 2010), neurocognitive deficits are not directly treated as part of typical clinical care following childhood trauma. Cognitive training has received increased clinical and research interest for the treatment of neurocognitive deficits that frequently accompany neurological, neurodevelopmental, and psychiatric disorders. Cognitive training or interventions (or rehabilitation/remediation) involves instruction and repeated exercise of specific cognitive tasks or processes, which is expected to improve abilities in the targeted neurocognitive domains. Training typically consists of working directly with a therapist in session or utilizing computerized programs with parental supervision (Robinson, Kaizar, Catroppa, Godfrey, & Yeates, 2014). These improved abilities are expected to transfer to untrained tasks, such as improvements in day-to-day functioning (Robinson et al., 2014; Tajik-Parvinchi, Wright, & Schachar, 2014).

A recent meta-analysis identified benefits of cognitive interventions in childhood neurological disorders, neurodevelopmental disorders, and acquired brain injuries, with large effects found for attention, working memory, and memory and small effects in academic achievement and attention/working memory behavioral rating scales (Robinson et al., 2014). While the implementation of cognitive training has demonstrated utility in treating neurocognitive deficits following *physical* trauma (i.e., traumatic brain injury; Robinson et al., 2014; Slomine & Locascio, 2009), there are no research studies or clinical programs (to our knowledge) that have examined cognitive training following *psychological* trauma. Prior research has indicated a need to examine the utility of cognitive training in "high risk" populations (Wass, 2015), with children that have experienced psychological trauma certainly representing a high-risk group. As cognitive training can be most effective when implemented alongside psychotherapeutic treatments for adult schizophrenia (Kluwe-Schiavon, Sanvicente-Vierira, Kristensen, & Grassi-Oliveira, 2013), there may be utility in implementing cognitive training into post-childhood trauma clinical care alongside psychotherapeutic and psychopharmacologic treatments.

One of the major limitations of prior research studies has been the significant variability in the implemented training programs and the characteristics of the many programs (Robinson et al., 2014; Tajik-Parvinchi et al., 2014). Limond, Adlam, and Cormack (2014) recently proposed a unified model for pediatric neurocognitive interventions (PNI), emphasizing the importance of a multi-tiered intervention targeting cognitive, emotional, and behavioral functioning within the context of ongoing child development. The basic foundation of

this model involves targeting the psychosocial and systemic needs of the child, such as implementing parent skills training, behavioral interventions, and psychotherapy. After addressing this critical foundation, interventions target specific neurocognitive impairments, moving from initial interventions in compensatory strategies with external support, to evaluative skill training, and independent implementation of compensatory strategies (Limond et al., 2014). It is hypothesized that a model such as the PNI model, given its emphasis on the critical importance of emotional-behavioral factors, would lend itself well to implementation following the experience of childhood maltreatment. However, no studies to date have examined the potential utility of cognitive training following childhood maltreatment (or any other traumatic experiences) and initial research on the topic is significantly needed.

Traumatic stress as a proposed cause of neurodevelopmental disorders

It has been previously suggested that child trauma sequelae should be regarded as a complex neurodevelopmental disorder (De Bellis, 2001). Neurodevelopmental disorders are conditions that involve an early insult or abnormality in the developing nervous system and manifest as developmental deficits that produce personal social, academic or occupational impairments (American Psychiatric Association [APA], 2013; Mahone & Slomine, 2008). These neurodevelopmental disruptions can have a genetic (e.g., Fragile × syndrome), environmental (e.g., fetal alcohol spectrum disorder, lead exposure), or a multifactorial cause (e.g., cerebral palsy, attention-deficit/hyperactivity disorder [ADHD]). Many neurodevelopmental disorders may be due to external or environmental factors, such as physical trauma (i.e., traumatic brain injury) and early exposure to alcohol, infections, and teratogens (Mahone & Slomine, 2008). Due to the disruption to neurodevelopment, neurodevelopmental disorders are frequently characterized by neuropsychological dysfunction and a chronic course that persists throughout the lifespan (APA, 2013; Mahone & Slomine, 2008). When compared to those established environmentally induced neurodevelopmental disorders, childhood trauma and its severe consequences fit well within a neurodevelopmental perspective (Perry, 2009). Similar to well-researched neurodevelopmental disorders, childhood trauma involves the presence of an environmental mechanism (i.e., traumatic event) that has a direct influence on the developing nervous system. We hypothesize that in the same manner as environmental causes such as lead exposure, physical trauma, or in utero alcohol exposure, childhood psychological trauma can cause neurodevelopmental disruption and the subsequent manifestation of a neurodevelopmental disorder. This developmental cascade, including the subsequent neurocognitive deficits described above that emerge during the developmental period, is highly consistent with the current criteria of a neurodevelopmental disorder (APA, 2013), and as such, childhood traumatic stress (including maltreatment) may be most appropriately classified as a potential environmental cause of neurodevelopmental disorders. In such a re-conceptualization, the severity of childhood traumatic stress should be considered along a large continuum. Certainly not all children with a trauma history will develop a neurodevelopmental disorder, including those with a history of high severity, and traumatic stress only represents a potential risk factor. As opposed to blindly or carelessly searching for a false or incorrect explanation of a child's areas of difficulty, it will be important for providers to use this framework cautiously and only in times of absolute certainty.

Limitations

It is also important to note that no studies have conducted pre-abuse, post-abuse studies to evaluate the causal direction between maltreatment and neurocognitive deficits. It is known that children with developmental and behavioral disorders are at greater risk for child abuse and neglect (Olson & Jacobson, 2014), potentially explaining current findings. Furthermore, the majority of the reviewed studies utilized very small sample sizes, potentially limiting the interpretability of such results. Ideally, future studies will build on initial studies and provide data that indicates a causal direction between maltreatment experience and neurocognitive deficits. While it is hypothesized that childhood maltreatment can cause the described developmental consequences, future studies are severely needed.

Conclusions

Due to large advances in the scientific research on childhood maltreatment, there is now a clearly described biological pathway to neurocognitive impairments, primarily due to the activation of the neurobiological stress response, the deleterious effects of prolonged stress response on the brain, and the subsequent brain abnormalities that result in compromised neurocognition. Compromised neurocognitive functioning following childhood maltreatment is most likely to occur in executive functions, although the majority of neurocognitive domains are vulnerable to disruption.

However, specific factors such as duration, severity, type, and timing during development are all associated with neurocognitive outcomes. Individual patient risk should be considered within the context of these factors, as opposed to the mere presence (or absence) of a childhood maltreatment history. No studies to date have examined the potential utility of interventions such as cognitive training in directly targeting compromised neurocognitive functioning. Cognitive training results in other populations have shown promise, suggesting that cognitive training may be a useful addition to standard clinical care following childhood maltreatment, alongside psychological and psychiatric treatment. However, initial research is needed.

As described here utilizing the childhood maltreatment research, childhood stress and trauma causes a severe alteration to the developing nervous system. Rigorous scientific research has identified evidence for such nervous system alterations following childhood stress at the neurobiological, neuroimaging, and neurocognitive levels of analysis. These abnormalities do not remit easily, and long-term severe adaptive, psychiatric, as well as medical consequences persist into adulthood. Unfortunately, childhood stress and trauma research continues to be hampered by the societal stigma associated with child abuse and neglect. Additionally, until recently, there was no neuroscientific explanation for the struggles following stress and trauma. Those biological, neurological, and neuropsychological researchers and clinicians understandably often referred to their psychiatric and psychological counterparts for research and treatment. However, the research is now well established. It is time that clinical practice integrate such research findings to provide a more comprehensive conceptualization of the "below the surface" neurobiological, neurological, and neurocognitive abnormalities contributing to the severe presentation of children and adolescents following childhood stress and trauma.

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