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REVIEW

Neuropsychological Impact of Trauma-Related Mental Illnesses: A Systematic Review of Clinically Meaningful Results

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Abstract

A trauma history is present in approximately 90% of adults in the United States. Comparatively, lifetime post-traumatic stress disorder (PTSD) prevalence is only 8.3% (Kilpatrick et al. *Journal of Traumatic Stress, 26,* 537-547, 2013). A neuropsychological understanding of trauma is essential to effective trauma-informed assessments and treatments. Prior reviews have focused on PTSD, specific neuropsychological domains, and statistically rather than clinically significant results. The current systematic review investigated standardized test performance across neuropsychological domains in participants with trauma histories and any psychiatric diagnosis. The review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. From 2350 records, the search returned 21 eligible studies: 8 for combat trauma, 2 for childhood trauma, 2 for intimate partner violence and sexual assault, 2 for accidental trauma, 1 for refugee trauma, and 6 for unspecified trauma. Mean neuropsychological scores ranged from low to high average, with one mean verbal memory score in the borderline range. These findings diverge from reports of between-group differences or experimental task performance, which suggest greater levels of static cognitive impairment. Current results are limited by lack of distinction between trauma types in the literature, a dearth of cognitive domains examined, wide use of self-report trauma measures, and publication and outcome reporting biases. Clinical implications for assessment and rehabilitation are discussed in relation to clinical significance, state versus trait based changes, intra-individual variability, changes from pre- to post-trauma, and within-group variability in resilience. Future directions are recommended in consideration of cultural factors, prospective and follow-up designs, and psychiatric diagnosis.

Keywords Trauma · PTSD · Standardized neuropsychological test · Neuropsychological, assessment · Neuropsychological rehabilitation

Introduction

The vast majority (89.7%) of adults in the United States have been exposed to trauma, with a smaller minority (8.3%) meeting Diagnostic and Statistical Manual of Mental Health Disorders – Fifth Edition (DSM-5) criteria for PTSD in their lifetime (Kilpatrick et al., 2013). A neuropsychological understanding of the brain-behaviour relationship in trauma is an emerging research focus that bridges the gap between the neurobiological stress response and the emotional and behavioural changes in survivors (e.g., Wilson, Hansen, & Li, 2011). Clinicians need to be mindful of this relationship, as trauma may be a primary etiology or secondary complicating factor in neuropsychological assessments. For instance, clients may sustain neurological insults in a traumatic context. Additionally, the neurological diagnosis as well as subsequent medical procedures and loss of abilities and roles may be experienced as traumatic. Furthermore, there may be a prior trauma history. Traumatic stress is a typical consideration in the realm of traumatic brain injury (TBI), and Kaplan et al. (2017) have summarized relevant trauma prevalence rates in surveys with US veterans returning from Afghanistan and Iraq – 17% of soldiers with mild TBI screened positive for PTSD

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and 31% were positive for depression. In addition, 43.9% of soldiers with TBI who reported loss of consciousness also met criteria for PTSD, and TBI doubled the likelihood of PTSD in marine and navy servicemen. Trauma also co-occurs with other acquired brain injuries, with 23% of stroke and transient ischemic attack patients diagnosed with PTSD within one year after the cardiovascular event, 11% holding the diagnosis thereafter (Edmondson et al., 2013), and 23% of patients with brain cancer meeting stringent criteria for Acute Stress Disorder (Goebel, Strenge, & Mehdorn, 2012).

A *trauma-informed* approach to neuropsychological assessment considers the client's trauma experience in all aspects of intake, testing, diagnosis, and feedback sessions, prioritizing the client's sense of safety, choice, and control (BC Mental Health & Substance Use Services, 2013). Provision of trauma-informed assessments begins with awareness of how trauma impacts the survivor's development, adaptive and coping skills, and physical and mental health, including neuropsychological functioning. Trauma alters several neuropsychological processes such as attention, memory, and executive functions, which are thought to underlie behavioural manifestations of PTSD, such as concentration difficulties, hypervigilance to threat, and intrusive memories (e.g., Van Der Kolk, 2006). After trauma exposure, PTSD is diagnosed when the survivor experiences symptoms from the following clusters for at least one month: (1) intrusive recollections, (2) avoidance of traumatic reminders, (3) negative cognitions or mood, and (4) physiological arousal and reactivity (American Psychiatric Association, 2013). Identification of neuropsychological sequelae is recommended to inform PTSD diagnosis, due to biases inherent in self-report measures and given that PTSD in particular is a highly suggestible disorder (Orme, 2012). Specific neuropsychological findings may also distinguish DSM-5 trauma- and stressor-related disorders (i.e., PTSD, acute stress disorder, adjustment disorders, and other specified or unspecified trauma and stressor-related disorders) from neurological illnesses and from mental disorders that pertain to behaviours that people often develop through learning, adapting, and coping in the context of trauma (i.e., anxiety disorders and obsessive-compulsive disorder, depressive disorders, personality disorders, dissociative disorders, conversion disorder, psychotic disorders, and attention deficit hyperactivity disorder [ADHD]; e.g.,Van Der Kolk, 2015). Particularly for survivors of childhood trauma, there is a move towards a new developmental trauma diagnostic category to capture their distinctive and complex constellation of symptoms (e.g., Van Der Kolk, 2015). Understanding the neuropsychological sequelae of trauma exposure can help the clinician to accurately interpret cognitive strengths and weaknesses and provide an appropriate diagnosis. This may further assist with identifying specific targets for cognitive rehabilitation and psychotherapy, and recommending strategies and supports to build on the survivor's cognitive strengths and increase engagement in daily activities, education, work, and relationships. Moreover, a trauma-informed neuropsychological assessment can help to prevent iatrogenic effects due to improper diagnosis and treatment of trauma.

Neuropsychological Sequelae of Trauma

Typologies of Trauma Exposure Neuropsychological effects of trauma may vary depending on the type of trauma exposure. *Acute or single-incident traumatic events* may include motor vehicle accidents and natural disasters, as well as trauma of an interpersonal nature such as sexual or physical assault. In terms of cognitive functioning, these single events may be viewed as less detrimental to cognitive functioning when they occur in the context of an otherwise supportive social network and healthy childhood development and attachment patterning. *Multi-incident or chronic trauma* includes childhood trauma, intimate partner violence, and combat or first-responder trauma. The repetitive and interpersonal nature of multi-incident trauma is thought to lead to more severe, pervasive, and persistent psychological sequelae, captured by the DSM-IV description of Disorders of Extreme Stress Not Otherwise Specified (Luxenberg, Spinazzola, & van der Kolk, 2001), and the International Classification of Diseases – 11th Revision (ICD-11) category of Complex PTSD. This entails disturbances in regulation of affect and impulses, alterations in attention, maladaptive self-perception and meaning-making, interpersonal issues, and somatic symptoms. *Childhood trauma* refers to chronic adverse events during early childhood. These typically occur interpersonally within the child's caregiving system, and include sexual, emotional, and physical abuse, as well as neglect, loss, and witnessing violence (Gabowitz, Zucker, & Cook, 2008). Childhood trauma interferes with healthy attachment and development, and in adulthood affected individuals demonstrate signs of executive dysfunction, attentional issues, learning and memory struggles, and emotion regulation problems (e.g., Wilson et al., 2011). *Intimate partner violence* is another interpersonal form of trauma that is likely to have especially poor neurocognitive outcomes to the extent that it is both multi-incident, overlapping with previous childhood abuse experiences (Bensley, Van Eenwyk, & Simmons, 2003), and associated with traumatic brain injury, the latter of which is estimated to occur in over 80% of survivors (Banks, 2007). Female survivors present with cognitive deficits associated with dysfunction in frontal-subcortical neural circuitry, evident on measures of working memory, visuoconstruction, and executive function (Stein, Kennedy, & Twamley, 2002). *Combat trauma* is also regarded as having severe mental health and cognitive consequences, as it is associated with repetitive trauma that often includes endangerment of lives, moral injury, involvement in grotesque scenes, as well as blows to the head such as those from blast-related injuries

(Currier, Holland, & Malott, 2015; Johnsen & Asbjørnsen, 2008; Karr, Areshenkoff, Duggan, & Garcia-Barrera, 2014). There is also a high risk of comorbid alcoholism and substance abuse among war veterans (Wagner et al., 2007). Furthermore, Johnsen and Asbjørnsen (2008) note that for older adult veterans who have endured PTSD for a long period of time, progressive cortisol abnormalities and hippocampal volume reduction may impact cognitive abilities (Kitayama, Vaccarino, Kutner, Weiss, & Bremner, 2005; Yehuda, 2001). As such, Johnsen and Asbjørnsen's (2008) meta-analysis revealed greater verbal memory deficits in veterans with PTSD in comparison to sexual and physical-assault related PTSD. First-line responders such as police officers are also often exposed to horrific scenes and detailed accounts of crimes on a daily basis, and those who suffer from PTSD have been reported to present with memory impairments (Lindauer, Olff, van Meijel, Carlier, & Gersons, 2006). Finally, *intergenerational trauma* is gaining recognition, and includes transmission of historical trauma emanating from genocide and colonialism (e.g., Indigenous residential schools), slavery, and war (BC Mental Health & Substance Use Services, 2013). Trauma-related coping patterns and neuropsychological substrates may be passed to offspring through attachment styles, learning, and epigenetics. For example, children of veterans are more likely to attend to war-related stimuli on a modified Stroop task than children of non-veterans (Motta, Joseph, Rose, Suozzi, & Leiderman, 1997). Overall, the research suggests that neuropsychological profiles vary in severity and cognitive domain according to the type of trauma exposure. Still, there is significant variation in cognitive outcomes reported across and within studies of different forms of trauma, and a broad review would clarify the cognitive effects associated with each type of exposure.

Across different types of trauma exposure, a PTSD diagnosis is often associated with lower overall intellectual functioning and significantly lower verbal reasoning in comparison to perceptual abilities, although it is unclear whether this is a risk factor for PTSD or an outcome of the disorder itself (Wilson et al., 2011). The lack of distinction between risk factor and outcome is a downfall of using the PTSD diagnosis as the sole rubric for studying neuropsychological sequelae of trauma. Monozygotic twin studies suggest that cognitive function can be either a risk or protective factor for veterans to develop PTSD (Gilbertson et al., 2006). For people who survive natural disasters, it is similarly suggested that poor cognitive functioning is a risk factor for PTSD rather than an outcome of the trauma (e.g., Parslow & Jorm, 2007). The confounding issues of risk and protective factors also emerge in between-group comparisons of participants who develop trauma-related pathology and healthy trauma-exposed controls. Any statistically significant cognitive differences may be related to lower premorbid functioning among cases and higher premorbid abilities in controls.

Mechanisms of Neuropsychological Impact

Psychophysiological models outline the *traumatic stress response*, which refers to trauma-induced alterations of the neurochemical cascade that typically helps to preserve homeostasis in the context of stress (Wilson et al., 2011). When an individual encounters a traumatic event or trauma-related stimuli, the hypothalamic-pituitary-adrenal axis and sympathetic nervous system are activated, causing a rise in physiological indices of cortisol and heart-rate, and an eventual decline in immune functioning and heart-rate variability (Bremner & Pearce, 2016; Wilson et al., 2011). Stress is a normal part of everyday life, and itself has a physiological substrate. However, the traumatic stress response is maladaptive, as it does not organize an effective behavioural response and it persists beyond cessation of the original threat. In this case, homeostasis is disrupted, to the detriment of frontal and limbic regions involved in the feedback cycle. A survivor's experience of cognitive difficulties in everyday life is illustrated by Van Der Kolk's (2015) model of neuroanatomical and functional changes occurring during a flashback or exposure to trauma-related stimuli. Several structures are at play, including: the lateral nucleus of the thalamus, which fails to appropriately filter and integrate sensory information, and the amygdala, which is either hyper-responsive or hypo-responsive (i.e., in instances of dissociation) to perceived threatening stimuli. Furthermore, there are changes in responsiveness of the prefrontal cortex, which relates to self-referential processing and understanding the threatening stressor in the context of time and space, as well as executive function, working memory, and higher-order attention abilities (Shin et al. 2006).

Neuroimaging studies in the trauma field use resting state paradigms as well as symptom provocation methods such as presenting traumatic sounds, images, faces, and scripts to reveal trauma-related changes in the brain. Two of the most robust imaging findings yielded from both of these methodologies are decreased structural integrity and altered functional connectivity in the medial prefrontal cortex (mPFC), coupled with increased amygdalar activation (Francati, Vermetten, & Bremner, 2007; Peterson, Thome, Frewen, & Lanius, 2014; Wilson et al., 2011). In an alternate model of frontal-limbic changes in the context of dissociation and childhood trauma, it has been speculated that amygdala activity is dampened and mPFC activity actually increases (Lanius et al., 2010; Van Der Kolk, 2015). The mPFC is involved in inhibiting the amygdala and associated fear response. It also plays a role in the default mode network, contributing to self-referential functions such as self-awareness and self-reflection (Daniels, Frewen, McKinnon, & Lanius, 2011). Furthermore, hippocampal activation is typically reduced during memory-related tasks, although some studies have revealed inconsistent activation during tasks with emotional content. In their review of functional imaging of PTSD, Francati et al. (2007) note that differentiating types of trauma exposure would reduce inconsistencies in regional activations and improve the framework for studying neurological impact. Similarly, findings of unique neural and default mode network alterations related to each of the anxiety disorders, including PTSD, highlights the clinical utility of examining neuropsychological functioning associated with the array of trauma-related psychological disorders.

Cognitive models of trauma present a conceptual framework in line with neuroimaging and neuropsychological findings. Metcalfe and Jacobs's (1996) network model refers to hippocampal functions (i.e., spatial perception, spatial memory, and episodic memory) as *cool cognition*, and the fear conditioning associated with the amygdala as *hot emotion*. In PTSD, the cool system is thought to be disabled, while the hot system becomes hyper-responsive. Fear-provoking stimuli are consequently encoded and retrieved without temporal-spatial context. *Attentional bias* to threat is also posited in conjunction with increased amygdala activity in PTSD (El Khoury-Malhame et al., 2011). Pineles, Shipherd, Mostoufi, Abramovitz, and Yovel (2009) explain attentional bias as a type of interference effect in which there is difficulty with disengaging attention from trauma-related stimuli. Attentional biases may utilize the survivor's cognitive resources and impact not only attentional abilities but also working memory and processing speed (Morey et al., 2009; Scott et al., 2015).

Current Study Objectives

Prior reviews of neuropsychological sequelae have considered various types of trauma exposure, though they have not captured the range of mental health and cognitive outcomes associated with trauma beyond PTSD. Scott et al. (2015) and Qureshi et al. (2011) have conducted meta-analyses synthesizing statistical comparisons of neurocognitive performance between individuals with PTSD and trauma-exposed controls without the disorder. This research approach excludes individuals living with long-lasting neurological and mental health effects after trauma, which are currently labeled with a host of psychiatric diagnoses other than PTSD. Thus, a review of different types of trauma exposure would ideally incorporate all studies of participants with trauma histories who have developed clinically significant symptoms, including disorders other than PTSD. Furthermore, as noted by Scott and colleagues (Scott et al., 2015), statistically significant differences are not necessarily clinically meaningful, as they do not reflect cognitive impairment in the context of appropriate normative standards. Looking only at statistically significant differences limits the clinical utility of these findings in routine clinical practice with individual clients. Additionally, the issue of risk factor versus cognitive outcome is greater when comparing participants with potentially lower premorbid functioning to controls with potentially higher and protective cognitive abilities. The research thus far lacks a clear picture of clinically meaningful effects of trauma, beyond statistically significant group differences. Other reviews have narrowly focused on either particular cognitive outcomes, such as executive functions and verbal memory, or specific trauma histories, especially childhood trauma (e.g., Polak, Witteveen, Reitsma, & Olff, 2012; Johnsen & Asbjørnsen, 2008; Malarbi, Abu-Rayya, Muscara, & Stargatt, 2017; Masson, East-Richard, & Cellard, 2016; Woon, Farrer, Braman, Mabey, & Hedges, 2017). Such focus does not capture the differential cognitive outcomes associated with various types of trauma.

Effective trauma-informed assessments and treatments necessitate a holistic understanding of trauma, supported by a review of the neuropsychological impact of trauma. An inclusive review would encompass a full range of types of trauma and clinically meaningful descriptors of performance across cognitive domains. Therefore, the primary aim of the current review is to evaluate empirical studies of adults who have experienced any type of trauma and have developed clinically significant psychiatric symptoms. The outcome of interest is performance in any neurocognitive domain relative to normative datasets, as measured by standardized neuropsychological test results.

A narrative review, rather than a meta-analysis, was deemed to be ideally suited to the current study objective. Meta-analysis is a rigorous approach to investigating whether an aggregate of statistically significant results amounts to findings that are clinically meaningful. An alternate way of looking at clinical meaningfulness is to examine standardized and norm-referenced neuropsychologist test scores. We aimed to provide clinical neuropsychologists with an understanding of whether trauma is associated with standardized scores within or outside of "normal limits", as this is clinically meaningful information within the context of routine neuropsychological assessments with individual clients. The reader is referred to Scott et al.' (2015) meta-analysis for an empirically rigorous review of the (non-standardized) neurocognitive effects associated with PTSD, in terms of effect size statistics.

Methods

Literature Search

A search strategy was devised to identify empirical studies of standardized neuropsychological test performance among participants ages 18–64 with a trauma history and a diagnosis of a mental illness believed to cause clinically significant distress or impairment in social, occupational, or behavioural functioning (e.g., PTSD, acute stress disorder, ADHD, schizophrenia, mood disorders). Three databases (PsycINFO, MedLine with Full Text, and Published International Literature on Traumatic Stress) were searched for articles published between January 2013 and August 2018. Searches were limited to peer-reviewed journal articles, and empirical studies in human populations, particularly, in adult age groups. Search limits and protocols specific to each database are outlined in Online Resource 1. Search terms were provided by all three study authors in consultation with a research librarian at the University of Victoria. Search protocols consisted of subject headings or keyword terms for trauma, including "child abuse", "PTSD", and "combat disorders", paired with terms for neuropsychological performance and specific domains assessed in a typical neuropsychological test battery, such as "neuropsychological assessment", "cognitive ability", "executive function", "attention", and "memory". The final list of search terms was obtained by consensus by all study authors. All three authors established consistency of abstract screening based on the first 10% of articles in the first database. Two authors screened the remaining abstracts independently, and mutually decided whether or not to include any discrepantly rated abstracts.

The following studies were systematically excluded during the search: (1) Treatment studies in which neuropsychological data was collected before or after an intervention. Treatment studies were excluded for several reasons. In most instances, treatment studies focus only on participants with PTSD, and exclude those with comorbid disorders. Further, treatment-seeking individuals differ from those who are not pursuing treatment (e.g., Ray, Bujarski, Yardley, Roche, & Hartwell, 2017). For example, they may be older, have longer illness duration, have higher levels of education, and have more severe psychiatric symptoms. Levels of intelligence, education, and reading ability may also be higher because of the inclusion criteria of the intervention. It would be an empirical question to compare treatment studies and non-treatment studies to see whether participants in the former have higher symptoms and associated neurocognitive deficits than the latter. However, this is beyond the scope and purpose of the current review. (2) Studies using cognitive tasks other than standardized neuropsychological tests. (3) Studies not reporting standardized neuropsychological test scores, such as standard, scaled, T, or Z scores. (4) Studies with experimental manipulations before or during the task. (5) Studies reporting neuropsychological performance prior to trauma exposure or during the peri-traumatic period (i.e., during trauma exposure or up to three days immediately following the traumatic event), due to the distinction in the trauma literature between cognitive risk factors and effects. (6) Studies reporting test performance of adolescents below the age of 18 or older adults above the age of 65, in consideration of the confounds of normative cognitive development and decline. For this final age criterion, it is noted that the majority of included studies did not specify an upper age limit. For studies that explicitly included adolescents or older adults, results were included if they were reported separately for the different age groups such that younger and older participants could be removed from the final analysis.

Assessing Risk of Bias

Risk of bias within each selected study was assessed by the first author. As Zeng et al. (2015) note in their summary of tools for assessing risk of bias in observational studies, there are currently no universally accepted tools designed for cross-sectional studies. Still, the items recommended by the Agency for Healthcare Research and Quality (AHRQ) provided a useful framework for assessing bias in the studies in this review. Eleven items were rated "Yes", "No", or "Unclear" with respect to whether or not the following information was specified in each study: source of information, inclusion and exclusion criteria, time period for identifying participants, use of consecutive sampling if recruitment was not population-based, blinding of assessors to participants' status, quality assurance assessments, explanation of participant exclusions from analyses, assessment or controlling for confounding factors, explanation of handling of missing data, summary of participant response rates, and percentage of participants with incomplete data or follow-up data.

The criteria for satisfactory fulfilment of these items would be expected to vary depending on the purpose of the review. For example, in the current review, adequate outlining of inclusion and exclusion criteria reflected specification of factors known to impact cognitive outcomes, such as psychiatric comorbidities, neurological illness, and age. A study met criterion for blind assessors if neuropsychological test administrators were masked to participants' trauma and diagnostic status. Quality assurance assessments referred to effort tests. Finally, confounding variables were adequately addressed if (1) psychiatric disorders co-occurring with the sample's primary diagnosis were either assessed and reported or controlled via exclusion criteria, and (2) neuropsychological results were reported for a group of participants who shared the same type of trauma history. Factors such as age, education, and gender were not considered as confounds because standardized test scores are typically determined using demographically matched normative groups.

Data Extraction

Data from selected studies was extracted by the first author, using a standardized protocol and extraction spreadsheet created by all three authors. This included the following information: participants' demographic characteristics, exclusion criteria regarding cognitive functioning and co-occurring disorders, type of trauma, trauma assessment tools and scores, mental health or brain injury diagnoses, standardized neuropsychological test scores, performance and symptom validity testing, and psychotherapeutic or psychopharmacological treatment status, the latter because of the potential differences between treatment-seeking and non-treatment-seeking individuals, as described above, and also because neuropsychological functioning may improve after treatment. The neuropsychological results were reported in terms of means, standard deviations, and qualitative descriptors of performance for each test.

Results

Study Selection

The automated search protocol returned 2350 records. 2096 records were deemed to be ineligible (e.g., no standardized neuropsychological tests; child or adolescent participant groups; trauma or mood induction paradigms). Of the 254 remaining records, 84 were duplicates. The 170 remaining full-text articles were assigned to two raters (of the three study authors), who independently assessed the appropriateness of each article for inclusion. When there was a discrepancy in this adjudication process, a third rater evaluated the discrepancy and made a final decision. Throughout this rating process, 147 articles were excluded with the following rationale: 26 articles did not use standardized neuropsychological tests, 58 articles used standardized neuropsychological tests, but did not report standardized scores (i.e., instead reported raw scores, regression analyses, or other statistical analyses of performance), 33 articles did not report test scores specifically for participants with trauma exposure, seven articles included participant groups characterized by trauma exposure but not psychopathology, 13 articles reported including participants outside of the 18–64 age range, four articles only included standardized neuropsychological measures of premorbid cognitive functioning, five articles reported baseline or follow-up results from intervention studies, and one article reported identical cognitive results from the same participant sample as a later study that was included in this review. This exclusion process resulted in a total of 21 published articles eligible for inclusion in the final systematic review. See Online Resource 2 for a PRISMA Flow Diagram of the Search Process.

Study Characteristics

The 21 eligible studies included a total *N* of 1051 participants, with individual study sample sizes ranging from 11 to 285 participants. Demographic and clinical characteristics varied across studies (Table 1). Demographically, mean age ranged from 27.5 to 47 years. The gender proportions tended to differ depending on the type of trauma, with a higher representation of males than females in studies on combat trauma, vice versa for studies on intimate partner violence and sexual assault, and varying proportions of males and females in studies on other types of trauma. Ethnicity was only reported in one third of the studies, and samples in these studies tended to consist predominantly of Caucasian participants (i.e., ranging from 52.4 to 92% Caucasian). Years of education were reported in about 71% of studies. The average level of education in these study samples ranged from some high school to some university (i.e., 9.9 to 15.2 years). In terms of clinical considerations, diagnostic categories represented in the studies under review were: PTSD, psychotic disorders, adjustment disorder, and major depressive disorder (MDD), as well as PTSD with comorbid TBI, MDD, or psychogenic nonepileptic seizures. All of the studies under review used criteria from either the fourth edition of DSM (DSM-IV) or its text revision (DSM-IV-TR) to classify groups by trauma exposure and psychiatric diagnosis. Exclusion of previous or current psychiatric or neurological conditions occurred in the following number of studies for each disorder: neurological disorder ($n = 10$), TBI ($n = 6$), substance use disorder ($n = 5$), psychosis or psychotic disorder ($n = 5$), seizures or epilepsy ($n = 4$), head injury with specific loss of consciousness or personality change criteria ($n = 4$), any co-occurring psychiatric disorder ($n = 3$), bipolar disorder ($n = 3$), childhood ADHD ($n = 2$), post-deployment mild TBI (mTBI; $n = 2$), mTBI ($n = 1$), moderate to severe TBI ($n = 1$), “serious” TBI amnestic disorder ($n = 1$), dementia ($n = 1$), delirium ($n = 1$), depression ($n = 1$), anxiety ($n = 1$), alcohol abuse ($n = 1$), psychiatric disorder other than anxiety and depression ($n = 1$), psychiatric disorder other than depression ($n = 1$), active suicidal or homicidal ideation requiring crisis intervention ($n = 1$), pre-trauma borderline personality disorder ($n = 1$), panic disorder ($n = 1$), generalized anxiety disorder ($n = 1$), obsessive compulsive disorder ($n = 1$), or major depressive disorder ($n = 1$).

Eight studies screened out participants who did not meet specific intellectual and educational criteria, based on factors such as intellectual disability, learning disability, IQ below 70, or education level cut-offs. Participant psychotherapeutic and psychopharmacological treatment status varied across studies. Finally, nine of 21 studies included at least one measure of performance or symptom validity.

Risk of Bias

Risk of bias assessments are presented according to the AHRQ criteria in Table 2. As no numeric threshold for acceptability has been published for this set of criteria, results are described here in terms of number of studies meeting each criterion. Each of the 21 studies under review met the first criterion of defining their source of information. Fulfillment of other criteria was more variable, with anywhere from 1 study to 10 studies meeting each criterion. Regarding

Table 1 Demographic and clinical sample characteristics

Study	Diagnostic Group	Demographic Characteristics					Clinical Characteristics			
		N	Mean Age (SD)	% Male	% White	Mean Years Education (SD)	Psychiatric and Neurological Disorder Exclusions	Cognitive Ability Exclusions	Treatment Information	Performance/Symptom Validity Tests
Bae et al., 2014	PTSD	25	45.2 (13.19)	52	NR	9.88 (4.36)	Brain injury; Amnestic disorder; Personality change due to head trauma; Psychiatric disorder other than PTSD or adjustment disorder	Intellectual disability; IQ <70	All participants taking medication	NR
	Adjustment Disorder	24	44.21 (14.25)	54.17	NR	11.33 (2.58)				
Campbell et al., 2013	First Episode Psychosis	21	37.76 (9.26)	47.62	NR	13.48 (2.2)	TBI	Premorbid learning disability	92% taking antipsychotic medication	
Chung et al., 2014	PTSD	28	36.68 (9.14)	NR	NR	13.64 (2.3)	Central nervous system disease (e.g., epilepsy, tumor, serious brain injury); Psychiatric disorders other than anxiety and depression; "Serious" TBI	Middle school education	Medication and/or psychotherapy prescribed to participants	NR
Combs et al., 2015	PTSD	32	31.53 (7.24)	87.5	71.9	14.25 (1.95)	Post-deployment mTBI; Childhood ADHD	None	NR	Letter Memory Test; Miller Forensic Assessment of Symptoms Test; Minnesota Multiphasic Personality Inventory – 2 Restructured Form
	PTSD and mTBI	50	30.04 (7.73)	98	82	13.62 (1.32)				
Cooper et al., 2018	PTSD	21	37.76 (6.47)	90.5	52.4	NR	mTBI; Psychosis; Uncontrolled seizures	None	No treatment-related exclusion criteria	TOMM; Neurobehavioral Symptom Inventory validity-10
Dunkley et al., 2015	PTSD	18	37.38 (6.69)	100	NR	NR	TBI; Seizures; Neurological disorders	NR	All participants currently taking psychotropic medication	NR
Flaks et al., 2014	PTSD	70	37.93 (11.8)	31.4	NR	11.1 (2.09)	Significant disease affecting CNS; Pre-trauma borderline personality disorder, Bipolar disorder, Panic disorder, Generalized anxiety disorder, Obsessive compulsive disorder, Major depressive disorder; Head trauma with LOC; Substance sbuse	At least 4 years education	No medication 6 months prior to testing; Treatment-seeking population	NR
Grigorovich et al., 2013	PTSD	11	39.00 (12.10)	82	NR	11.8 (2.0)	Substance abuse; Psychosis; Dementia; Delirium; TBI; Pychiatric disorder; LOC > 5 min	None	Sample of patients from rehabilitation hospital	Test of Memory Malingering (TOMM); Clinical interview
Lipinska et al., 2014	PTSD	16	26.71 (6.15)	NR	NR	12.18 (2.19)	DSM Axis 1 disorder other than depression associated with PTSD; Substance abuse; Neurological conditions (e.g., TBI, epilepsy)	None	Excluded participants prescribed psychoactive medication	NR
Lopez et al., 2017	PTSD and mTBI	12	34.5 (8.8)	75	75	14.4 (1.8)	Depression; Anxiety; Alcohol abuse	NR	50% of participants in therapy for PTSD; 67% taking medication for PTSD	Green's Medical Symptom Validity Test
Meyers et al., 2014	PTSD	20	29.35 (7.18)	95	65	12.7 (1.26)	NR	None	NR	Slick criteria for probable malingerers
Myers et al., 2014	PTSD and Psychogenic Nonepileptic Seizures	17	45.53 (10.74)	0	NR	14.06 (2.54)	Epilepsy	IQ >70	88% of participants taking psychotropic medications	TOMM; Behavioural observations; Active pursuit of personal injury suit or disability pension

Table 1 (continued)

Study	Diagnostic Group	Demographic Characteristics					Clinical Characteristics			
		N	Mean Age (SD)	% Male	% White	Mean Years Education (SD)	Psychiatric and Neurological Disorder Exclusions	Cognitive Ability Exclusions	Treatment Information	Performance/Symptom Validity Tests
Parlar et al., 2016	Major Depressive Disorder	23	40.4 (14.2)	55.82	NR	15.2 (3.7)	Bipolar disorder; psychotic disorder; Substance abuse; TBI; Neurological disease	None	NR	NR
Scheiner et al., 2014	PTSD and Major Depressive Disorder	25	35.32 (10.32)	12	72	14.76 (2.42)	Neurological disease	IQ > 70; WAIS-III Vocabulary scale score ≥ 6	No medication 2 to 6 weeks prior to testing	NR
Shandera-Ochsner et al., 2013	PTSD	19	32.47 (6.96)	89.47	73.68	13.61 (1.28)	Psychosis; Childhood ADHD; Neurological disorder (e.g., Stroke, Epilepsy, Tumor, post-deployment TBI)	None	NR	Digit Memory Test; Letter Memory Test; Morel Emotional Numbing Test; Miller Forensic Assessment of Symptoms Test
	PTSD and mTBI	21	30.14 (7.43)	95.24	85.71	13.71 (1.55)				
Shin et al., 2017	PTSD	30	47 (7)	10	0	NR	NR	None	46.7% of participants currently taking psychiatric medication	NR
Sideli et al. 2014	Psychosis	44	29.4 (8.92)	64.9	NR	NR	None	Severe learning disability (IQ < 50)	NR	NR
Soble et al., 2013	PTSD	59	33.5 (10.7)	98	90	13 (1.6)	Psychosis; Head injury with LOC > 30 min; Other neurological condition	NR	NR	Embedded measures; TOMM
	PTSD and mTBI	66	27.5 (4.8)	98	92	13 (1.6)				
Stricker et al., 2017	PTSD	92	31.4 (7.8)	83	72	14 (1.9)	Moderate to severe TBI; Serious neurological illness; Suicidal/homicidal ideation requiring crisis intervention; Bipolar disorder; Psychotic disorder (except psychosis NOS); Substance use disorder	At least 12 years education	Non treatment-seeking participants	Medical Symptom Validity Test
Todd et al., 2015	PTSD	22	37.6 (6.8)	100	NR	NR	TBI; Seizures; Other neurological disorders	NR	All participants in therapy and prescribed psychotropic medication; Excluded participants taking anti-convulsants, benzodiazepines and GABA antagonists	NR
Yang et al., 2017	PTSD	285	45 (9)	50.53	NR	NR	Other psychiatric disorders	NR	NR	NR

recruitment information, 19 studies outlined their psychiatric, neurological, or cognitive inclusion and exclusion criteria. However, only six studies identified lower and upper limits for the age range of included participants. Seven studies specified their recruitment time period. Four studies indicated that recruitment was consecutive if not population-based. Two studies summarized participant response rates. With respect to quality of evidence, only one study indicated that assessors of neuropsychological performance were blind to participant trauma or diagnostic status. Effort testing was included in eight studies. Co-occurring psychiatric conditions were adequately characterized or excluded in 13 studies. In terms of completeness of neuropsychological data collection, 19 studies reported how many participants had complete or incomplete data. In cases of missing and excluded data, eight studies explained why they excluded any participants from the calculation of mean assessment scores. Four studies explained how they handled any missing neuropsychological data.

Summary of Findings

Neuropsychological data is presented according to domain and test in Table 3. Characteristics of trauma exposure and symptom measurement are outlined in Table 4. The following sections describe results in relation to each type of trauma exposure. Considering that many potential mental health difficulties can arise in relation to trauma, including undiagnosed and sub-threshold clinical symptoms, results from the seven studies that focused on trauma exposure in participants without the necessary criterion of psychopathology are included for the interested reader in Tables 5, 6, and 7.

Combat Trauma Eight studies examined neuropsychological test performance among veterans and active duty military service members ($n = 247$)). Three of these studies included veterans with PTSD alone as well as veterans with co-occurring PTSD with mTBI. Soble, Spanierman, and Smith (2013) assessed Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) veterans diagnosed with either PTSD or PTSD with mTBI ($n = 59$ and 66) on tests of attention, working memory, verbal memory, visual memory, executive functions, language, perceptual intelligence, and fine motor skills. Results ranged from low average to high average, with both groups performing in the low average range on the Trail Making Test A (i.e., attention) and California Verbal Learning Test – Second Edition (CVLT-II) Recognition Hits (i.e., verbal memory).

Both groups also exhibited high average standard scores with respect to Wisconsin Card Sorting Test (WCST) Perseverative Responses, and the PTSD + mTBI group additionally had high average standard scores for WCST Perseverative Errors. For these latter two measures, higher standardized scores equate to better performance in terms of fewer perseverative responses and errors. In Combs et al. (2015), OIF and OEF veterans in both diagnostic categories ($n = 32$ and 50) scored in the average range on tests of attention, verbal memory, processing speed, motor speed, and executive functions. Shandera-Ochsner et al. (2013) similarly found average results for OIF and OEF veterans suffering from PTSD alone or with mTBI ($n = 19$ and 21) on tests of verbal memory, visual memory, processing speed, and executive functions. Of the three studies comparing PTSD alone to PTSD with mTBI, neurocognitive performance was only significantly different between the two groups in Combs et al. (2015). The combined group had significantly lower scores on D-KEFS Visual Scanning, and an effect size comparison revealed a small effect for the difference between the two groups on number sequencing, delayed verbal memory, and processing speed.

Four studies reported cognitive functioning for veterans and service members diagnosed with PTSD (without mTBI; $n = 81$). Dunkley et al. (2015) and Todd et al. (2015) both reported average intellectual functioning in members of the Canadian Armed Forces with a post-deployment PTSD diagnosis ($n = 18$ and 22). The sample in Todd et al. (2015) consisted of veterans who served in Afghanistan. Given potential secondary gain in terms of disability and pension packages particular to military samples, it is notable that the two studies by Dunkley et al. (2015) and Todd et al. (2015) were the only studies on combat trauma that did not report any performance or symptom validity testing. Cooper et al. (2018) found average results for military service members diagnosed with PTSD ($n = 21$) on tests of verbal memory, processing speed, executive functions, and working memory. Meyers, Miller, and Tuita (2014) assessed the following domains in a sample of military service members who were stationed at the Schofield Barracks in Hawaii and diagnosed with PTSD ($n = 20$), specifically verbal intelligence, performance intelligence, perceptual intelligence, working memory, language, visuospatial functioning, fine motor skills, attention, executive functions, verbal memory, visual memory, and processing speed. Performance was in the average range for several domains, and fell in the low average range on specific tests of performance intelligence (e.g., Wechsler Adult Intelligence Scale – Fourth Edition Digit Symbol test), executive function (i.e., verbal fluency; Controlled Oral Word Association Test), language (e.g., Boston Naming Test), fine motor skills (e.g., Finger Tapping – Dominant Hand), verbal memory (e.g., Auditory-Verbal Learning Test (AVLT) Total, Immediate, Delayed, and Recognition), and visual memory (e.g., Complex Figure Test Immediate and Delayed).

In the eighth study reviewed, Stricker et al. (2017) examined neuropsychological performance in the context of PTSD without depression as well as PTSD with depression, among veterans and service members of OEF, OIF, and Operation New Dawn ($n = 92$). Domains assessed were attention, verbal

Table 2 Bias assessments according to Agency for Healthcare Research and Quality criteria

Study	Source of Inform-ation Defined	Inclusion and Exclusion Criteria Listed	Recruitment Time Period Indicated	Indicated Consecutive if not Population-based Recruitment	Participant Response Rates Summarized	Evaluators of Subjective Components Masked to Status of Participants	Quality Assurance Assessment	Confounding Variables Assessed or Controlled	Participant Exclusions from Analysis Explained	Handling of Missing Data Explained	Specified Percentage of Participants with Incomplete Data
Bae et al., 2014	Y	Y	N	N	N	N	N	Y	NA	NA	Y
Campbell et al., 2013	Y	Y	Y	N	Y	N	N	Y	NA	NA	Y
Chung et al., 2014	Y	Y[a]	N	N	N	N	N	Y	Y	NA	Y
Combs et al., 2015	Y	Y	N	N	N	N	Y	Y	Y	NA	Y
Cooper et al., 2018	Y	Y	N	N	N	Y	Y	N	Y	Y	Y
Dunkley et al., 2015	Y	Y	N	N	N	N	N	Y	Y	NA	Y
Flaks et al., 2014	Y	Y[a]	N	Y	N	N	N	N	NA	NA	Y
Grigorovich et al., 2013	Y	Y	Y	N	N	N	Y	Y	NA	NA	Y
Lipinska et al., 2014	Y	Y[a]	N	N	Y	N	N	Y	NA	NA	Y
Lopez et al., 2017	Y	Y	Y	N	N	N	Y	N	Y	Y	Y
Meyers et al., 2014	Y	Y	N	Y	N	N	Y	Y	Unclear	Unclear	N
Myers et al., 2014	Y	Y	Y	Y	N	N	Y	N	N	N	Y
Parlar et al., 2016	Y	Y	N	N	N	N	N	N	NA	NA	Y
Scheiner et al., 2014	Y	Y	Y	N	N	N	N	N	Y	Y	Y
Shandera-Ochsner et al., 2013	Y	Y	N	N	N	N	Y	Y	NA	NA	Y
Shin et al., 2017	Y	N	Y	N	N	N	N	Y	Y	Y	Y
Soble et al., 2013	Y	Y	Y	NA	N	N	Y	Y	Unclear	Unclear	N
Sideli et al. 2014	Y	N[a]	N	N	N	N	N	N	NA	NA	Y
Stricker et al., 2017	Y	Y	N	Y	N	N	Y	Y	NA	NA	Y
Todd et al., 2015	Y	Y[a]	N	N	N	N	N	Y	Y	NA	Y
Yang et al., 2017	Y	Y[a]	N	N	N	N	N	N	NA	NA	Y

[a] Study indicated age range of included participants

Table 3 Standardized Neuropsychological Test Results, by Domain

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
Attention						
Continuous Performance Test – Second Edition (CPT-II) Commissions	Combs et al., 2015	Combat	PTSD	T	49.9 (6.69)	Average
			PTSD and mTBI	T	49.5 (9.78)	Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	52.5 (11.8)	Average
CPT-II d’	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	0.11 (1.02)	Average
CPT-II Hit Rate	Combs et al., 2015	Combat	PTSD	T	46.3 (7.13)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	48.13 (12.47)	Average
CPT-II Hit Reaction Time Block Change	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	48.3 (7.8)	Average
CPT-II Hit Reaction Time ISI	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	46.5 (12.1)	Average
CPT-II Omissions	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	54.8 (40.5)	Average
CPT-II Standard Error	Combs et al., 2015	Combat	PTSD	T	52.16 (9.99)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	51.49 (13.33)	Average
Ruff 2 & 7 Total Accuracy	Soble et al., 2013	Combat	PTSD	Standard	94.4 (15.5)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	96.5 (10.3)	Average
Ruff 2 & 7 Total Speed	Soble et al., 2013	Combat	PTSD	Standard	92 (14.8)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	90.1 (15.6)	Average
Seashore Rhythm Test	Lopez et al., 2017	Various	PTSD and mTBI	T	40.9 (11.6)	Low Average
Test of Variables of Attention – Attention Performance Index	Stricker et al., 2017	Combat	PTSD	Z	−0.92 (1.75)	Low Average
	Stricker et al., 2017	Combat	PTSD and Depression	Z	−0.6 (1.66)	Average
Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) Digit Span Forward	Stricker et al., 2017	Combat	PTSD	Scaled	9.12 (2.93)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	10.0 (2.82)	Average
Working Memory						
A not B Reaction Time	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	0.3 (1.17)	Average
Auditory Consonant Trigrams- 36″ Trial	Sticker et al. 2017	Combat	PTSD	Z	−0.29 (1.42)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Z	−0.44 (1.27)	Average
Sentence Repetition	Meyers et al., 2014	Combat	PTSD	T	43.5 (13.8)	Average
WAIS-IV Arithmetic	Meyers et al., 2014	Combat	PTSD	T	43.0 (7.2)	Average
WAIS-IV Digit Span	Meyers et al., 2014	Combat	PTSD	T	48.1 (9.4)	Average
WAIS-IV Digit Span Backward	Stricker et al., 2017	Combat	PTSD	Scaled	9.69 (2.64)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	11.0 (3.18)	Average
WAIS-IV Working Memory Index	Cooper et al., 2018	Combat	PTSD	T	49.27 (10.46)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
	Lopez et al., 2017	Various	PTSD and mTBI	T	51.0 (12.6)	Average
Wechsler Memory Scale – Third Edition (WMS-III) Digit Span	Soble et al., 2013	Combat	PTSD	Standard	95.8 (13.1)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	97.1 (12.9)	Average
WMS-III Letter-Number Sequencing	Soble et al., 2013	Combat	PTSD	Standard	99 (11.1)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	??	Average
Executive Function						
Booklet Category Test	Lopez et al., 2017	Various	PTSD and mTBI	T	44.6 (8.6)	Average
Colour Trails Test Part 1	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	54.6 (9.0)	Average
Colour Trails Test Part 2	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	56.4 (7.5)	Average
Controlled Oral Word Association Test	Meyers et al., 2014	Combat	PTSD	T	40.8 (9.5)	Low Average
Delis-Kaplan Executive Function System (D-KEFS) Category Switching	Combs et al., 2015	Combat	PTSD	Scaled	10.13 (3.04)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.74 (4.00)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	10.16 (2.52)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	9.67 (3.01)	Average
D-KEFS Colour Word Interference Test (CWIT) Inhibition	Combs et al., 2015	Combat	PTSD	Scaled	8.88 (3.7)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.76 (3.54)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	9.37 (2.97)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	8.86 (3.47)	Average
	Stricker et al., 2017	Combat	PTSD	Scaled	9.98 (2.63)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	10.76 (2.42)	Average
	Grigorovich et al., 2013	Electrical injury	PTSD	Scaled	8.7 (3.6)	Average
D-KEFS CWIT Inhibition Switching	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	9.42 (2.36)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	8.71 (3.24)	Average
D-KEFS Letter Fluency	Combs et al., 2015	Combat	PTSD	Scaled	9.38 (3.04)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	10.16 (3.09)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	8.37 (2.85)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	8.9 (2.93)	Average
	Soble et al., 2013	Combat	PTSD	Standard	95.6 (17.7)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	95.1 (15.8)	Average
D-KEFS Number Letter Switching	Combs et al., 2015	Combat	PTSD	Scaled	10.28 (2.02)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.18 (3.27)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	9.74 (2.28)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	8 (3.65)	Average
	Stricker et al., 2017	Combat	PTSD	Scaled	9.57 (2.96)	Average
	Stricker et al., 2017	Combat	PTSD and mTBI	Scaled	10.74 (2.02)	Average
FAS Phonemic Fluency	Stricker et al., 2017	Combat	PTSD	Scaled	10.97 (2.97)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	10.71 (3.09)	Average
Intra/Extra Dimensional (IED) Set Shift Total Errors	Stricker et al., 2017	Combat	PTSD	Z	0.23 (0.96)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Z	−0.003 (0.73)	Average
Trails B	Meyers et al., 2014	Combat	PTSD	T	50.9 (5.9)	Average
	Cooper et al., 2018	Combat	PTSD	T	48.52 (10.00)	Average
	Soble et al., 2013	Combat	PTSD	Standard	91.4 (17.2)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	92.0 (15.2)	Average
	Lopez et al., 2017	Various	PTSD and mTBI	T	44.1 (7.9)	Average
Wisconsin Card Sorting Test (WCST) Total Correct	Combs et al., 2015	Combat	PTSD	T	47.00 (10.79)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	51.18 (5.86)	Average
WCST Total Errors	Combs et al., 2015	Combat	PTSD	T	45.75 (11.01)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	50.44 (7.35)	Average
	Soble et al., 2013	Combat	PTSD	Standard	104.3 (15.3)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	106.9 (14.7)	Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	48.7 (8.8)	Average
	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.15 (1.02)	Average
WCST Perseverative Errors	Combs et al., 2015	Combat	PTSD	T	44.44 (8.42)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	47.94 (5.67)	Average
	Soble et al., 2013	Combat	PTSD	Standard	109.3 (21.2)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	116.7 (19.5)	High Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	50.2 (9.8)	Average
	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.16 (1.13)	Average
WCST Perseverative Responses	Soble et al., 2013	Combat	PTSD	Standard	111.0 (21.8)	High Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	119.0 (20.5)	High Average
WCST Non-perseverative Errors	Combs et al., 2015	Combat	PTSD	T	44.75 (10.27)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	T	48.54 (7.1)	Average
	Soble et al., 2013	Combat	PTSD	Standard	102.1 (14.1)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	104.7 (11.7)	Average
WCST Conceptual Level Responses	Soble et al., 2013	Combat	PTSD	Standard	104.7 (14.8)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	107.0 (12.2)	Average
WCST Categories	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.24 (0.64)	Average
WCST Failure to Maintain Set	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.41 (0.6)	Average
Processing Speed						
Complex Figure Test (CFT) Time	Meyers et al., 2014	Combat	PTSD	T	50.1 (6.8)	Average
D-KEFS CWIT Colour Naming	Combs et al., 2015	Combat	PTSD	Scaled	8.09 (3.17)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.28 (3.00)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	9.11 (3.05)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	8.43 (3.12)	Average
	Stricker et al., 2017	Combat	PTSD	Scaled	9.78 (2.27)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	9.91 (2.01)	Average
D-KEFS Word Reading	Combs et al., 2015	Combat	PTSD	Scaled	8.72 (3.32)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.26 (3.75)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	8.89 (3.53)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	9.67 (3.02)	Average
	Stricker et al., 2017	Combat	PTSD	Scaled	10.34 (2.26)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	10.74 (2.57)	Average
D-KEFS Visual Scanning	Combs et al., 2015	Combat	PTSD	Scaled	10.31 (2.65)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	8.86 (3.84)	Average
D-KEFS Letter Sequencing	Combs et al., 2015	Combat	PTSD	Scaled	10.16 (2.71)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	10.00 (3.05)	Average
D-KEFS Number Sequencing	Combs et al., 2015	Combat	PTSD	Scaled	10.25 (2.81)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.44 (2.88)	Average
	Stricker et al., 2017	Combat	PTSD	Scaled	11.0 (2.11)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	10.62 (2.64)	Average
Trails A	Meyers et al., 2014	Combat	PTSD	T	47.4 (4.9)	Average
	Soble et al., 2013	Combat	PTSD	Standard	84.7 (19.4)	Low Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	85.0 (15.1)	Low Average
	Lopez et al., 2017	Various	PTSD and mTBI	T	42.3 (11.2)	Average
WAIS-IV Digit Symbol	Combs et al., 2015	Combat	PTSD	Scaled	10.19 (2.49)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	9.24 (2.85)	Average
	Meyers et al., 2014	Combat	PTSD	T	40.8 (5.2)	Low Average
	Stricker et al., 2017	Combat	PTSD	Scaled	9.66 (2.07)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Scaled	9.53 (2.43)	Average
WAIS-IV Symbol Search	Combs et al., 2015	Combat	PTSD	Scaled	9.88 (2.6)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	10.18 (2.88)	Average
WAIS-IV Processing Speed Index	Combs et al., 2015	Combat	PTSD	Standard	100.03 (11.8)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Standard	98.46 (14.12)	Average
	Cooper et al., 2018	Combat	PTSD	T	53.05 (8.94)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Standard	98.16 (9.98)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Standard	93.14 (12.54)	Average
	Lopez et al., 2017	Various	PTSD and mTBI	T	46.8 (7.4)	Average
Intelligence						
Wechsler Abbreviated Scale of Intelligence (WASI) Full Scale IQ	Dunkley et al., 2015	Combat	PTSD	Standard	108.67 (14.07)	Average
	Todd et al., 2015	Combat	PTSD	Standard	108.8 (13.9)	Average
	Myers et al., 2014	Various	PTSD and Psychogenic Nonepileptic Seizures	Standard	89.41 (10.9)	Low Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	Standard	114 (13.7)	High Average
WASI 2 test version	Campbell et al., 2013	Childhood	First Episode Psychosis	Standard	93.71 (3.9)	Average
WASI Performance IQ	Lipinska et al., 2014	Sexual asault	PTSD	Standard	82.73 (12.91)	Low Average
WAIS-III Five subtest abbreviated version	Sideli et al. 2014	Childhood	Psychosis	Standard	89.33 (15.91)	Low Average
WAIS-IV Similarities	Meyers et al., 2014	Combat	PTSD	T	43.5 (6.5)	Average
WAIS-IV Information	Meyers et al., 2014	Combat	PTSD	T	49.6 (6.5)	Average
WAIS-IV Picture Completion	Meyers et al., 2014	Combat	PTSD	T	49.0 (8.0)	Average
WAIS-IV Block Design	Meyers et al., 2014	Combat	PTSD	T	48.2 (8.1)	Average
	Soble et al., 2013	Combat	PTSD	Standard	107.6 (14.2)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	106.8 (12.0)	Average
WAIS-IV Vocabulary	Chung et al., 2014	Domestic violence	PTSD	Scaled	9.93 (1.81)	Average
WAIS-III Vocabulary and Block Design	Flaks et al., 2014	Various	PTSD	Standard	98.94 (12.05)	Average
WAIS-III Vocabulary and Matrix Reasoning	Chung et al., 2014	Domestic violence	PTSD	Standard	100.55 (11.55)	Average
Korean-WAIS (K-WAIS) Full Scale IQ	Shin et al., 2017	Refugee	PTSD	Standard	91.9 (10.49)	Average
K-WAIS Verbal IQ	Shin et al., 2017	Refugee	PTSD	Standard	92.1 (11.49)	Average
K-WAIS Performance IQ	Shin et al., 2017	Refugee	PTSD	Standard	92.8 (9.56)	Average
K-WAIS Abbreviated Form	Bae et al., 2014	Motor vehicle accident	PTSD	Standard	97.12 (13.31)	Average
	Bae et al., 2014	Motor vehicle accident	Adjustment Disorder	Standard	103.13 (7.13)	Average
WAIS-Revised Chinese (WAIS-RC) Full Scale IQ	Yang et al., 2017	Various	PTSD	Standard	90.63 (1.45)	Average
WAIS-RC Verbal IQ	Yang et al., 2017	Various	PTSD	Standard	90.57 (1.42)	Average
WAIS-RC Performance IQ	Yang et al., 2017	Various	PTSD	Standard	94.45 (1.26)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
Test not specified	Grigorovich et al., 2013	Electrical injury	PTSD	Standard	97.13 (11.3)	Average
Visual Memory						
Brief Visual Memory Test-Revised (BVMT-R) Total Recall	Stricker et al., 2017	Combat	PTSD	T	39.38 (9.93)	Low Average
	Stricker et al., 2017	Combat	PTSD and Depression	T	38.56 (11.4)	Low Average
BVMT-R Delayed Recall	Shandera-Ochsner et al., 2013	Combat	PTSD	T	45.37 (12.85)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	T	45.33 (12.93)	Average
	Stricker et al., 2017	Combat	PTSD	T	40.28 (9.76)	Low Average
	Stricker et al., 2017	Combat	PTSD and Depression	T	38.62 (10.17)	Low Average
BVMT-R Trials 1–3 Total	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	50.5 (10.3)	Average
CFT Immediate Recall	Meyers et al., 2014	Combat	PTSD	T	42.0 (12.8)	Low Average
CFT Delayed Recall	Meyers et al., 2014	Combat	PTSD	T	42.0 (12.3)	Low Average
CFT Recognition	Meyers et al., 2014	Combat	PTSD	T	45.9 (11.4)	Average
Rey Complex Figure Test (RCFT) Immediate Recall	Soble et al., 2013	Combat	PTSD	Standard	98.3 (20.4)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	92.9 (20.8)	Average
RCFT Delay Recall	Soble et al., 2013	Combat	PTSD	Standard	93.3 (23.0)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	91.0 (19.6)	Average
RCFT Recognition	Soble et al., 2013	Combat	PTSD	Standard	96.5 (14.6)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	97.2 (19.4)	Average
Rey Osterrieth Complex Figure (ROCF) Immediate Trial	Grigorovich et al., 2013	Electrical injury	PTSD	T	37.7 (12.6)	Average
ROCF 30-min Delay Trial	Grigorovich et al., 2013	Electrical injury	PTSD	T	35.4 (13)	Average
Verbal Memory						
Auditory Verbal Learning Test (AVLT) Trial 1	Meyers et al., 2014	Combat	PTSD	T	43.1 (8.0)	Average
AVLT Total	Meyers et al., 2014	Combat	PTSD	T	38.5 (9.9)	Low Average
AVLT Immediate Recall	Meyers et al., 2014	Combat	PTSD	T	41.3 (12.3)	Low Average
AVLT Delayed Recall	Meyers et al., 2014	Combat	PTSD	T	38.2 (10.3)	Low Average
AVLT Recognition	Meyers et al., 2014	Combat	PTSD	T	39.0 (12.9)	Low Average
Buschke Selective Reminding Test (SRT) Total Recall	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.98 (1.41	Low Average
Buschke SRT Long-term Retrieval	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.96 (1.39)	Low Average
Buschke SRT Short-term Retrieval	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.81 (1.37)	Low Average
Buschke SRT Long-term Storage	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−0.78 (1.46)	Low Average
Buschke SRT Consistent Long-term Retrieval	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−1.12 (1.54)	Low Average
Buschke SRT Delayed Recall	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−1.15 (2.06)	Low Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
Buschke SRT Forgetting	Scheiner et al., 2014	Various	PTSD and Major Depressive Disorder	Z	−1.84 (1.95)	Borderline
California Verbal Learning Test – Second Edition (CVLT-II) Trials 1–5	Cooper et al., 2018	Combat	PTSD	T	53.10 (11.71)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	T	46.26 (8.41)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	T	43.1 (8.31)	Average
	Soble et al., 2013	Combat	PTSD	Standard	96.5 (17.3)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	99.0 (15.9)	Average
	Lopez et al., 2017	Various	PTSD and mTBI	T	47.2 (9.2)	Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	T	52.0 (9.9)	Average
	Grigorovich et al., 2013	Electrical injury	PTSD	T	41.6 (6.1)	Average
CVLT-II Short Delay Free Recall	Combs et al., 2015	Combat	PTSD	Z	−0.06 (0.948)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Z	−0.29 (1.19)	Average
	Soble et al., 2013	Combat	PTSD	Standard	95.5 (17.3)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	94.9 (13.6)	Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	Z	0.17 (0.5)	Average
	Grigorovich et al., 2013	Electrical injury	PTSD	Z	−1.1 (1.02)	Low Average
CVLT-II Long Delay Free Recall	Combs et al., 2015	Combat	PTSD	Z	−0.23 (1.047)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Z	−0.58 (1.26)	Average
	Soble et al., 2013	Combat	PTSD	Standard	93.0 (19.9)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	92.6 (16.0)	Average
	Stricker et al., 2017	Combat	PTSD	Z	−0.27 (1.06)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	Z	−0.279 (1.34)	Average
	Lopez et al., 2017	Various	PTSD and mTBI	T	42.9 (11.2)	Low Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	Z	−0.08 (0.5)	Average
CVLT-II Long Delay Cued Recall	Combs et al., 2015	Combat	PTSD	Z	−0.28 (1.016)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Z	−0.53 (1.16)	Average
CVLT-II Total Learning	Stricker et al., 2017	Combat	PTSD	T	48.5 (8.62)	Average
	Stricker et al., 2017	Combat	PTSD and Depression	T	48.91 (12.49)	Average
CVLT-II Learning Slope	Soble et al., 2013	Combat	PTSD	Standard	100.5 (15.8)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	100.4 (13.9)	Average
CVLT-II Proactive Interference	Soble et al., 2013	Combat	PTSD	Standard	101.1 (14.0)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	97.7 (13.2)	Average
CVLT-II Retroactive Interference	Soble et al., 2013	Combat	PTSD	Standard	102.1 (11.6)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	97.7 (10.6)	Average
CVLT-II Recognition Hits	Soble et al., 2013	Combat	PTSD	Standard	83.3 (26.5)	Low Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	81.6 (22.1)	Low Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	Z	−0.48 (0.8)	Average
CVLT-II Recognition False Positives	Soble et al., 2013	Combat	PTSD	Standard	99.9 (11.0)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	99.9 (12.8)	Average
	Parlar et al., 2016	Various	Major Depressive Disorder (Recurrent)	Z	0.15 (0.7)	Average
CVLT-II Total Intrusions	Soble et al., 2013	Combat	PTSD	Standard	97.0 (20.5)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	95.6 (20.5)	Average
Memory (Verbal and Visual)						
Rey-Kim Memory Test – Memory Quotient	Shin et al., 2017	Refugee	PTSD	Standard	100.1 (12.8)	Average
Language						
Animal Naming	Meyers et al., 2014	Combat	PTSD	T	47.0 (10.1)	Average
Boston Naming Test	Meyers et al., 2014	Combat	PTSD	T	41.4 (7.4)	Low Average
D-KEFS Category Fluency	Combs et al., 2015	Combat	PTSD	Scaled	11.00 (2.79)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	10.02 (2.96)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD	Scaled	10.0 (3.11)	Average
	Shandera-Ochsner et al., 2013	Combat	PTSD and mTBI	Scaled	10.76 (2.77)	Average
	Soble et al., 2013	Combat	PTSD	Standard	102.5 (20.6)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	103.7 (18.3)	Average
Token Test	Meyers et al., 2014	Combat	PTSD	T	50.0 (7.8)	Average
Visuospatial Function						
CFT Copy	Meyers et al., 2014	Combat	PTSD	T	46.1 (7.1)	Average
Judgment of Line Orientation	Meyers et al., 2014	Combat	PTSD	T	43.0 (6.5)	Average
Fine Motor Skills						
D-KEFS Motor Speed	Combs et al., 2015	Combat	PTSD	Scaled	11.13 (1.68)	Average
	Combs et al., 2015	Combat	PTSD and mTBI	Scaled	11.22 (1.61)	Average
Finger Tapping – Dominant Hand	Meyers et al., 2014	Combat	PTSD	T	42.6 (9.0)	Low Average
	Soble et al., 2013	Combat	PTSD	Standard	93.0 (17.2)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	92.1 (16.5)	Average
Finger Tapping – Nondominant Hand	Meyers et al., 2014	Combat	PTSD	T	45.8 (10.7)	Average
	Soble et al., 2013	Combat	PTSD	Standard	96.5 (17.1)	Average
	Soble et al., 2013	Combat	PTSD and mTBI	Standard	94.4 (16.1)	Average
Finger Localization – Dominant Hand	Meyers et al., 2014	Combat	PTSD	T	53.7 (4.6)	Average
	Meyers et al., 2014	Combat	PTSD	T	49.6 (3.1)	Average

Table 3 (continued)

Test	Study	Trauma Type	Diagnosis	Standard Score	M (SD)	Performance Description
Finger Localization – Nondominant hand						
Other						
Category (Victoria Version)	Meyers et al., 2014	Combat	PTSD	T	48.0 (13.5)	Average

memory, visual memory, processing speed, executive function, and working memory. For participants with PTSD alone, performance was average across domains, with the exceptions of low average performance on the Attention Performance Index of the Test of Variables of Attention and the Brief Visuospatial Memory Test – Revised Total Recall and Delayed Recall indices of visual memory. Participants with PTSD and depression also showed average performance in most domains and low average performance on both visual memory indices.

Childhood Trauma Two studies examined intellectual functioning in adults presenting with a history of childhood trauma and current diagnosis of psychotic disorder ($n = 65$). Sidlei et al. (2014) assessed a sample of adults with histories of childhood abuse who fulfilled International Statistical Classification of Diseases and related Health Problems – 10th Revision (ICD-10) criteria for psychosis with no known organic cause ($n = 44$). The criteria for abuse in this study were limited to physical abuse resulting in injuries and penetrative sexual abuse. Intelligence was low average in this sample. Campbell et al. (2013) assessed participants who had been exposed to child abuse or neglect ($n = 21$), although Campbell and colleagues noted that these participants also endorsed significantly more traumatic experiences related to the Troubles ethno-nationalist conflict in Northern Ireland in comparison to participants in the non-childhood trauma group. Participants had a first psychotic episode and met International Statistical Classification of Diseases and Related Health Problems – 10th Revision (ICD-10) criteria for one of the following disorders: schizophrenia or schizoaffective disorder, bipolar disorder or mania or hypomania, psychotic depression, alcohol or drug-induced psychosis, or delusional disorder. Intelligence was average in the childhood trauma group. Sidlei et al. (2014) also assessed a sample of adults with histories of childhood abuse who fulfilled ICD-10 criteria for psychosis with no known organic cause ($n = 44$). The criteria for abuse in this study were limited to physical abuse resulting in injuries and penetrative sexual abuse. Intelligence was low average in this sample.

Intimate Partner Violence and Sexual Assault Two studies included this type of interpersonal trauma (n = 44). Chung, Tang, Shie, Tsai, and Chou (2014) assessed intellectual functioning in female survivors of domestic violence who were diagnosed with PTSD ($n = 28$). Overall IQ and verbal intelligence were both within the average range. Performance intelligence was also average in a study by Lipinska, Timol, Kaminer, and Thomas (2014), which included participants who experienced sexual assault outside of childhood or adolescent trauma ($n = 16$).

Accidental Trauma Two studies assessed participants who experienced accidental traumas, specifically motor vehicle

Table 4 Characteristics of trauma exposure and post-traumatic stress symptomology

Study	Diagnosis	Trauma Type	Trauma Exposure Measure	Mean Trauma Exposure Score (SD)	Post-Traumatic Stress Disorder (PTSD) Symptom Measure	Mean PTSD Symptom Score (SD)	Time Since Trauma
Combs et al., 2015	PTSD	Combat	NR	NR	Clinician Administered PTSD Scale (CAPS)	NR	NR
	PTSD and mTBI						
Cooper et al., 2018	PTSD	Combat	NR	NR	CAPS; PTSD Checklist – Military Form (PCL-M)	[a]PCL-M: 60.95 (12.12)	NR
Dunkley et al., 2015	PTSD	Combat	NR	NR	Semi-structured interview; PTSD Checklist (PCL)	NR	NR
Meyers et al., 2014	PTSD	Combat	NR	NA	DSM-IV criteria for PTSD	NA	NR
Todd et al., 2015	PTSD	Combat	NR	NR	Structured Clinical Interview for DSM-IV (SCID-IV); PCL	NR	NR
Shandera-Ochsner et al., 2013	PTSD	Combat	NR	NR	CAPS; PTSD Checklist – Civilian Version (PCL-C)	CAPS: 55.00 (13.59)	NR
	PTSD and mTBI					CAPS: 68.76 (19.51)	
Soble et al., 2013	PTSD	Combat	NR	NR	DSM-IV Text Revision criteria for PTSD	NA	NR
	PTSD and mTBI						
Stricker et al., 2017	PTSD	Combat	NR	NR	CAPS	NR	NR
	PTSD and Depression						
Campbell et al., 2013	First Episode Psychosis	Childhood abuse or neglect	Traumatic Experiences Checklist	NR	NR	NR	NR
Sideli et al. 2014	Psychosis	Childhood physical abuse (resulting in injuries) and sexual abuse (penetrative)	Childhood Experience of Care and Abuse Questionnaire	NR	NR	NR	NR
Chung et al., 2014	PTSD	Domestic violence	NR	NR	Chinese Version of Davidson Trauma Scale	86.89 (25.31)	33.9 months (51.73)
Lipinska et al., 2014	PTSD	Sexual assault; Excluded childhood or adolescent trauma	NR	NR	CAPS; Mini International Neuropsychiatric Interview	NR	2.33 years (1.75)
Bae et al., 2014	PTSD	Motor vehicle accident	NR	NR	SCID-IV	NA	108.68 days (99.66)
	Adjustment Disorder						84.38 days (66.91)
Grigorovich et al., 2013	PTSD	Electrical injury	NR	NR	PCL-C	[a]60.3 (8.7)	57.2 months (60.1)
Shin et al., 2017	PTSD	Refugee-related events	NR	NR	CAPS; Minnesota Multiphasic Personality Inventory (MMPI) PTSD Scale	CAPS: 51.7 (24.45); MMPI PTSD Scale: 29.5 (5.63)	NR
Flaks et al., 2014	PTSD	Various	NR	NR	CAPS; SCID-IV	CAPS: 66 (26.1)	NR
Lopez et al., 2017	PTSD and mTBI	Various	NR	NR	PCL	[a]54.9 (10.4)	810.8 days (691.5)
Myers et al., 2014	PTSD and Psychogenic Nonepileptic Seizures	Various	NR	NR	DSM-IV and Trauma Symptom Inventory-2	NR	NR
Parlar et al., 2016	Major Depressive Disorder (Recurrent)	Various		CTQ: Emotional Abuse =	CAPS	NR	NR

Table 4 (continued)

Study	Diagnosis	Trauma Type	Trauma Exposure Measure	Mean Trauma Exposure Score (SD)	Post-Traumatic Stress Disorder (PTSD) Symptom Measure	Mean PTSD Symptom Score (SD)	Time Since Trauma
			Childhood Trauma Questionnaire (CTQ)	13.3 (6.4); Physical Abuse =7.5 (2.8); Sexual Abuse = 7.5 (5.4); Emotional Neglect = 13.7 (5.4); Physical Neglect = 9.11 (5.12)			
Scheiner et al., 2014	PTSD and Major Depressive Disorder	Various; Overrepresentation of physical and sexual abuse histories before age 15	NR	NR	SCID-IV	NA	NR
Yang et al., 2017	PTSD	NR; Cancer survivors	NR	NR	DSM-IV; Chinese version of CAPS	NR	NR

[a] PCL cut-off scores suggested by the U.S. Department of Veterans Affairs (VA) National Center for PTSD (2012): 30–35 for civilian primary care general population samples, or Department of Defense screening; 36–44 for specialized medical clinics or VA primary care; and 45–50 for VA or civilian specialty mental health clinics

accidents and electrical injuries (e.g., Bae, Hyun, & Lee, 2014; Grigorovich, Gomez, Leach, & Fish, 2013; $n = 60$). Bae et al. (2014) grouped survivors of motor vehicle accidents according to diagnosis of either PTSD or Adjustment Disorder ($n = 25$ and 24). Both groups achieved average intelligence scores. Grigorovich et al. (2013) examined participants who developed PTSD after electrical injuries ($n = 11$). Neuropsychological results were average in the domains of intelligence, verbal memory, and visual memory, with the exception of low average performance on the CVLT-II Short Delay Free Recall test of delayed verbal memory.

Refugee Trauma Shin et al. (2017) evaluated intellectual and memory abilities in North Korean refugees living in South Korea ($n = 30$). Refugees with PTSD performed in the average range on tests of overall intelligence, verbal intelligence, performance intelligence, and verbal and visual memory.

Various Trauma Histories Six studies included participants with various trauma histories or did not indicate the specific type of trauma endured ($n = 432$). Yang, Guo, and Jiang (2017) assessed inpatients with PTSD who were survivors of various types of "early or mid-cancer" without metastasis ($n = 285$). This study was included in the subsection of various traumas because cancer was not specified as the index traumatic event for posttraumatic stress, and there are multiple traumatic etiologies that may be relevant. That is, cancer may develop because of changes in immune functioning after earlier chronic adverse experiences, especially childhood trauma (Kelly-Irving, Mabile, Grosclaude, Lang, & Delpierre, 2013), or the medical diagnosis itself may be traumatizing, as may be the medical procedures and treatment of the cancer. It is also unclear whether participants were assessed pre or post cancer treatment. Intelligence, verbal intelligence, and performance intelligence were average in the in-patients in the Yang et al. (2017) study. In Flaks et al. (2014), participants diagnosed with PTSD, "urban violence" histories ranged from accidents and injuries to assaults and deaths of loved ones ($n = 70$). Intelligence in this sample was average. Myers, Zeng, Perrine, Lancman, and Lancman (2014) found intelligence to be low average for participants with unspecified trauma histories who presented with comorbid psychogenic nonepileptic seizures and PTSD ($n = 17$).

Lopez et al. (2017) evaluated attention, verbal memory, processing speed, executive function, and working memory in a group of participants with comorbid PTSD and mTBI, some of whom had sustained combat-related injuries ($n = 12$). Head injury was not specified as the index trauma for the development of PTSD. Participants scored in the low average to average range, with low average scores on tests of processing speed (i.e., Trail Making Test A), verbal memory (i.e., CVLT-II Long Delay Free Recall), and attention (i.e., Seashore Rhythm Test).

Table 5 Demographic and clinical characteristics of trauma-exposed samples with unspecified psychopathological status

Study	Demographic Characteristics					Clinical Characteristics			
	N	Mean Age (SD)	% Male	% White	Mean Years Education (SD)	Psychiatric and Neurological Disorder Exclusions	Cognitive Ability Exclusions	Treatment Information	Performance/ Symptom Validity Tests
Dannlowski et al., 2013	150	34.5 (10.6)	47.33	52.4	15.6 (2.2)	Psychiatric history; Neurological abnormalities; Seizures; Head trauma or unconsciousness; Beck Depression Inventory scores ≥10	None	Excluded psychotropic medications	NR
Daly, Hildenbrand, Turner, Berkowitz, & Tarazi, 2017	66	20.31 (1.45)	26	43	NR	Head injury with loss of consciousness >15 min or overnight hospitalization	None	Excluded participants currently on psychotropic medications; 31% previously received therapy; 3% currently in therapy; 8% prescribed psychotropic medications in past	Childhood Trauma Questionnaire validity scales; Behaviour Rating Inventory of Executive Function-Adult Version validity scales
Disner et al., 2017	295	32.6 (1.84)	94	72	NR	Neurological conditions including moderate or severe TBI; Current psychotic symptoms; Drug abuse; Significant imminent risk of suicide or homicide	None	NR	Victoria Symptom Validity Test; WAIS-III Digit Span (Scaled Score ≤ 5); CVLT-II Forced Choice (Raw Score ≤ 14); Trails A (≥48 s)
Fortenbaugh et al. 2017	18	34.22 (7.98)	94.44	NR	NR	History of neurological illness other than mTBI; Seizures; Current psychotic disorder; Active suicidal or homicidal ideation, intent, or plan requiring crisi intervention	Cognitive disorder due to general medical condition	NR	NR
Lee & DePrince, 2017	236	33.4 (11.0)	0	47	NR	NR	NR	NR	NR
Lovallo, Farag, Sorocco, Acheson, & Cohoon, 2013	110	NR	30	NR	NR	Substance abuse within past two months; History of any DSM-IV Axis I disorder other than depression (>60 days prior)	None	Not taking prescription medications	NR
Rivera-Veléz et al., 2014	12	NR	0	0	NR	None	None	All participants receiving psychological treatment; 42% receiving psychiatric treatment	NR

Table 6 Characteristics of trauma exposure and post-traumatic stress symptomology in samples with unspecified psychopathological status

Study	Trauma Type	Trauma Exposure Measure	Mean Trauma Exposure Score (SD)	Post-Traumatic Stress Disorder (PTSD) Symptom Measure	Mean PTSD Symptom Score (SD)	Time Since Trauma
Daly et al., 2017	Childhood trauma	Childhood Trauma Questionnaire – Short Form	37.50 (12.46)	NR	NR	NR
Dannlowski et al., 2013	Childhood trauma	Childhood Trauma Questionnaire	34.2 (10.7)	NR	NR	NR
Disner et al., 2017	Combat	NR	NR	Clinician Administered PTSD Scale (CAPS)	CAPS Intrusions: 12.35 (7.81); CAPS Avoidance: 7.39 (3.81); CAPS Dysphoria: 19.64 (12.36); CAPS Hyperarousal: 7.57 (3.32)	NR
Fortenbaugh et al. 2017	Childhood trauma (among veterans)	Traumatic Life Events Questionnaire (TLEQ); Deployment Risk and Resilience Inventory (DRRI)	NR	CAPS	CAPS: 50.61 (23.57)	NR
Lee & DePrince, 2017	Intimate partner violence	Revised Conflict Tactics Scale (CTS-2)	CTS-2 Physical assault items: 3.01 (2.75)	NR	NR	6-months plus median of 26 days post-incident
Lovallo et al., 2013	Childhood trauma	NR	NR	Computerized version of the Diagnostic Interview Schedule-IV (C-DIS-IV) events; and placement in upper, middle, or lower third of SES distribution	Sum of C-DIS-IV and SES score: ≥3	NR
Rivera-Veléz et al., 2014	Childhood trauma	Physical and Childhood Sexual Abuse Short Scale	NR	Davidson Trauma Scale (DTS)	DTS: 54.75 (23.08)	NR

Table 7 Standardized neuropsychological test results, by domain, for trauma-exposed samples with unspecified psychopathological status

Test	Study	Trauma Type	Standard Score	M (SD)	Performance Description
Attention					
California Verbal Learning Test – Second Edition (CVLT-II) Attention Span	Disner et al., 2017	Combat	Z	−1.17 (2.06)	Low Average
Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) Digit Span Forward	Rivera-Veléz et al., 2014	Childhood	Z	0.14 (0.72)	Average
Working Memory					
Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) Digit Span	Disner et al., 2017	Combat	Scaled	9.93 (2.50)	Average
WAIS-III Digit Span Backward	Rivera-Veléz et al., 2014	Childhood	Z	−0.11 (1.16)	Average
WAIS-III Letter-Number Sequencing	Rivera-Veléz et al., 2014	Childhood	Scaled	10.17 (2.48)	Average
WAIS-IV Letter-Number Sequencing	Lee & Lee & DePrince, 2017	Intimate Partner Violence	Scaled	9.14 (3.04)	Average
Executive Function					
Controlled Oral Word Association Test	Disner et al., 2017	Combat	Z	−0.48 (1.01)	Average
Delis-Kaplan Executive Function System (D-KEFS) Category Switching	Daly et al., 2017	Childhood	Scaled	12.31 (2.77)	High Average
D-KEFS Colour Word Interference Test (CWIT) Inhibition	Daly et al., 2017	Childhood	Scaled	11.24 (2.36)	Average
D-KEFS CWIT Inhibition Switching	Daly et al., 2017	Childhood	Scaled	10.77 (2.52)	Average
D-KEFS Letter Fluency	Daly et al., 2017	Childhood	Scaled	11.98 (2.83)	Average
D-KEFS Number Letter Switching	Daly et al., 2017	Childhood	Scaled	10.83 (2.30)	Average
D-KEFS Tower	Daly et al., 2017	Childhood	Scaled	10.52 (2.25)	Average
Stroop Color and Word Test	Disner et al., 2017	Combat	Z	−0.17 (0.89)	Average
Trails B	Disner et al., 2017	Combat	T	49.96 (9.97)	Average
Color Trails Test – Part B	Rivera-Veléz et al., 2014	Childhood	Standard	85.58 (19.38)	Low Average
Processing Speed					
D-KEFS CWIT Colour Naming	Daly et al., 2017	Childhood	Scaled	10.21 (2.16)	Average
D-KEFS Word Reading	Daly et al., 2017	Childhood	Scaled	10.88 (2.27)	Average
D-KEFS Visual Scanning	Daly et al., 2017	Childhood	Scaled	11.11 (1.93)	Average
D-KEFS Letter Sequencing	Daly et al., 2017	Childhood	Scaled	11.21 (2.28)	Average
D-KEFS Number Sequencing	Daly et al., 2017	Childhood	Scaled	10.89 (2.27)	Average
Trails A	Disner et al., 2017	Combat	T	50.20 (10.33)	Average
Color Trail Test – Part A	Rivera-Veléz et al., 2014	Childhood	Standard	82.17 (20.23)	Low Average
WAIS-III Digit Symbol-Coding	Disner et al., 2017	Combat	Scaled	9.85 (2.50)	Average
	Rivera-Veléz et al., 2014	Childhood			
WAIS-IV Symbol Search	Lee & Lee & DePrince, 2017	Intimate partner violence	Scaled	8.41 (2.99)	Average
Intelligence					
	Daly et al., 2017	Childhood	Standard	113.62 (9.70)	High Average

Table 7 (continued)

Test	Study	Trauma Type	Standard Score	M (SD)	Performance Description
Wechsler Abbreviated Scale of Intelligence (WASI) Full Scale IQ					
WAIS-III Information	Disner et al., 2017	Combat	Scaled	11.70 (2.11)	Average
WAIS-III Block Design	Disner et al., 2017	Combat	Scaled	12.27 (2.79)	High Average
WAIS-III Picture Arrangement	Rivera-Veléz et al., 2014	Childhood	Scaled	14.08 (5.63)	High Average
Mehrfachwahl-Wortschatz-Intelligenztest Verbal Intelligence	Dannlowski et al., 2013	Childhood trauma	Standard	117.5 (11.6)	High Average
Shipley Institute of Living Scale	Lovallo et al., 2013	Childhood trauma (with family history of alcoholism)	Mental Age	17.3 (0.14)	NA
	Lovallo et al., 2013	Childhood trauma (without family history of alcoholism)	Mental age	17.7 (0.23)	NA
Test not specified	Fortenbaugh et al. 2017	Childhood trauma (among veterans)	Standard	100.29 (14.56)	Average
Visual Memory					
Wechsler Memory Scale - Third Edition (WMS-III) Visual Reproduction I	Rivera-Veléz et al., 2014	Childhood	Scaled	10.58 (3.40)	Average
WMS-III Visual Reproduction II	Rivera-Veléz et al., 2014	Childhood	Scaled	10.67 (2.67)	Average
WMS-III Visual Reproduction – Recognition	Rivera-Veléz et al., 2014	Childhood	Scaled	9.67 (2.90)	Average
WMS-III Visual Reproduction – Retention %	Rivera-Veléz et al., 2014	Childhood	Scaled	10.67 (2.02)	Average
ROCF 30-min Delay Trial	Disner et al., 2017	Combat	Z	−0.49 (1.20)	Average
Verbal Memory					
CVLT-II Learning	Disner et al., 2017	Combat	Z	0.51 (2.66)	Average
CVLT-II Long Delay Free Recall	Disner et al., 2017	Combat	Z	−0.72 (4.51)	Low Average
CVLT-II Inaccurate Recall	Disner et al., 2017	Combat	Z	0.18 (1.72)	Average
Rey Auditory Verbal Learning Test (RAVLT) I-IV	Rivera-Veléz et al., 2014	Childhood	Z	−0.61 (0.99)	Average
RAVLT VI	Rivera-Veléz et al., 2014	Childhood	Z	−0.21 (1.27)	Average
RAVLT VII	Rivera-Veléz et al., 2014	Childhood	Z	−0.12 (1.00)	Average
RAVLT Recognition	Rivera-Veléz et al., 2014	Childhood	Z	−0.58 (1.24)	Average
WMS-III Logical Memory I	Rivera-Veléz et al., 2014	Childhood	Scaled	9.50 (2.24)	Average
WMS-III Logical Memory I – Themes	Rivera-Veléz et al., 2014	Childhood	Scaled	10.92 (2.78)	Average
WMS-III Logical Memory II	Rivera-Veléz et al., 2014	Childhood	Scaled	10.33 (2.39)	Average
WMS-III Logical Memory II – Themes	Rivera-Veléz et al., 2014	Childhood	Scaled	11.09 (2.61)	Average
WMS-III Logical Memory – Retention %	Rivera-Veléz et al., 2014	Childhood	Scaled	11.25 (2.09)	Average
Language					
D-KEFS Category Fluency	Daly et al., 2017	Childhood	Scaled	11.80 (2.84)	Average
Fine Motor Skills					
D-KEFS Motor Speed	Daly et al., 2017	Childhood	Scaled	12.08 (1.45)	High Average

Scheiner et al. (2014) reported results of participants with comorbid PTSD and major depressive disorder who had various trauma histories ($n = 25$), although Scheiner and colleagues noted an overrepresentation of child and adolescent physical and sexual abuse histories. Verbal memory in this sample ranged from borderline to low average on the Buschke Selective Reminding Test (SRT). Five SRT indices were low average, and the sixth SRT Forgetting index was borderline. Scheiner and colleagues reported Z scores for all indices, however they indicated that age and sex corrected normative information was not available for the Forgetting index. Attention, working memory, and executive functions were average. Parlar, Frewen, Oremus, Lanius, and McKinnon (2016) presented neuropsychological results for participants with unspecified trauma histories and recurrent major depressive disorder ($n = 23$). Performance was average for attention, verbal memory, visual memory, and executive function. Intelligence was high average.

Discussion

This systematic review is, to our knowledge, the first scientific inquiry investigating observational studies on standardized neuropsychological test performance of adults with various trauma histories and psychiatric diagnoses. The following discussion of samples, outcomes, and limitations associated with each type of trauma exposure culminates in recommendations for clinical practice, considerations related to biases in the literature, and suggestions for further research on the neuropsychological impact of trauma.

Interpretation of Main Findings

Combat Trauma Cognitive performance did not qualitatively differ between studies evaluating neuropsychological functioning in persons with PTSD alone, PTSD with deployment-related mTBI, and PTSD with depression (e.g., Combs et al., 2015; Cooper et al., 2018; Dunkley et al., 2015; Meyers et al., 2014; Shandera-Ochsner et al., 2013; Soble et al., 2013; Stricker et al., 2017; Todd et al., 2015). Across studies, performance was average for overall intelligence, processing speed, executive functions, and visuospatial function, with additional high average scores in Soble et al. (2013) reflecting lack of perseverative tendencies. Results ranged from low average to average for attention, verbal memory, and visual memory. An exception to this pattern was the Meyers et al. (2014) study, in which results were low average for certain indices of verbal memory, executive function, performance intelligence, language, and fine motor skills.

Regardless of whether the service members in combat trauma samples had formal diagnoses of psychopathology, low average performance was predominantly confined to attention, verbal memory, and visual memory. This supports the centrality of attentional and memory dysfunction as risk factors or consequences associated with post-traumatic stress symptomology and alterations in fronto-limbic circuitry (e.g., Jelinek et al., 2006; Van Der Kolk, 2006; Verfaellie & Vasterling, 2009). The current research findings highlight the pervasiveness of subtle (i.e., low average) attentional and memory difficulties across neutral material, controlled testing environments, and verbal and visual modalities. Reported difficulties on standardized tasks that do not include mood manipulations or intentionally emotional material (i.e., as in the case of emotional Stroop tasks) adds to the literature suggesting that alterations in attention and memory are seen even in the context of neutral material (e.g., Verfaellie & Vasterling, 2009). Furthermore, the findings attest to either or both of the following ideas: (1) that underlying difficulties in attention and memory may precipitate post-traumatic stress reactions, and (2) that post-traumatic symptomology may interfere with attention and memory even in controlled environments. Ongoing trauma-related arousal changes related to depression and insomnia may also continue to play a role in the standardized test environment, impacting attention and memory (e.g., Fortier-Brochu & Morin, 2014; Scott et al., 2015). Sleep disturbance is a core feature of PTSD, and is an important consideration in this regard. Verfaellie, Lee, Lafleche, and Spiro (2016) examined a cohort of veterans exposed to blasts, and found that greater disruptions in sleep mediated an association between PTSD severity and worse neurocognitive performance across domains of processing speed, verbal and visual memory, motor speed, and cognitive control. The mechanisms by which sleep impacts cognitive dysfunction are unclear, and it may be that sleep worsens emotion regulation and consequently influences cognition (e.g., Killgore, 2010). Conversely, Verfaellie et al. (2016) suggest that poor sleep exerts a global impact on alertness and attention, which are integral to cognitive performance across domains, and which may impact participants even in emotionally neutral environments.

The current study findings also add to prior research suggesting that trauma-related encoding and retrieval difficulties span across both verbal and visual domains of memory (e.g., Jelinek et al., 2006). This diverges from studies suggesting memory dysfunction is left-lateralized and confined to verbal processing areas (e.g., Scott et al., 2015). It is possible that low average visual memory performance was evidenced due to factors such as: inclusion of substance use and depression diagnoses, both of which are known to impact visual memory; and use of visual neuropsychological tests that lend themselves to both verbal and visual encoding strategies (e.g., Jelinek et al., 2006; Scott et al., 2015).

As results pertaining to combat trauma were within normal limits, they partially differ from the conclusions of Dolan et al. (2012) that neuropsychological functioning is typically in the normal to mildly impaired range in veterans with PTSD or co-occurring PTSD and mTBI. Many theoretical and empirical studies suggest even greater neuropsychological disturbances in military samples than the low average-to-average results found in the current review. For instance, Johnsen and Asbjørnsen (2008) concluded from their meta-analysis that verbal memory is most strongly impaired in military samples in comparison to other types of trauma. This meta-analysis quantified differences in performance on standardized memory measures between PTSD and healthy controls or trauma-exposed controls. The apparent discrepancy between findings of the current review and the previous meta-analysis suggests that effect sizes at the group level differ from clinically significant impairments relative to normative populations on standardized tests. A reasonable explanation for statistical rather than clinical significance is that normative groups are based on the general population, of which nearly 90% are exposed to trauma (e.g., Kilpatrick et al., 2013). In other words, a normative sample would include individuals with histories of trauma exposure. Thus, when compared to the general trauma-exposed population, standardized test scores of clients with trauma-related pathology might not be significantly impaired. Control groups, on the other hand, are typically screened on the basis of trauma exposure. Thus, when compared to control groups, participants with trauma-related pathology may score statistically lower on standardized tests. Approximately 43% of studies in the current review reported statistically significant between-group differences in standardized scores. It appears that many of the significant group differences in scores may not withstand comparisons to normative groups that include an assortment of people with and without trauma exposure and related pathology.

It is also possible that the discrepant findings are related to length of illness duration, with greater chronicity of PTSD associated with detrimental effects on hippocampal volume, cortisol secretion, and cognitive abilities (Kitayama et al., 2005; Yehuda, 2001). Military samples in Johnsen and Asbjørnsen's (2008) meta-analysis were comprised primarily of Vietnam war veterans, who had likely suffered longer illness duration relative to military service members in the current review, who had mainly served in more recent missions in Iraq and Afghanistan. Age is another factor in this regard, as PTSD is theorized to interact with older age such that memory abilities decline below levels expected in healthy aging (e.g., Yehuda, Golier, Tischler, Stavitsky, & Harvey, 2005). The current review may have neglected to find clinical impairment because of its exclusion of studies on older adults above the age of 65. Another consideration is that certain memory tests may be more or less sensitive to trauma-related difficulties. Johnsen and Asbjørnsen (2008) reported that studies using the AVLT or Wechsler Memory Scale produced greater effect sizes relative to the CVLT, the latter of which lends itself to semantic clustering strategies. In the present review, only one study used the AVLT, and performance was low average for all verbal recall indices (Meyers et al., 2014). Finally, publication date of the articles under review may moderate the observed effects, with more recent studies likely using more rigorous methods in terms of sample selection, neuropsychological assessments, and data analysis. The most recent meta-analysis by Scott et al. (2015) included articles published before March 2014. The current review spanned the timeframe of January 2013 through August 2018, therefore including articles published up to four years following the synthesis of literature by Scott et al., and over a decade after Johnsen and Asbjørnsen's (2008) synthesis.

Accidental Trauma, Combat Trauma, and Co-Occurring Brain Injury Particularly for military samples and accidental traumas, head injuries often co-occur with traumatic events, such as blast-related incidents and motor vehicle accidents. A few studies on military trauma and one study on various traumas in the current review reported neuropsychological profiles for participants with PTSD and co-occurring mTBI, but none included participants with co-occurring moderate or severe TBI (Combs et al., 2015; Lopez et al., 2017; Shandera-Ochsner et al., 2013; Soble et al., 2013). Furthermore, none of the aforementioned studies specified TBI as the index traumatic event for the development of PTSD. It is possible that participants' post-traumatic stress was in relation to an incident separate from the TBI, making it difficult to draw conclusions about the co-occurrence of PTSD and TBI per se. Moreover, head injury altogether was an exclusion criterion in Grigorovich et al. (2013) with participants who developed PTSD after electrical injuries – intelligence and visual memory were average and verbal memory was low average to average in this study. Although the finding of low average results in the absence of head injury can attest to the impact of the PTSD itself on verbal memory, it would also be useful for research to demonstrate potentially more impaired neuropsychological profiles of individuals with co-occurring PTSD and TBI. Bae et al. (2014) also excluded TBI in their study, which found average intellectual ability in survivors of motor vehicle accidents with either PTSD or Adjustment Disorder. Scott et al. (2015) noted a similar trend of head injury exclusion criteria in their meta-analysis. Vasterling et al. (2012) reported that TBI status was not associated with neurocognitive impairment or cognitive-related functional impairment in their sample of veterans with PTSD and predominantly mild TBI. It will be useful to expand the literature focus on PTSD co-occurring with the full range of mild, moderate, and severe TBI. Understanding the clinical-neuropsychological profiles of each may help to aid in differential diagnosis, especially given noted overlap in traumatic stress and TBI symptomology in terms of emotional numbing, dissociation, reduced concentration, amnesia, social withdrawal, depression, anxiety, and aggressive or selfdestructive behaviour (Bryant, 2011). Furthermore, elucidating instances of PTSD and co-occurring moderate and severe brain injuries with impairment on clinical-neuropsychological tests would contribute to accumulating evidence that PTSD can indeed develop following TBI (e.g., Bryant, Marosszeky, Crooks, & Gurka, 2000; Stein & McAllister, 2009; Vasterling, Verfaellie, & Sullivan, 2009). This evidence would strengthen models of PTSD development, and delineate cognitive domains in which impairments are conducive to developing PTSD. For example, observance of specific memory impairments in PTSD comorbid with TBI would support hypotheses that implicit fear conditioning or traumatic memory reconstruction can lead to development of PTSD (e.g., Bryant, 2011). Findings of executive dysfunction would shed light on controversial findings that damage to certain prefrontal cortical regions and associated executive and self-regulatory abilities may have either detrimental or protective effects on adverse psychological outcomes (e.g., Bryant, 2011; Vasterling et al., 2009).

Various Trauma Histories Almost one third of the studies under review did not specify or limit the type of trauma exposure in their samples (e.g., Flaks et al., 2014; Lopez et al., 2017; Myers et al., 2014; Parlar et al., 2016; Scheiner et al., 2014; Yang et al., 2017). Among these studies, many diagnostic groups were represented (i.e., PTSD, PTSD comorbid with mTBI, PTSD and psychogenic nonepileptic seizures, MDD, and PTSD with co-occurring MDD), and several neuropsychological domains were assessed. However, given that the cognitive impact of trauma is expected to differ according to factors such as life stage, interpersonal context, and chronicity (e.g., Johnsen & Asbjørnsen, 2008; Wilson et al., 2011), the lack of distinction between multiple types of trauma is a major limitation of this literature. The only results in the impaired range in this systematic review were verbal memory indices ranging from borderline to low average for participants with PTSD and MDD and various trauma histories in which childhood and adolescent trauma were noted to be predominant (Scheiner et al., 2014). Scheiner and colleagues used the Buschke SRT, which is said to be more sensitive to verbal memory deficits in comparison to the CVLT and AVLT, due to its lack of semantic and serial positioning cues. Notably, verbal memory was regarded in Masson, East-Richard, and Cellard's (2016) meta-analysis as the most affected cognitive domain for adults with psychiatric disorders and histories of childhood maltreatment.

Childhood Trauma With respect to studies specific to childhood trauma, intelligence scores were the only standardized results available. Intelligence was in the low average-to-average range among adults with psychotic disorders and histories of childhood abuse or neglect (Campbell et al., 2013; Sideli et al. 2014). It is interesting that the low average results were for participants with potentially more severe self-reported trauma histories, in terms of physical abuse resulting in injuries and penetrative sexual abuse. However, low average results do not warrant an interpretation of intellectual deficits. Rivera-Veléz, González-Viruet, Martínez-Taboas, and Peréz-Mojica (2014) did assess multiple cognitive domains in a sample of Latinas with histories of childhood physical or sexual trauma, without the criterion of psychopathology. The authors noted a high level of PTSD symptomology in the sample, with 10 of the 12 participants having "probable" PTSD. Results were generally average, with low average scores on Part A and B of the Color Trails Test of processing speed and executive function.

The paucity of neuropsychological domains for which standardized results were available is a major limitation of the childhood trauma literature from 2013 to 2018. Examining IQ in isolation is a gross oversimplification of neuropsychological functioning, as normal overall intelligence may be accompanied by specific strengths or weaknesses in verbal versus visual intelligence or discrete cognitive impairments. Childhood and adolescent trauma are known to be especially detrimental given the development of executive functions and underlying neural regions at the age of the trauma. For example, Lu et al. (2017) found childhood trauma to be associated with adulthood executive deficits and decreased default mode network connectivity in the left ventromedial prefrontal cortex, left orbitofrontal cortex, and right cerebellum. Cognitive disruptions have also been reported in the areas of attention, learning, and memory, with the most salient impact in adulthood on verbal memory, visuospatial problem solving, and attention (e.g., Masson, East-Richard, & Cellard, 2016; Wilson et al., 2011).

Intimate Partner Violence and Sexual Assault Two studies of intimate partner violence and sexual assault in the present review suggested that survivors with PTSD possess average intellectual skills in terms of overall, verbal, and performance intelligence (Chung et al., 2014; Lipinska et al., 2014). The limitations of this area of the literature are akin to those of the childhood trauma literature, in that it is necessary to examine domains other than intelligence in these populations. Particularly for intimate partner violence, neurocognitive deficits are likely to be evidenced in areas associated with frontal-subcortical circuitry, such as executive function, working memory, and visuospatial abilities (Stein et al., 2002).

Refugee Trauma Refugee-related trauma was represented by one study in this review (e.g., Shin et al., 2017). For North Korean refugees with PTSD, results were average for overall IQ, verbal and performance intelligence, and verbal and visual memory. Barriers to interpreting these results are similar to those posed by studies that amalgamated various trauma histories in one sample. That is, several factors may warrant subgroups of specific refugee-related events, such as age at the time of leaving the region and type of traumas endured (e.g., physical or sexual assault, separation from family).

Intraindividual Variability as a Marker of Trauma-Related Cognitive Dysfunction

Trauma survivors often present with cognitive complaints in neuropsychological assessment and rehabilitation settings. For example, Vasterling and Proctor (2011) comment on the presence of neuropsychological complaints among Western military personnel returning from almost every major operation. Furthermore, numerous studies referred to in this review have outlined significant cognitive deficits seen in trauma survivors in the context of comparisons with control groups on experimental or standardized task performance. This systematic review attempted to elucidate the clinical-neuropsychological test profiles that clinicians can expect to see in clients with traumatic histories.

Based on the studies reviewed, results suggest that post-traumatic changes in cognition may be context-dependent. That is, trauma survivors may struggle to concentrate, remember, and plan during daily activities when triggers, stressors, and distractors are prevalent. Yet they may not experience this interference in thinking abilities in the containment of standardized test environments or at times when they are in a more regulated state. That is, there may be within-group or within-person variability in neuropsychological assessment performance that was not captured by the results reported in this review. While experimental-cognitive tasks such as reaction time tasks lend themselves well to quantifying intra-individual variability, standardized neuropsychological tests are less equipped to do so, where variability is rarely if ever taken as a performance metric. Response variability has been demonstrated in PTSD in the context of experimental tests of executive function (Swick, Honzel, Larsen, & Ashley, 2013), suggesting that this is a promising avenue for exploration.

Research involving clinical neuropsychological assessment applications on cell phones and tablets could be ecologically valid methods of capturing intra-individual variability in everyday cognition after trauma. Neuropsychological intra-individual variability has also been demonstrated in mTBI, and is especially salient in veterans with histories of repetitive injury. Specifically, Merritt and colleagues (Merrit et al., 2018) posit that measures of dispersion and variability are more likely to reflect mTBI-related impairment, in comparison to mean neuropsychological test scores. In the present review, standardized neuropsychological performance was within normal limits in cases of PTSD alone as well as comorbid PTSD and mTBI. These findings may be interpreted in the context of intra-individual cognitive variability as well as Bryant's (2011) suggestion that cognitive changes after mTBI are related to psychological stress reactions following the injury rather than to actual neurological insult.

Clinical Implications for Conducting Trauma-Informed Assessments

Based on the authors' clinical experience and drawing on principles of trauma-informed practice (e.g., BC Mental Health & Substance Use Services, 2013), it is possible that neuropsychological assessments themselves may trigger an acute stress reaction that interferes with frontal-limbic functioning. For instance, intrusive trauma memories, physiological hyperarousal, and emotional distress in terms of grief, anger, or worry may arise due to the perception that one is undergoing an assessment to delineate cognitive abilities that have been lost, or in the case of interpersonal violence, taken away, due to trauma. Moreover, in a neuropsychological assessment, a vast amount of information about a client's history is gathered during the intake interview in a relatively brief period of time. This data gathering is in contrast to a psychotherapy context, where such disclosures may take place over the course of many sessions, as rapport is built and trust is established in the client-therapist relationship. This rapid collection of highly sensitive information by someone who is relatively unknown to the client could be experienced as highly invasive, and could therefore possibly re-activate traumatic memories, either consciously or subconsciously. This re-experiencing could, in turn, make completing the assessment quite challenging and, depending on the client's baseline self-regulation skills, adversely impact or cause variability in their test performance. The BC Mental Health & Substance Use Services (2013) outlines several recommendations for trauma-informed practice, and a select few of these are outlined below.

Intake Assessment When gathering information from clients, clinicians are advised to consider the purpose of the requested information, and keep the conversation connected to present functioning and health. Clinicians should remember (and inform clients) that trauma-informed care does not require discussing the details of the client's trauma experience. Further, clinicians should provide a rationale for querying trauma history, such as indicating that trauma may have an impact on self-regulation and cognition, and this is a normal part of human survival and coping. It is additionally recommended that clinicians should take steps to support the client's autonomy during the assessment, such as indicating the client's choice to answer or "skip" any questions, or to take breaks when needed.

Follow-up Questions on Trauma When a client's self-reported cognitive difficulties are not apparent on standardized testing, it is especially important to inquire about a trauma history, if not already queried during the initial intake interview. In light of changes in self-regulation occurring after trauma, neuropsychologists should also consider standardized scores on self-report measures of executive function in conjunction with objective test performance. The mPFC, which is highly implicated in trauma, is heavily involved in emotional aspects of executive function, such as affective processing and regulation (Etkin, Egner, & Kalisch, 2011), in contrast to the preponderance of executive function tasks that tend to tap more dorsolateral or "cool" aspects of executive function. Self-report instruments such as the Behavior Rating Inventory of Executive Function and the Frontal Systems Behaviour Scale may be more ecologically valid than objective tasks in their ability to detect changes in self-regulation. Karr et al. (2019) found that among variables including injury-related characteristics and post-injury objective neuropsychological performance, PTSD severity independently predicted perceived change in executive function on the Frontal Systems Behaviour Scale in a sample of veterans with blast-related mTBI. In another sample of veterans, perception of cognitive dysfunction on the Neurobehavioural Symptom Inventory, but not objective neurocognitive performance, mediated the relationship between PTSD diagnosis and physical, emotional, and social functioning (i.e., after controlling for TBI, depression, education, and premorbid IQ; Samuelson et al., 2017).

Trauma-Informed Feedback In consideration of the potential discrepancy between clients' everyday cognitive struggles and neuropsychological results, intra-individual variability, and potential cognitive changes from pre-to-post trauma, it is imperative that regardless of objective test performance, clinicians provide therapeutic feedback that acknowledges and validates clients' distress associated with impaired daily functioning and perceived loss of abilities (e.g., Samuelson et al., 2017). At the same time, however, Bryant (2011) explains that psychoeducation should not communicate neural dysfunction as a permanent or salient explanation for lapses in cognitive function. An emphasis on brain damage can promote hypervigilance, catastrophizing, and maladaptive appraisals of cognitive lapses, which can in turn heighten the stress reaction, exacerbate trauma-related symptomology, increase depression, and reduce sense of self-efficacy and hope for recovery (Bryant, 2011; Ehlers & Clark, 2000). This cycle is especially likely to occur in trauma-related disorders such as PTSD, where there is an attentional bias to threat and stimuli of concern, and a tendency to catastrophize about external threats as well as one's own capabilities (Ehlers & Clark, 2000). Mattson, Nelson, Sponheim, and Disner (2019) recommend that feedback should emphasize cognitive changes as being symptoms of trauma-related psychopathology – which can be remediated through the treatment of said psychopathology – rather than as permanent cognitive impairment.

Neuropsychologically-Informed Treatment Approaches The rehabilitation approach should be client-centered with the objective of increasing self-efficacy and empowering clients with tools and strategies to manage specific challenges in everyday life, which may differ depending on factors unique to each client, such as trauma experience, personal values, career goals, and social network. Such an approach is similar to Clare and Woods' (2004) model of cognitive rehabilitation, which utilizes compensatory strategies such as environmental aids and modifications to help clients thrive in everyday life, rather than aiming for restitution of cognitive functions and improvement of test performance through methods such as computerized training. That said, if self-regulatory challenges during moments of threat perception and stress are underlying state-based cognitive struggles, then rehabilitation should aim to bolster clients' resilience and self-regulatory capacity. To this end, somatic (i.e., interoceptively-focused) approaches such as mindfulness and yoga may be beneficial. Specifically, *bottom-up* techniques which manage and lower emotional reactions without reliance on cognitive appraisal and prefrontal cortical engagement are ideal, given that prefrontal cortical integrity is compromised during the traumatic stress response (Chiesa, Serretti, & Jakobsen, 2013). An obvious example of this is the many grounding techniques that are routinely taught to traumatized clients, such as orienting to the five senses or engaging in gentle movement. Notably, bottom-up regulation can be practiced in the absence of rational or identifiable triggers, as may occur in cases of implicit trauma memories, and especially in cases of post-traumatic amnesia or co-occurring brain injury. The usefulness of interoceptively-focused and mindfulness-based approaches in the realm of building resilience is illustrated in emerging evidence suggesting their effectiveness for increasing heart rate variability (e.g., Tyagi & Cohen, 2016) and for enhancing cognition in cases of intra-individual variability (e.g., Smart, Segalowitz, Mulligan, Koudys, & Gawryluk, 2016).

Limitations

Risk of Bias Several factors limit the clinical implications of the current review. Importantly, the review provides a limited five-year window into the literature published from 2013 to 2018. The conclusions drawn – particularly those relating to gaps and biases in standardized neuropsychological test data – must be interpreted within the context of this timeframe and major limitation. Nevertheless, an extremely large number of abstracts initially screened for inclusion in this review were ultimately eliminated because they did not use standardized neuropsychological tests. Furthermore, more than one third of the full-text articles considered had employed standardized neuropsychological tests but did not report standardized scores. There is a tendency in the literature for studies to only report raw scores or statistical analyses demonstrating between-group differences or associations between trauma and raw or standardized test performance. The paucity of research reporting standardized test scores – even when using standardized tests – may be related to publication bias and outcome reporting bias, both of which are prevalent in healthcare research (e.g., Dwan et al. 2013). In terms of publication bias, studies that find clinically meaningful results (i.e., intact or impaired performance on neuropsychological assessments) may be less likely to be published relative to those reporting statistically significant between-group differences on experimental cognitive tasks.

Results indicating neuropsychological performance within normal limits are especially likely to be viewed and dismissed as a null finding, even though they are clinically relevant. For studies that use standardized tests but neglect to report standardized scores, the selective reporting of raw scores or analyses may be related to the higher likelihood of significant outcomes to be reported and published. As Scott et al. (2015) explain, these biases may be especially pronounced in research on cognitive outcomes of trauma, given that it is a less established area of research and therefore researchers are less likely to pursue publication or to be accepted to publish what appear to be equivocal results. Researchers may also choose not to interpret results in the context of normative scores if the quality or relevance of the norms is questionable, for example in terms of lack of recently updated norms, non-representative samples, and lack of cross-cultural validation. Based on only 21 studies reporting standardized test results, it is difficult to make definitive conclusions about clinically meaningful neuropsychological impairment in clients with histories of trauma. The assessments pertaining to risk of bias within the studies under review highlight methodological weaknesses limiting the quality of neuropsychological findings. First, nearly all of the studies under review lacked test administrators who were blind to participants' trauma and diagnostic history. Masking of assessors is a gold standard that should be strived for in order to reduce risk of differential treatment from the assessor and expectancy effects on the part of participants.

Another bias-related methodological consideration is the ascertainment of trauma exposure. According to the Newcastle-Ottawa Quality Assessment Scale, which Zeng et al. (2015) recommend for assessing risk of bias in cohort studies, measuring exposure via secure record or blind structured interview is ideal. Interviewers in this case would be blinded to participant self-reported or diagnosed trauma and mental health history. In the current review, however, most studies used self-report questionnaires, some studies used structured or semi-structured interviews, and a few studies did not report how participants were determined to meet criteria for trauma exposure or trauma-related diagnosis. Weaker methods of trauma assessment could have diluted neuropsychological results in many of the samples examined.

Performance and Symptom Validity Testing Another limitation is that the majority of studies did not use any effort measures to identify and exclude participants whose performance suggested invalid neuropsychological performance or clinical symptom presentation. When conducting neuropsychological assessments with clients with trauma histories, there is potential for litigation and secondary gains pertaining to TBI, motor vehicle accidents, assault, and occupational stress injuries. The necessity of validity considerations is demonstrated by Wisdom et al. (2013), who compared veterans with mTBI and PTSD to healthy veterans. Those veterans who failed a performance validity test showed cognitive deficits with large effect sizes across domains, whereas no deficits were detected in those who passed the validity measure. Also, a survey of neuropsychologists in the Veterans Health Administration estimated failure rates on symptom or performance validity tests as high as 23.0% for outpatients, 12.9% for inpatients, and 46.4% and 39.3% respectively for disability evaluations investigating the effects of mTBI and PTSD (Young, Roper, & Arentsen, 2016). It is especially important to note the lack of validity testing in the current study, as the low average test results were primarily in the realm of memory, which is the domain most likely to be affected by inadequate effort. Still, the vast majority of neuropsychological results were within normal limits across all studies, despite the paucity of effort tests.

Insufficient Sample Characterization Almost half of the studies did not adequately address potential confounding factors in that they neglected to stratify results by trauma type or characterize the psychiatric conditions in their sample. Given the focus in the literature to date on neuropsychological effects associated with PTSD in particular, it is imperative for ongoing research to specify whether the trauma-related neuropsychological effects in question are seen in the context of PTSD, another diagnosis, or a combination of conditions. As a sound reporting example, Todd et al. (2015) specified that although their research focused on PTSD, comorbid diagnoses were prevalent in their sample, with 68.2% suffering from depression, 22.7% diagnosed with substance abuse disorder, and 13.6% having another anxiety disorder. This information indicates that any neuropsychological findings seen in this study may not be exclusive to PTSD.

Notably, the current review intentionally excluded baseline or outcome data associated with treatment studies. This limits the generalizability of findings to treatment-seeking clients, who may experience greater durations and intensities of trauma-related symptomology, and also may have higher levels of intelligence and academic achievement (e.g., Ray et al., 2017). Still, varying treatment statuses were noted across samples in the current review, and one third of the studies neglected to comment on treatment status in their sample. Psychotherapeutic and psychopharmacological intervention may mask the neuropsychological impact of trauma in individuals who experience cognitive and emotional disruptions and are motivated to seek treatment.

Greater Inclusivity in Population Sampling Another limitation of the current literature is a possible heterosexist and cisgender bias, particularly evident in the inclusion of only female survivors in research on neuropsychological outcomes of sexual assault and intimate partner violence (e.g., Chung et al., 2014; Lipinska et al., 2014). Understanding neuropsychological sequelae of trauma in LGBTQ+ participants is especially important as the risk for violence, abuse, hypervigilance to threat, chronic stress, and posttraumatic stress disorder are higher in this community relative to the rest of the population (e.g., Mink, Lindley, & Weinstein, 2014; Roberts, Austin, Corliss, Vandermorris, & Koenen, 2010).

Intergenerational transmission of trauma also appears to have been overlooked in the research to date. Particularly with regard to historical and intergenerational trauma in Indigenous people, targeting future research efforts towards understanding its neuropsychological impact is in line with the BC Mental Health and Substance Use Service (2013) guide for trauma-informed practice, as well as national movements to improve policy and community supports. Along these lines, in their review of intergenerational trauma in refugee families, Sangalang and Vang (2017) state that future research on trauma experiences of non-Western refugees would reflect the current refugee crisis in Western countries. In the current review, only one study included a refugee sample. Moving forward, research efforts are needed to help understand the neuropsychological processes of trauma and its intergenerational transmission among refugee families.

Conclusions

Initial evidence from the 21 studies of neuropsychological assessment in people with trauma histories and psychiatric diagnoses suggests that clinically meaningful impairment is not reflected in standardized test performance. It is likely that the cognitive challenges clients experience are state-based, occurring in everyday life when triggers and stressors are present. Cognitive functioning can also be expected to differ between clients due to unique levels of resilience and vulnerability, related in part to factors such as premorbid cognitive ability and heart-rate variability. As this is a new area of neuropsychological inquiry, several future steps are suggested to: (1) examine neuropsychological functioning separately for each type of trauma exposure, as different profiles may emerge for each type of exposure, (2) utilize ecologically valid measurement of intra-individual variability and self-reported neuropsychological measures, in order to better capture state-based changes occurring in trauma-related disorders as well as those comorbid with TBI, (3) use both structured clinical interviews and self-reports to ascertain trauma exposure and diagnoses, (4) expand on the breadth of neuropsychological domains investigated for childhood trauma survivors beyond intelligence, (5) evaluate co-occurring moderate to severe TBI especially in cases of combat trauma, and (6) better reflect our experience of trauma through specific inclusion of LGBTQ+ participants as well as refugee and Indigenous families living with intergenerational trauma.

The current review aimed to decipher clinically meaningful results in terms of objective test performance. The results of the review suggest that there is not currently a sufficient amount of studies or the requisite homogeneity (e.g., in study design, trauma type, and outcome measures; Valentine, Pigott, & Rothstein, 2010) in the literature for a meta-analysis to be employed. Unfortunately, it is also not possible to support conclusions regarding cognitive differences between trauma types and diagnoses. As more studies reporting standardized neuropsychological test scores among trauma survivors accumulate, future researchers are encouraged to employ meta-analytic techniques to investigate clinically meaningful results in terms of neurocognitive effect sizes. Such analyses may employ moderators including trauma type, psychiatric diagnosis, chronicity of exposure, number of instances of exposure, and years since trauma exposure, in addition to demographic considerations such as gender and age. Another research question arising from this review is: How can clinicians build validity considerations into assessments in regard to potentially inconsistent and variable performance of trauma survivors? Additional research endeavours in this field can use prospective and follow-up designs to uncover whether clinically meaningful changes in standardized neuropsychological performance occur from pre to post trauma. Furthermore, to expand on the movement to relate trauma to psychiatric diagnoses other than PTSD, it will be worthwhile to compare neuropsychological functioning between people with and without trauma histories in the context of disorders such as depression, anxiety, and substance abuse. These steps may help to clarify a clinically relevant understanding of the neuropsychological and diagnostic sequelae of trauma.

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