

Questioning the Link Between PTSD and Cognitive Dysfunction

Angela Danckwerts^{1,2} and Janet Leathem¹

Posttraumatic stress disorder (PTSD) has been linked with impairment in cognitive functioning, but anomalies appear to arise on several levels, masking the true nature of the relationship. On one level, there is a blurring of the emotional and physical causes of cognitive dysfunction, especially with memory problems that are similar to those due to neurological disorders. At other levels, problems are evident due to issues such as overgeneralizing from specific populations to the general population, and the use of narrow-focused neuropsychological assessment instruments that neither dissociate among precise memory components nor relate to everyday situations. In this review we highlight methodological problems and concerns, and make suggestions to establish valid links between PTSD and cognitive dysfunction.

KEY WORDS: PTSD; memory; Cognition.

Posttraumatic Stress Disorder (PTSD) develops after a person has been exposed to an extreme traumatic stressor such as a car accident, rape, natural disaster, violent, or terrorist attack in which they or others were threatened with death or serious injury, and to which they responded with fear, helplessness, or horror. The condition is a relatively common and predictable psychological syndrome (Miller, 1999) and is characterised by a diagnostic triad consisting of reexperiencing of the trauma through intrusive memories, avoidance behaviors, and heightened arousal. The full symptom picture must have been present for more than 1 month and must also cause clinically significant distress, or impairment in social, occupational, and other areas of functioning (American Psychiatric Association [APA-TR], 2000).

The psychological consequences of the events of September 11th, 2001, highlighted PTSD as an increasingly important health issue worldwide, and in addition established that more than those directly involved in the traumatic experience run the risk for PTSD sequelae. Significant others and professional helpers have also been shown to be susceptible to PTSD symptomatology af-

ter close association with horrific events (e.g., Lindeman *et al.*, 1996). As a rule of thumb 75% of the general population are likely to experience a traumatic experience that is capable of precipitating PTSD (Green *et al.*, 1994), and a quarter (25%) to a third (33%) of those exposed will go on to develop PTSD symptoms (McCarroll *et al.*, 1997; Yehuda *et al.*, 1992).

Research has found the most commonly reported symptom is that of intrusive recollections or reexperiencing memories of the event through recurrent dreams of the event, hallucinations, and dissociative flashbacks. These intrusive recollections are different from the recurrent intrusive thoughts experienced by in those with Obsessive-Compulsive Disorder (OCD). Although OCD intrusive recollections are inappropriate and not related to an experienced traumatic event, PTSD recollections may include intrusive thoughts, images, or perceptions, or acting or feeling that the traumatic event is recurring, and are generally triggered automatically by cues relating to the traumatic experience.

The individual will also try to avoid stimuli associated with the original trauma. Efforts to evade people, places, feelings, thoughts, conversations, or participation in activities that arouse recollections of the trauma are common. The person may feel numb, experience flat affect, feel detached from others, and have a sense of foreshortened future. At the same time they may show

¹Massey University, Auckland, New Zealand.

²To whom correspondence should be addressed at School of Psychology, Massey University, Albany Campus, P.B. 102 904, North Shore Mail Centre, Auckland, New Zealand; e-mail: A.M.Danckwerts@xtra.co.nz.

persistent signs of hypervigilance or increased arousal, irritability or outbursts of anger, difficulty concentrating, and have difficulty in falling asleep (APA-TR, 2000).

However, although lawyers and treating therapists routinely assume that beneath PTSD symptoms the disorder lurks, this is not necessarily always the case. Having a diagnosis according to strict DSM-IV-TR diagnosis and experiencing PTSD symptomatology are not necessarily equivalent. For instance, most individuals in the general population can easily see themselves as having symptoms described in the DSM-IV-TR PTSD criteria B, C, and D, at one time or another *without* a definitive Criterion A stressor. Included among possible precursors to potential PTSD symptomatology are experiences such as divorce, failure to receive tenure, getting fired, loss of income or lifestyle, and being the brunt of chronic harassment. Any of these traumatic experiences may predispose or contribute to the development of PTSD symptoms. There needs to be some recognition of the possibility that some experience PTSD symptoms without full-blown Criterion A criteria, and PTSD symptoms are not specific to the 75% of the population who experience a true Criterion A traumatic event.

COGNITIVE FUNCTIONING

In addition to the emotional sequelae, and aside from the intrusive memories of the past that intrude into the present, disturbed cognitive functions in the form of deficits in declarative memory (remembering events, facts or lists), have been listed as an integral component of PTSD since the inception of DSM criteria in 1980 (Pitman, 1989).

Yet despite the acceptance of memory dysfunctions as a symptom of PTSD, the specific nature of the reported disturbances remains unclear. This paper highlights pertinent inconsistencies and anomalies occurring at several levels in the relationship between PTSD and cognitive dysfunction (see Fig. 1), and offers suggestions for clarifying that link. The paper is limited to studies using standard neuropsychological assessment instruments, and those focusing on intrusive memory for trauma-related stimuli or autobiographical memory of the individual are not examined.

MEMORY DISTINCTIONS

It is important when discussing memory dysfunction in those with PTSD, that a distinction is made between nondeclarative (sometimes termed implicit or procedural) and declarative (explicit) memory processes (Baddeley, 1995; Squire, 1992). This is because the disorder affects

nondeclarative and declarative memory processes in different ways (Brewin, 2001). Implicit memory is not conscious. Instead, information may come to mind or influence current behavior even when a person has no awareness or recollection of the prior occurrence. The literature suggests that implicit memory is related to automatic priming of trauma-related material and underlies fear conditioning or conditioned emotional responses, such as the persistent intrusive reexperiencing of the traumatic event in PTSD (Charney *et al.*, 1995; Elzinga and Bremner, 2001). Even the most inconsequential of triggers, like a door slamming, the crackle of thunder, or the sight of a person in paramedic uniform, may evoke autonomic arousal, intrusive thoughts, and vivid images of the accident. There is substantial evidence that memories can be encoded outside awareness, that these memories can influence ongoing emotions and behaviors (Hamner *et al.*, 1999; Schacter *et al.*, 1993). Studies that report those with PTSD show an attentional bias towards such threatening or trauma-related stimuli are demonstrating implicit memory processes (e.g., Bryant and Harvey, 1997; McNally, 1997; Zeitlin and McNally, 1991). On the other hand, declarative or explicit memory refers to the ability to remember and reproduce events and memory related facts. This type of memory is typically accompanied by conscious awareness, is concerned with reduced memory functioning due to impaired encoding or retrieval abilities, and is strongly influenced by the degree of attention and organization, reflecting the importance of the depth of processing for setting up memory structures that are accessible to retrieval.

The concept of memory is also frequently explained on a continuum from short-term memory (STM) to long-term memory (LTM; Squire, 1986; 1992; Squire, Knowlton, and Musen, 1993). The type of memory disturbance in those with PTSD is concerned with impaired memory functioning due to diminished encoding, storage, and/or retrieval abilities, and refers to impairments among the processes that are critical to achieving these fundamental procedures successfully.

SEVERITY OF PTSD SYMPTOMATOLOGY

There are two factors that are reported to greatly influence the severity of PTSD symptomatology. The first is the extent or gravity of the actual exposure to a stressful event per se. For instance, a common trauma such as the sudden unexpected death of a loved one carries a risk of 14.3% for triggering PTSD (Breslau *et al.*, 1998). This can be compared with the risk for PTSD to those exposed to extremely high stressful events such as combat, bombing, or mass violence who can have incidences of PTSD as high as 20–40% (Breslau *et al.*, 1991; Davidson and Faribank,

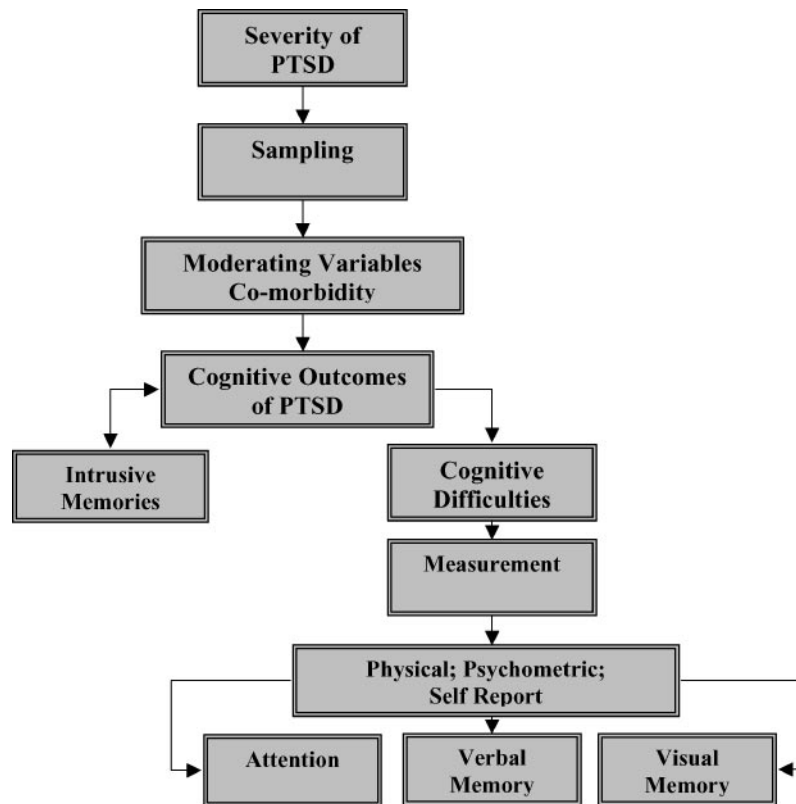


Fig. 1. Factors influencing the link between cognition and PTSD.

1993; McFarlane, 1989; Schneider and Levenson, 2002). Recent postconflict rates in Gaza, Cambodia, and Algeria, were estimated at 17.8, 28.4, and 37.4%, respectively (de Jong *et al.*, 2001).

The second is the subjective severity of the exposure to the stressful event, that is, the more that an event is perceived by the victim to be adverse, uncontrollable, and/or unpredictable, the more likely it is to elicit higher levels of PTSD (Blanchard *et al.*, 1995; Folkman *et al.*, 1986; Foy *et al.*, 1984). These findings hold for combat situations as well as for victims of traumatic experiences, such as rape, natural disasters, or terrorist attacks, and highlight the importance of stressor severity and subjective appraisal of the traumatic threat and/or danger (Jones and Barlow, 1990; van der Kolk, 1994). Although there is a clear link between gravity and subjective severity of the traumatic incident and PTSD symptomatology, it is unclear whether a similar link exists between the gravity of the actual exposure to a stressful event, the subjective severity of the incident, and severity of specific cognitive difficulties. It is therefore important to delineate both the gravity (i.e., stressor severity per se), and subjective severity of the traumatic incident if true cognitive (dis)functioning of those with PTSD is to be explicated.

Many also argue the case for PTSD after traumatic brain injury (TBI) where the event is often a relatively frequent occurrence (minor motor vehicle accident, assault) and in cases where the survivor had coma and/or extended posttraumatic amnesia (PTA) and has no specific memory for the event (e.g., Bryant, 2001). Cognitive problems may be compounded by the fact that there is often insufficient data to determine that the memory problem resulted from the supposed event and was not preexisting. The same holds for emotion. This highlights the importance of taking into account the individual's prior cognitive and emotional functioning as well as conducting current cognitive and emotional assessments.

SAMPLING AND METHODOLOGICAL PROBLEMS

Generalizations are sometimes inappropriately made to the general population when sampling confounds have not been recognised. In the PTSD literature, this can occur when sample size is small (e.g., Bremner *et al.*, 1993; Uddo *et al.*, 1993; Yehuda *et al.*, 1995) and/or specific, for example, military and veterans populations that differ

from civilian PTSD groups in that they tend to be older, predominantly male, and to have been traumatised by different events (Breslau *et al.*, 1998; Kessler *et al.*, 1995). The latter issue is highlighted in Table I, where studies 1–10 focus on PTSD-diagnosed military and war veterans, whereas studies 11–15 have been conducted on civilian PTSD victims. The danger in not recognising these sampling confounds is that findings from veteran's studies are generalized to civilian populations when the extent to which this is appropriate is unclear (Norris, 1992).

COMORBIDITY

PTSD is associated with increased rates of Major Depressive Disorder (MDD), Generalized Anxiety Disorder (GAD), Substance Related Disorders, Panic Disorder, Agoraphobia, Obsessive-Compulsive Disorder, and Phobias (APA-TR, 2000, p. 465). Many prior studies have not utilized stringent criteria to exclude these and other potential comorbid confounds. Most of the research examining the cognitive status of PTSD groups has been conducted on groups with coexisting psychiatric conditions (e.g., Barrett *et al.*, 1996; Bremner *et al.*, 1995b; Gil *et al.*, 1990; Zalewski *et al.*, 1994), with as many as 80% of those diagnosed with PTSD likely to present in clinical settings with one or more other psychiatric diagnoses (Zalewski *et al.*, 1994). The effect of depressed mood and other emotional conditions on neuropsychological functioning is well known (Parker, 1990; Synder and Nussbaum, 1999). This means that neuropsychological complaints assessed in PTSD are likely to coexist with and be influenced by features such as depression: markedly diminished interest in activities, sleep difficulties, recurrent thoughts of death, and detachment from others (Karam, 1997; Kudler *et al.*, 1987; McFarlane, 1992), anxiety/panic disorders (Davidson, 1992; Hickling and Blanchard, 1992), and substance abuse (Foy, 1992; Hoffman and Sasaki, 1997).

One of the few PTSD studies using nonveteran participants (Gil *et al.*, 1990), cognitive deficits in the areas of visual and verbal memory and executive functioning were reported, although there was no significant difference between the PTSD group and a group of participants with a variety of other psychiatric diagnoses. Therefore, it is not clear if there are similarities or differences in the cognitive deficits reported for those presenting with PTSD alone and those presenting with PTSD and at least one other psychiatric complaint such as depression, anxiety/panic disorder, or substance abuse. Jenkins *et al.* (1998, 2000) included in their exclusionary criteria the existence of neu-

rologic, anxiety, affective, schizophrenia spectrum, or substance use disorders predating the assault, but although results showed a clear trend towards lower performance by those with PTSD, these participants may have acquired comorbid conditions posttrauma. This suggests that cognitive impairments in such studies should be interpreted cautiously, as the findings leave open the question as to whether deficits are attributable to PTSD per se or other uncontrolled factors.

Further, imaging techniques that have demonstrated alterations in brain structures including the hippocampus in long-term sufferers of mood disorders such as depression (Axelson *et al.*, 1993; Krishnan *et al.*, 1991) highlight the complex interplay between emotional and physical states. Reports on the outcomes of neuropsychological assessment of cognitive function in those with PTSD without comorbid psychiatric difficulty is very limited (Everly and Horton, 1989; Gilbertson *et al.*, 1997; Goldstein *et al.*, 1987). Nevertheless, studies that have controlled for comorbid conditions have reported cognitive deficits suggesting that PTSD per se does contribute to observed group differences. Moreover, it has been suggested that the comorbidity course-of-illness onset of PTSD may be different to other psychiatric conditions such as generalized anxiety disorder and past substance abuse. Despite the fact that PTSD symptoms almost always surface soon after exposure to trauma, the mean onset of comorbid disorders usually occurs later than PTSD symptoms (Mellman *et al.*, 1992). Thus, identification of time lapsed since the original trauma may be important to elucidating the cognitive deficits in those with PTSD.

BLURRING OF COGNITIVE DIFFICULTIES

Cognitive difficulties associated with PTSD further highlight the interplay between emotional and physical states. Intrusive memories are a PTSD-specific set of "cognitive difficulties" that have an emotional basis, whereas brain impairment causes a different set of cognitive difficulties particularly with the acquisition of new memories. That is not to say that cognition cannot be compromised by emotional as well as physical factors. Indeed, intrusive memories may be so crippling to the sufferer as to undermine normal cognitive tasks (Wolfe and Schlesinger, 1997). It is just that it is important to emphasise that the cognitive difficulties referred to in most of the studies purporting to examine the cognition/ PTSD link are those involving acquisition and recall in the cognitive domains of attention, learning, memory, information processing, and higher executive function. Accordingly, care should

Table I. Characteristics of Studies of Cognitive Deficits in PTSD Study

Study	PTSD measure	Participants	Measures	Outcomes
Bremner <i>et al.</i> (1993)	a. Clinical Interview (SCID) ¹ b. Mississippi Scale for Combat-Related PTSD ²	1) 26 PTSD veterans 2) 15 non-PTSD volunteers	<i>Intelligence</i> WAIS-R ³ : arithmetic; vocabulary; picture arrangement; block design <i>Verbal memory</i> WMS-R ⁴ : logical memory Selective reminding test (SRT) ⁵ <i>Visual memory</i> WMS-R: figural memory SRT	NS PTSD < controls on logical (verbal) tests of memory (immediate & delayed) NS
Uddo <i>et al.</i> (1993)	a. (MMPI)-derived PTSD Scale ⁶ b. SCID c. Mississippi Scale for Combat-Related PTSD d. Personal and demographic information interview	1) 16 PTSD veterans 2) 15 non-PTSD National Guard volunteers	<i>Intelligence</i> WAIS-R or Shipley Institute of Living Scale ⁷ <i>Verbal memory</i> Auditory verbal learning test (AVLT) ⁸ WMS-R: digit-span <i>Visual memory</i> Complex figure test (RCFT) ⁹ WMS-R: visual memory-span <i>Executive function</i> Controlled oral word association test (COWAT) ¹⁰	NS PTSD < controls across all learning trials, perseverence errors, proactive interference PTSD < control immediate recall NS delayed recall PTSD < control
Sutker <i>et al.</i> (1995)	(MMPI)-derived PTSD Scale	108 POW survivors	<i>Attention and mental tracking</i> WMS-R: digit-span, visual memory Trailmaking tests A and B ¹¹ <i>Learning and memory</i> WMS-R: logical memory, visual reproduction <i>Executive function</i> Category Test ¹² Wisconsin card sorting test (WCST) ³	PTSD associated with cognitive deficits
Yehuda <i>et al.</i> (1995)	a. Combat Exposure Scale ¹⁴ b. Mississippi Scale for Combat-Related PTSD c. Clinician Administered PTSD Scale ¹⁵ d. Clinical history	1) 20 PTSD veterans 2) 12 healthy volunteers	<i>Intelligence</i> WAIS ^{16,2} <i>Memory</i> Initial attention and immediate (STM) memory, cumulative learning, active interference from previous learning, retroactive interference, delayed recall CVLT ¹⁷	NS NS attention, STM, cumulative learning PTSD < controls retroactive interference, recall, interference, memory for information relevant and nonrelevant to trauma
Barrett <i>et al.</i> (1996)	National Institute of Mental Health Diagnostic Interview Schedule ¹⁸	1) 236 PTSD veterans without MDD, GAD, and/or substance abuse 2) 128 PTSD veterans with MDD, GAD, and/or substance abuse 3) 1,835 healthy veterans	<i>Intelligence</i> WAIS-R <i>Attention, vis-spatial, motor skills</i> RCFT CVLT <i>Executive functioning</i> WCST	NS Groups 1 and 2 on all measures Groups 1 and 2 < Group 3 on all measures

Table I. (Continued)

Study	PTSD measure	Participants	Measures	Outcomes
Vasterling <i>et al.</i> (1998)	SCID	1) 19 PTSD Gulf War recruits 2) 24 healthy recruits	<i>Attention</i> Letter cancellation ¹⁹ Stroop color-word test ²⁰ Continuous performance test ²¹ <i>Verbal memory</i> WAIS-R: digit-span, arithmetic AVLT <i>Visual memory</i> Continuous visual memory test (CVMT) ²² <i>Executive function</i> WCST	PTSD < controls Intrusion errors PTSD < controls acquisition, retroactive interference NS memory recall or proactive interference
Gilbertson <i>et al.</i> (1997)	a. Structured Clinical Interview for DSM-III-R ²³ b. Clinician Administered PTSD Scale	1) 19 veterans with PTSD 2) 14 healthy veterans	<i>Intelligence</i> WAIS-R <i>Attention</i> WAIS-R: digit-span Trail-making test Symbol digit modalities <i>Memory</i> WMS ²⁴ [verbal, visual, delayed] <i>Visuospatial</i> RCFT <i>Executive function</i> WCST	PTSD < non-PTSD attention, memory NS NS
Goldstein <i>et al.</i> (1987)	a. Semistructured interview b. DSM-III PTSD criteria c. Record review, follow-up contact d. MMPI	1) "Half" of 41 veterans with PTSD 2) Other "half" of veterans without PTSD	No particular cognitive domains tested, but reports of subjective cognitive difficulties	Most PTSD < non-PTSD
Zalewski <i>et al.</i> (1994)	a. DSM-III PTSD criteria b. Diagnostic Interview Schedule ²⁵	1) 241 veterans with PTSD no GAD 2) 241 veterans with GAD no PTSD 3) 241 healthy veterans	<i>Attention, Mental speed and control, computational ability</i> Paced auditory serial addition test (PASAT) ²⁶ <i>Visual-spatial perception, concentration, capacity sustained effort, nonverbal concept formation</i> WAIS-R: block design <i>Memory for visual material</i> RCFT <i>Verbal memory</i> (immediate [STM] and delayed) CVLT	NS Groups 1, 2 and 3 on all measures

Sachinvala <i>et al.</i> (2000)	<p>a. PTSD Diagnostic Sale (PDS; Foa, 1995)²⁷ b. Hamilton-D Depression Rating Sale (1960)²¹</p>	<p>1) 36 veterans with PTSD. Diagnosis of depression allowed 2) 18 healthy employees Vets Administration</p>	<p><i>Attention, functional capacities, short-term memory, extended memory</i> Cognitive Evaluation Scale²⁹</p>	<p>PTSD patients < controls on all attention tests, numbers, words, extended memory tests, all function tests, and reaction time</p>
Gil <i>et al.</i> (1990)	<p>a. DSM-III PTSD criteria b. Severity of psychiatric disturbance scored on Clinical Global Impression Scale (CGI; Guy, 1976)³⁰</p>	<p>1) 12 PTSD civilians 2) 12 non-PTSD psychiatric patients 3) 12 healthy civilians</p>	<p><i>Intelligence</i> WAIS-R "Organicity" Bender-Gestalt³¹ Verbal new learning WMS Mental control <i>Nonverbal memory</i> RCFT Benton visual reproduction test (form c)³² <i>Executive function</i> COWAT Hebrew letter test³³ <i>Remote memory</i> Famous Events Questionnaire³⁴ Self-report Subjective memory disturbance</p>	<p>NS Groups 1 and 2 on all measures Groups 1 and 2 < Group 3 on all measures</p>
Bremner <i>et al.</i> (1995b)	<p>a. Early Trauma Inventory (ETI) b. Axis I disorder (semistructured interview) c. Schedule for Affective Disorders and Schizophrenia—Life version (SADS-L)³⁵ All patients met criteria for PTSD</p>	<p>1) 21 PTSD adult survivors of severe childhood physical/sexual abuse "many" with comorbid disorders 2) 21 Healthy, nonabused adults</p>	<p><i>Intelligence</i> WAIS-R: arithmetic, vocabulary, block design, picture arrangement <i>Verbal short-term memory</i> WMS: logical SRT <i>Visual short-term memory</i> WMS: figural SRT</p>	<p>NS PTSD < non-PTSD on verbal STM, immediate, and delayed recall NS</p>

Table I. (Continued)

Study	PTSD measure	Participants	Measures	Outcomes
Everly and Horton (1989)	DSM-III-R PTSD criteria	14 clinical PTSD patients	<i>Verbal memory</i> Four word short-term memory test (Ryan and Butters, 1980) ³⁶	PTSD < normative group
Jenkins <i>et al.</i> (1998)	a. DSM-III-R PTSD criteria b. Mississippi Scale for Combat-related PTSD, modified c. SCID d. Beck Depression Inventory(BDI) ³⁷ e. Michigan Alcoholism Screening Test (MAST) ³⁸	1) 15 PTSD rape victims 2) 16 non-PTSD rape victims 3) 16 nontraumatised healthy controls	<i>Verbal memory</i> (immediate free recall, short, long delay recall, recognition, meaning-related, serial clustering of encoding) CVLT	PTSD rape < other groups on delayed free recall PTSD rape < non-PTSD rape plus controls, on immediate free recall, number of words learned but results NS
Jenkins <i>et al.</i> (2000)	a. DSM-III-R PTSD criteria b. Mississippi Scale for Combat-Related PTSD, modified c. SCID d. Beck Depression Inventory(BDI) ³⁷ e. Michigan Alcoholism Screening Test (MAST) ³⁸	1) 15 PTSD rape victims 2) 16 non-PTSD rape victims 3) 16 nontraumatised healthy controls	<i>Sustained and focused attention</i> PASAT ³⁹ WAIS-R: digit-span; digit symbol <i>Sustained attention for visual stimuli</i> Continuous performance test (CPT) ⁴⁰ <i>Psychomotor processing speed, sustained, divided attention, switch cognitive sets</i> Trail-making tests A and B ⁴¹ <i>Covert shifting of attention</i> Posner visual selective attention task ⁴²	PTSD group < other groups Digit span backward PTSD < other groups PTSD < other groups PTSD > omission errors than other groups Trails B PTSD < other groups NS

Note. ¹Structured Clinical Interview for DSM-III-R(SCID); Spitzer *et al.*, 1987); ²Mississippi Scale for Combat-Related PTSD (Keane *et al.*, 1988); ³Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981); ⁴Wechsler Memory Scale—Revised (WMS-R; Weschler, 1987); ⁵Selective Reminding Test (Hannay and Levin, 1985); ⁶(MMPI)-derived PTSD Scale of Keane *et al.*, (1984); ⁷Shipley Institute of Living Scale (Shipley, 1967); ⁸Rey Auditory Verbal Learning Test (AVLT; Lezak, 1983; Rey, 1964); ⁹Rey Complex Figure Test (RCFT; Osterreith, 1944); ¹⁰Controlled Oral Word Association Test (COWAT; Benton and Hamsher, 1978); ¹¹Trailmaking Tests Parts A and B (Army Individual Test Battery; U.S. Department of War, Adjutant General's Office, 1944; see Sutker *et al.*, 1995); ¹²Category Test (Halstead, 1947); ¹³Wisconsin Card Sorting Test (WCST; Berg, 1948; Heaton, 1981); ¹⁴Combat Exposure Scale (Laufer *et al.*, 1985); ¹⁵Clinician Administered PTSD Scale (Black *et al.*, 1990); ¹⁶Wechsler Adult Intelligence Scale (Wechsler and Stone, 1955); ¹⁷CVLT (Delis *et al.*, 1987); ¹⁸National Institute of Mental Health Diagnostic Interview Schedule (Robins *et al.*, 1981); ¹⁹Letter cancellation (Tailland, 1965); ²⁰Stroop Color-Word Test (Stroop, 1935); ²¹Continuous Performance Test (CPT; Conners, 1992); ²²Continuous Visual Memory Test (Robins and Helzer, 1985); ²³DSM-III-R criteria (American Psychiatric Association, 1987); ²⁴Wechsler Memory Scale (Wechsler and Stone, 1945); ²⁵Diagnostic Interview Schedule Rating Scale (Hamilton, 1960); ²⁶Paced Auditory Serial Addition Test (PASAT; Gronwall and Sampson, 1974); ²⁷Posttraumatic Stress Diagnostic Scale (PDS; Foa, 1995); ²⁸Hamilton-D Depression Reproduction Test (form c); ²⁹Cognitive Evaluation Protocol (CEP; McGuire *et al.*, 2000); ³⁰Clinical Global Impression Scale (Guy, 1976); ³¹Bender-Gestalt (Hut, 1977); ³²Benton Visual (SADS-L; Endicott and Spitzer, 1978); ³³Hebrew Letter Test (see Gil *et al.*, 1990); ³⁴Famous Events Questionnaire (see Gil *et al.*, 1990); ³⁵Schedule for Affective Disorders and Schizophrenia—Life version (³⁸Michigan Alcoholism Screening Test (MAST; Westmayer and Neider, 1988); ³⁹PASAT (Levin *et al.*, 1987); ⁴⁰Continuous Performane Test (CPT; Loong, 1988); ⁴¹Trailmaking Test A and B (TMT-A and TMT-B; Reitan, 1967); ⁴²Posner Visual Selective Attention Task (Posner, Walker, Friedrich, and Rafal, 1984).

be taken when reading the PTSD research literature to ensure that it is clear which of the two subsets of cognitive difficulties is being referred to.

IDENTIFICATION OF COGNITIVE FUNCTION

The cognitive difficulties associated with PTSD have been identified from three sources: structural changes are reported on MRI in areas of the brain traditionally associated with memory, measures borrowed from clinical neuropsychology have quantified the difficulties, and those with PTSD self-report cognitive difficulties as they relate to the everyday situation. When the means by which cognitive difficulties have been identified are quite different, there is a danger in assuming that the entity so identified is the same in each case. Further, it is entirely possible that cognitive difficulty, identified by one source may not be identified in either of the other two.

For example, MRI studies have reported evidence of decreased hippocampal volume in veterans with combat-related PTSD (Bremner *et al.*, 1995a; Gurvits *et al.*, 1996), in adults with a history of childhood abuse and PTSD (Bremner *et al.*, 1997), and one study found decreased hippocampal volume in breast-cancer patients diagnosed with PTSD (Kato *et al.*, 2000). As the hippocampal area appears to be responsible for declarative (explicit) memory processing (Tranel and Damasio, 1995) it could be concluded (on the basis of neuroimaging) that the cognitive impairments associated with PTSD are associated with subcortical damage, especially in the hippocampal area. If there is structural damage secondary to PTSD (possibly due to biochemical changes in the brain associated with chronic arousal that leads to tissue damage), it is not clear if cognitive problems are related to a continuum of severity of PTSD and a continuum of tissue damage. Furthermore, empirical research that connects subtle alterations in hippocampal brain structures to quantifiable cognitive changes in those diagnosed with PTSD victims is limited (Wolfe and Schlesinger, 1997), that is, although structural changes appear to be linked with cognitive difficulties, the research literature does not support a one-to-one relationship between structural change and predictable change on neuropsychological assessment measures (Stein *et al.*, 1997) especially as these relate specifically to PTSD.

The fact that self-report of cognitive changes is not always associated with corresponding changes on formal neuropsychological assessment, or brain structure has been frequently reported in the research literature. Discrepancy between self-report and formal assessment of cognitive difficulty has been noted after traumatic brain injury (TBI; Ponsford *et al.*, 1995; Viguier *et al.*, 2001),

mood disorders (Branca *et al.*, 1996; Miller, 1980), and various other disorders affecting cognitive functioning (e.g., Ravdin *et al.*, 1996). Ravdin and associates reported that Lyme borreliosis patients rated their subjective memory as more impaired than objective memory scores implied, but also reported increased fatigue. Notwithstanding that self-report validity may be confounded by motivational factors such as the tendency for some to underestimate their symptoms (e.g., TBI patients; Prigatano, 2000), or the tendency for others to overestimate their symptoms when there is litigation involvement (Kay, 1999), the literature suggests self-report of impaired memory performance may be confounded by mood states such as depression, anxiety, or fatigue. Thus, the importance of excluding coexisting emotional states is crucial. However, the importance of item content of self-report measures must also be stressed. Bennett-Levy *et al.* (1980) initially reported that laboratory tasks and self-report of memory complaints had low correlation, but when items focused on real life, "everyday" memory skills, there were significant correlations between subjective and objective measurement measures.

Self-reported complaints of memory difficulties associated with PTSD generally highlight lower concentration and attention, as well as problems with new learning and recall (Archibald and Tuddenham, 1965; Sutker *et al.*, 1991, 1995; White, 1983; Wolfe and Charney, 1991). However, as with other disorders, the difficulties reported in this everyday sense are not always confirmed on formal neuropsychological assessment (e.g., Roca and Freeman, 2001). Furthermore, when significant results are reported, other researchers (sometimes using the same assessment measures) just as commonly report negative findings. For instance, as can be seen in Table I, Barret *et al.* (1996) reported immediate and delayed verbal memory differences between those with PTSD and healthy controls whereas Zalewski *et al.* (1994) reported no differences. These discrepancies have received little attention in the PTSD literature. In addition, of the studies listed in Table I, less than 30% include self-report to check for everyday interactions relative to environment or other ecological validity. Future research should employ more tests of "everyday" of cognitive functioning such as the Everyday Memory Scale (Crook and Larrabee, 1990), or the Rivermead Behavioral Memory Test (RBMT; Wilson *et al.*, 1989). As its name suggests, the RBMT includes practical, relevant tests of everyday functioning such as remembering: a name associated with a photograph, an appointment, a new route, delivering a message, and orientation for time and place, which may better match the patients' self-reports of attention, concentration, and memory disturbance.

NEUROPSYCHOLOGICAL ASSESSMENT

Cognitive difficulties that cannot be readily explained by the moderating effect of comorbid conditions such as mood, emotion, and/or substances, require careful examination by means of psychometric assessment. However, although it is useful to know via psychometric measurement that a person has difficulty with a particular task, it is just as important to know *why* the individual has the difficulty performing the task. Therefore, examination of all components of a cognitive domain such as memory (from sensation and attention, through to encoding, storage of information to subsequent recall), using a process approach (Kaplan, 1988) is essential. A process approach is more likely to elucidate the focal points at which the attention/memory processes become dysfunctional as a consequence of psychological or physiological damage. For example, a low result on a standardised measure of memory, may be due to the undermining influence of an attentional problem, rather than a problem of memory *per se* (Lezak, 1995). Here, impaired attention prevents proper registration of information to be learned, which in turn precludes consolidation and retrieval of memory, that is, there is nothing stored to remember. Significant differences in scoring on measures of attention have been reported for PTSD and control groups (e.g., Sutker *et al.*, 1995; Uddo *et al.*, 1993; Vasterling *et al.*, 1998).

Findings also suggest that those with PTSD experience impairments in working memory (i.e., the ability to temporarily maintain and manipulate information in order to perform cognitive tasks), and processing inefficiencies including sequencing and organizational skills. These impairments that (combined with attentional difficulties) undermine scores on measures of memory have been associated with damage to the orbito-frontal (Damasio and Anderson, 1993) and/or the amygdaloid regions and their numerous projections. The role of the amygdala in anxiety and mood states may mean that cognitive function is impaired by the disruptive influence of heightened arousal rather than actual damage to the area.

It has already been established that interference conditions contribute to the memory difficulties of PTSD victims (e.g., Uddo *et al.*, 1993; Vasterling *et al.*, 1998; Yehuda *et al.*, 1995), causing impairments in memory for relevant, as well as information that is neither personally relevant or emotional (Yehuda *et al.*, 1995). Although distraction by irrelevant stimuli can have a profound impact on memory and once again suggests frontal lobe damage (Damasio and Anderson, 1993), susceptibility to memory problems regarding relevant information may be a product of anxiety or fear responses involving the amygdala (Damasio, 1994; Davis, 1997; LeDoux *et al.*, 1990; Tranel

and Damasio, 1995). This highlights once again the complex interplay between physical and psychological states, and the need to dissociate between disruption to memory caused through mood or anxiety states and that caused by structural abnormalities.

This also supports an assessment of mood states at the time of testing as cognitive deficits including impairments in attention (particularly in the face of competing stimuli or distraction), reduced ability to absorb new information (often attributable to impaired attention) and apparent executive deficits (Gil *et al.*, 1990) may be the product of mood, anxiety, or fear responses and may be mistaken for brain damage. The challenge lies in distinguishing between them (Rankin and Adams, 1999).

Of the various aspects of memory, verbal memory has been highlighted as a common problem associated with PTSD. Bremner *et al.* (1993) employing both the Logical Memory subtest of Wechsler Memory Scale—Revised (WMS-R) as well as the Verbal Component of Selective Reminding Test (SRT; where stimuli not recalled are represented on multiple occasions) reported significant short-term memory (STM) deficits. However, Sutker *et al.* (1995) utilizing only the score on the Logical Memory component of the WMS-R to assess verbal memory deficits of PTSD victims reported no significant results. It is plausible then that one-off subsets such as the Logical Memory of WMS-R in which stimuli are presented only once, may be insufficiently sensitive to the memory impairments reported by individuals with PTSD. This underscores the need to use assessment instruments that evaluate the different component processes of verbal memory and attention, as they pertain to the self-reported problem areas as well as the functioning mediated by areas of the brain believed to be damaged.

In comparison to verbal memory, there has been little examination of visual memory relating to individuals with PTSD. However, the importance of assessment for visual memory impairments experienced by those with PTSD should not be ignored. To begin with, skills such as the ability to remember patterns and spatial positions are crucial in employment areas such as art and graphic design, architecture, driving a car, or piloting a helicopter or an aeroplane (Shum *et al.*, 2000). Perhaps even more important for those experiencing PTSD, the ability to remember visual patterns and spatial relations underpins everyday activities such as locating where one has put an article or finding one's way in an unfamiliar environment (Mapou, 1992). Nonetheless, visual impairments would be supported by studies documenting that removal of portions of certain structures lying deep within the subcortical areas (e.g., right hippocampus) produce declines in visual memory (Trennery *et al.*, 1996). In addition, when the studies

investigating the links between visual memory difficulties and PTSD are scrutinised, it is apparent that much of the relevant information pertaining to visual memory impairments in those with PTSD is too subtle and sensitive to be elicited by imprecise assessment measures employed thus far. Of the studies reviewed, all but two reported non-significant visual impairments. However, as suggested by Shum *et al.* (2000), these findings may be due to the use of very limited visual assessment instruments (more often than not a single measure, over one trial) that do not allow in-depth examination of diverse visual memory functions such as the rate, speed, or degree of new learning, retention of material after interference, or delayed retention of information by comparing performances across trials. In addition, some measures (e.g., WMS-R visual memory) do not assess recognition and remote memory (Kane, 1991), and using a delay period of only 30 min may not be long enough to elicit various precise visual impairments. Generally, the longer the space between stimulus presentation and recall, the more sensitive the measure may be in detecting visual memory disturbance, especially concerning right temporal lobe lesions (Delaney *et al.*, 1980). It is therefore likely that much of the relevant information pertaining to the relationship between visual memory and PTSD is too subtle and sensitive to be elicited by simple, unidimensional measures.

Support for the value of a more comprehensive examination of visual memory is provided by Bremner *et al.* (1993) and Vasterling *et al.* (1998). Although their results did not reach significance, Bremner and colleagues demonstrated that the lower percentage of retention for the Figural Memory subtest of WMS-R was related to greater PTSD symptom severity and Vasterling and colleagues reported impaired initial learning of visuo-spatial information in their PTSD groups. These nonsignificant yet pertinent findings support an association between PTSD and visual memory impairments, and give provisional support to the significant results of Uddo *et al.* (1993). Heilbronner (1992) suggested that the administration procedure involved with the WMS-R visual reproduction subtest confuses participants (requiring the copying of four geometric designs immediately and again after 30-min delay) in that the assessment of visual memory is contaminated by the constructional component of the task. As a result an observed impairment may stem from a physiological, visuo-perceptual or visuo-spatial memory impairment, a practice deficit, or a blend of any of these, and will likely confound interpretations of performance (Heilbronner, 1992). Moreover, the extent to which an individual is familiar with the visual material presented is a crucial factor, as increased familiarity heightens the likelihood of the material being dependent on language-related skills rather than

on visual-spatial abilities, and on language-related rather than visual-related areas of the brain (De Renzi, 1982). Heilbronner (1992) argues that WMS-R visual reproduction tests load high on factors comprised of nonmemory measures, leading Eadie and Shum (1995) to suggest that nonsense figures may be more sensitive than geometric figures. Correspondingly, a visual testing instrument without a visual-constructional component such as the Shum Visual Learning Test (SVLT; Shum *et al.*, 1999; Eadie and Shum, 1995) may have the power to detect visual anomalies in those with PTSD. The SVLT is a newly developed test of visual memory and learning in which unfamiliar, complex Chinese characters assess an individual's ability to recognize visual patterns. It may simply be that isolated measures used to assess attention and memory in PTSD groups borrowed from clinical neuropsychology such as the Wechsler Memory Scales are insufficiently precise to elucidate the specific deficits likely to result from hippocampal or other structural changes. Clearly, the use of more sophisticated tests that dissociate among specific memory components, are necessary.

Research findings have been confounded so far by methodological inconsistencies and flawed neuropsychological testing procedures that neither provide a comprehensive examination of memory domains, nor incorporate memory as related to everyday situations, or take into account how frontal lobe tests may impact on memory (e.g., attention). Although most studies have focused on older, male, war veterans, there has also been little consideration given to the relationship between severity of the subjective response to the traumatic event experienced by those with PTSD, severity of PTSD symptomatology, or time lapsed since original trauma, and their impact on formal and everyday cognitive functioning.

Understanding the memory processes underlying cognitive functioning in those with PTSD would provide information pertinent to lesion localization, rehabilitation, and defining relationships with the brain. Future research needs to identify both the type (i.e., gravity), subjective severity of the traumatic incident, and time lapsed since the original trauma if valid cognitive (dis)functioning of civilians with PTSD is to be revealed. Stringent criteria to exclude potential preexisting, and comorbid criteria, is crucial. The importance of item content of self-report measures is also stressed. Forthcoming research should also employ more assessment of "everyday" functioning such as RBMT that may better match the patients' self-reports of attention, concentration, and memory disturbance relative to their everyday environmental cognitive functioning. Furthermore, instruments that allow multiple exposures of the information to be learned, measurement of initial encoding and retention over delayed intervals,

and that allow an analysis of qualitative processes may be the only way to elucidate precise impairments in the processes underlying cognitive deficits. Clearly, the quantification alone of performance decrements and test scores that reveal a person's success or failure to perform a specific task is not enough to elucidate the link between PTSD and cognitive functioning. Rather, any psychometric evaluation should involve a systematic assessment to elucidate the *nature* of the impairments. The use of more elaborate tests that separate among precise memory components, and that thus enable improved content analysis, are urgently needed. The greater likelihood of elucidating coherent cognitive deficits if more comprehensive nonverbal tools such as SVLT and verbal assessment instruments such as the CVLT are used, also adds weight to the argument that shortened forms may be inappropriate.

This review has endeavoured to address and clarify the reasons for the vague link between PTSD and cognitive functioning, and elucidated a much broader topic in neuropsychology involving the overinterpreting of data due to a failure to take significant intervening variables into account. Also highlighted are problems inherent in transferring the veteran data to the general population, as well as many anomalies and methodological weaknesses involved in the measurement of memory. Taken together, the gaps in our understanding provide a strong rationale to employ more comprehensive/sophisticated neuropsychological testing measures and evidence-based neuroimaging to establish underlying causes (i.e., nature) of the effects of PTSD on cognition. Thus, in order to establish links that have as yet only been implied, it is vital that future neuropsychological research applies and combines these more sophisticated assessment approaches. Until this eventuates, the exact nature of the relationship between PTSD and cognitive functioning remains elusive.

REFERENCES

- American Psychiatric Association. (1980). *Diagnostic and Statistical Manual of Mental Disorders*, 3rd edn., American Psychiatric Association, Washington, DC.
- American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders*, 4th edn., text Rev., American Psychiatric Association, Washington, DC.
- Archibald, H. C., and Tuddenham, R. D. (1965). Persistent stress reaction after combat. *Arch. Gen. Psychiatry* **12**: 475–481.
- Axelson, D. A., Doraiswamy, P. M., McDonald, W. M., Boyko, O. B., Tupler, L. A., Patterson, L. J., et al. (1993). Hypercortisolemia and hippocampal changes in depression. *Psychiatry Res.* **47**: 163–173.
- Beck, A. T., Ward, C. H., Mendelson, M. Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of General Psychiatry*, **4**: 561–571.
- Barrett, D. H., Green, M. L., Morris, R. G., Giles, W. H., and Croft, J. B. (1996). Cognitive functioning and post-traumatic stress disorder. *Am. J. Psychiatry* **153**: 1492–1494.
- Baddeley, A. D. (1995). The psychology of memory. In A. D. Baddeley, B. A. Wilson, and F. A. Watts (Eds.), *Handbook of Memory Disorders*. (pp. 3–25). London: John Wiley & Sons Ltd.
- Bennett-Levy J., Polkey, C. E., and Powell, G. E. (1980). Self-report of memory skills after temporal lobectomy: The effect of clinical variables. *Cortex* **16**: 543–557.
- Benton, A. L., and Hamsher, K. (1978). *Multilingual Aphasia Examination Manual*, rev., University of Iowa, Iowa City, IA.
- Berg, E. A. (1948). A simple objective test for measuring flexibility in thinking. *J. Gen. Psychol.* **39**: 15–22.
- Black, D., Weathers, F., Nagy, D., Laoupek, G., Klauminzer, D., Charney, D., and et al. (1990). *Clinician-Administered PTSD Scale*, National Centre for Post-traumatic Stress Disorder, New Haven, CT.
- Blanchard, E. B., Hickling, E. J., Mitnick, N., Taylor, A. E., Loos, W. R., and Buckley, T. C. (1995). The impact of severity of physical injury and perception of life threat in the development of post-traumatic stress disorder in motor vehicle accident victims. *Behav. Res. Ther.* **33**: 529–534.
- Branca, B., Giordani, B., Lutz, T., and Saper, J. R. (1996). Self-report of cognition and objective test performance in posttraumatic headache. *Headache* **36**: 300–306.
- Bremner, J. D., Randall, P., Scott, T. M., Bronen, R. A., Seibyl, J. P., Southwick, S. M., et al. (1995a). MRI-based measures of hippocampal volume in patients with PTSD. *Am. J. Psychiatry* **152**: 973–981.
- Bremner, J. D., Randall, P., Scott, T. M., Capelli, S., Delaney, R., McCarthy, G., et al. (1995b). Deficits in short-term memory in adult survivors of childhood abuse. *Psychiatry Res.* **59**: 97–107.
- Bremner, J. D., Randall, P., Vermetten, E., Staib, L., Bronen, R. A., Mazure, C., et al. (1997). Magnetic resonance imaging-based measurement of hippocampal volume in posttraumatic stress disorder related to childhood physical and sexual abuse—a preliminary report. *Biol. Psychiatry* **41**: 23–32.
- Bremner, J. D., Scott, T. M., Delaney, R. C., Southwick, S. M., Mason, J. W., Johnson, D. R., et al. (1993). Deficits in short-term memory in posttraumatic stress disorder. *Am. J. Psychiatry* **150**: 1015–1019.
- Breslau, N., Davis, G., Andreski, P., and Peterson, E. (1991). Traumatic events and posttraumatic stress disorder in an urban population of young adults. *Arch. Gen. Psychiatry* **48**: 216–222.
- Breslau, N., Kessler, R. C., and Chilcott, H. D. (1998). Trauma and post-traumatic stress disorder in the community. *Arch. Gen. Psychiatry* **55**: 626–632.
- Brewin, C. R. (2001). Memory processes in post-traumatic stress disorder. *Int. Rev. Psychiatry* **13**: 159–163.
- Bryant, R. A. (2001). Posttraumatic stress disorder and traumatic brain injury: Can they co-exist? *Clin. Psychol. Rev.* **21**: 931–948.
- Bryant, R. A., and Harvey, A. G. (1997). Attentional bias in posttraumatic stress disorder. *J. Trauma. Stress* **10**: 635–644.
- Charney, D. S., Deutch, A., Southwick, S., and Krystal, J. (1995). Neural circuits and mechanisms of posttraumatic stress disorder. In: Friedman, M., Charney, D., and Deutch, A. (eds.), *Neurobiological and Clinical Consequences of Stress: From Normal Adaptation to Posttraumatic Stress Disorder*, New York, Lippincott-Raven, pp. 271–287.
- Conners, C. K. (1992). *Conners' Continuous Performance Test Computer Program User's Guide*. Toronto, Canada: Multi-Health Systems.
- Crook, T. H., and Larrabee, G. J. (1990). A self-rating scale for evaluating memory in everyday life. *Psychol. Aging* **5**(1): 48–57.
- Damasio, A. R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain*, Grosset/Putnam, New York.
- Damasio, A. R., and Anderson, S. W. (1993). The frontal lobes. In: Heilman, K., and Valenstein, E. (eds.), *Clinical Neuropsychology*, Oxford University Press, New York, pp. 400–460.
- Davidson, J. R. T. (1992). Drug therapy of posttraumatic stress disorder. *Br. J. Psychiatry* **160**: 309–314.
- Davidson, J. R. T., and Fairbank, J. A. (1993). The epidemiology of posttraumatic stress disorder. In: Davidson, J. R. T., and Foa, E.

- B. (eds.), *Posttraumatic Stress Disorder: DSM-IV and Beyond*, American Psychiatric Press, Washington, pp. 147–172.
- Davis, M. (1997). Neurobiology of fear responses: The role of the amygdala. *J. Neuropsychiatry Clin. Neurosci.* **9**(3): 382–402.
- de Jong, J. T., Komprou, I. H., and Van Ommeren, M. (2001). Lifetime events and posttraumatic stress disorder in 4 post conflict settings. *J. Am. Med. Assoc.* **286**: 555–562.
- Delaney, R. C., Rosen, A. J., Mattson, R. H., and Novelly, R. A. (1980). Memory function in focal epilepsy: A comparison of non-surgical, unilateral temporal lobe and frontal lobe samples. *Cortex* **16**: 103–117.
- Delis, D., Kramer, J., Ober, B., and Kaplan, E. (1987). *The California Verbal Learning Test Manual*, Psychological Corp., New York.
- De Renzi, E. (1982). *Memory Disorders Following Focal Neocortical Damage*, Philosophical Transactions Royal Society, London.
- Eadie, K., and Shum, D. (1995). Assessment of visual memory: A comparison of Chinese characters and geometric figures as stimulus materials. *J. Clin. Exp. Neuropsychol.* **17**: 731–739.
- Elzinga, B. M., and Bremner, J. D. (2002). Are the Neural Substrates of Memory the Final Common Pathway in Posttraumatic Stress Disorder (Ptd)? *Journal of Affective Disorders*, **70**: 1–17.
- Endicott, J., and Spitzer, R. L. (1978). A diagnostic interview: The Schedule for Affective Disorders and Schizophrenia. *Arch. Gen. Psychiatry* **35**: 837–844.
- Everly, G. S., and Horton, A. M. (1989). Neuropsychology of post-traumatic stress disorder: A pilot study. *Percept. Mot. Skills* **68**: 807–810.
- Foa, E. B. (1995). *Posttraumatic Stress Diagnostic Scale*, National Computer Systems, Minneapolis, MN.
- Foy, D. W., Sippelle, R. C., Rueger, D. B., and Carroll, E. M. (1984). Etiology of posttraumatic stress disorder in Vietnam veterans. *Journal of Consulting and Clinical Psychology*, **40**: 1323–1328.
- Folkman, S., Lazarus, R. S., Gruen, R. J., and De Longis, A. (1986). Appraisal, coping, health status and psychological symptoms. *J. Pers. Soc. Psychol.* **50**: 571–579.
- Foy, D. W. (1992). Introduction and description of the disorder. In: Foy, D. W. (ed.), *Treating PTSD: Cognitive-Behavioral Strategies*, Guilford Press, London, pp. 1–13.
- Gil, T., Calev, A., Greenberg, D., Kugelmass, S., and Lerer, B. (1990). Cognitive functioning in posttraumatic stress disorder. *J. Trauma. Stress* **3**: 29–46.
- Gilbertson, M. W., Gurvits, T. V., Lasko, N. B., and Pitman, R. K. (1997). Neuropsychological assessment of Vietnam combat veterans with and without PTSD. In: Yehuda, R., and McFarlane, A. C. (eds.), *Psychobiology of Posttraumatic Stress Disorder*, Annals of the New York Academy of Sciences, New York, pp. 476–480.
- Goldstein, G., van Kammen, W., Shelly, C., Miller, D. J., and van Kammen, D. P. (1987). Survivors of imprisonment in the Pacific theatre during World War two. *Am. J. Psychiatry* **144**: 1210–1213.
- Green, J., Green, B. L., and Lindy, J. D. (1994). Posttraumatic stress disorder in victims of disasters. *Psychiatr. Clin. North Am.* **17**: 301–309.
- Gronwall, D., and Sampson, H. (1974). *The Psychological Effects of Concussion*, Oxford University Press, Auckland, NZ.
- Gurvits, T. V., Shenton, M. E., Hokama, H., Ohta, H., Lasko, N. B., Gilbertson, M. W., et al. (1996). Magnetic resonance imaging study of hippocampal volume in chronic, combat-related posttraumatic stress disorder. *Biol. Psychiatry* **40**: 1091–1099.
- Guy, W. (1976). *ECDEU Assessment Manual for Psychopharmacology*, U.S. Department of HEW, Bethesda.
- Halstead, W. C. (1947). *Brain and Intelligence*, University of Chicago Press, Chicago.
- Hamilton, M. I. (1960). A rating scale for depression. *J. Neurol. Neurosurg. Psychiatry* **23**: 56–62.
- Hamner, M. B., Lorberbaum, J. P., and George, M. S. (1999). Potential role of the anterior cingulate cortex in PTSD: Review and hypothesis. *Depress. Anxiety* **9**: 1–14.
- Hannay, H. J., and Levin, H. S. (1985). Selective Reminding Test: An examination of the equivalence or four forms. *Journal of Clinical and Experimental Neuropsychology*, **7**: 251–263.
- Heaton, R. K. (1981). *The Wisconsin Card Sorting Test Manual*, Psychological Assessment Resources, Odessa, FL.
- Heilbronner, R. L. (1992). The search for a “pure” visual memory test: Pursuit of perfection? *Clin. Neuropsychol.* **6**: 105–112.
- Hickling, E. J., and Blanchard, E. B. (1992). Posttraumatic stress disorder and motor vehicle accidents. *J. Anxiety Disord.* **6**: 285–291.
- Hoffman, K. J., and Sasaki, J. E. (1997). Comorbidity of substance abuse and PTSD. In: Fullerton, C. S., and Ursano, R. J. (eds.), *Posttraumatic Stress Disorder: Acute and Long-Term Responses to Trauma and Disaster*, Psychiatric Press, London, pp. 159–174.
- Hutt, M. L. (1977). *The Hutt Adaptation of the Bender-Gestalt Test*, Grune and Stratton, New York.
- Jenkins, M. A., Langlais, P. L., Delis, D., and Cohen, R. (1998). Learning and memory in rape victims with posttraumatic stress disorder. *Am. J. Psychiatry* **155**: 278–279.
- Jenkins, M. A., Langlais, P. L., Delis, D., and Cohen, R. (2000). Attentional dysfunction associated with posttraumatic stress disorder among rape survivors. *Clin. Neuropsychol.* **14**: 7–12.
- Jones, J. C., and Barlow, D. H. (1990). The etiology of post-traumatic stress disorder. *Clin. Psychol. Rev.* **10**: 299–328.
- Kane, R. (1991). Standardized and flexible batteries in neuropsychology: An assessment update. *Neuropsychol. Rev.* **2**: 281–339.
- Kaplan, E. (1988). A process approach to neuropsychological assessment. In: Boll, T., and Bryant, B. K. (eds.), *Clinical Neuropsychology and Brain Function: Research Measurement and Practice*, American Psychological Association, Washington, DC, pp. 129–167.
- Karam, E. G. (1997). Comorbidity of posttraumatic stress disorder and depression. In: Fullerton, C., and Ursano, R. (eds.), *Posttraumatic Stress Disorder: Acute and Long Term Responses to Trauma and Disaster*, Psychiatric Press, London, pp. 77–90.
- Kato, N., Nishimura, T., Imai, H., and Liu, Y. (2000). Corticosterone and cytokines in the hippocampus: Neurotoxicity vs. neuroprotection. *Int. J. Neuropsychopharmacol.* **3**: S43 (abstract).
- Kay, T. (1999). Interpreting apparent neuropsychological deficits: What is really wrong? In: Sweet, J. J. (ed.), *Forensic Neuropsychology: Fundamentals and Practice*, Swets Zeitlinger, Lisse, pp. 145–185.
- Keane, T. M., Caddell, J., and Taylor, K. (1988). Mississippi Scale for combat-related post-traumatic stress disorder: Three studies in reliability and validity. *J. Consult. Clin. Psychol.* **56**: 85–90.
- Keane, T. M., Malloy, P. F., and Fairbank, J. A. (1984). Empirical development of an MMPI scale for the assessment of combat related post-traumatic stress disorder. *J. Consult. Clin. Psychol.* **52**: 888–891.
- Kessler, R., Sonnega, A., Bromet, E., Hughes, M., and Nelson, C. B. (1995). Posttraumatic stress disorder in the National Co-morbidity survey. *Arch. Gen. Psychiatry* **52**: 1048–1060.
- Krishnan, K. R. R., Doraiswamy, P. M., Figiel, G. S., Husain, M. M., Shaw, S. A., Na, C., et al. (1991). Hippocampal abnormalities in depression. *J. Neuropsychiatry Clin. Neurosci.* **3**: 387–391.
- Kudler, H., Davidson, J., Meador, K., Lipper, S., and Ely, T. (1987). The DST and posttraumatic stress disorder. *Am. J. Psychiatry* **144**: 1068–1071.
- Laufer, R. S., Frey-Wouters, E., and Gallops, M. S. (1985). Traumatic stressors in the Vietnam war and posttraumatic stress disorder. In: Figley, C. (ed.), *Trauma and Its Wake: The Study and Treatment of Posttraumatic Stress Disorder*, Brunner/Mazel, New York, pp. 22–56.
- LeDoux, J. E., Cicchetti, P. O., Xagoraris, A., and Romanski, L. M. (1990). The lateral amygdaloid nucleus: Sensory interface of the amygdala in fear conditioning. *J. Neurosci* **10**: 1062–1069.
- Levin, H. S., Mattis, S., Ruff, R. M., Eisenberg, H., Marshall, L. F., Tabaddor, K., et al. (1987). Neurobehavioral outcome following minor head injury: A three center study. *J. Neurosurg.* **66**: 234–243.
- Lezak, M. D. (1983). *Neuropsychological Assessment*, Oxford University Press, New York.

- Lezak, M. D. (1995). *Neuropsychological Assessment*, Oxford University Press, New York.
- Lindeman, M., Saari, S., Verkasalo, M., and Prytz, H. (1996). Traumatic stress and its risk factors among peripheral victims of the M/S Estonia Disaster. *Eur. Psychol.* **1**: 255–270.
- Loong, J. W. K. I. (1988). *The Continuous Performance Test*, Wand Neuropsychological Laboratory, San Luis Obispo, CA.
- Mapou, R. L. (1992). Memory assessment in clinical practice and research. In: Crawford, M. P., and McKinlay, W. (eds.), *A Handbook of Neuropsychological Assessment*, Erlbaum, Hove, UK, pp. 73–101.
- McCarroll, J. E., Ursano, R. J., and Fullerton, C. S. (1997). Exposure to traumatic death in disaster and war. In: Fullerton, C. S., and Ursano, R. (eds.), *Posttraumatic Stress Disorder: Acute and Long-Term Responses to Trauma and Disaster*, American Psychiatric Press, Washington, DC, pp. 37–58.
- McFarlane, A. C. (1989). The etiology of posttraumatic morbidity: Predisposing, precipitating, and perpetuating factors. *Br. J. Psychiatry* **154**: 221–228.
- McFarlane, A. C. (1992). Multiple diagnoses in posttraumatic stress disorder in the victims of natural disaster. *J. Ment. Disord.* **180**: 498–504.
- McGuire, M., Bakst, K., Fairbanks, L., McGuire, M., Sachinvala, N., von Scotti, H., et al. (2000). Cognitive, mood, and functional evaluations using touchscreen technology. *J. Nerv. Ment. Disord.* **188**(12): 813–817.
- McNally, R. J. (1997). Implicit and explicit memory for trauma-related information in PTSD. In: Yehuda, R., and McFarlane, A. C. (eds.), *Psychobiology of Posttraumatic Stress Disorder*, Annals of the New York Academy of Sciences, New York, pp. 219–225.
- Mellman, T. A., Randolph, C. A., Brawman-Mintzer, O., Flores, L. P., and Milanes, F. J. (1992). Phenomenology and course of psychiatric disorders associated with combat-related posttraumatic stress disorder. *Am. J. Psychiatry* **149**: 1568–1574.
- Miller, L. (1999). Atypical psychological responses to traumatic brain injury: PTSD and beyond. *NeuroRehabilitation* **13**: 79–90.
- Miller, N. I. (1980). The measurement of mood in senile brain disease: Examiner ratings and self-reports. In: Cole, J., and Barrett, J. (eds.), *Psychopathology in the Aged*, Raven Press, New York, pp. 97–108.
- Norris, F. H. (1992). Epidemiology of trauma: Frequency and impact of different potentially traumatic events on different demographic groups. *J. Consult. Clin. Psychol.* **60**: 409–418.
- Osterreith, P. A. I. (1944). Le Test de copie d'une figure complexe. *Arch. Psychol.* **30**: 206–356.
- Parker, R. S. (1990). *Traumatic Brain Injury and Neuropsychological Impairment*, Springer, London.
- Pitman, R. K. (1989). Post-traumatic stress disorder, hormones, and memory. *Biol. Psychiatry* **26**: 221–223.
- Ponsford, J., Sloan, S., and Snow, P. (1995). *Traumatic Brain Injury: Rehabilitation for Every Day Adaptive Living*, Psychology Press, Hove, East Sussex, UK.
- Posner, M. I., Walker, J. A., Freidrich, F. J., and Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *J. Neurosci.* **4**: 1863–1874.
- Prigatano, G. P. (2000). *Principles of Neuropsychological Rehabilitation*, Oxford University Press, Oxford.
- Rankin, E. J., and Adams, R. L. (1999). The neuropsychological evaluation. In: Sweet, J. J. (ed.), *Forensic Neuropsychology: Fundamentals and Practice*, Swets and Zeitlinger, Lisse, pp. 83–121.
- Ravdin, L. D., Hilton, E., Primeau, M., Clements, C., and Barr, W. B. (1996). Memory functioning in Lyme Borreliosis. *J. Clin. Psychiatry* **57**: 282–286.
- Reitan, R. M. (1967). Psychological changes associated with aging and with cerebral damage. *Mayo Clin. Proc.* **42**: 653–673.
- Rey, A. (1964). *L'examen clinique en psychologie*, Presses Universitaires de France, Paris.
- Robins, L. N., & Helzer, J. E. (1985). *The Diagnostic Interview Schedule (DIS): Version III-A*. St. Louis: Washington University School of Medicine.
- Robins, L. N., Helzer, J. E., Croughan, J., and Ratcliffe, K. S. (1981). The National Institute of Mental Health Diagnostic Interview Schedule: Its history, characteristics, and validity. *Arch. Gen. Psychiatry* **38**: 381–389.
- Roca, V., and Freeman, T. (2001). Complaints of impaired memory in veterans with PTSD. *Am. J. Psychiatry* **158**: 1738–1740.
- Ryan, C., and Butters, N. (1980). Learning and memory impairments in young and old alcoholics: Evidence for the premature aging hypothesis. *Alcoholism* **4**: 190–198.
- Sachinvala, N., von Scotti, H., McGuire, M., Fairbanks, L., Bakst, K., and McGuire, M. (2000). Memory, attention, function, and mood among patients with chronic posttraumatic stress disorder. *J. Nerv. Ment. Dis.* **188**(12): 818–823.
- Schacter, D. L., Chiu, C. Y. P., and Ochsner, K. N. (1993). Implicit memory: A selective review. *Annu. Rev. Neurosci.* **6**: 159–182.
- Schneider, R. K., and Levenson, J. L. (2002). Update in Psychiatry. *Ann. Intern. Med.* **137**: 671–677.
- Shipley, W. C. (1967). *Shipley Institute of Living Scale: Manual of Directions and Scoring Key*, Western Psychological Service, Beverly Hills, CA.
- Shum, D. H. K., Harris, D., and O'Gorman, J. (2000). Effects of severe traumatic brain injury on visual memory. *J. Clin. Exp. Neuropsychol.* **22**: 25–40.
- Shum, D. H. K., O'Gorman, J., and Eadie, K. (1999). Normative data for a new memory test. The Shum Visual Learning Test. *Clin. Neuropsychol.* **13**: 121–125.
- Snyder, P. J., and Nussbaum, P. D. (1999). *Clinical Neuropsychology: A Pocket Handbook for Assessment*, American Psychological Association, Washington, DC.
- Spitzer, R. L., Williams, J. B. W., and Gibbon, M. (1987). *Structured Clinical Interview for DSM-III-R (SCID)*, Psychiatric Institute, Biometrics Research, New York.
- Squire, L. R. (1986). Mechanisms of memory. *Science*, **232**: 1612–1619.
- Squire, L. R. (1992). Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. *J. Cogn. Neurosci.* **4**: 232–243.
- Squire, L. R., Knowlton, B., and Musen, G. (1993). The structure and organization of memory. *Annual Review of Psychology*, **44**: 453–495.
- Stein, M. B., Hanna, C., Koverola, C., Torchia, M., McClarty, B., Yehuda, R., et al. (1997). Structural brain changes in PTSD. Does trauma alter neuroneuroanatomy? In: Yehuda, R., and McFarlane, A. C. (eds.), *Psychobiology of Posttraumatic Stress Disorder*, Annals of the New York Academy of Sciences, New York, pp. 57–76.
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *J. Exp. Psychol.* **18**: 643–661.
- Sutker, P. B., Vasterling, J. J., Brailey, K., and Allain, A. N. (1995). Memory, attention, and executive deficits in POW survivors: Contributing biological and psychosocial factors. *Neuropsychology* **9**: 118–125.
- Sutker, P. B., Winstead, D. K., Galina, Z. H., and Allain, A. N. (1991). Cognitive deficits and psychopathology among former prisoners of wars and combat veterans of the Korean conflict. *Am. J. Psychiatry* **148**: 67–72.
- Tailland, G. A. (1965). *Deranged Memory*, Academic Press, New York.
- Trahan, D. E., and Larrabee, G. J. (1988). *Continuous Visual Memory Test Professional Manual*, Psychological Assessment Resources, Odessa, FL.
- Tranel, D., and Damasio, A. R. (1995). Neurobiological foundations of human memory. In: Baddeley, A. D., Wilson, B. A., and Watts, F. N. (eds.), *Handbook of Memory Disorders*, Wiley, London, pp. 27–50.
- Trennery, M. R., Jack, C. R., Cascino, G. D., Sharbrough, F. W., and Ivnik, R. J. (1996). Sex differences in the relationship between visual memory and MRI hippocampal volumes. *Neuropsychology* **10**: 343–351.
- Uddo, M., Vasterling, J. J., Brailey, K., and Sutker, P. B. (1993). Memory and attention in post-traumatic stress disorder. *J. Psychopathol. Behav. Assess.* **15**: 43–52.

- van der Kolk, B. A. (1994). The body keeps the score: Memory and the evolving psychobiology of post-traumatic stress. *Harv. Rev. Psychiatry* **1**: 253–265.
- Vasterling, J. J., Brailey, K., Constans, J. I., and Sutker, P. (1998). Attention and memory dysfunction in post traumatic stress disorder. *Neuropsychology* **12**: 125–133.
- Viguiet, D., Dellatolas, G., Gasquet, I., Martin, C., and Choquet, M. (2001). A psychological assessment of adolescent and young adult inpatients after traumatic brain injury. *Brain Inj.* **15**: 263–271.
- Weschler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale—Revised*, Psychological Corporation, New York.
- Weschler, D. (1987). *Wechsler Memory Scale—Revised Manual*, The Psychological Corporation, San Antonio, TX.
- Weschler, D., and Stone, C. P. (1955). *A Standardized Memory Scale for Clinical Use*, Psychological Corporation, New York.
- Weschler, D., and Stone, C. P. (1955). *Manual for the Wechsler Adult Intelligence Scale*, Psychological Corporation, New York.
- Westermeyer, J., and Neider, J. (1988). Social networks and psychopathology among substance abusers. *American Journal of Psychiatry*, 1265–1269.
- White, N. S. I. (1983). Posttraumatic stress disorder. *Hosp. Community Psychiatry* **34**: 1061–1062.
- Wilson, B., Cockburn, J., Baddeley, A., and Hiorns, R. (1989). Development and validation of a test battery for detecting and monitoring everyday memory problems. *J. Clin. Exp. Neuropsychol.* **11**, 855–870.
- Wolfe, J., and Charney, D. S. (1991). Use of neuropsychological assessment in post-traumatic stress disorder. *Psychol. Assess.* **3**: 573–580.
- Wolfe, J., and Schlesinger, L. K. (1997). Performance of PTSD patients on standard tests of memory: Implications for trauma. In: Yehuda, R., and McFarlane, A. (eds.), *Psychobiology of Post-Traumatic Stress Disorder*, Annals of the New York Academy of Sciences, New York, pp. 208–219.
- Yehuda, R., Keefe, R. S. E., Harvey, P. D., Levengood, R. A., Gerber, D.K., Geni, J., et al. (1995). Learning and memory in combat veterans with posttraumatic stress disorder. *Am. J. Psychiatry* **152**: 137–139.
- Yehuda, R., Southwick, S. M., and Giller, E. L., Jr. (1992). Exposure to atrocities and severity of chronic posttraumatic stress disorder in Vietnam combat veterans. *Am. J. Psychiatry* **149**: 333–336.
- Zalewski, C., Thompson, W., and Gottesman, I. (1994). Comparison of neuropsychological test performance in PTSD, generalised anxiety disorder, and control Vietnam veterans. *Assessment* **1**: 133–142.
- Zeitlin, S. B., and McNally, R. J. (1991). Implicit and explicit memory bias for threat in post-traumatic stress disorder. *Behavioural Research Therapy*, **29**: 451–457.