Neuropsychological Outcomes of U.S. Veterans with Report of Remote Blast-Related Concussion and Current Psychopathology

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Abstract

This study explored whether remote blast-related MTBI and/or current Axis I psychopathology contribute to neuropsychological outcomes among OEF/OIF veterans with varied combat histories. OEF/OIF veterans underwent structured interviews to evaluate history of blast-related MTBI and psychopathology and were assigned to MTBI ($n = 18$), Axis I ($n = 24$), Co-morbid MTBI/Axis I ($n = 34$), or post-deployment control ($n = 28$) groups. A main effect for Axis I diagnosis on overall neuropsychological performance was identified ($F(3,100) = 4.81$; $p = .004$), with large effect sizes noted for the Axis I only ($d = .98$) and Co-morbid MTBI/Axis I ($d = .95$) groups relative to the control group. The latter groups demonstrated primary limitations on measures of learning/memory and processing speed. The MTBI only group demonstrated performances that were not significantly different from the remaining three groups. These findings suggest that a remote history of blast-related MTBI does not contribute to objective cognitive impairment in the late stage of injury. Impairments, when present, are subtle and most likely attributable to PTSD and other psychological conditions. Implications for clinical neuropsychologists and future research are discussed. (*JINS*, 2012, *18*, 845–855)

Keywords: Operation Iraqi Freedom, Mild Traumatic Brain Injury, Post-traumatic Stress Disorder, Cognition

INTRODUCTION

A growing literature has documented disconcerting rates of combat-related mild traumatic brain injury (concussion) among personnel serving in support of Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF; Hoge et al., 2008; Polusny et al., 2011; Schneiderman, Braver, & Kang, 2008; Tanielian & Jaycox, 2008; Terrio et al., 2009). Explosive blast represents a common injury mechanism (Murray et al., 2005; Nelson et al., in press; Owens et al., 2008; Sayer et al., 2008; Wilk et al., 2010), and it appears that combat-related concussion, blast-related concussion (BRC) in particular, may be unprecedented in the current conflicts (Owens et al., 2008; Warden, 2006).

Many returning OEF/OIF personnel with concussion histories report cognitive limitations for months or even years post-injury. A survey of 2525 Army infantry personnel conducted approximately 4 months post-deployment revealed that 15% endorsed prior injury with loss or alteration of consciousness (Hoge et al., 2008). Of those with previous loss of consciousness, 24.6% endorsed enduring memory problems and 31.4% endorsed concentration problems. Polusny et al. (2011) found an even higher rate of chronic cognitive symptoms in a sample of National Guard soldiers surveyed 1 year after return from Iraq. Of 86 respondents who reported a history of concussion, 72 (83.7%) endorsed ongoing memory problems and 74 (86.0%) endorsed ongoing concentration difficulties.

It is, therefore, not surprising that neuropsychologists working within the Departments of Defense (DoD) and Veterans Affairs (VA) receive regular requests to assess whether reports of chronic cognitive difficulties reflect a

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history of BRC(s). Addressing this request is often challenging due to the complexity of coincident non-concussive conditions that may negatively impact cognitive functioning. Post-traumatic stress (Brewin, Kleiner, Vasterling, & Field, 2007; Marx et al., 2009), depression (cf., Vasterling et al., 2006; Zakzanis, Leach, & Kaplan, 1998), and other Axis I comorbidities may contribute to varied cognitive difficulties and obscure whether cognitive limitations reflect concussion history. Moreover, chronic "post-concussive" symptoms (PCS) are highly non-specific and cannot be reliably linked with concussion itself. Research reveals that PCS are common to post-traumatic stress and other psychological difficulties (Hoge et al., 2008; Iverson, 2006; Meares et al., 2008; Polusny et al., 2011), chronic pain (Iverson & McCracken, 1997), and also frequently endorsed in healthy non-concussion samples (e.g., Iverson & Lange, 2003; Paniak et al., 2002). As such, clinical neuropsychologists are unable to reliably link current *subjective* cognitive complaints to a remote history of concussive injury. Importantly, this does not rule out the possibility that previous BRC and/or psychological difficulties contribute to *objective* neuropsychological impairment.

Relatively few studies have examined objective neuropsychological outcomes in OEF/OIF samples with BRC histories (Belanger, Kretzmer, Yoash-Gantz, Pickett, & Tupler, 2009; Brenner et al., 2010; Luethcke, Bryan, Morrow, & Isler, 2011; Nelson, Yoash-Gantz, Pickett, & Campbell, 2009; Vasterling et al., 2006). Although these studies have provided important preliminary information regarding cognitive outcomes in military/veteran concussion samples, two primary limitations warrant comment. First, to our knowledge, no study has compared neuropsychological performances of OEF/OIF concussion groups with an OEF/OIF non-concussion, non-psychiatric control group. Inclusion of the latter group will control for the unique contribution that the combat environment may have on long-term cognition. Indeed, results of at least one longitudinal study of OEF/OIF cohorts suggest that the deployment process itself may be associated with cognitive limitations (Vasterling et al., 2006). Additionally, comparison of an OEF/OIF concussion sample with an OEF/OIF non-concussion sample will allow for direct examination of long-term impairments that may be associated with BRC, or alternatively define whether outcomes mimic favorable long-term outcomes reported in civilian concussion samples (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Belanger & Vanderploeg, 2005; Frencham, Fox, & Maybery, 2005; Iverson, 2005; McCrea et al., 2005; Rohling et al., 2011; Schretlen & Shapiro, 2003). Results of the latter studies suggest that cognitive impairment associated with concussion is time-limited; the great majority of individuals attain baseline function within days, weeks, to no more than a few months post-injury.

Second, previous researchers have investigated cognitive performances in OEF/OIF veterans with co-morbid histories (BRC with psychiatric distress), without investigating the independent impact of Axis I pathology in veterans without concussion histories. A design that compares performances of a co-morbidity group (i.e., with remote concussion and

Axis I psychopathology) with an Axis I pathology group (without concussion) would elucidate whether an interaction exists between concussion and psychopathology on cognitive performances.

The current study adds to the BRC literature by examining neuropsychological outcomes in a sample of OEF/OIF veterans with diverse combat histories. The study specifically explores whether a history of remote BRC and/or current Axis I diagnosis contribute to, either independently or in conjunction, significant long-term cognitive impairments. The authors hypothesized that: (1) veterans with remote BRC history (and without Axis I co-morbidity) will demonstrate cognitive performances that are not significantly different from a veteran control group; (2) veterans with current Axis I diagnoses (regardless of concussion history) will perform less proficiently than a veteran control group; (3) BRC and Axis I pathology will not interact significantly in their impact on cognitive performance.

METHOD

Recruitment and Procedures

One-hundred eighteen OEF/OIF veterans were recruited through the Minneapolis Veterans Affairs Health Care System in accordance with local institutional review board approval. Beginning in April 2006, participants were recruited from a cohort of National Guard soldiers deployed 16 months to OIF as a single Brigade Combat Team from March 2006 to July 2007 ($n = 65$; see Polusny et al., 2011 for additional cohort information). Beginning in October 2009, the research team initiated parallel recruitment of OEF/OIF veterans through Polytrauma rehabilitation and PTSD clinics to diversify the number of participants with BRC and Axis I pathology ($n = 53$). The first of the 118 participants underwent neuropsychological testing in January 2009 and the last participant underwent neuropsychological testing in December 2010. Sixty-seven of the participants were included in a separate report investigating the role of effort on cognitive performances (Nelson et al., 2010).

Blast-Related Concussion Assessment

Extended blast exposure interviews were conducted to approximate frequencies of prior blast exposure ("felt a pressure wave from an explosion"), even if these exposures did not necessarily contribute to concussion. Detailed descriptions of the three most significant blast events were then obtained to determine whether blast events resulted in concussion as defined by acute-injury symptoms. The decision to elicit information regarding the three most significant blast exposures was based on the notion that greater than two concussions may increase one's odds of experiencing subsequent concussion and extend recovery (Guskiewicz et al., 2003), and to identify participants who might be at increased risk for poor cognitive outcome.

Efforts were also taken to estimate the number of lifetime non-BRCs (e.g., sports-related or other recreational concussions sustained before time of military service).

Next, regular consensus meetings attended by at least three doctoral level psychologists were held to determine whether participants' reported blast events were likely to have resulted in concussion (see Nelson et al., 2011, for further review of this concussion consensus process). This process allowed researchers to opine whether a previous blast *exposure* contributed to blast-related *concussion*, as defined by criteria outlined by the American Congress of Rehabilitation Medicine (ACRM; Kay et al., 1993). Although blast exposure was determined to be involved in the set of events that ultimately culminated in concussion, blast was not necessarily identified as the primary contributing mechanism for the concussion (concussions may also be sustained through secondary or tertiary blast effects, as described by DePalma, Burris, Champion, & Hodgson, 2005). Specifically, concussion was defined by: (a) any period of loss of consciousness (LOC), (b) any loss of memory for events surrounding the event, (c) any alteration in mental state (e.g., feeling dazed, disoriented, confused), and (d) focal neurologic deficits. By definition, LOC cannot persist beyond 30 min, and post-traumatic amnesia (PTA) cannot extend beyond 24 h. The consensus team was blind to Axis I pathology at the time of rating.

Axis I Pathology Assessment

The Clinician-Administered PTSD Scale (CAPS; Blake et al., 1995), a structured clinical interview based on DSM-IV criteria, was used to evaluate symptoms of posttraumatic stress within the past month and lifetime periods. The current researchers implemented the F1-I2 scoring algorithm of the CAPS (i.e., "frequency" of at least 1; "severity" of at least 2), and then relied on DSM-IV criteria for PTSD to establish formal diagnosis. Recognized as the 'gold standard' for formal PTSD diagnosis, the CAPS has established reliability and validity based on its concurrence with other diagnostic measures and stability of results over time (Weathers et al., 2001). Other Axis I conditions were diagnosed through the Structured Clinical Interview for DSM-IV-TR Axis I Disorders (SCID; First, Spitzer, Gibbon, & Williams, 2007). The SCID is a semi-structured clinical interview that reviews DSM-IV criteria to support formal diagnosis of various psychiatric disorders. Researchers administering the CAPS and SCID were blind to results of the TBI consensus process.

Exclusion Criteria

Exclusion criteria were as follows: (a) current substance-induced psychotic disorder or psychotic disorder due to a general medical condition ($n = 0$), (b) current/past DSM-IV-defined substance abuse/dependence disorder other than alcohol, caffeine, or nicotine ($n = 31$), (c) other DSM-IV-defined psychological condition diagnosed before deployment ($n = 54$), (d) neurologic condition diagnosed before deployment ($n = 18$), (e) current/predeployment unstable

medical condition that would likely affect brain functioning ($n = 7$), (f) significant risk of suicidal/homicidal behavior ($n = 6$), and (g) history of traumatic brain injury that was greater than mild in severity according to ACRM criteria ($n = 57$). Exclusionary pre-deployment neurological conditions included: seizures ($n = 4$), spinal meningitis ($n = 3$), anoxic episodes ($n = 2$), stroke/aneurysm ($n = 2$), brain tumor ($n = 2$), Bell's palsy ($n = 1$), transient ischemic attack ($n = 1$), multiple sclerosis ($n = 1$), unspecified tremor ($n = 1$), electrocution with loss of consciousness ($n = 1$). Exclusionary pre-deployment medical conditions included: uncontrolled diabetes ($n = 2$), uncontrolled thyroid disease ($n = 2$), multiple heart attacks ($n = 1$), tuberculosis ($n = 1$), and Hepatitis C ($n = 1$).

Participants were also excluded if they demonstrated insufficient effort on either of two symptom validity tests (Rey-15 Item & Recognition Test, Combination Score, Boone, Salazar, Lu, Warner-Chacon, & Razani, 2002; Victoria Symptom Validity Test, VSVT, Difficult Items, Grote et al., 2000). On this basis, 14 (11.9%) subjects were excluded; nine (7.6%) of these participants had a history of both MTBI and current Axis I pathology, three (2.5%) had a history of current Axis I pathology alone, one (0.8%) had a history of MTBI alone, and one (0.8%) participant had neither current Axis I pathology or MTBI history.

Participants

The remaining 104 participants (61 VA; 43 National Guard) spoke English as a primary language and resided within the Midwestern region of the USA/Veterans Integrated Service Network (VISN) 23. Ninety-seven (93.3%) were male and 101 (97.1%) were Caucasian. Mean age of the sample was 33.0 years ($SD = 8.4$), ranging from 22 to 59 years. Participants recruited from the VA clinics ($M = 29.3$; $SD = 6.3$ years) were significantly younger than the research cohort ($M = 35.5$; $SD = 8.7$ years; [$t(102) = 3.9$; $p < .001$]), but education and premorbid WTAR FSIQ was comparable ($p > .31$). The sample as a whole had attained some college-level schooling ($M = 14.4$; $SD = 2.2$), ranging from 6 to 21 years of formal education. Estimates of premorbid intellectual ability were consistently within the average range (Mean Wechsler Adult Intelligence Scale-III, WAIS-III, Information Scaled Score = 11.9; $SD = 2.2$; Mean Wechsler Test of Adult Reading, WTAR, Premorbid FSIQ = 105.4; $SD = 7.9$).

Blast Exposure and Concussion

Most participants reported having been exposed to blast during deployment ($n = 88$; 84.6%), even if these blast events did not necessarily contribute to concussion. Time since most recent blast exposure was approximately 3.5 years before the time of undergoing neuropsychological evaluation ($M = 177.2$; $SD = 85.5$ weeks). The mean number of reported blast exposures was 10.5 ($SD = 21.7$), with a median of 3.0, and a range of 1 to 150. Acute-injury concussive symptoms and signs (LOC, PTA, alteration of mental status [AMS],

and/or neurologic symptoms) were judged to have been sustained in exactly half of the sample ($n = 52$), with a mean number of BRCs of 1.4 ($SD = 0.6$). Thirty-three (63.5%) of these individuals indicated history of one previous BRC, 16 (30.8%) two, and three (5.8%) participants indicated history of three or more BRCs.

Axis I Pathology Assessment

Overall, 58 (55.8%) participants met DSM-IV diagnostic criteria for an Axis I condition. Thirty-six (34.6%) participants met full criteria for PTSD, and many of these same individuals met criteria for additional co-morbid Axis I conditions. Among those with PTSD, additional Axis I conditions included: major depressive disorder ($n = 20$, 55.6%), either current ($n = 7$; 19.4%) or in partial/full remission ($n = 13$; 36.1%); alcohol dependency ($n = 19$; 52.8%), either current ($n = 8$; 22.2%) or in partial/full remission ($n = 11$; 30.6%); and panic disorder with ($n = 1$; 2.8%) and without ($n = 1$; 2.8%) agoraphobia.

Twenty-two (21.2%) participants did not meet criteria for PTSD, but did meet criteria for at least one current Axis I condition. These Axis I conditions included: major depressive disorder ($n = 12$; 54.6%); alcohol dependence ($n = 10$; 45.5%); anxiety disorders not otherwise specified ($n = 9$; 40.9%); dysthymic disorder ($n = 2$; 9.1%); panic disorder with agoraphobia ($n = 1$; 4.6%); generalized anxiety disorder ($n = 1$; 4.6%); obsessive-compulsive disorder ($n = 1$; 4.6%); and adjustment disorder with anxiety and depression ($n = 1$; 4.6%).

Forty-six participants did not meet criteria for any current Axis I condition, but did have past histories of major depressive episodes ($n = 6$; 13.0%); alcohol dependence ($n = 6$; 13.0%); and posttraumatic stress ($n = 5$; 10.9%).

Final Group Assignment

Participants were assigned to one of four groups according to BRC status (present or absent) and Axis I status (present or absent). Groups included: (a) controls without history of BRC or current Axis I diagnosis ($n = 28$), (b) MTBI only ($n = 18$), (c) current Axis I only ($n = 24$), and (d) co-morbid MTBI/Axis I pathology ($n = 34$). Table 1 presents background information for the four groups.

BRC frequencies were not significantly different between those with ($M = 1.5$; $SD = 0.6$) and without ($M = 1.3$; $SD = 0.6$) co-morbid Axis I pathology. Serial χ^2s among the injury parameters of LOC, PTA, and other acute-stage concussive symptoms presented in Table 1 revealed no significant differences between those with co-morbid MTBI/Axis I pathology and those with MTBI alone. Significant differences were observed for the number of blast exposures sustained across groups ($F(3,99) = 3.37$; $p = .02$). The co-morbid MTBI/Axis I group reported significantly greater blast exposure than the control group ($p = .02$) and the current Axis I only group ($p = .004$). Lifetime history of non-BRCs, sustained either before or during military service, was not significantly different across groups. Serial χ^2s verified that PTSD diagnosis was not

significantly more frequent between the MTBI/Axis I and current Axis I only groups ($p > .05$). CAPS Current Total Scores were significantly different across groups ($F(3,100) = 34.85$; $p < .0001$), with the co-morbid MTBI/Axis I showing higher scores than each of the other three groups ($p < .01$), and the Axis I only group showing higher scores than the control and MTBI groups ($p < .001$). CAPS scores were not significantly different between the MTBI and control groups. Some degree of past or present alcohol abuse/dependence was observed in each of the four groups, though serial χ^2s indicated that these diagnoses were significantly more frequent in the co-morbid MTBI/Axis I ($p = .001$) and current Axis I only group ($p = .014$) relative to the control group. Alcohol abuse/dependence was also significantly more frequent in the MTBI/Axis I group ($p = .02$) relative to the MTBI only group.

Neuropsychological Measures

Neuropsychological test selection was guided by the decision to evaluate broad domains of cognitive functioning that may be sensitive to current Axis I pathology and/or traumatic brain injury. Cognitive domains included: premorbid intellectual ability [WTAR, The Psychological Corporation, 2001; Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) Information subtest; Wechsler, 1997], working memory (WAIS-III Digit Span subtest), verbal fluency (Controlled Oral Word Association Test; Gladsjo et al., 1999), visual-spatial function (WAIS-III Block Design subtest; Rey-Osterrieth Complex Figure Copy, Meyers & Meyers, 1995), executive function (WAIS-III Digit-Symbol subtest; Trail Making Tests A and B, Reitan & Wolfson, 1993; Stroop Color Word Test, Golden, 1978), visual memory (Rey-Osterrieth 3' Delay), and verbal memory (California Verbal Learning Test – 2nd Edition, Delis, Kaplan, Kramer, & Ober, 2000).

Following the approach of others (Green, Rohling, Lees-Haley, & Allen, 2001; Rohling, & Demakis, 2010), an overall test battery mean (OTBM) was generated to represent a single, robust composite of cognitive function. The Rey-Osterrieth Copy Trial was not included in the OTBM related to distribution skewness (Miller & Rohling, 2001) and limited ability to translate normative percentile bands into true Z-scores (Meyers & Meyers, 1995). The OTBM was derived from standard score performances of 12 neuropsychological measures that were translated to Z-scores. Resulting Z-scores were then averaged across the measures. OTBM was derived from: WAIS-III (Digit-Span, Block Design, Digit-Symbol Coding); COWAT; CVLT-II (Trials 1–5; Long Free Recall); Rey-Osterrieth 3' Delay; TMT A and B; and Stroop (Word, Color, Interference).

RESULTS

Across the four comparison groups, years of education, $F(3,100) = 1.86$, $p = .14$, WAIS-III Information Scaled Scores, $F(3,100) = 1.74$, $p = .16$, and WTAR Standard Scores, $F(3,100) = .78$, $p = .51$, were not meaningfully different

Table 1. Background information across OEF/OIF groups

Variable	OEF/OIF sample			
	Control ($n = 28$)	MTBI only ($n = 18$)	Current Axis I only ($n = 24$)	MTBI/Axis I ($n = 34$)
Age	32.8 (8.5)	37.1 (8.6)[a]	34.8 (9.6)[a]	29.9 (6.0)
Education (years)	14.9 (2.2)	15.1 (2.1)	14.3 (2.1)	13.9 (1.8)
WAIS-III Information (SS)	11.9 (2.6)	12.8 (1.7)	11.3 (2.1)	11.8 (2.1)
WTAR (SS)	106.0 (9.2)	106.7 (10.1)	103.8 (7.5)	105.4 (5.7)
CAPS Current Total Score	5.4 (11.7)[a,b]	9.8 (12.1)[a,b]	39.9 (27.1)[a]	54.2 (25.5)
Previous non-blast concussions	2.4 (4.7)	5.0 (12.1)	2.2 (4.1)	1.8 (3.1)
Blast exposures	7.1 (11.3)[a]	9.2 (15.6)	3.0 (5.3)[a]	19.6 (33.2)
Blast-related concussions	n/a	1.5 (0.6)	n/a	1.3 (0.6)
	n (%)	n (%)	n (%)	n (%)
Gender				
Male	24 (85.7)	18 (100.0)	22 (91.7)	33 (97.1)
Female	4 (14.3)	0 (0.0)	2 (8.3)	1 (2.9)
Ethnicity				
Caucasian	25 (89.3)	18 (100.0)	24 (100.0)	34 (100.0)
Axis I diagnosis				
PTSD+	0 (0.0)	0 (0.0)	12 (50.0)	24 (70.6)
Alcohol abuse/ dependence	5 (17.9)[a,b]	5 (27.8)[a]	21 (61.8)	12 (50.0)
Other Axis I	0 (0.0)	0 (0.0)	12 (50.0)	10 (29.4)
MTBI symptom				
LOC	n/a	2 (11.1)	n/a	6 (17.6)
PTA	n/a	1 (5.6)	n/a	4 (11.8)
Headache	n/a	6 (33.3)	n/a	12 (35.3)
Dizziness	n/a	5 (27.8)	n/a	8 (23.5)
Disorientation	n/a	7 (38.9)	n/a	13 (38.2)
Tinnitus	n/a	8 (44.4)	n/a	13 (38.2)
Nausea	n/a	3 (16.7)	n/a	4 (11.8)
Photophobia	n/a	4 (22.2)	n/a	6 (17.6)
Phonophobia	n/a	4 (22.2)	n/a	4 (11.8)
Memory	n/a	1 (5.6)	n/a	4 (11.8)
Imbalance	n/a	2 (11.1)	n/a	4 (11.8)

Note. 'PTSD+' = formal diagnosis of PTSD, or PTSD and additional current Axis I co-morbidity. 'Other Axis I' = formal diagnosis of psychological conditions other than PTSD. MTBI = mild traumatic brain injury; WAIS-III = Wechsler Adult Intelligence Scale–3rd Edition; WTAR = Wechsler Test of Adult Reading; LOC = Loss of consciousness; PTA = Post-traumatic amnesia. Serial chi-squares conducted between the MTBI and MTBI/Axis I groups revealed no significant frequency differences in acute concussion symptoms.
[a]Denotes significantly different from the MTBI/Axis I group.
[b]Denotes significantly different from the Current Axis I only group.

(see Table 1). Age was significantly different across the groups, $F(3,100) = 3.37$, $p = .02$; the MTBI only group was significantly older than the co-morbid MTBI/Axis I group ($p = .003$), and the current Axis I only group was significantly older than the co-morbid MTBI/Axis I group ($p = .03$). Age was not covaried, however, as performance outcomes were derived from age-stratified norms.

The OTBM was significantly different across groups (see Figure 1; $F(3,100) = 4.81$, $p = .004$; see Table 2 for complete neuropsychological test performances). Performances were not significantly different between National Guard versus VA participants. Given inequality of variance (Levene statistic = 3.34; $p = .02$), Dunnett C *post hoc* comparisons were conducted to investigate differences between the four groups. The current Axis I only (Mean OTBM = −.15; $SD = .46$) and comorbid MTBI/Axis I (Mean OTBM = −.14; $SD = .45$) group performances were significantly lower than the control (Mean OTBM = .26; $SD = .38$) group performance at a .05 level, with large effect sizes noted for both groups relative to the control group ($d = .98$, .95, respectively). The MTBI only group performance (Mean OTBM = .14; $SD = .69$) was not significantly different from the control
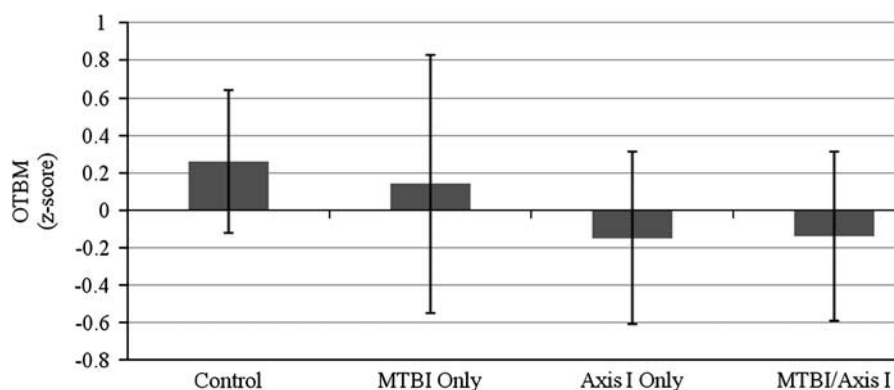
Fig. 1. Overall neuropsychological performance across groups. Note: OTBM = Overall Test Battery Mean performance as a composite index of cognitive function represented as a *z*-score (see Green et al., 2001; Rohling & Demakis, 2010). Bars represent standard deviations around the mean performance.

group performance, yielding a small overall effect size difference between groups (*d* = .23). Although the MTBI only group performance was not significantly different from the current Axis I and Axis I/MTBI overall group performances, moderate effect size differences were observed between these groups (*d* = .48, .49, respectively).

In light of the high base rate of alcohol abuse/dependency that was observed in the current Axis I samples, further analyses were conducted to explore a possible effect of alcohol on overall neuropsychological performances. Results of a 2 × 2 between-subjects ANOVA with alcohol dependence and self-reported MTBI history as independent variables and the OTBM as the dependent variable failed to identify a main effect for alcohol ($F(1,54) = 1.93$; $p = .17$), MTBI ($F(1,54) = .02$; $p = .97$), or an alcohol/MTBI interaction effect ($F(1, 54) = 3.39$; $p = .07$). Furthermore, among participants with current Axis I conditions, a small effect size (*d* = .27) was observed between those with (Mean OTBM = −.19; *SD* = .44) and without (Mean OTBM = −.07; *SD* = .45) alcohol abuse/dependency. A small effect size (*d* = .02) was also observed between those with (Mean OTBM = −.15; *SD* = .46) and without (Mean OTBM = −.14; *SD* = .45) self-reported MTBI.

Table 2. Mean neuropsychological test performances across groups

	OEF/OIF sample			
Variable	Control (*n* = 28)	MTBI only (*n* = 18)	Current Axis I only (*n* = 24)	MTBI/Axis I (*n* = 34)
WAIS-III				
Digit Span (SS)	10.9 (2.4)	9.9 (2.8)	9.4 (2.1)	9.9 (2.1)
Coding (SS)	11.1 (2.7)	10.9 (2.0)	10.1 (2.8)	9.8 (2.4)
Block Design (SS)	13.0 (2.9)	12.2 (2.6)	12.1 (2.5)	12.2 (3.1)
Stroop*				
Word (T)	48.3 (6.6)	49.4 (9.8)	46.2 (7.7)	46.2 (8.6)
Color (T)	48.9 (6.7)	49.5 (6.9)	46.2 (5.6)	45.8 (7.8)
C-W (T)	52.6 (7.0)[c,d]	51.1 (9.5)	45.9 (8.0)	48.3 (9.5)
TMT A (T)	51.8 (12.1)	50.0 (11.7)	49.0 (11.0)	50.5 (9.7)
TMT B (T)	53.6 (7.5)	51.0 (12.1)	50.1 (7.9)	48.4 (10.8)
COWA (T)	48.9 (9.7)	46.4 (11.0)	44.6 (10.4)	42.7 (9.5)
CVLT-II[+]				
Trials 1-5 (z)	0.8 (0.8)[c,d]	0.6 (0.9)	0.2 (0.9)	0.1 (1.0)
Long FR (z)	0.6 (0.8)[c,d]	0.5 (0.9)[d]	−0.1 (1.1)	−0.1 (1.1)
Rey CFT				
Copy Raw (SD)	32.0 (2.1)	31.3 (3.2)	32.8 (2.9)	31.5 (3.0)
3' Delay (z)	−0.3 (1.3)	−0.1 (1.3)	−0.6 (1.2)	−0.5 (.98)

Note. WAIS-III = Wechsler Adult Intelligence Scale-3rd Edition; C-W = Color-Word; TMT = Trailmaking Test; COWA = Controlled Oral Word Association; CVLT-II = California Verbal Learning Test-2nd Edition; CFT = Complex Figure Test
*$F(1,100) = 10.34$, $p = .002$.
[+]$F(1,100) = 7.54$, $p = .007$.
[c]Denotes significantly different from Axis I only group ($p < .05$).
[d]Denotes significantly different from MTBI/Axis I group ($p < .05$).

Follow-up analyses were conducted to explore the specific nature and quality of cognitive limitation that might be associated with BRC history or current Axis I diagnosis on individual neuropsychological measures. First, general linear modeling (GLM) multivariate analysis of variance (MANOVA) was conducted to determine whether groups differed on the ROCFT (3' Delay Trial), COWA, or WAIS Digit Span, Coding, and Block Design subtests. Concussion history (present or not) and current Axis I diagnosis (present or not) were entered as class variables to investigate potential interaction. Results for the previously noted measures failed to show main effects for concussion status ($F(5,96) = .43$; $p = .83$), current Axis I diagnosis ($F(5,96) = 1.75$; $p = .13$), or an interaction between concussion and current Axis I diagnosis ($F(5,96) = .52$; $p = .76$).

Next, mixed factorial ANOVAs were applied independently for the Stroop Test (Word, Color, Color-Word), TMT (A and B), and CVLT-II (Trials 1–5 Total Recall; Long Delay Free Recall). A within-subjects analytic approach was used to investigate these measures because the respective tests resulted in multiple scores per participant. Respective neuropsychological tests functioned as within-subject variables; concussion history (present or not) and current Axis I diagnosis (present or not) were between-subject variables. Within-subject effects were observed for the CVLT-II ($F(1,100) = 13.23$; $p < .001$) and Stroop test ($F(1.82,181.19) = 3.76$;[1] $p = .03$). Individuals achieved higher performance during immediate CVLT-II learning trials (Trials 1–5 Total Recall Z-score = .41; $SD = .91$) relative to delayed recall (Long Delay Free Recall Z-score = .19; $SD = 1.00$).

Overall, performance on Stroop Word (Mean T-score = 47.30; $SD = 8.11$) and Color (Mean T = 47.38; $SD = 6.97$) trials were somewhat below performance on the Color-Word Trial (Mean T = 49.37; $SD = 8.80$).

A between-subjects effect was observed for the CVLT-II and Stroop with current Axis I diagnosis (CVLT-II: $F(1,100) = 10.34$; $p = .002$; Stroop: $F(1,100) = 7.54$; $p = .007$), which reflects that those with Axis I diagnoses performed more poorly than those without a diagnosis. On the Stroop Color-Word trial, the Control group demonstrated significantly better performance relative to the current Axis I ($p = .005$) and MTBI/Axis I ($p = .039$) groups. The Control group also demonstrated significantly better performances on the CVLT-II Trials 1–5 acquisition relative to the MTBI/Axis I group ($p = .007$) and current Axis I only ($p = .036$) groups. The Control group also demonstrated significantly better performances on the CVLT-II Delayed Free Recall trial relative to the MTBI/Axis I group ($p = .019$) and current Axis I only ($p = .033$) groups. MTBI participants demonstrated significantly stronger performance than the MTBI/Axis I group on the CVLT-II Long Free Recall Trial ($p = .05$). There was no between-subject effect of current Axis I diagnosis on the TMT ($F(1,100) = 1.41$, $p = .24$).

Across the Stroop Test, TMT, and CVLT there was no between-subject effect for MTBI or interaction effect of MTBI and current Axis I condition (all p values $\geq .55$).

DISCUSSION

To our knowledge, this is the first study to compare neuropsychological performances of OEF/OIF MTBI and current Axis I samples with those of an OEF/OIF veteran control group. Three primary conclusions can be made on the basis of current findings. First, as anticipated, veterans with remote BRC histories (and without current Axis I pathology) demonstrated performances that were not significantly different than those of a veteran control group. Consistent with previous research suggesting a time-limited course of impairment following conventional concussive injuries (cf. Rohling et al., 2011), present results suggest that BRC does not in and of itself contribute to cognitive impairment months or years following injury. Veterans with remote histories of BRC should anticipate favorable long-term cognitive prognosis.

Second, regardless of BRC history, veterans with PTSD and other current Axis I diagnoses demonstrated significantly lower cognitive performances than the control group. This finding is consistent with research implicating PTSD (Brewin et al., 2007; Marx et al., 2009; Nelson et al., 2009), depression (Zakzanis et al., 1998), and other current Axis I pathology as contributing to meaningful, albeit subtle, objective cognitive limitations. Participants with PTSD and other current Axis I conditions were most likely to show diminished performances on measures of executive (Stroop Interference trial) and learning/memory function (CVLT-II trials).

Finally, as expected, no significant interaction was observed between MTBI and current Axis I pathology on neuropsychological performance. The finding that neuropsychological performances were not significantly different between the MTBI/Axis I group and the current Axis I only groups provides further evidence that psychological conditions meaningfully impact objective cognitive performances. Although blast exposure may increase one's risk of developing PTSD and other emotional disorders after return from deployment (Belanger et al., 2009), present results do not support the notion of a unique interaction between blast-related MTBI and emotional disorders on cognitive function.

Present results complement the findings of recent survey research in OEF/OIF samples (e.g., Hoge et al., 2008; Polusny et al., 2011). Results of the latter studies suggest that *subjective* cognitive limitations and other chronic "post-concussive symptoms" in the month or years after deployment are largely attributable to PTSD, depression, and other forms of emotional distress, rather than MTBI itself. Likewise, on the basis of current findings, there is evidence that current Axis I pathology is a greater determinant of *objective* cognitive impairment than remote MTBI. Taking findings together, veterans should be encouraged to recognize that both their subjective experience of cognitive difficulty and objective performance limitations are more likely to represent a manifestation of emotional difficulties than remote concussion.

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[1] Huyn-Feldt corrected degrees of freedom were used to evaluate the significance of the corresponding within-subjects Stroop test F because Mauchly's test of sphericity was significant (Mauchly's W = .85, $p < .001$).

Current results should also be considered in the context of other neuropsychological studies in OEF/OIF concussion samples (Brenner et al., 2010; Nelson et al., 2009). Diminished Stroop Interference performances in the current study among those with current Axis I conditions is consistent with the findings of Nelson et al. (2009), who also found significantly diminished Stroop performances in their MTBI/PTSD group relative to the MTBI only group. These findings contrast, however, with those of Brenner et al. (2010), who did not find meaningful performance differences between OEF/OIF concussion samples with and without PTSD diagnoses. Lack of cognitive performance effect between those with and without PTSD in the latter study may reflect limited sample size (PTSD $n = 17$; non-PTSD $n = 28$), but is as likely to reflect the heterogeneity of diagnoses that appear to have been present in the researchers' non-PTSD group. Approximately 21% of the non-PTSD group included in the Brenner et al. study met criteria for other mental health diagnoses. As PTSD, depression, anxiety, and other forms of emotional distress are likely to contribute to similar and non-distinct patterns of cognitive limitation, it is possible that comparison of PTSD with other current Axis I conditions attenuated possible effects in cognitive performances.

Current Limitations

Several limitations should be noted. First, similar to previous researchers (Belanger et al., 2009; Brenner et al., 2010; Gordon, Fitzpatrick, & Hilsabeck, 2011; Nelson et al., 2009), concussion assessment was conducted on the basis of self-report information long after blast exposures were sustained. Reliance on self-report information in the late-stage of concussive injury is perhaps the single biggest flaw of the current OEF/OIF concussion literature (Nelson et al., in press). VA providers do not typically have access to primary documents pertaining to combat activities (Belanger et al., 2009), and it is hoped that future researchers, perhaps through a VA/DoD collaboration, will integrate acute-stage injury information with what is reported in the late stages of injury to verify reliability of self-report information.

Furthermore, sample sizes in the current study were limited, though similar to those observed in previous examinations (Belanger et al., 2009; Brenner et al., 2010; Gordon et al., 2011; Nelson et al., 2009). The MTBI only group was especially limited ($n = 18$), and in our clinical experience, this subgroup can be especially difficult to recruit given the high incidence of Axis I co-morbidity that exists for OEF/OIF concussion groups. To illustrate the significance of this issue, *post hoc* power analysis revealed that the current study had sufficient power (power = .80; $\alpha = .05$) to detect only large effect sizes between the MTBI only group and each of the other groups. Sample sizes >100 would be needed to detect a small effect size ($d = .30$) between the MTBI only and control group, while sample sizes of approximately 50 would likely be needed to detect a moderate effect size ($d = .50$). Furthermore, small sample sizes likely account for the significant performance variability observed in neuropsychological performances

(see Figure 1). Current results should be considered preliminary; performance comparisons of MTBI and current Axis I groups with a post-deployment control group in larger OEF/OIF veteran samples will allow for greater confidence in identifying the potential effects of these factors on cognitive function.

Additionally, although rates of alcohol abuse/dependence were much higher in the current Axis I groups, some level of alcohol abuse/dependence history was observed in the control and MTBI only groups. Prevalence of alcohol-related disorders is known to be quite high in OEF/OIF veteran samples (Calhoun, Elter, Jones, Kudler, & Straits-Troester, 2008; Erbes, Curry, & Leskela, 2009; Hoge et al., 2004). Although we did not find a main effect for alcohol abuse/dependence on overall neuropsychological function in the Axis I groups, this could very well reflect limited sample size. Future researchers are encouraged to explore the potential role of alcohol abuse/dependency in moderating neuropsychological outcomes among OEF/OIF veterans with reported histories of MTBI and/or alternate Axis I conditions in larger-scale samples.

Results of the current study should also be interpreted with the understanding that while current Axis I pathology was a significant contributor to cognitive performance in the current sample on the group level, Axis I-related cognitive impairments, when present, were typically rather mild and not necessarily *clinically*-meaningful for most individual participants. For instance, clinically 'impaired' performance is often operationalized at or below specific percentile cut-scores (e.g., ninth percentile; sixteenth percentile) relative to age and education-based norms (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006). Among the 58 participants who evidenced current Axis I pathology, only 9 (15.5%) showed performance at or below the ninth percentile on the Stroop Interference task, and only 12 (20.7%) participants performed at or below the 16th percentile on this task. On the CVLT-II Trials Immediate Recall (Trials 1–5), only six (10.3%) participants performed at or below the ninth percentile, and eight (13.8%) performed at or below the 16th percentile.

Finally, the current sample of OEF/OIF concussion participants reported relatively few historical BRCs, with a majority (63.5% of all participants reporting MTBI) sustaining only a single injury. This precluded formal examination of a potential effect of recurrent BRC on cognitive performances. The issue of recurrent concussion continues to gain attention in both civilian and military samples, and there is concern that individuals who sustain multiple concussions may demonstrate a less favorable course of recovery relative to those who sustain isolated injuries. A recent meta-analytic investigation of recurrent concussion on cognitive function revealed a relatively minimal effect of multiple injuries on overall cognitive function (Belanger, Spiegel, & Vanderploeg, 2010). However, there was some indication of poorer performances demonstrated in memory and executive function following multiple concussions. Clearly, future research in this area is needed among OEF/OIF personnel with extensive BRC histories.

For example, inclusion of a sample with more extended histories of BRC might allow for examination of a potential dose effect of BRC in OEF/OIF samples.

Summary

The current study adds to a growing OEF/OIF BRC literature. Although available findings to date suggest that injury severity (mild, moderate, severe), more than injury mechanism (blast-associated *vs.* not), is the greater determinant of cognitive outcomes in OEF/OIF TBI samples (Belanger et al., 2009), the reality is that the natural history of BRC has yet to be established. Until longitudinal examination of neuropsychological performances is conducted on a much larger scale and with much larger OEF/OIF samples, as has been conducted in sports concussion samples (e.g., McCrea et al., 2005), the nature of cognitive recovery following BRC will remain unclear.

For now, paired with the findings of other research groups (Brenner et al., 2010; Nelson et al., 2009), present findings suggest that blast-related MTBI does not typically result in chronic objective cognitive impairments. Similar to what has been documented in civilian concussion samples, OEF/OIF veterans should anticipate favorable recovery following BRC. PTSD, depression, anxiety, and other forms of current Axis I psychopathology are more likely to result in diminished cognitive performances in the months and years following uncomplicated BRC. Neuropsychologists and other providers of OEF/OIF veterans are encouraged to provide psychoeducation to patients regarding the favorable course of recovery that typically follows BRC, and emphasize the role of emotional difficulties as a common source of chronic cognitive limitations.

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