Sequelae of Deployment TBI in Iraq and Afghanistan Veterans

Sarah L. Martindale, PhD and Jared A. Rowland, PhD

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Chronic Effects of Neurotrauma Consortium

U.S. Department of Veterans Affairs

Disclaimer

This presentation is based on work supported, in part, by the Department of Defense and the Department of Veterans Affairs but does not necessarily represent the views of the Department of Defense, Department of Veterans Affairs, or the United States Government.

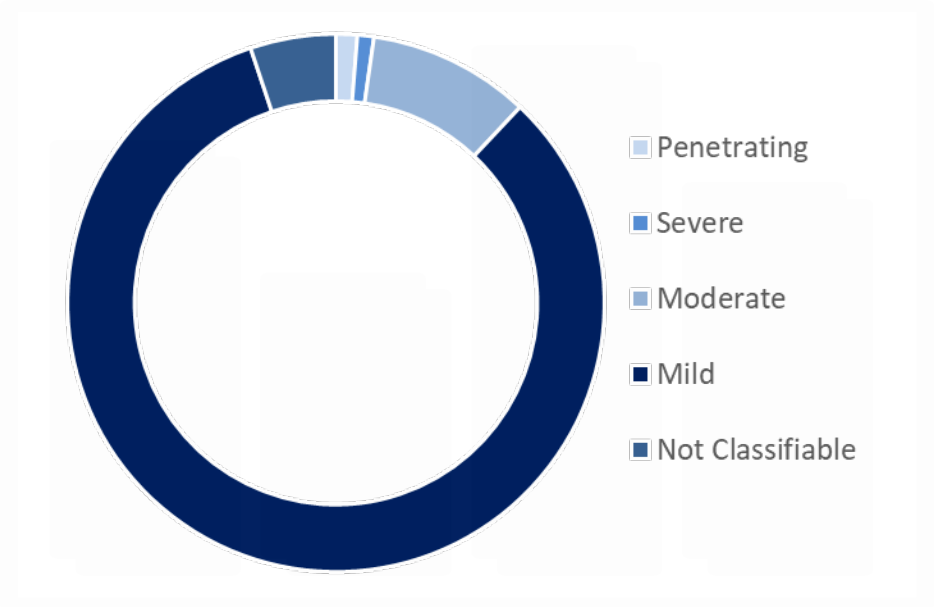
TBI in Veterans

Most are mild in severity (82.8%)

Alteration of consciousness (< 24 hours)

Loss of consciousness (< 30 minutes)

Posttraumatic amnesia (< 24 hours)



Symptoms expected to resolve within 3-6 months

Vestibular
- nausea
- dizziness
- balance problems

Sensory
- altered vision
- headaches
- tinnitus

Cognitive
- forgetfulness
- lack of focus

Emotional
- irritability
- depression

CDC, 2015; DVBIC, 2019

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TBI in Veterans

Frequency

- Time between TBI
- Number of TBI

Mechanism

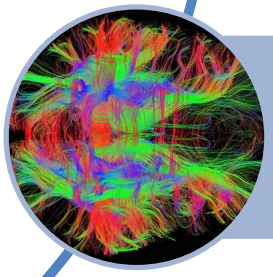
- Blast
- Blunt Force
- Contra Coup

Environment

- Physical & Practical
- Emotional & Mental
- Social

Behavioral

Physical

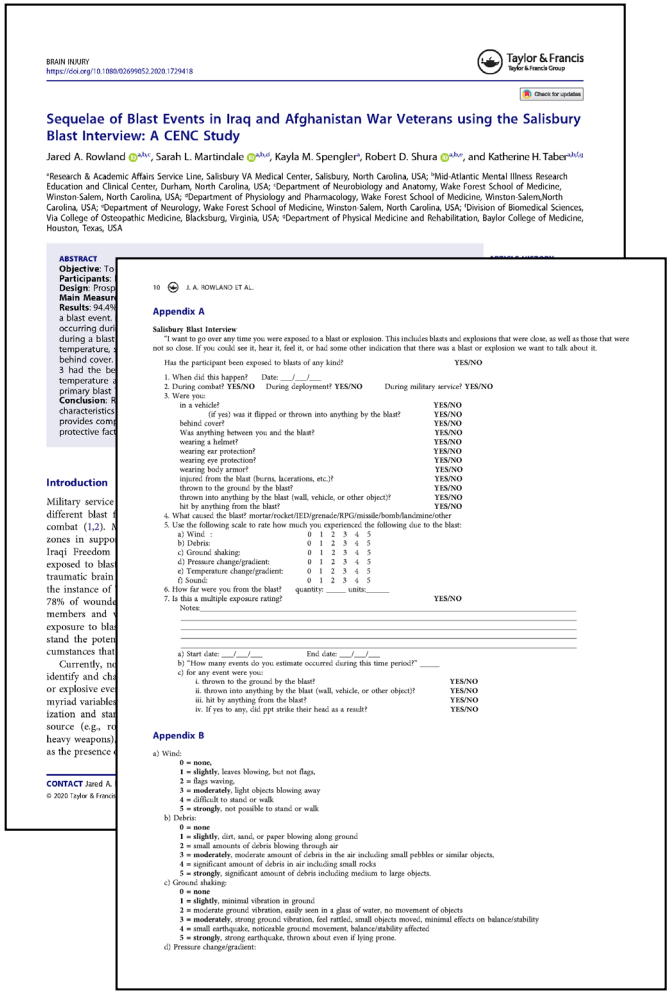


Functional

Samples and Methods

	CENC-34	PDMH	Pilot
Cross-sectional	✓	✓	✓
Iraq/Afghanistan Veterans	✓	✓	✓
Neuroimaging	✓		✓
Sample Size	341	1399	28
Age	41.16 (10.13)	37.55 (10.38)	39.0 (9.5)
Male	86.2%	81.7%	100%
Years since Deployment	9.71 (3.53)	6.64 (5.01)	6.2 (2.70)

Salisbury Blast Interview



BRAIN INJURY
https://doi.org/10.1080/02699052.2020.1729418

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Sequelae of Blast Events in Iraq and Afghanistan War Veterans using the Salisbury Blast Interview: A CENC Study

Jared A. Rowland [a,b,c], Sarah L. Martindale [a,b,d], Kayla M. Spengler[a], Robert D. Shura [a,b,e], and Katherine H. Taber[a,b,f,g]

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ABSTRACT

Objective: To
Participants:
Design: Prosp
Main Measure
Results: 94.4%
a blast event
occurring duri
during a blast
temperature,
behind cover,
3 had the be
temperature
primary blast
Conclusion:
characteristics
provides comp
protective fact

Introduction

Military service
different blast
combat (1,2).
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exposed to blas
traumatic brain
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Currently, n
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heavy weapons)
as the presence

CONTACT Jared A.

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10 J. A. ROWLAND ET AL.

Appendix A

Salisbury Blast Interview

"I want to go over any time you were exposed to a blast or explosion. This includes blasts and explosions that were close, as well as those that were not so close. If you could see it, hear it, feel it, or had some other indication that there was a blast or explosion we want to talk about it.

Has the participant been exposed to blasts of any kind? YES/NO

1. When did this happen? Date: ___/___/___
2. During combat? YES/NO During deployment? YES/NO During military service? YES/NO
3. Were you:
   in a vehicle? YES/NO
   (if yes) was it flipped or thrown into anything by the blast? YES/NO
   behind cover? YES/NO
   Was anything between you and the blast? YES/NO
   wearing a helmet? YES/NO
   wearing ear protection? YES/NO
   wearing eye protection? YES/NO
   wearing body armor? YES/NO
   injured from the blast (burns, lacerations, etc.)? YES/NO
   thrown to the ground by the blast? YES/NO
   thrown into anything by the blast (wall, vehicle, or other object)? YES/NO
   hit by anything from the blast? YES/NO
4. What caused the blast? mortar/rocket/IED/grenade/RPG/missile/bomb/landmine/other
5. Use the following scale to rate how much you experienced the following due to the blast:
   a) Wind: : 0 1 2 3 4 5
   b) Debris: 0 1 2 3 4 5
   c) Ground shaking: 0 1 2 3 4 5
   d) Pressure change/gradient: 0 1 2 3 4 5
   e) Temperature change/gradient: 0 1 2 3 4 5
   f) Sound: 0 1 2 3 4 5
6. How far were you from the blast? quantity: ____ units:____
7. Is this a multiple exposure rating? YES/NO

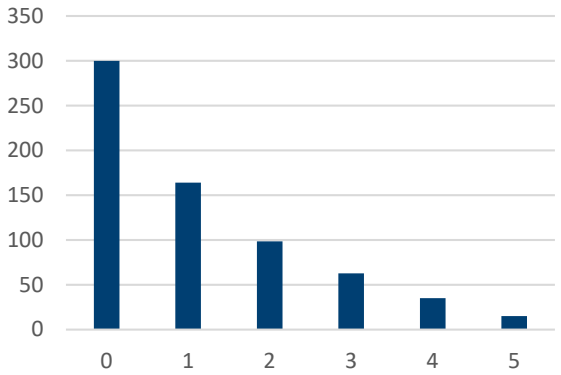
Notes:_____

a) Start date: ___/___/___ End date: ___/___/___
b) "How many events do you estimate occurred during this time period?" ____
c) for any event were you:
   i. thrown to the ground by the blast? YES/NO
   ii. thrown into anything by the blast (wall, vehicle, or other object)? YES/NO
   iii. hit by anything from the blast? YES/NO
   iv. If yes to any, did ppt strike their head as a result? YES/NO

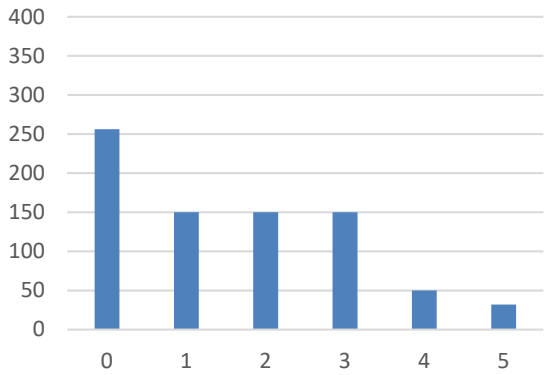
Appendix B

a) Wind:
   0 = none,
   1 = slightly, leaves blowing, but not flags,
   2 = flags waving,
   3 = moderately, light objects blowing away
   4 = difficult to stand or walk
   5 = strongly, not possible to stand or walk
b) Debris:
   0 = none
   1 = slightly, dirt, sand, or paper blowing along ground
   2 = small amounts of debris blowing through air
   3 = moderately, moderate amount of debris in the air including small pebbles or similar objects,
   4 = significant amount of debris in air including small rocks
   5 = strongly, significant amount of debris including medium to large objects.
c) Ground shaking:
   0 = none
   1 = slightly, minimal vibration in ground
   2 = moderate ground vibration, easily seen in a glass of water, no movement of objects
   3 = moderately, strong ground vibration, feel rattled, small objects moved, minimal effects on balance/stability
   4 = small earthquake, noticeable ground movement, balance/stability affected
   5 = strongly, strong earthquake, thrown about even if lying prone.
d) Pressure change/gradient:

Pressure Median Distance



Wind Median Distance



	Behind Cover	No Cover
Wind*	1.19 (1.4)	1.42 (1.6)
Debris	1.56 (1.6)	1.71 (1.7)
Ground*	2.44 (1.4)	2.66 (1.5)
Pressure*	1.24 (1.4)	1.55 (1.5)
Temp	0.63 (1.1)	0.70 (1.2)
Sound*	3.18 (1.2)	3.44 (1.3)

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Rowland, Martindale, Spengler et al., 2020; Rowland, Martindale, Shura et al., 2020

Behavioral Outcomes

ACRM AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2018;99:2485-95

ORIGINAL RESEARCH

Behavioral and Health Outcomes Associated With Deployment and Nondeployment Acquisition of Traumatic Brain Injury in Iraq and Afghanistan Veterans

Sarah L. Martindale, PhD [a,b,c] Erica L. Epstein, PsyD [a,b] Katherine H. Taber, PhD [a,b,d,e] VA

Table 3 Outcome and covariate descriptive measures for aims 1 and 2

		Nondeployment TBI		Deployment TBI		PTSD Diagnosis	
Measure	Total Sample (N=1399) Mean ± SD	− (n=835) Mean ± SD	+ (n=564) Mean ± SD	− (n=1071) Mean ± SD	+ (n=328) Mean ± SD	− (n=786) Mean ± SD	+ (n=613) Mean ± SD
BDI-II	14.79±12.67	14.08±12.98	15.84±12.12	12.74±12.08*	21.50±12.24*	9.23±10.13*	21.92±12.02*
DTS	41.30±39.67	39.20±40.32	44.42±38.52	33.82±36.98*	65.73±38.37*	19.67±26.60*	69.02±36.30*
PSQI	9.57±4.90	9.29±4.96	9.98±4.77	8.78±4.75*	12.16±4.46*	7.49±4.38*	12.24±4.19*
AUDIT	5.11±6.00	4.65±5.63	5.79±6.44	4.76±5.75	6.24±6.45	4.20±4.86*	6.27±7.03*
DAST	1.08±2.82	0.94±2.62	1.28±3.07	1.03±2.82*	1.24±2.80*,†	0.75±2.14*	1.51±3.45*
BPI‡	3.34±2.51	3.22±2.61	3.50±2.38	3.05±2.51*	4.28±2.30*	2.67±2.36*	4.23±2.43*
CES	11.97±10.36	11.08±10.22	13.30±10.44	9.51±9.11*	20.02±10.12*	8.02±8.69*	17.03±10.13*

NOTE. Results from aims 1 and 2. Independent samples *t* tests were conducted on the CES to report differences between groups; however, they are not reported in the body of the article because the CES was included in analyses as a covariate. − = absence of condition, + = presence of condition.
Abbreviations: AUDIT, Alcohol Use Disorders Identification Test; BDI-II, Beck Depression Inventory II; BPI, Brief Pain Inventory; CES, Combat Exposure Scale; DAST, Drug Abuse Screening Test; DTS, Davidson Trauma Scale; PSQI, Pittsburgh Sleep Quality Index.
* Significant differences after applying FDR ($p<.05$).
† Difference was only significant for aim 1 analyses, not adjusting for the current diagnosis of PTSD.
‡ The BPI was administered to fewer participants (n=807) in this sample.

(MIRECC) of the Department of Veterans Affairs Mental Health Services.
Disclosures: none.

mental health and/or medical problems,[2,5-7] including

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https://doi.org/10.1016/j.apmr.2018.04.029

Martindale et al., 2018

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DAST					1.24±2.80*,†
BPI‡					4.28±2.30*
CES					20.02±10.12*

Measures	Non-Deployment TBI ($n = 160$)			Deployment TBI ($n = 140$)		
	M	*SD*	range	*M*	*SD*	range
AUDIT	4.89	4.69	0-29	5.58	4.87	0-23
PCL-5	32.14	18.75	1-74	**36.83**	**19.27**	**0-75**
PHQ-9	11.75	6.66	0-27	**13.15**	**6.78**	**0-27**
PROMIS-PI	19.41	9.43	8-40	**21.24**	**9.82**	**8-40**
PSQI	**11.12**	**4.21**	**1-21**	**11.76**	**4.24**	**1-21**
NSI	25.59	15.51	1-72	**30.26**	**17.01**	**2-74**

Martindale et al., 2018; Martindale et al., *in submission*

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Archives of Physical Medicine and Rehabilitation 2018;99:2485-95

ORIGINAL RESEARCH

Behavioral and Health Outcomes Associated With Deployn Traumat Veteran

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Sarah L. Ma
Mid-Atlant

From the [a]Resear Research, Educati Winston-Salem, N and Rehabilitatio Winston-Salem, N

Abstract
Objective: To ch deployment settin
Design: Cross-se diagnoses.
Setting: Veteran
Participants: Ira
Interventions: N
Main Outcome M and behavioral ar
Results: There w and pain. Veteran stress disorders th
Conclusions: TB nondeployment e lifetime prevalenc persist chronically treatment alterations to improve engagement and outcomes.

Archives of Physical Medicine and Rehabilitation 2018;99:2485-95
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	Non-Deployment TBI				Deployment TBI				Current PTSD Diagnosis			
	- (n = 835)	+ (n = 564)			- (n = 1071)	+ (n = 328)			- (n = 786)	+ (n = 613)		
Lifetime Diagnosis	n (%)	n (%)	ϕ	OR	n (%)	n (%)	ϕ	OR	n (%)	n (%)	ϕ	OR
Major Depressive Disorder	344 (41.2)	265 (47.0)			**404 (37.7)**	**205 (62.5)[c]**	.21	2.75	**201 (25.6)**	**408 (66.6)**	.38	5.50
Dysthymic Disorder	24 (2.9)	27 (4.8)			36 (3.4)	15 (4.6)			**16 (2.0)**	**35 (5.7)[b]**	.08	2.39
Alcohol Use Disorder	**204 (24.4)**	**182 (32.3)**	.09	1.47	**271 (25.3)**	**115 (35.1)[c]**	.09	1.59	**147 (18.7)**	**239 (39.0)**	.24	2.93
Polysubstance Use Disorder	**3 (0.4)**	**11 (2.0)[c]**	.08	5.52	10 (0.9)	4 (1.2)			4 (0.5)	10 (1.6)		
Posttraumatic Stress Disorder	351 (42.0)	262 (46.5)			**375 (35.0)**	**238 (72.6)**	.32	4.91	-	-		
Anxiety Disorder NOS	16 (1.9)	13 (2.3)			23 (2.1)	6 (1.8)			**25 (3.2)**	**4 (0.7)[b]**	-.09	0.07

Supported by the Department of Veterans Affairs Office of Academic Affiliations Advanced Fellowship Program in Mental Illness, Research, and Treatment, the Salisbury VA Health Care System, Durham Veterans Affairs Medical Center, Hunter Holmes McGuire Veterans Affairs Medical Center, and the VA Mid-Atlantic Mental Illness Research, Education, and Clinical Center (MIRECC) of the Department of Veterans Affairs Mental Health Services.
Disclosures: none.

Traumatic brain injury (TBI) is an increasing concern for the US military. The incidence of nonpenetrating TBI is more common among veterans returning from the wars in Iraq and Afghanistan than previous conflicts, with reports of explosion-related injuries an estimated 16% higher.[1-4] TBI is a major concern for health professionals because patients often present with cooccurring mental health and/or medical problems,[2,5-7] including

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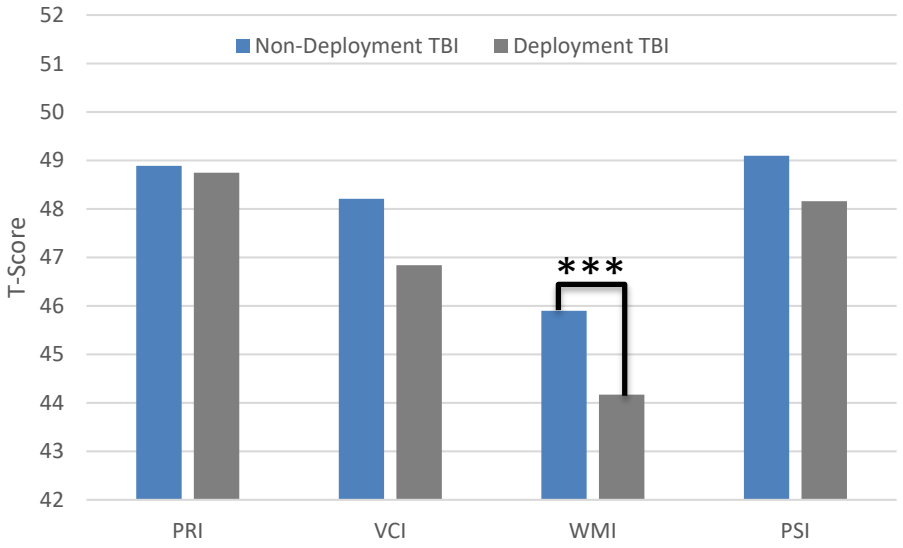

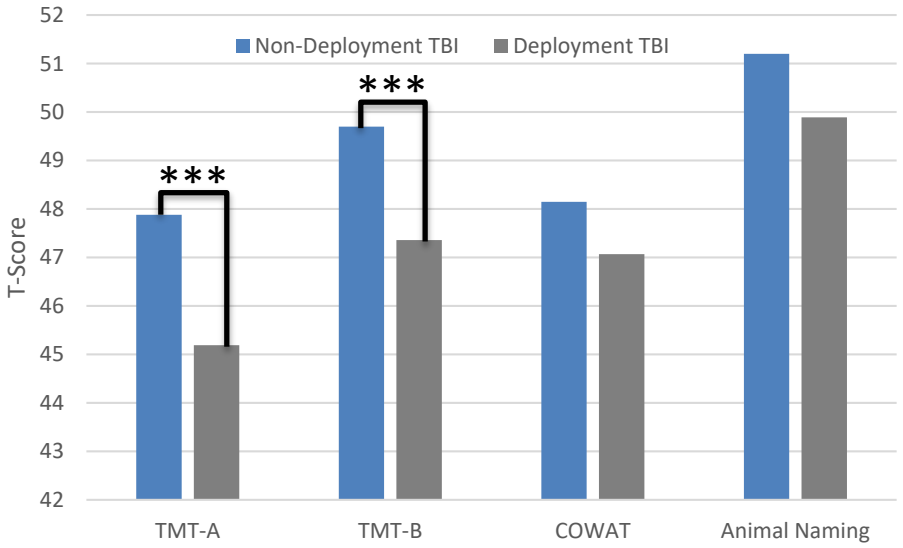

	Non-Deployment TBI		Deployment TBI	
Measures	F	η_{sp}^2	F	η_{sp}^2
WAIS-IV PRI	1.47	.005	1.80	.006
WAIS-IV VCI	0.00	< .001	4.88	.017
WAIS-IV WMI	0.01	< .001	**5.62**	**.019**
WAIS-IV PSI	1.07	.004	4.09	.014
TMT-A	0.19	.001	**15.32**	**.049**
TMT-B	0.18	< .001	**9.36**	**.031**
COWAT	0.15	< .001	4.14	.014
Animal Naming	0.89	.003	1.60	.006

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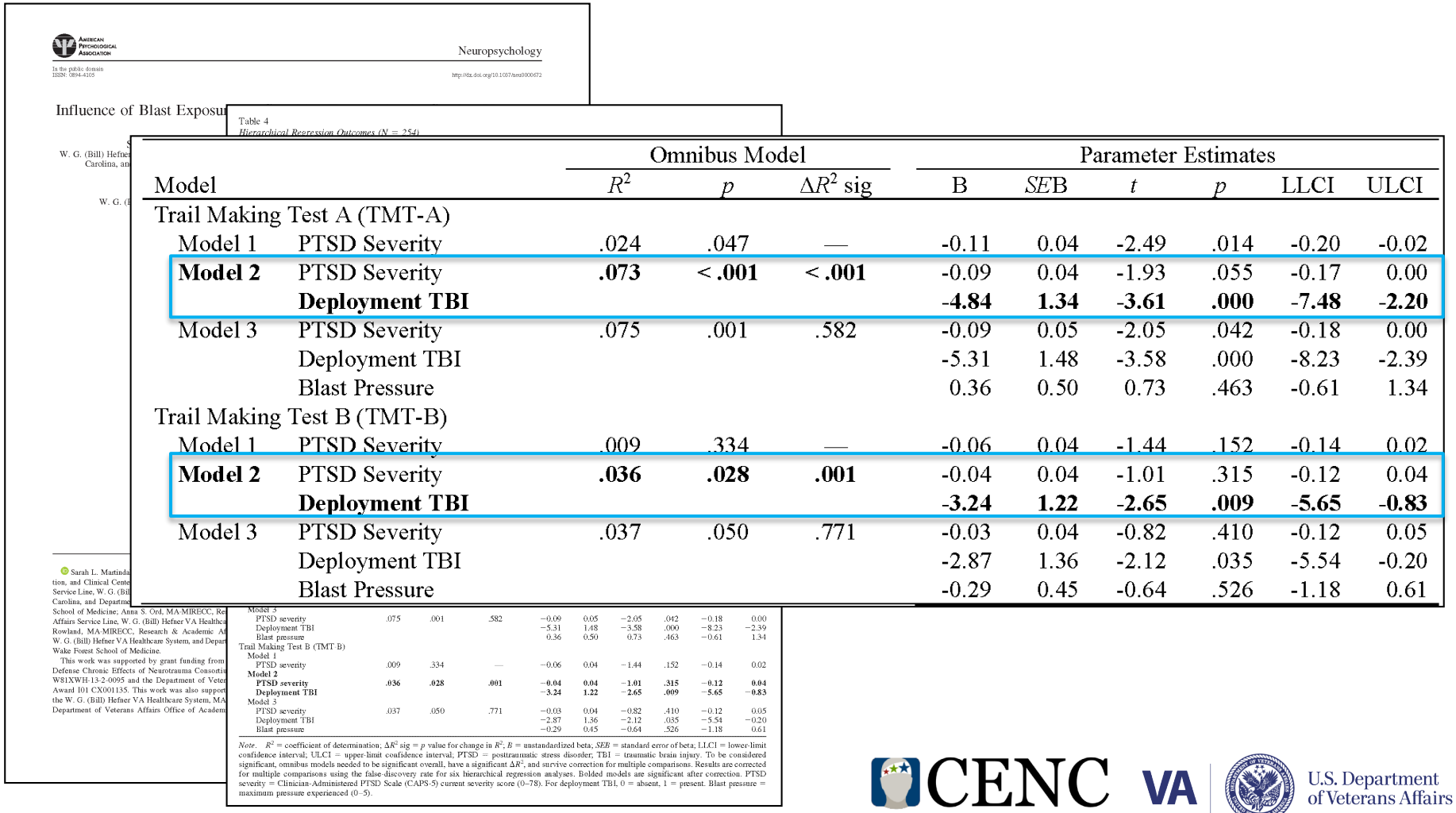

Neuropsychology

Influence of Blast Exposu

Table 4
Hierarchical Regression Outcomes (N = 254)

Model		Omnibus Model R^2	Omnibus Model p	Omnibus Model ΔR^2 sig	Parameter Estimates B	*SE*B	*t*	*p*	LLCI	ULCI
Trail Making Test A (TMT-A)										
Model 1	PTSD Severity	.024	.047	—	-0.11	0.04	-2.49	.014	-0.20	-0.02
Model 2	PTSD Severity	**.073**	**< .001**	**< .001**	-0.09	0.04	-1.93	.055	-0.17	0.00
	Deployment TBI				**-4.84**	**1.34**	**-3.61**	**.000**	**-7.48**	**-2.20**
Model 3	PTSD Severity	.075	.001	.582	-0.09	0.05	-2.05	.042	-0.18	0.00
	Deployment TBI				-5.31	1.48	-3.58	.000	-8.23	-2.39
	Blast Pressure				0.36	0.50	0.73	.463	-0.61	1.34
Trail Making Test B (TMT-B)										
Model 1	PTSD Severity	.009	.334	—	-0.06	0.04	-1.44	.152	-0.14	0.02
Model 2	PTSD Severity	**.036**	**.028**	**.001**	**-0.04**	**0.04**	**-1.01**	**.315**	**-0.12**	**0.04**
	Deployment TBI				**-3.24**	**1.22**	**-2.65**	**.009**	**-5.65**	**-0.83**
Model 3	PTSD Severity	.037	.050	.771	-0.03	0.04	-0.82	.410	-0.12	0.05
	Deployment TBI				-2.87	1.36	-2.12	.035	-5.54	-0.20
	Blast Pressure				-0.29	0.45	-0.64	.526	-1.18	0.61

Note. R^2 = coefficient of determination; ΔR^2 sig = p value for change in R^2; *B* = unstandardized beta; *SE* = standard error of beta; LLCI = lower-limit confidence interval; ULCI = upper-limit confidence interval; PTSD = posttraumatic stress disorder; TBI = traumatic brain injury. To be considered significant, omnibus models needed to be significant overall, have a significant ΔR^2, and survive correction for multiple comparisons. Results are corrected for multiple comparisons using the false-discovery rate for six hierarchical regression analyses. Bolded models are significant after correction. PTSD severity = Clinician-Administered PTSD Scale (CAPS-5) current severity score (0–78). For deployment TBI, 0 = absent, 1 = present. Blast pressure = maximum pressure experienced (0–5).

Martindale, Ord, Rowland, 2020

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ISSN: 0894-4105

Influence of Blast Exposure on Cognitive Functioning in Combat

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Objective: We evaluated the contribution of blast-pressure severity to cognitive functioning beyond posttraumatic stress disorder (PTSD) severity and traumatic brain injury (TBI). ***Method:*** Post-9/11 veterans (N = 254, 86.22% male) completed the Wechsler Adult Intelligence Scale (WAIS-IV) and Trail Making Test (TMT). The Clinician-Administered PTSD Scale (CAPS-5), Mid-Atlantic MIRECC Assessment of TBI, and the Salisbury Blast Interview evaluated PTSD diagnosis/severity, deployment TBI history/severity, and blast-exposure history/severity, respectively. ***Results:*** Veterans with mild deployment TBI had overall significantly lower T scores on the WAIS-IV Verbal Comprehension Index (d = .13), Working Memory Index (d = .30), and Processing Speed Index (d = .25); the Trail Making Test A (TMT-A; d = .50); and the Trail Making Test B (TMT-B; d = .37). Mild deployment TBI was significantly associated with TMT-A (ΔR^2 = .05, p < .001) and TMT-B (ΔR^2 = .03, p = .001) performance. Blast-pressure severity moderated the association between mild deployment TBI and TMT-A (ΔR^2 = .02, p = .039, B = −2.01). ***Conclusion:*** Blast-pressure severity exacerbated the effects of mild TBI on a simple attention task, such that participants with TBI had gradual decrements in attention as blast severity increased. Veterans who incur a TBI and are exposed to blasts during deployment may experience persisting difficulties with cognitive functioning as a result of alterations in basic attention abilities.

Key Points

Question: Does experiencing a blast/explosion during deployment affect cognitive functioning beyond other mental health factors? **Findings:** Exposure to a blast/explosion was not a primary factor in cognitive outcomes but exacerbated the negative effects of other conditions on cognitive outcomes. **Importance:** Exposure to blasts/explosions during deployment may contribute to lower cognitive functioning when other conditions are present. **Next Steps:** Identifying specific characteristics of blast exposure (e.g., number of exposures, distance) that are predictive of functional outcomes will be important in elucidating how exposure to blasts affects veterans long term.

Keywords: blast, veteran, cognition, posttraumatic stress disorder, traumatic brain injury

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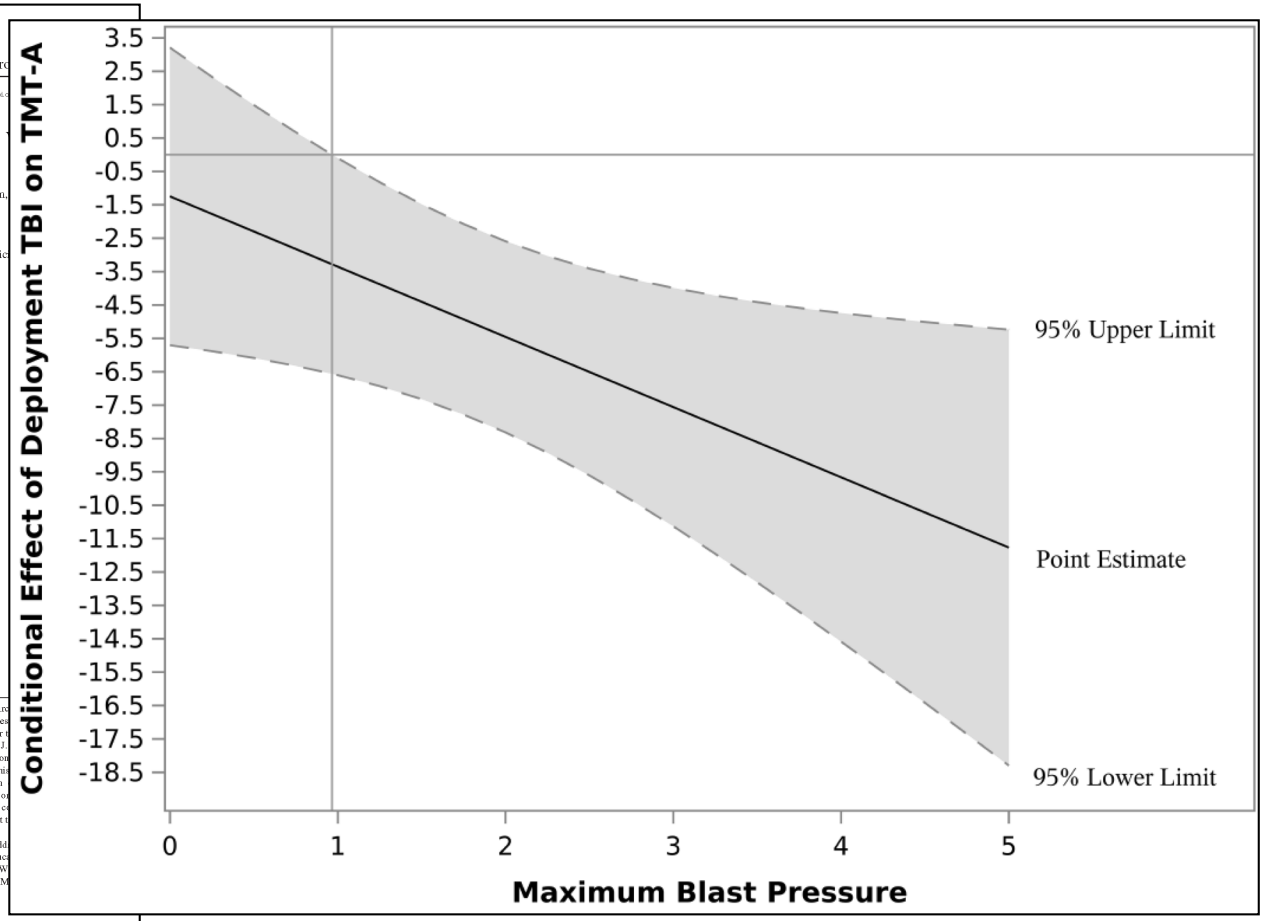

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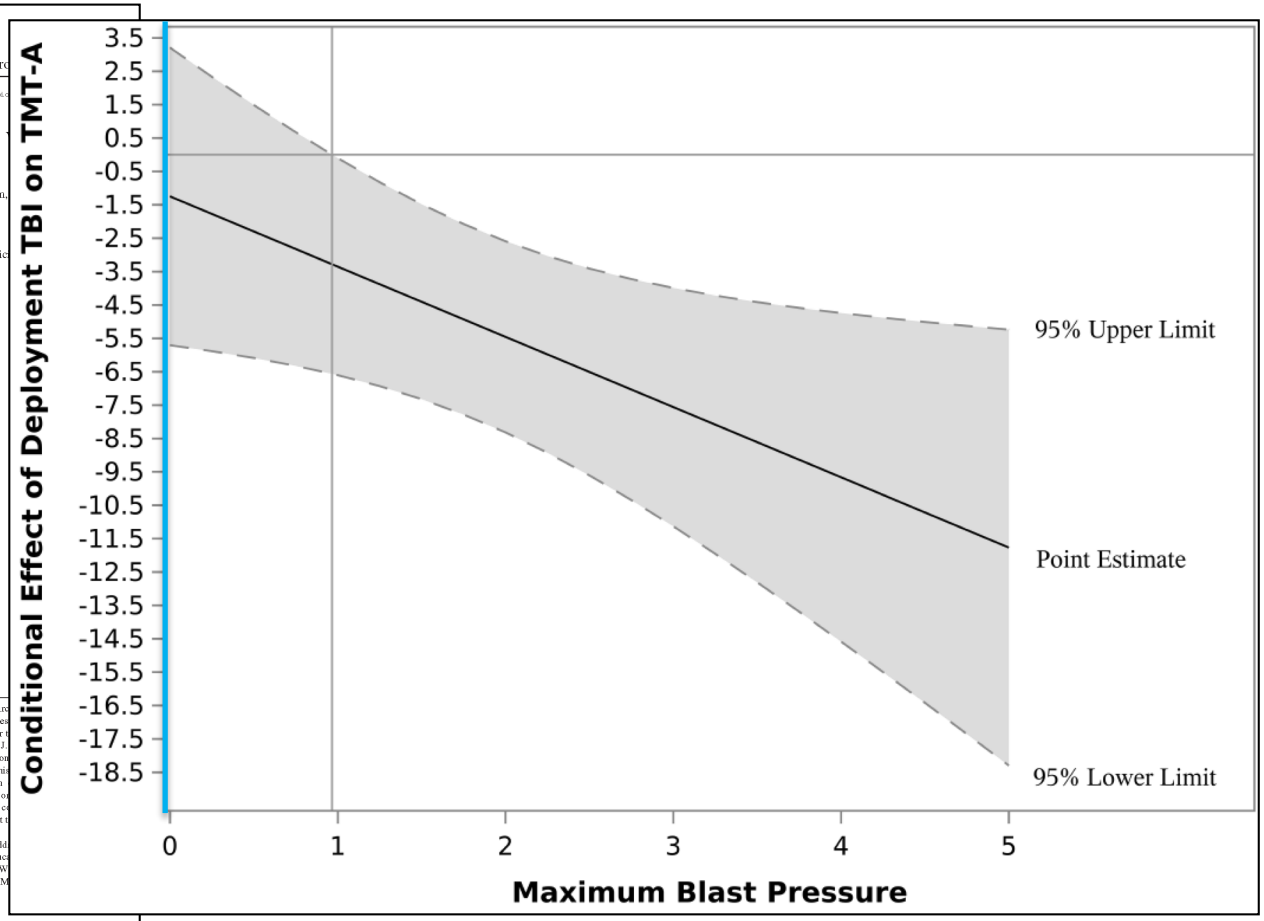

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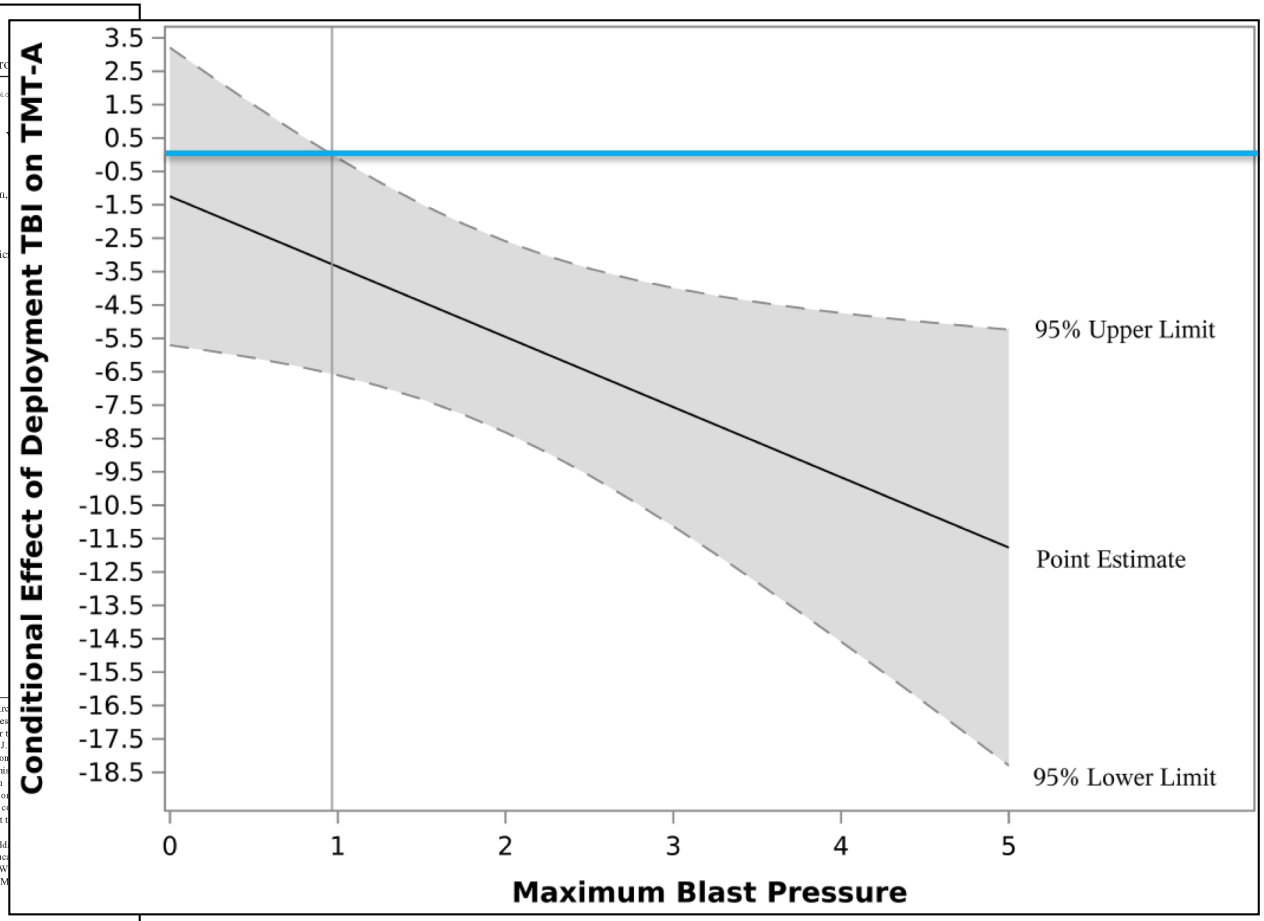

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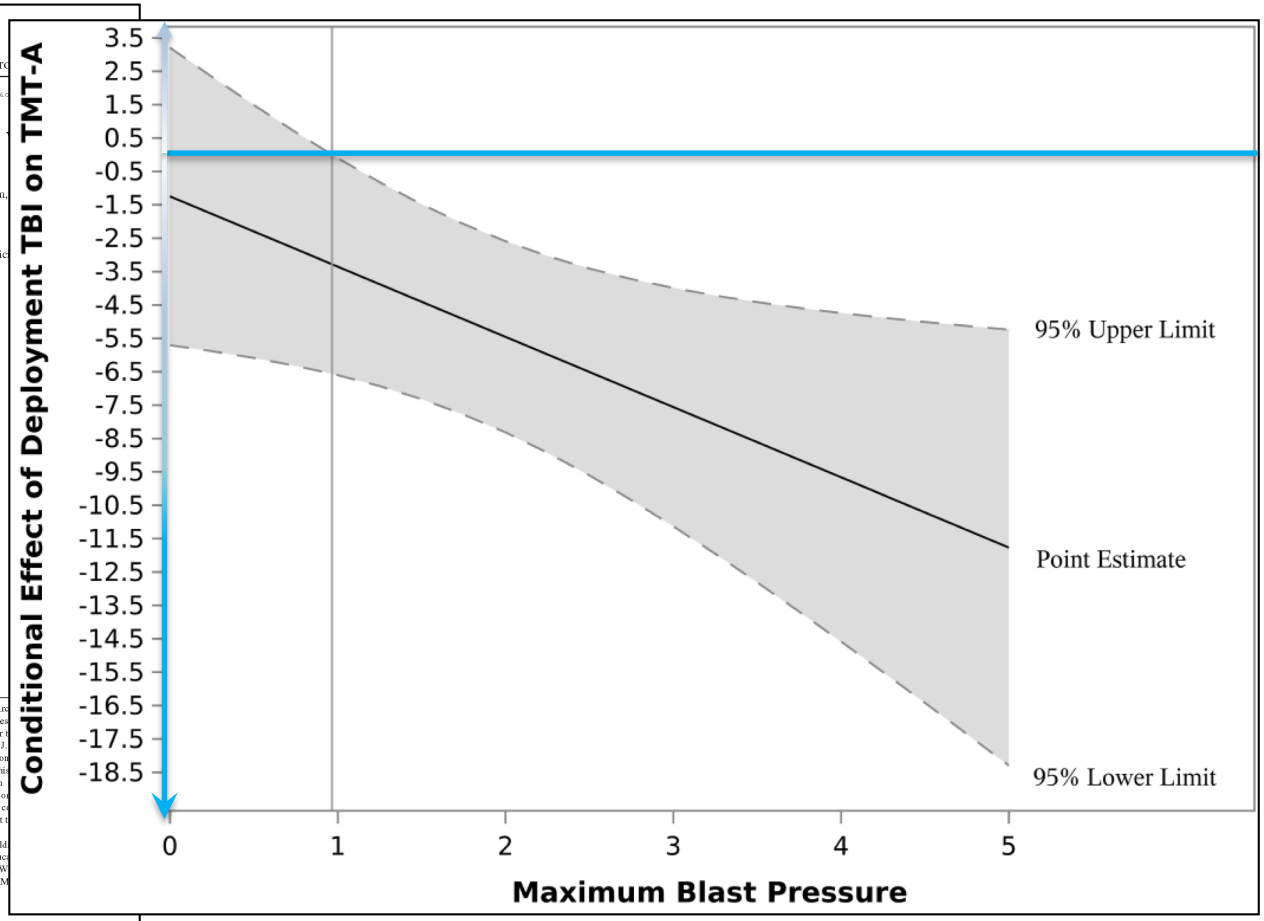

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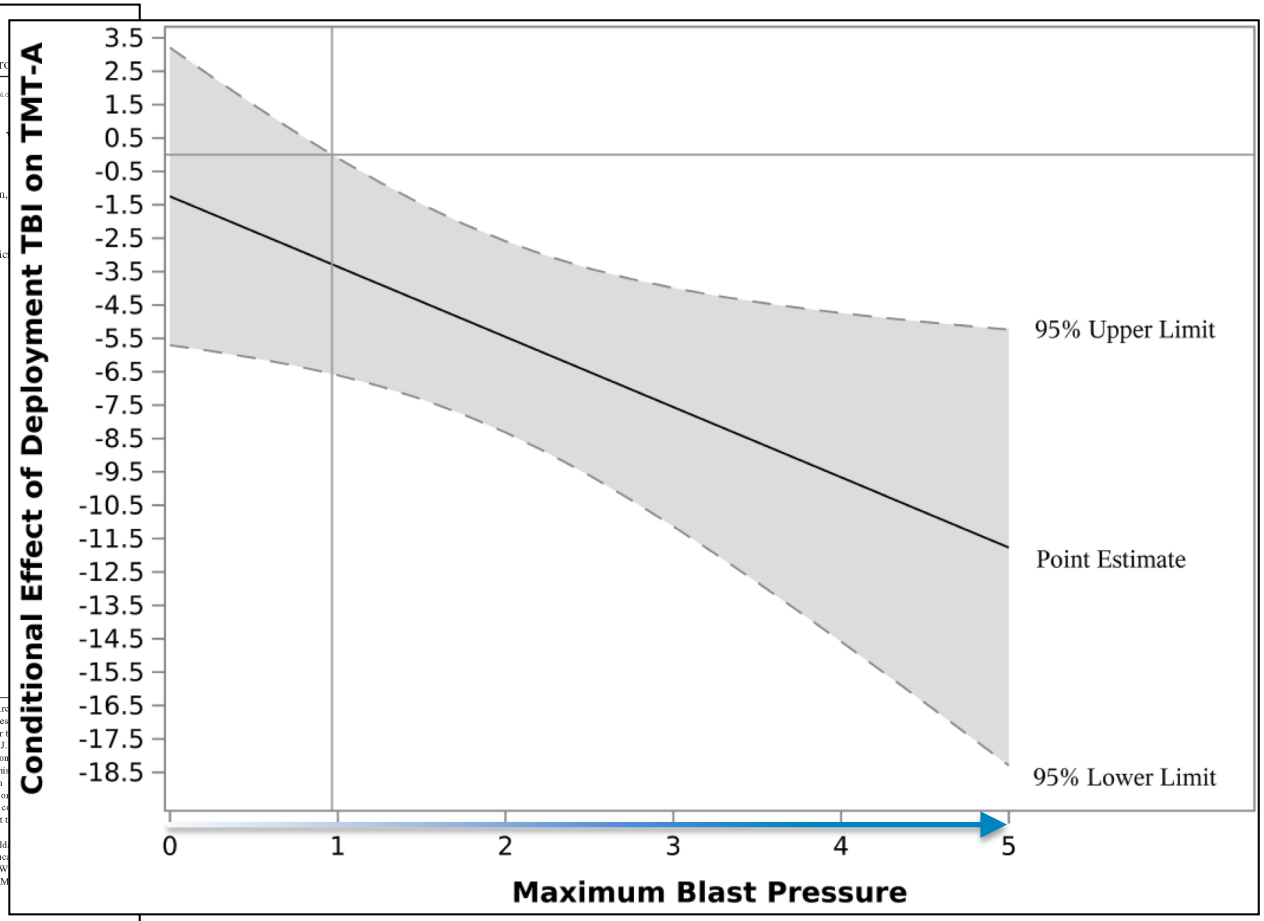

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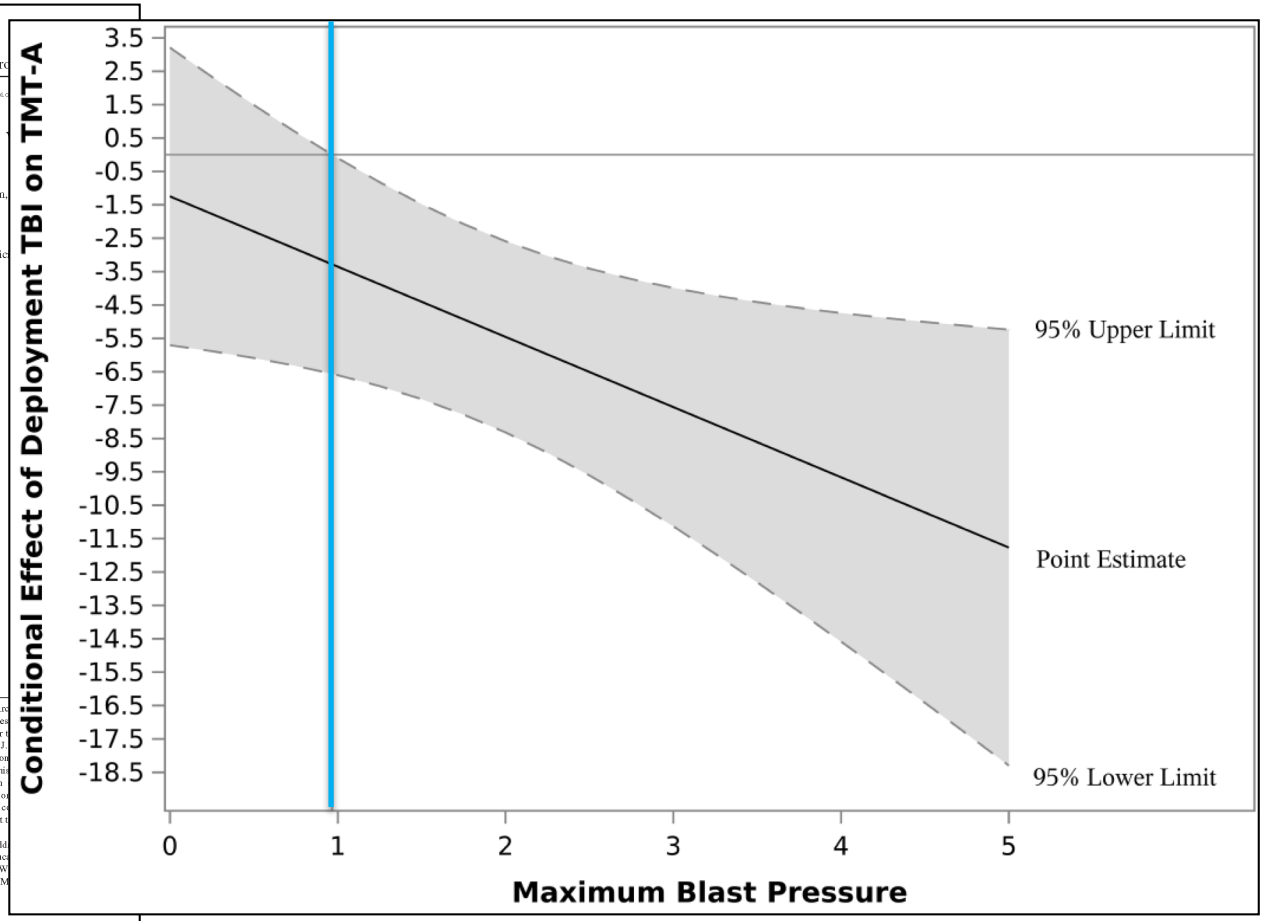

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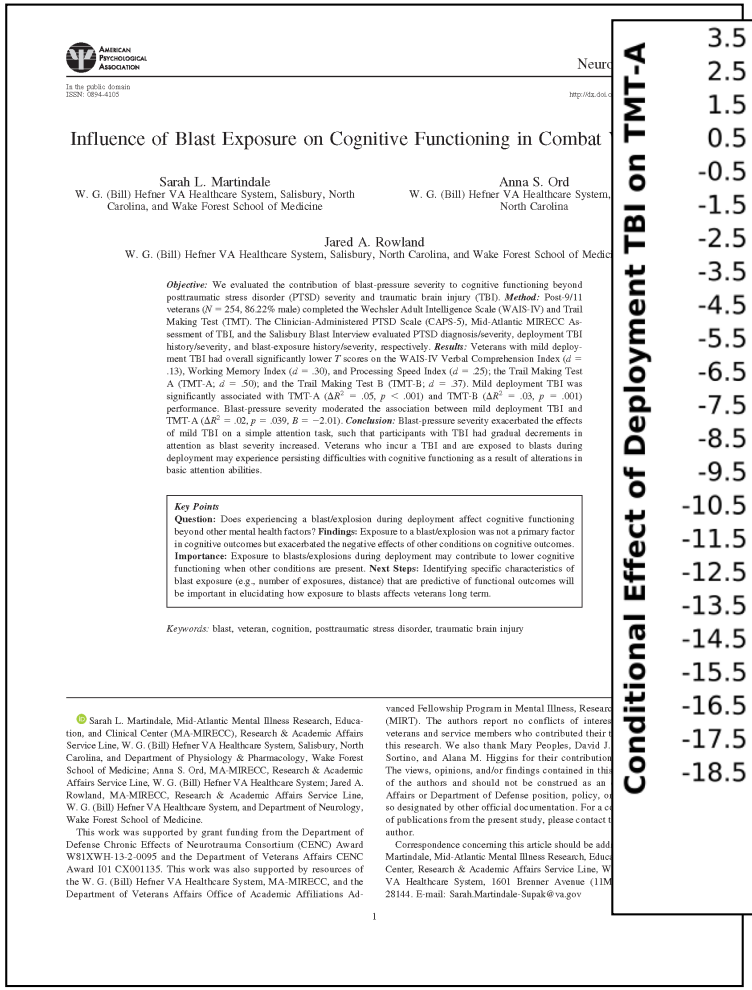

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Question: Does experiencing a blast/explosion during deployment affect cognitive functioning beyond other mental health factors? **Findings:** Exposure to a blast/explosion was not a primary factor in cognitive outcomes but exacerbated the negative effects of other conditions on cognitive outcomes. **Importance:** Exposure to blasts/explosions during deployment may contribute to lower cognitive functioning when other conditions are present. **Next Steps:** Identifying specific characteristics of blast exposure (e.g., number of exposures, distance) that are predictive of functional outcomes will be important in elucidating how exposure to blasts affects veterans long term.

Keywords: blast, veteran, cognition, posttraumatic stress disorder, traumatic brain injury

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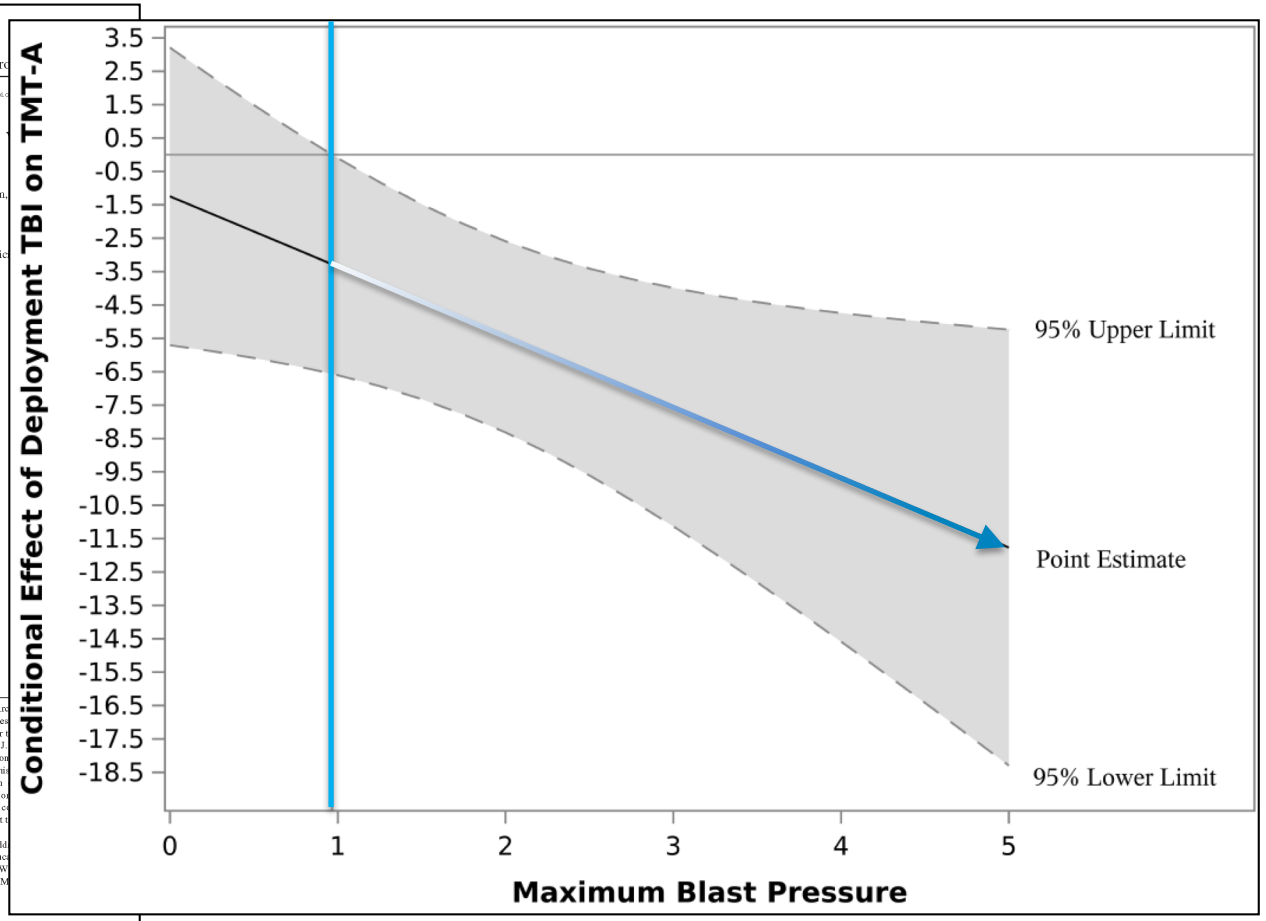

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Behavioral Summary

Cognitive Function

- Attention
- Executive function
- Altered by blast exposure

Symptom Report

- Posttraumatic stress symptoms
- Depressive
- Sleep
- Neurobehavioral
- Pain
- Substance use

Psychiatric Diagnoses

- Posttraumatic Stress Disorder
- Depression
- Alcohol Use Disorder

Neuroimaging: Structural Volume

J Head Trauma Rehabil

Brain Volume in Veterans: Relationship to Posttraumatic Stress Disorder and Mild Traumatic Brain Injury

Sarah L. Martindale, PhD; Ramona Rostami, PhD; Robert D. Shura, PsyD; Katherine H. Taber, PhD; Jared A. Rowland, PhD

Objective: Clarify associations between diagnosis of posttraumatic stress disorder (PTSD) and deployment traumatic brain injury (TBI) on salient regional brain volumes in returning combat veterans. **Participants:** Iraq and Afghanistan era combat veterans, $N = 163$, 86.5% male. **Main Measures:** Clinician-administered PTSD Scale (CAPS-5), Mid-Atlantic MIRECC Assessment of TBI (MMA-TBI), magnetic resonance imaging. **Methods:** Hierarchical regression analyses evaluated associations and interactions between current and lifetime PTSD diagnosis, deployment TBI, and bilateral volume of hippocampus, anterior cingulate cortex, amygdala, orbitofrontal cortex, precuneus, and insula. **Results:** Deployment TBI was associated with lower bilateral hippocampal volume ($P = .007$-$.032$) and right medial orbitofrontal cortex volume ($P = .006$). Neither current nor lifetime PTSD diagnosis was associated with volumetric outcomes beyond covariates and deployment TBI. **Conclusion:** History of deployment TBI is independently associated with lower volumes in hippocampus and medial orbitofrontal cortex. These results support TBI as a potential contributing factor to consider in reduced cortical volume in PTSD. **Key words:** *anterior cingulate cortex, brain volume, hippocampus, PTSD, TBI, veteran*

Author Affiliations: *Mid-Atlantic Mental Illness Research, Education, and Clinical Center (MA-MIRECC), Research & Academic Affairs Service Line (Drs Martindale, Taber, and Rowland), and Mental Health & Behavioral Sciences Service Line (Drs Rostami and Shura), Salisbury VA Medical Center, Salisbury, North Carolina; Departments of Physiology & Pharmacology (Dr Martindale), Neurology (Dr Shura), and Neurobiology & Anatomy (Dr Rowland), Wake Forest School of Medicine, Winston-Salem, North Carolina; Division of Biomedical Sciences, Via College of Osteopathic Medicine, Blacksburg, Virginia (Dr Taber); and Department of Physical Medicine & Rehabilitation, Baylor College of Medicine, Houston, Texas (Dr Taber). Dr Rostami is now with the Edith Nourse Rogers Bedford VA Medical Center, Bedford, Massachusetts.*

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POSTTRAUMATIC STRESS DISORDER (PTSD) is one of the most commonly diagnosed psychiatric disorders among veterans who have deployed in support of Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn (OEF/OIF/OND), with prevalence rates estimated at 13.8%.[1,2] In addition to PTSD, service members experience many events that can lead to a traumatic brain injury (TBI) during deployment. Veterans with mild TBI acquired during combat are 2.37 times more likely to meet criteria for PTSD,[3] and those with PTSD are more likely to report postconcussive symptoms persisting at 5 or more months after the injury.

Evidence links PTSD to several brain structures through functional connections and structural volumes as both potential risk factors and outcomes. Structures most commonly implicated are involved in emotional processing, including hippocampus, amygdala, anterior cingulate cortex (ACC), prefrontal cortex, and insula.[4–7] Prevailing evidence supports differences in neuroanatomical structural volume as a premorbid risk

DOI: 10.1097/HTR.0000000000000559

TABLE 2 *Hierarchical regressions (N = 163)*[a]

	ANOVA			Model change		Parameter estimates					
Model	R^2	F	P	ΔR^2	P	B	SEB	t	P	LLCI	ULCI
L Hippocampus											
Model 1											
Current PTSD	0.063	3.55	.016	0.008	.509	−0.18	0.50	−0.35	.723	−1.16	0.81
Lifetime PTSD						−0.07	0.45	−0.14	.886	−0.96	0.83
Model 2											
Current PTSD	**0.090**	**3.91**	**.005**	**0.027**	**.032**	**0.06**	**0.50**	**0.12**	**.904**	**−0.93**	**1.05**
Lifetime PTSD						**0.16**	**0.46**	**0.35**	**.726**	**−0.75**	**1.07**
Deployment TBI						**−0.88**	**0.40**	**−2.18**	**.031**	**−1.67**	**−0.08**
R Hippocampus											
Model 1											
Current PTSD	0.038	2.07	.106	0.009	.477	−0.16	0.51	−0.31	.758	−1.17	0.85
Lifetime PTSD						0.04	0.47	0.09	.926	−0.88	0.97
Model 2											
Current PTSD	**0.082**	**3.54**	**.009**	**0.044**	**.007**	**0.15**	**0.51**	**0.29**	**.771**	**−0.87**	**1.17**
Lifetime PTSD						**0.34**	**0.47**	**0.72**	**.474**	**−0.59**	**1.27**
Deployment TBI						**−1.14**	**0.41**	**−2.77**	**.006**	**−1.96**	**−0.33**
L Rostral ACC											
Model 1											
Current PTSD	0.002	0.19	.827	—	—	0.03	0.56	0.05	.963	−1.07	1.13
Lifetime PTSD						−0.29	0.53	−0.55	.585	−1.35	0.76
Model 2											
Current PTSD	0.014	0.77	.513	0.012	.166	0.23	0.57	0.40	.692	−0.91	1.36
Lifetime PTSD						−0.12	0.55	−0.23	.822	−1.20	0.96
Deployment TBI						−0.66	0.48	−1.39	.167	−1.60	0.28
R Rostral ACC											
Model 1											
Current PTSD	0.035	1.92	.129	0.009	.529	0.47	0.46	1.02	.312	−0.44	1.38
Lifetime PTSD						−0.08	0.43	−0.20	.844	−0.93	0.76
Model 2											
Current PTSD	0.035	1.43	.226	0.000	.898	0.48	0.48	1.01	.312	−0.46	1.42
Lifetime PTSD						−0.07	0.44	−0.16	.871	−0.95	0.80
Deployment TBI						−0.05	0.39	−0.12	.902	−0.81	0.72
L Caudal ACC											
Model 1											
Current PTSD	0.031	1.71	.166	0.004	.698	−0.03	0.57	−0.06	.956	−1.16	1.10
Lifetime PTSD						−0.43	0.54	−0.80	.428	−1.49	0.64

(*continues*)

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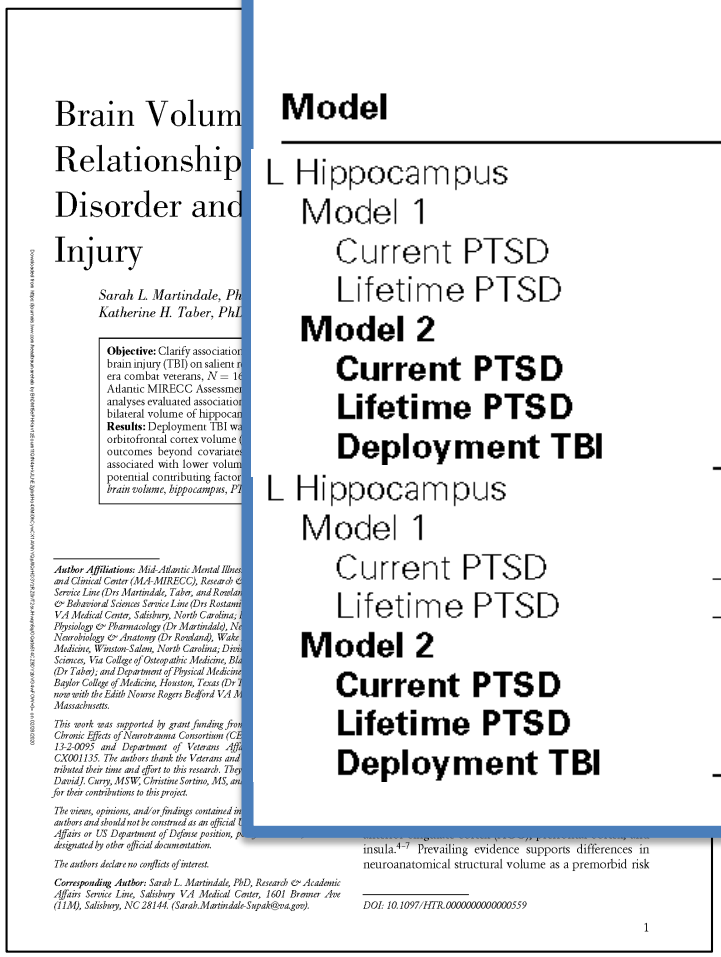
Neuroimaging: Structural Volume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Parameter estimates

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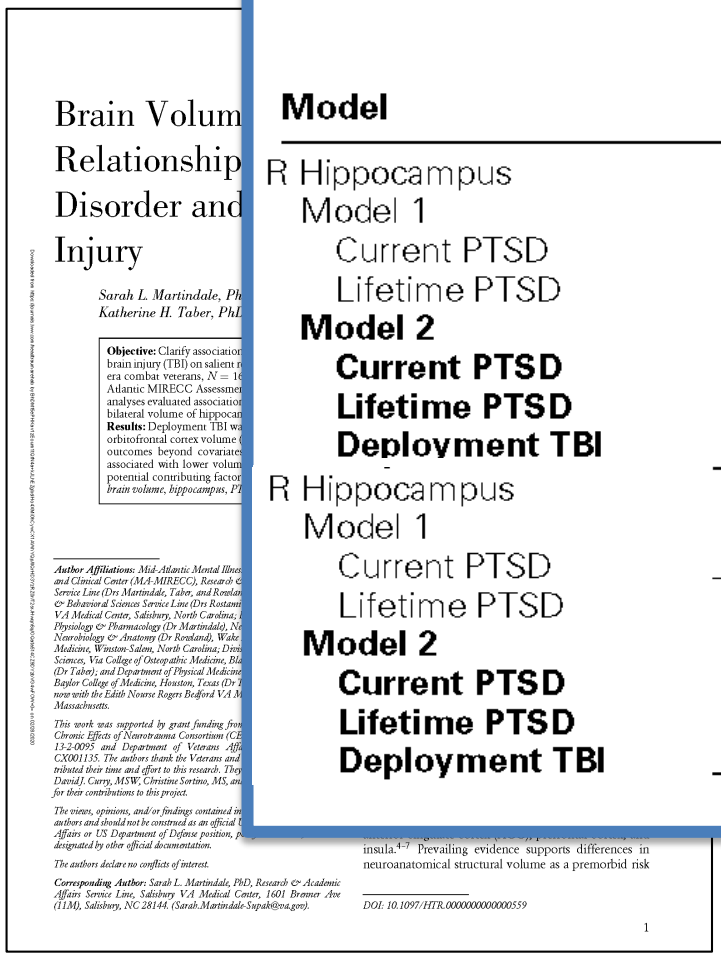
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Deployment TBI					

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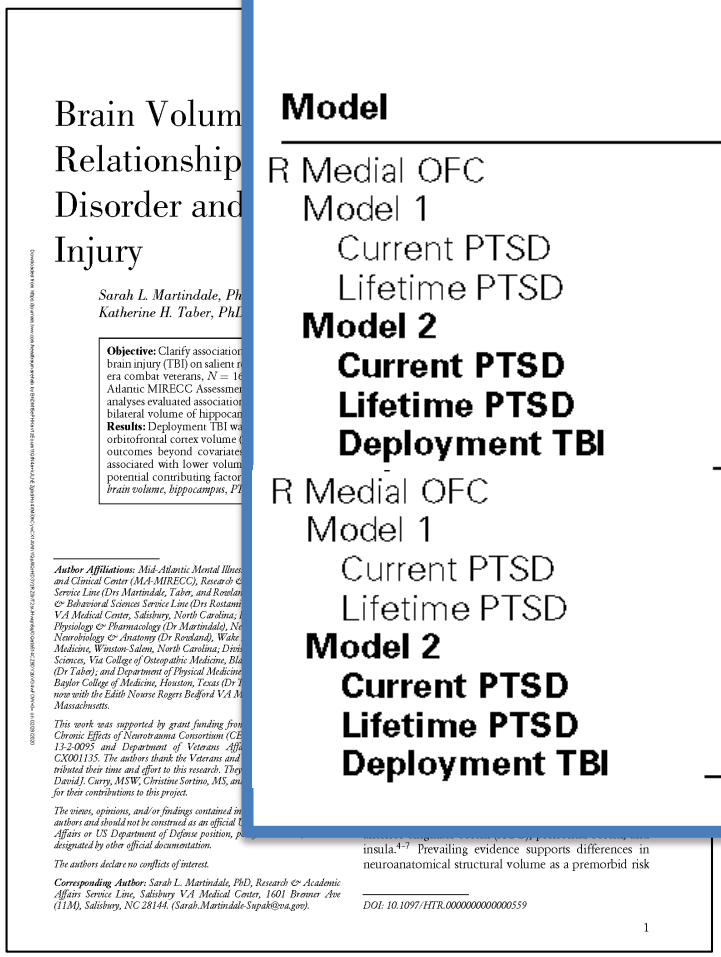
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Model	ANOVA R^2	ANOVA F	ANOVA P	Model change ΔR^2	Model change P
R Medial OFC					
Model 1					
Current PTSD	0.053	2.95	.034	0.003	.778
Lifetime PTSD					
Model 2					
Current PTSD	**0.097**	**4.24**	**.003**	**0.044**	**.006**
Lifetime PTSD					
Deployment TBI					

Parameter estimates

	B	SEB	t	P	LLCI	ULCI
R Medial OFC						
Model 1						
Current PTSD	0.40	0.65	0.62	.537	−0.89	1.70
Lifetime PTSD	0.31	0.63	0.49	.627	−0.94	1.56
Model 2						
Current PTSD	**0.86**	**0.66**	**1.30**	**.197**	**−0.45**	**2.16**
Lifetime PTSD	**0.74**	**0.64**	**1.16**	**.246**	**−0.52**	**2.00**
Deployment TBI	**−1.55**	**0.56**	**−2.78**	**.006**	**−2.65**	**−0.45**

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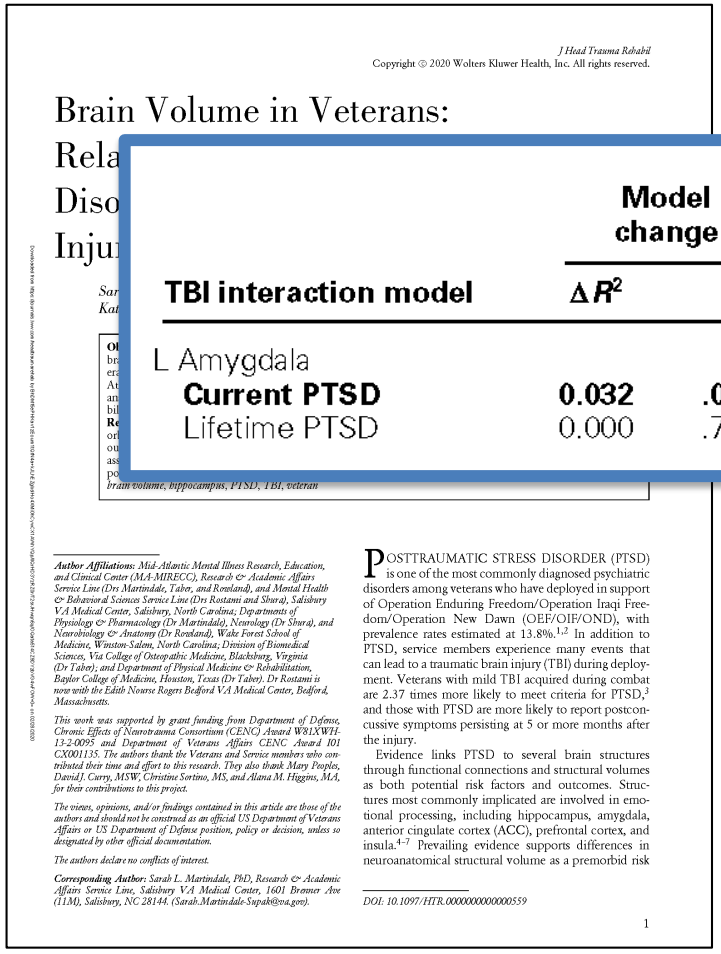
TABLE 3 *Moderation analyses (N = 163)*[a]

TBI interaction model	Model change ΔR^2	Model change *P*	Parameter estimates *B*	*SEB*	*t*	*P*	LLCI	ULCI
L Hippocampus								
Current PTSD	0.001	.739	0.29	0.88	0.33	.739	−1.44	2.03
Lifetime PTSD	0.002	.569	−0.49	0.85	−0.57	.569	−2.17	1.20
R Hippocampus								
Current PTSD	0.003	.474	0.64	0.90	0.72	.474	−1.13	2.42
Lifetime PTSD	0.002	.591	0.47	0.87	0.54	.591	−1.25	2.20
L Rostral ACC								
Current PTSD	0.000	.795	−0.27	1.04	−0.26	.795	−2.32	1.78
Lifetime PTSD	0.004	.445	0.76	0.99	0.77	.445	−1.20	2.71
R Rostral ACC								
Current PTSD	0.002	.626	−0.41	0.84	−0.49	.626	−2.07	1.25
Lifetime PTSD	0.001	.629	−0.39	0.81	−0.48	.629	−1.99	1.20
L Caudal ACC								
Current PTSD	0.008	.257	−1.19	1.04	−1.14	.257	−3.25	0.87
Lifetime PTSD	0.009	.219	1.23	1.00	1.23	.219	−0.74	3.20
R Caudal ACC								
Current PTSD	0.006	.349	−1.00	1.07	−0.94	.349	−3.11	1.10
Lifetime PTSD	0.001	.691	0.41	1.02	0.40	.691	−1.61	2.43
L Amygdala								
Current PTSD	**0.032**	**.020**	**1.02**	**0.43**	**2.35**	**.020**	**0.16**	**1.88**
Lifetime PTSD	0.000	.789	−0.11	0.43	−0.27	.789	−0.96	0.73
R Amygdala								
Current PTSD	0.017	.091	0.82	0.48	1.70	.091	−0.13	1.78
Lifetime PTSD	0.000	.822	−0.11	0.48	−0.23	.822	−1.05	0.83
L Lateral OFC								
Current PTSD	0.000	.810	0.37	1.56	0.24	.810	−2.70	3.45
Lifetime PTSD	0.001	.703	0.57	1.49	0.38	.703	−2.37	3.51
R Lateral OFC								
Current PTSD	0.013	.139	2.31	1.56	1.49	.139	−0.76	5.39
Lifetime PTSD	0.011	.172	−2.06	1.50	−1.37	.172	−5.02	0.90
L Medial OFC								
Current PTSD	0.002	.625	0.61	1.24	0.49	.625	−1.83	3.04
Lifetime PTSD	0.014	.131	1.78	1.17	1.52	.131	−0.54	4.10
R Medial OFC								
Current PTSD	0.008	.234	1.43	1.20	1.20	.234	−0.93	3.79
Lifetime PTSD	0.001	.777	−0.33	1.15	−0.28	.777	−2.59	1.94
L Precuneus								
Current PTSD	0.000	.986	0.05	2.53	0.02	.986	−4.94	5.04
Lifetime PTSD	0.005	.377	2.11	2.38	0.89	.377	−2.60	6.82
R Precuneus								
Current PTSD	0.002	.556	1.54	2.60	0.59	.555	−3.60	6.67
Lifetime PTSD	0.007	.280	2.67	2.47	1.08	.280	−2.20	7.55
L Insula								
Current PTSD	0.001	.755	−0.51	1.64	−0.31	.755	−3.74	2.72
Lifetime PTSD	0.000	.909	−0.18	1.57	−0.11	.909	−3.27	2.91
R Insula								
Current PTSD	0.005	.371	−1.39	1.55	−0.90	.371	−4.46	1.67
Lifetime PTSD	0.001	.653	0.67	1.49	0.45	.653	−2.27	3.61

Martindale, Rostami, et al., 2020

Neuroimaging: Structural Volume



J Head Trauma Rehabil

Brain Volume in Veterans:
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brain volume, hippocampus, PTSD, TBI, veteran

Author Affiliations: Mid-Atlantic Mental Illness Research, Education, and Clinical Center (MA-MIRECC), Research & Academic Affairs Service Line (Drs Martindale, Taber, and Rowland), and Mental Health & Behavioral Sciences Service Line (Drs Rostami and Shura), Salisbury VA Medical Center, Salisbury, North Carolina; Departments of Physiology & Pharmacology (Dr Martindale), Neurology (Dr Shura), and Neurobiology & Anatomy (Dr Rowland), Wake Forest School of Medicine, Winston-Salem, North Carolina; Division of Biomedical Sciences, Via College of Osteopathic Medicine, Blacksburg, Virginia (Dr Taber); and Department of Physical Medicine & Rehabilitation, Baylor College of Medicine, Houston, Texas (Dr Taber). Dr Rostami is now with the Edith Nourse Rogers Bedford VA Medical Center, Bedford, Massachusetts.

This work was supported by grant funding from Department of Defense, Chronic Effects of Neurotrauma Consortium (CENC) Award W81XWH-13-2-0095 and Department of Veterans Affairs CENC Award I01 CX001135. The authors thank the Veterans and Service members who contributed their time and effort to this research. They also thank Mary Peoples, David J. Curry, MSW, Christine Sortino, MS, and Alana M. Higgins, MA, for their contributions to this project.

The views, opinions, and/or findings contained in this article are those of the authors and should not be construed as an official US Department of Veterans Affairs or US Department of Defense position, policy or decision, unless so designated by other official documentation.

The authors declare no conflicts of interest.

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POSTTRAUMATIC STRESS DISORDER (PTSD) is one of the most commonly diagnosed psychiatric disorders among veterans who have deployed in support of Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn (OEF/OIF/OND), with prevalence rates estimated at 13.8%.[1,2] In addition to PTSD, service members experience many events that can lead to a traumatic brain injury (TBI) during deployment. Veterans with mild TBI acquired during combat are 2.37 times more likely to meet criteria for PTSD,[3] and those with PTSD are more likely to report postconcussive symptoms persisting at 5 or more months after the injury.

Evidence links PTSD to several brain structures through functional connections and structural volumes as both potential risk factors and outcomes. Structures most commonly implicated are involved in emotional processing, including hippocampus, amygdala, anterior cingulate cortex (ACC), prefrontal cortex, and insula.[4–7] Prevailing evidence supports differences in neuroanatomical structural volume as a premorbid risk

DOI: 10.1097/HTR.0000000000000559

TABLE 3 *Moderation analyses (N = 163)*[a]

TBI interaction model	Model change ΔR^2	Model change *P*	Parameter estimates *B*	*SEB*	*t*	*P*	LLCI	ULCI
L Hippocampus								
Current PTSD	0.001	.739	0.29	0.88	0.33	.739	−1.44	2.03
Lifetime PTSD	0.000	.822	−0.11	0.48	−0.23	.822	−1.05	0.83
L Lateral OFC								
Current PTSD	0.000	.810	0.37	1.56	0.24	.810	−2.70	3.45
Lifetime PTSD	0.001	.703	0.57	1.49	0.38	.703	−2.37	3.51
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Current PTSD	0.013	.139	2.31	1.56	1.49	.139	−0.76	5.39
Lifetime PTSD	0.011	.172	−2.06	1.50	−1.37	.172	−5.02	0.90
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Lifetime PTSD	0.001	.653	0.67	1.49	0.45	.653	−2.27	3.61

TBI interaction model	Model change ΔR^2	Model change *P*	Parameter estimates *B*	*SEB*	*t*	*P*	LLCI	ULCI
L Amygdala								
Current PTSD	**0.032**	**.020**	**1.02**	**0.43**	**2.35**	**.020**	**0.16**	**1.88**
Lifetime PTSD	0.000	.789	−0.11	0.43	−0.27	.789	−0.96	0.73

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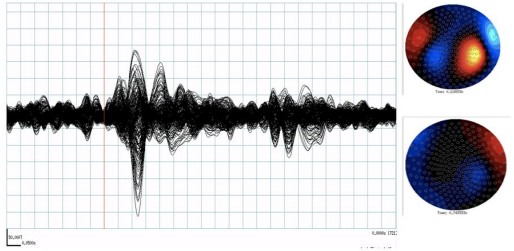
Neuroimaging: Networks

A.



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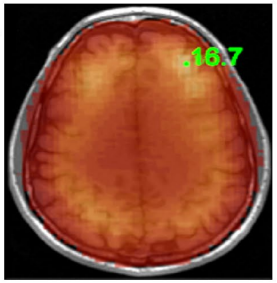

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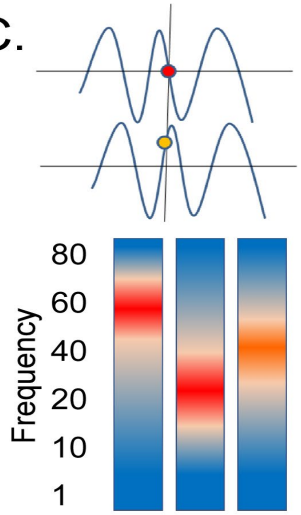
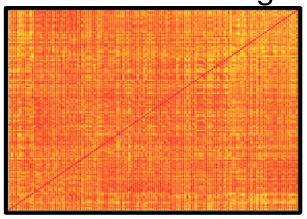
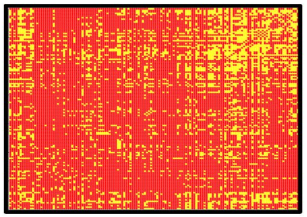


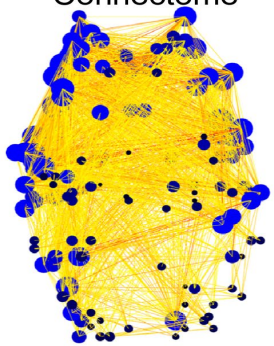
D. UnThresholded Weighted



Thresholded Binarized

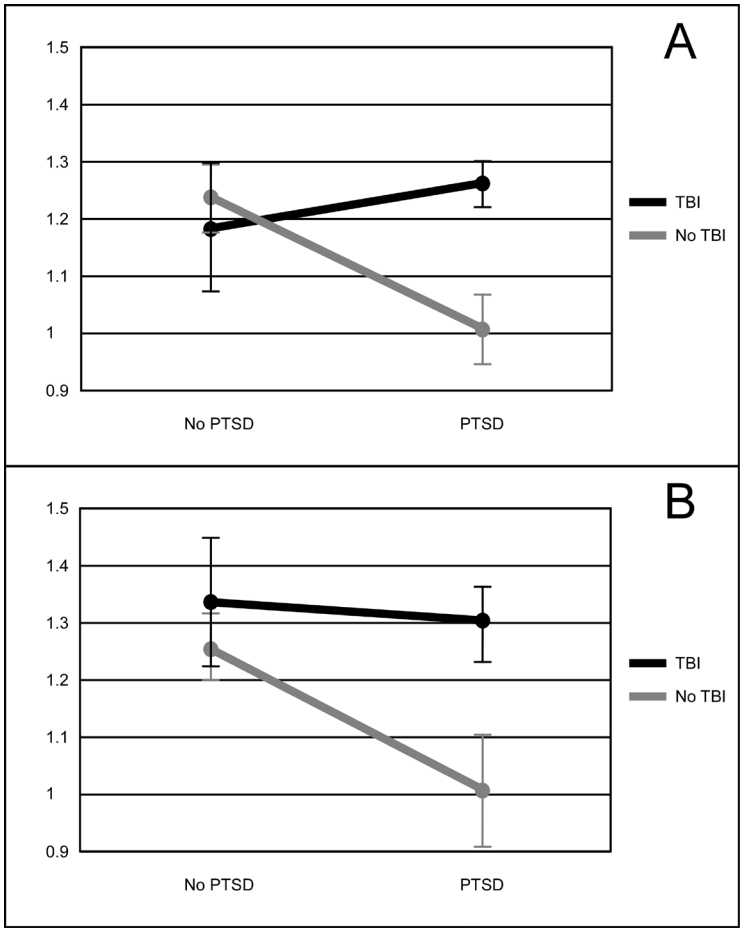


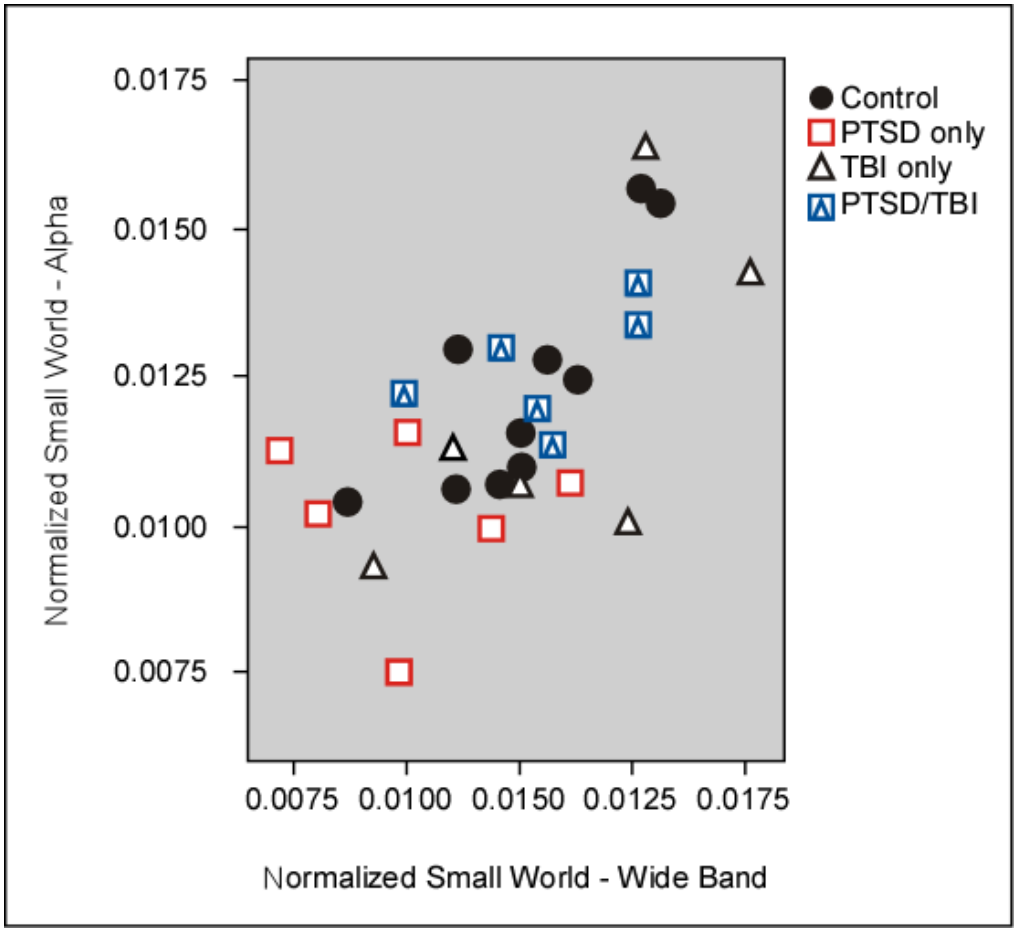
E. Participant Specific Connectome



Metrics
Clustering Coefficient = 0.15
Global Efficiency = 0.81

Neuroimaging: Networks





Rowland et al., 2017

Neuroimaging: Networks

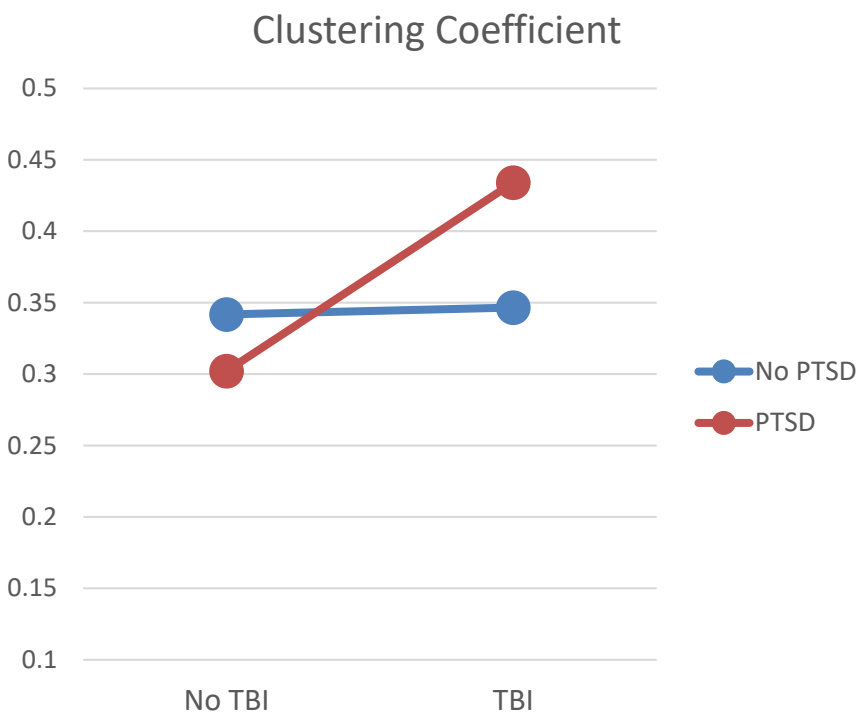
Non-Standardized Parameter Estimates

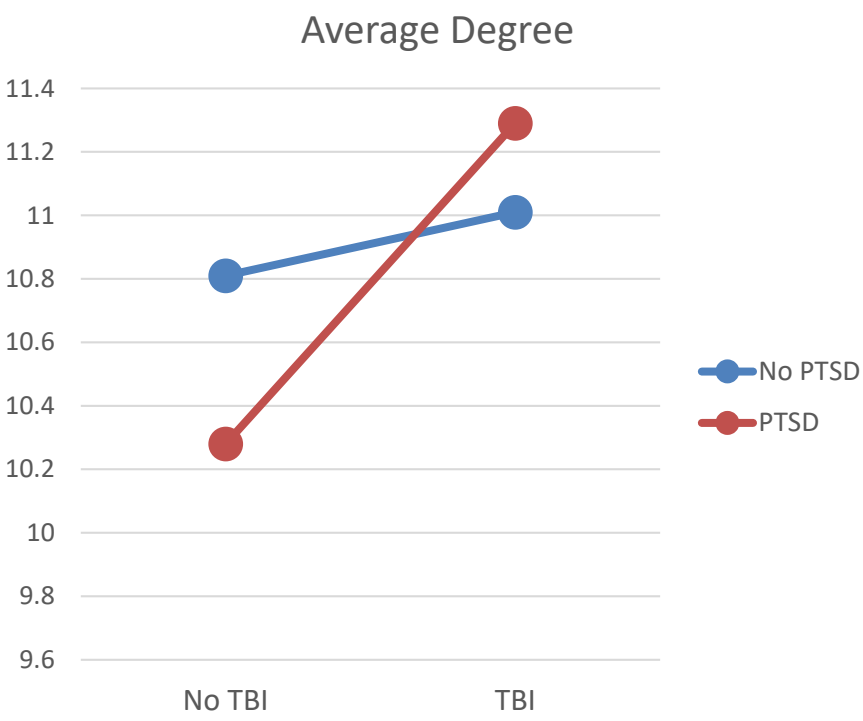
	Deployment TBI	PTSD	PTSD-TBI Interaction
Nodes	-2.01	**9.64***	**-14.32***
Average Degree	.203	**-.534***	**.813***
Theta Connections	.003	.230	.238
Global Efficiency	1.65	**-7.07***	9.69
Modularity	.038	-.033	**.083***
Cluster Coefficient	.005	-.040	**.127***
Rich Club Coefficient	.039	-.077	.341

Note. n = 181, *significant following FDR correction at p<.05.

Rowland et al., *in submission*

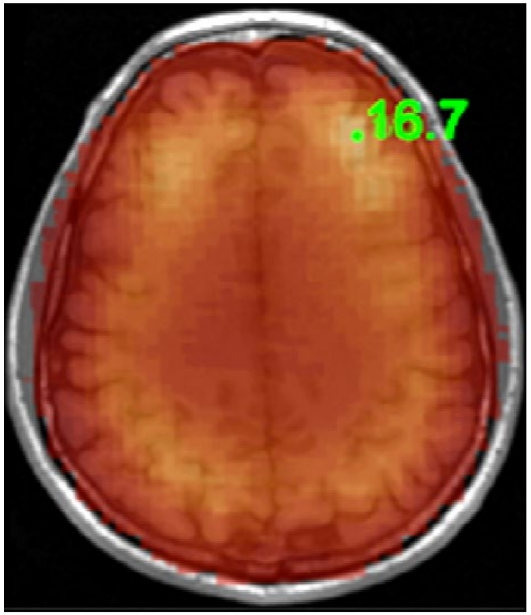
Neuroimaging: Networks

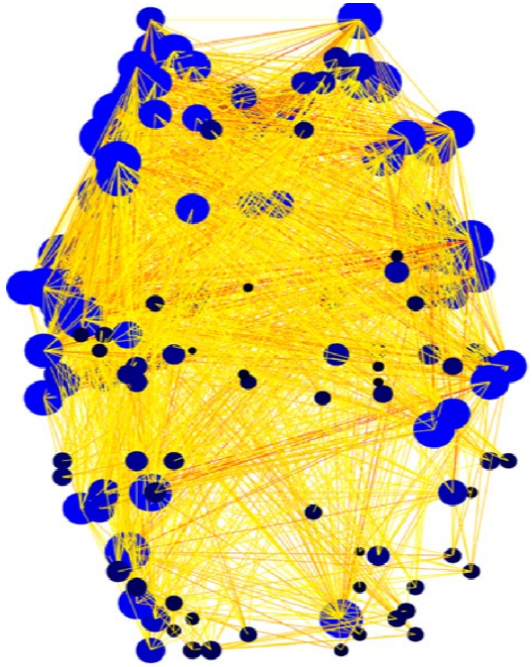




Rowland et al., *in submission*

Summary





Conclusions

Deployment TBI is uniquely associated with negative outcomes.

Conclusions

Deployment TBI is uniquely associated with

Table 3 Outcome and covariate descriptive measures for aims 1 and 2

		Nondeployment TBI		Deployment TBI	
Measure	Total Sample (N=1399) Mean ± SD	− (n=835) Mean ± SD	+ (n=564) Mean ± SD	− (n=1071) Mean ± SD	+ (n=328) Mean ± SD
BDI-II	14.79±12.67	14.08±12.98	15.84±12.12	12.74±12.08*	21.50±12.24*
DTS	41.30±39.67	39.20±40.32	44.42±38.52	33.82±36.98*	65.73±38.37*
PSQI	9.57±4.90	9.29±4.96	9.98±4.77	8.78±4.75*	12.16±4.46*
AUDIT	5.11±6.00	4.65±5.63	5.79±6.44	4.76±5.75	6.24±6.45
DAST	1.08±2.82	0.94±2.62	1.28±3.07	1.03±2.82*	1.24±2.80*,†
BPI‡	3.34±2.51	3.22±2.61	3.50±2.38	3.05±2.51*	4.28±2.30*
CES	11.97±10.36	11.08±10.22	13.30±10.44	9.51±9.11*	20.02±10.12*

Conclusions

Deployment TBI is uniquely associated with

Table 3 Outcome and covariate descriptive measures for aims 1 and 2

	Nondeployment TBI				Deployment TBI							
	Non-Deployment TBI				Deployment TBI				Current PTSD Diagnosis			
	- (*n* = 835)	+ (*n* = 564)			- (*n* = 1071)	+ (*n* = 328)			- (*n* = 786)	+ (*n* = 613)		
Lifetime Diagnosis	*n* (%)	*n* (%)	ϕ	OR	*n* (%)	*n* (%)	ϕ	OR	*n* (%)	*n* (%)	ϕ	OR
Major Depressive Disorder	344 (41.2)	265 (47.0)			**404 (37.7)**	**205 (62.5)**[c]	.21	2.75	**201 (25.6)**	**408 (66.6)**	.38	5.50
Dysthymic Disorder	24 (2.9)	27 (4.8)			36 (3.4)	15 (4.6)			**16 (2.0)**	**35 (5.7)**[b]	.08	2.39
Alcohol Use Disorder	**204 (24.4)**	**182 (32.3)**	.09	1.47	**271 (25.3)**	**115 (35.1)**[c]	.09	1.59	**147 (18.7)**	**239 (39.0)**	.24	2.93
Polysubstance Use Disorder	**3 (0.4)**	**11 (2.0)**[c]	.08	5.52	10 (0.9)	4 (1.2)			4 (0.5)	10 (1.6)		
Posttraumatic Stress Disorder	351 (42.0)	262 (46.5)			**375 (35.0)**	**238 (72.6)**	.32	4.91	-	-		
Anxiety Disorder NOS	16 (1.9)	13 (2.3)			23 (2.1)	6 (1.8)			**25 (3.2)**	**4 (0.7)**[b]	-.09	0.07

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Conclusions

Deployment TBI is uniquely associated with

Table 3 Outcome and covariate descriptive measures for aims 1 and 2

	Nondeployment TBI				Deployment TBI			
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						4 (1.2)		
						238 (72.6)	.32	4.91
						6 (1.8)		

	Non-Deployment TBI		Deployment TBI	
Measures	F	η_{sp}^2	F	η_{sp}^2
WAIS-IV PRI	1.47	.005	1.80	.006
WAIS-IV VCI	0.00	< .001	4.88	.017
WAIS-IV WMI	0.01	< .001	**5.62**	**.019**
WAIS-IV PSI	1.07	.004	4.09	.014
TMT-A	0.19	.001	**15.32**	**.049**
TMT-B	0.18	< .001	**9.36**	**.031**
COWAT	0.15	< .001	4.14	.014
Animal Naming	0.89	.003	1.60	.006

Current PTSD Diagnosis			
- (n = 786)	+ (n = 613)		
n (%)	n (%)	ϕ	OR
201 (25.6)	**408 (66.6)**	.38	5.50
16 (2.0)	**35 (5.7)**[b]	.08	2.39
147 (18.7)	**239 (39.0)**	.24	2.93
4 (0.5)	10 (1.6)		
-	-		
25 (3.2)	**4 (0.7)**[b]	-.09	0.07

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Conclusions

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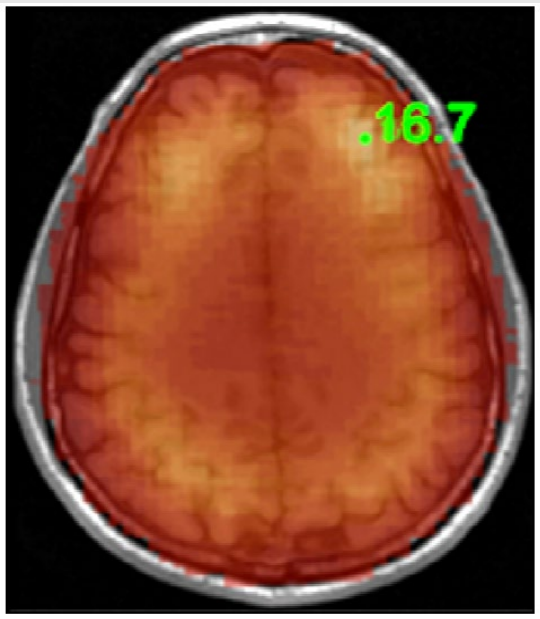

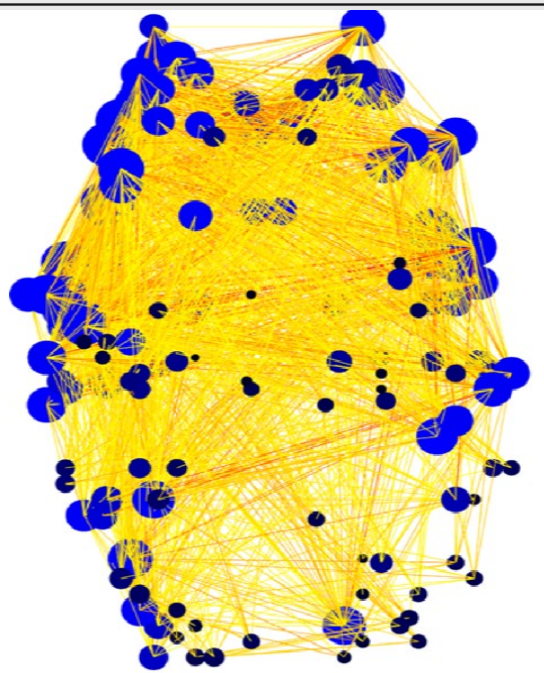

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Conclusions

Deployment TBI is uniquely associated with negative outcomes.

1.Mechanisms of injury

Conclusions

Deployment TBI is uniquely associated with negative outcomes.

1.Mechanisms of injury

Conclusions

Deployment TBI is uniquely associated with negative outcomes.

1. Mechanisms of injury
2. Deployment Environment

Conclusions

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2. Deployment Environment

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- Deployment TBI is uniquely associated with negative outcomes.
- The effect of Deployment TBI is not limited to the acute stage, but may have a stronger effect much later in the chronic stage.

Conclusions

- Deployment TBI is uniquely associated with negative outcomes.
- The effect of Deployment TBI is not limited to the acute stage, but may have a stronger effect much later in the chronic stage.
- Negative outcomes are not a foregone conclusion.

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ACKNOWLEDGEMENTS

Funding

- Department of Defense, Chronic Effects of Neurotrauma Consortium (CENC) Award W81XWH-13-2-0095
- Department of Veterans Affairs CENC Award 01 CX001135
- Mid-Atlantic (VISN 6) Mental Illness Research, Education, and Clinical Center (MIRECC)
- W. G. (Bill) Hefner VA Healthcare System
- Wake Forest School of Medicine Clinical Translational Science Institute (UL1TR001420)

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