Verbal memory and central auditory testing in blast-exposed Veterans

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Introduction

- Many military Veterans with mild traumatic brain injury (mTBI) secondary to blast exposure report hearing problems despite normal results on standard hearing tests. Several also have comorbid Post-Traumatic Stress Disorder (PTSD).
- Central auditory processing (CAP) assessments are sometimes used to evaluate this population's hearing complaints (Gallun et al., 2012).
- One drawback to this approach is that many tests of CAP are dependent on non-CAP skills such as memory, attention, and other executive functioning abilities–all of which are particularly susceptible to impairment in those with mTBI and PTSD.
- Having mTBI and/or PTSD increases risk of cognitive fatigue, hypersensitivity, and hypervigilance, which can limit access to and use of cognitive resources for memory demanding tasks (Combs et al., 2015; Gallun et al., 2017; Honzel et al., 2013).
- Successful aural rehabilitation requires accurate assessment of auditory and cognitive abilities.
- Consequently, it is important to understand the extent to which verbal memory influences performance on certain CAP tests.

Research Questions

- Do Veterans who performed in the top half of the Rey Auditory Verbal Learning Test (RAVLT) or Digit Span Test (DST) exhibit advantages on CAP tests beyond Veterans who performed in the bottom half of these tests?
- Do the CAP tests used in this study demonstrate differential performance by verbal memory load and clinical populations?

Participants

- 203 Veterans, aged 20-50 years, with normal or near-normal hearing on standard audiometric tests
- Veterans were dichotomized into high- and low-performing groups based on their performance on the RAVLT and the DST

Demographics

Variable		mTBI		PTSD		mTBI+PTSD		Control	
N		57		20		49		77	
Sex	M	51		11		43		53	
	F	6		9		6		24	
		High	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*
Median Split$_{RAVLT}$	n (%)	31 (63)	18 (37)	17 (89)	2 (11)	19 (48)	21 (52)	56 (82)	12 (18)
Median Split$_{DST}$	n (%)	30 (58)	22 (42)	12 (60)	8 (40)	12 (27)	32 (73)	42 (61)	27 (39)
Median HHIA		34		24		54		0	
Age (years)		36.22		34.54		35.09		35.50	
PTA (dB HL)	R	12.06		10.63		12.36		9.87	
	L	11.60		10.19		12.63		9.87	
SRT (dB HL)	R	8.37		7.45		9.43		7.08	
	L	9.14		8.05		9.80		7.57	

Table 1. Median Split$_{RAVLT}$ = dichotomized groups by RAVLT-interference median = 5; Median Split$_{DST}$ = dichotomized groups by DST-auditory backwards median = 7; HHIA = Hearing Handicap Inventory-Adults, a measure of self-perceived hearing impairment; PTA = pure tone average (.5, 1, 2, 4 kHz) hearing test; SRT = speech reception threshold; n for Median Split$_{RAVLT}$ and Median Split$_{DST}$ do not sum to N because of drop out and ongoing data collection.

Methods

- Tasks Completed:
  1. **Central Auditory Processing Tests**: selected in response to possible CAP deficits that might occur with blast-exposure and PTSD
     - Staggered Spondaic Words (SSW)
     - Dichotic Digits Test (DDT)
     - Masking Level Difference (MLD-tone & MLD-speech)
     - Gaps in Noise (GIN)
     - Listening in Spatialized Noise-Sentences (LiSN-S)
     - Words in Quiet (WIQ)
     - Competing Sentences (CS)
     - Words in Noise (WIN)
  2. **Digit Span Test (DST)**
     - Digits Backwards (auditory condition) was used for median splits
  3. **Rey Auditory Verbal Learning Test (RAVLT)**
     - Interference condition (RAVLT_INT) was used for median splits

Results

Did the Blast-Related Veteran Groups Differ on the Verbal Memory Tasks?

Veterans with mTBI+PTSD performed poorly on both verbal memory measures. The more semantically demanding RAVLT revealed that the blast-exposed Veterans had the worst verbal memory performance.

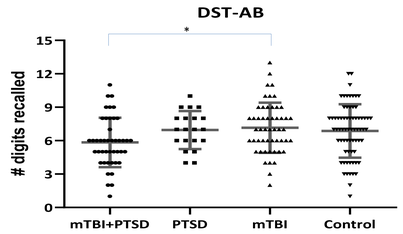

Figure 1. DST by group. AB = auditory backward; error bars = SD; n: mTBI+PTSD (69); mTBI (51); PTSD (20); Control (44)

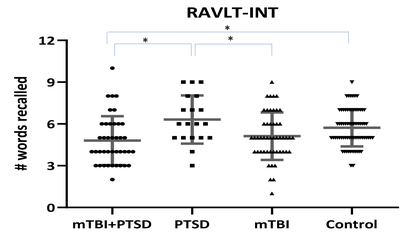

Figure 2. RAVLT words correctly recalled by group. INT = interference; error bars = SD; n: mTBI+PTSD (68); mTBI (48); PTSD (19); Control (40)

Memory Group (Median Split) Differences per CAP Test

Veterans who performed in the top half of the verbal memory tests demonstrated advantages on the DDT, SSW, and LiSN-S. These CAP tests may have relatively higher memory loads, whereas the MLD, GIN, WIN, WIQ, and CS may demand less memory resources.

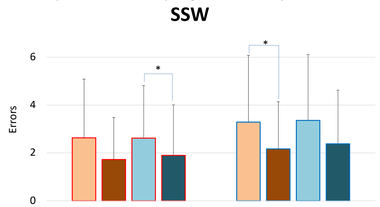

Figure 3. SSW by group and condition. RF_Total = RE First, Total Errors; LF_Total = LE First, Total Errors. n: Low$_{RAVLT}$ (50); High$_{RAVLT}$ (110); Low$_{DST}$ (76); High$_{DST}$ (88)

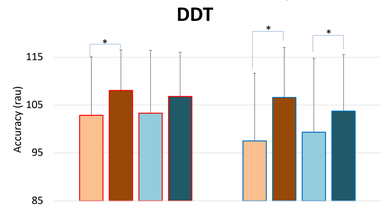

Figure 4. DDT by group and ear. Scores were rationalized arc sine transformed. n: Low$_{RAVLT}$ (51); High$_{RAVLT}$ (110); Low$_{DST}$ (77); High$_{DST}$ (88)

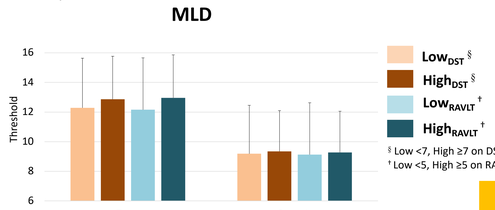

Figure 5. DDT by group and stimuli. n: Low$_{RAVLT}$ (48); High$_{RAVLT}$ (101); Low$_{DST}$ (71); High$_{DST}$ (82)

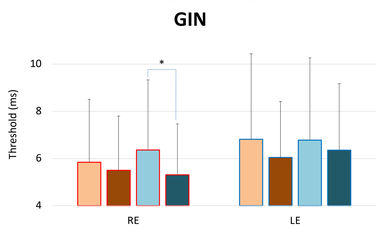

Figure 6. GIN by group and ear. n: Low$_{RAVLT}$ (50); High$_{RAVLT}$ (110); Low$_{DST}$ (76); High$_{DST}$ (88)

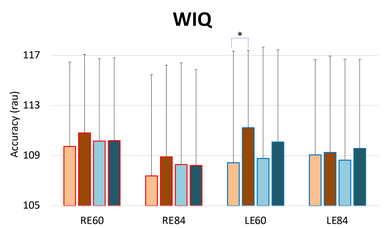

Figure 7. WIQ by group and listening condition. Level varied by ear at either 60 or 84 dB HL. Scores were rationalized arc sine transformed. n: Low$_{RAVLT}$ (52); High$_{RAVLT}$ (117); Low$_{DST}$ (85); High$_{DST}$ (93)

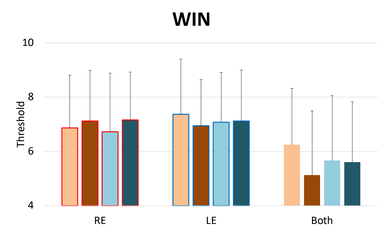

Figure 8. WIN by group and listening condition. n: Low$_{RAVLT}$ (52); High$_{RAVLT}$ (116); Low$_{DST}$ (85); High$_{DST}$ (92)

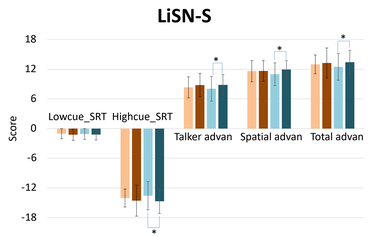

Figure 9. LiSN-S by group and condition. SRT = speech reception threshold; Advan = advantage. n: Low$_{RAVLT}$ (51); High$_{RAVLT}$ (114); Low$_{DST}$ (85); High$_{DST}$ (90)

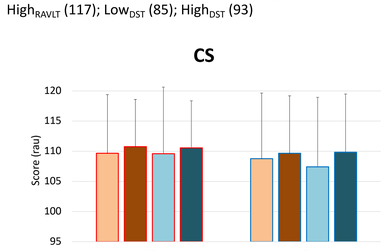

Figure 10. CS by group and ear. Scores were rationalized arc sine transformed. n: Low$_{RAVLT}$ (48); High$_{RAVLT}$ (117); Low$_{DST}$ (80); High$_{DST}$ (91)

- Several **RM-mixed design ANOVAs** were conducted to evaluate group differences on tests of CAP.
  - ✓ False discovery rate corrections
  - ✓ Significant effects of condition, ear, and stimuli were not plotted.
  - ✓ *p < .05
- **Bivariate correlations** were computed between the verbal memory tasks and CAP measures.
  - ✓ Correlations were small and most were not significant (p < .05), and therefore not displayed on the poster. See QR code for these analyses.
  - ✓ Spearman and Pearson correlation results were similar.

Do Verbal Memory Measures Predict Performance on CAP Tests?

Positive histories of blast exposure predicted verbal memory deficits, which predicted poor performance on 4/9 selected CAP tests.

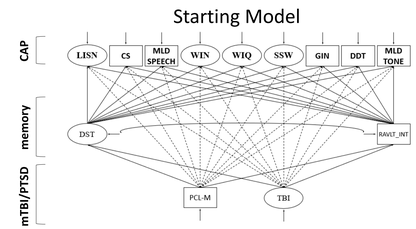

Figure 11A. Starting **structural equation model** predicting CAP with memory. Indicators for latent variables (ovals) were not shown.

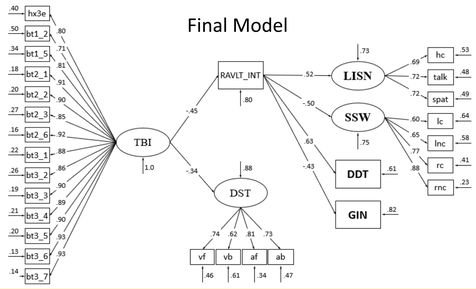

Figure 11B. Final model. $\chi^2(347) = 542.84$, p < .001; CFI = .949; TLI = .945; RMSEA = .053; SRMR = .117; n: 203, combining all four clinical groups.

General Conclusions

- **RQ1:** The high memory group outperformed the low memory group on 4/9 CAP tests when median split by RAVLT and on 3/9 tests when split by DST.
- **RQ2:** In line with RQ1 findings, a structural equation model revealed that verbal memory showed significant associations with 4/9 selected CAP tests.
  - ✓ Results suggest that the LiSN-S, SSW, DDT, and possibly GIN have relatively higher working memory loads than other selected CAP tests for blast-exposed Veterans.
  - ✓ Notably, a model that excluded mTBI (not shown) failed to identify significant relationships between measures of verbal memory and CAP.
- **Clinical Groups:**
  - ✓ Most (73%) Veterans with mTBI+PTSD grouped into the low memory group for both the DST and RAVLT.
  - ✓ Veterans with mTBI+PTSD performed poorly on the auditory backwards DST and the RAVLT-interference. The Veterans with PTSD-only performed better than the blast-exposed groups on the RAVLT.

Discussion

- Overall, verbal memory showed a significant association with 4/9 selected CAP tests.
- Since a structural equation model excluding mTBI was not notable, this suggests that at least 4/9 of the selected CAP tests were influenced by the memory abilities of the blast-exposed Veteran population.
- **It is important to account for potential verbal memory deficits and histories of mTBI during CAP testing in the Veteran population to ensure accurate assessment of their hearing and hearing-related cognitive complaints.**
- The moderate residual variance between CAP test results and memory suggest that the selected CAP tests assessed additional auditory and executive processes that may contribute to performance beyond verbal memory.
- Future studies should investigate the role of other unexamined processes such as attention, inhibition, and sensory perception on CAP.
- Investigating these processes may elucidate the contributions of PTSD.
- See QR code for additional analyses of the clinical group differences.

Acknowledgements

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