Theta Networks of Memory In Traumatic Brain Injury

Richard Adamovich-Zeitlin[1], Paul Wanda[1], Ethan Solomon[1], Tung Phan[1], Brad Lega[2], Kan Ding[3], Ramon Diaz-Arrastia[4], Michael Kahana[1]

Computational Memory Lab
University of Pennsylvania

1) Department of Psychology, University of Pennsylvania; 2) Department of Neurosurgery, University of Texas Southwestern;
3) Department of Neurology, University of Texas Southwestern; 4) Department of Neurology, University of Pennsylvania

Introduction

Traumatic brain injury (TBI) produces lasting impairments in context-based episodic memory and executive function. (Vakil, 2020)

Previous work has identified a set of electrophysiological biomarkers of human memory function. (Burke, 2015; Solomon, 2017)

- Are these memory biomarkers conserved across people with Traumatic Brain injury?
- Can we use these biomarkers to predict memory success?

Methods

Participants:

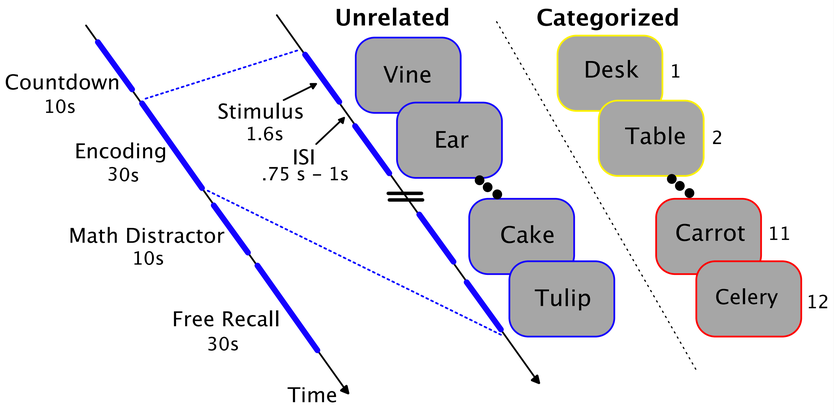
148 epilepsy patients with implanted intracranial electrodes (iEEG)

- 37 with history of moderate-severe TBI, 111 non-TBI matched controls
- Matching algorithm identified 3 subjects from a 346 subject database that had similar characteristics to each TBI subject.

Significant matching covariates

	Age	Male (%)	Right Frontal Coverage (%)	Left Temporal SOZ (%)	Right Temporal SOZ (%)
TBI	42.9 ± 11.0	73.0	75.0	2.8	5.6
Matched non-TBI	40.0 ± 11.5	70.3	73.3	2.9	5.7
All non-TBI	36.4 ± 11.3	48.0	65.4	15.1	11.0

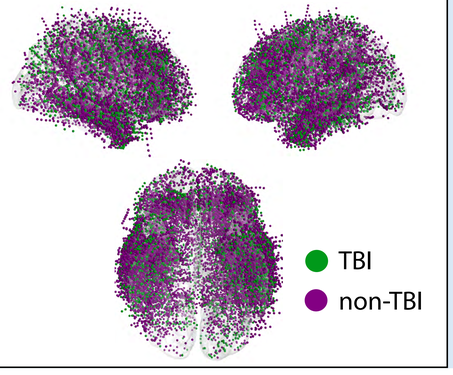
Task: Each subject completed a delayed free-recall task



Recording of neural signals:

EEG signals from subdural grids, strips and depth electrodes dispersed throughout the brain.

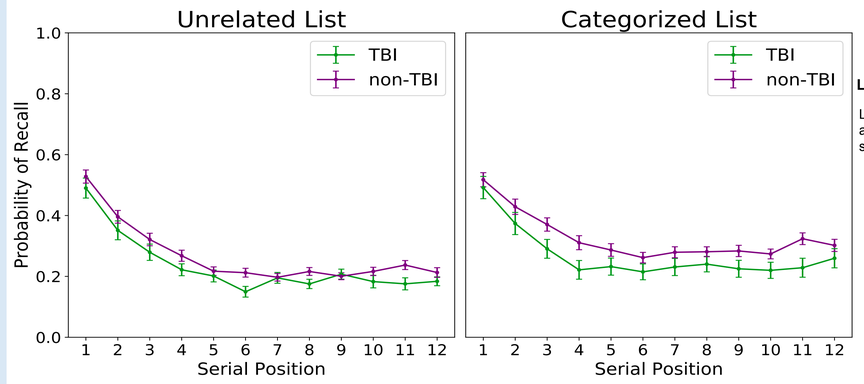
- ~129 electrode contacts per subject



Work supported by the DARPA Restoring Active Memory (RAM) program (Cooperative Agreement N66001-14-2-4032). The views, opinions, and/or findings contained in this material are those of the authors and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.

Analyses and Results

TBI subjects had lower recall rates than non-TBI subjects, and similar recall clustering

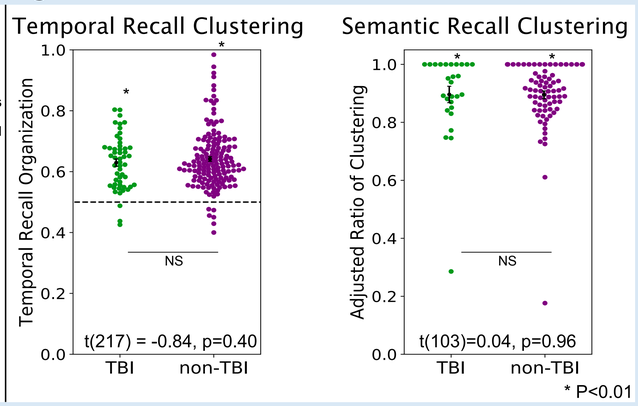


Linear Mixed Effects Models

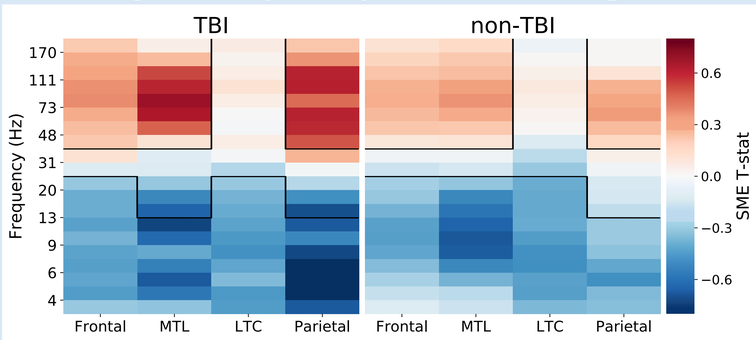
Likelihood ratio tests between full and partial models to assess significance

TBI vs. no TBI:
$X^2(1)=3.2$, p=0.074

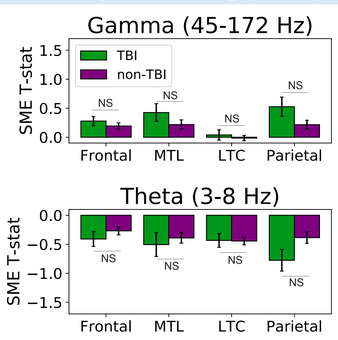
Task x Group Interaction:
$X^2(1)=5.87$, p=0.015



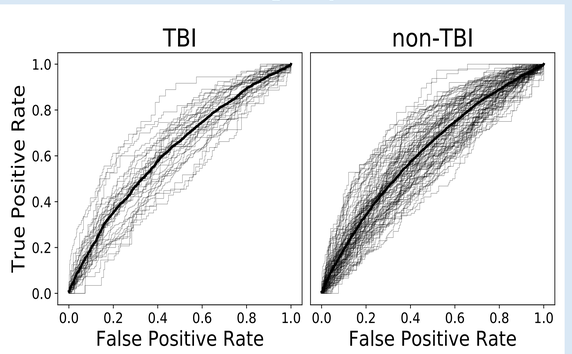
Statistically similar spectral power trends during successful memory encoding (SME) in the TBI and non-TBI groups



Single sample t-test for each frequency-band/region SME distribution compared to chance (0.0). Boxed regions = p<0.05



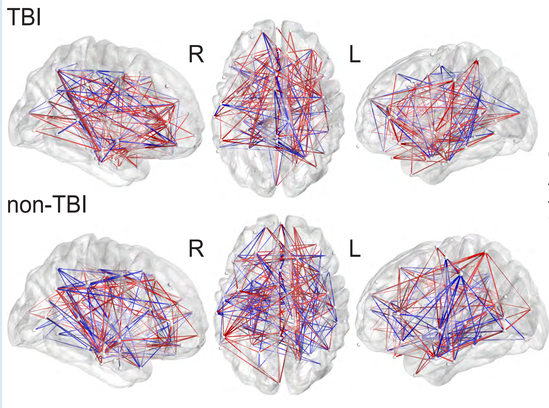
Welch's t-test between each frequency-band/region (p>0.3)

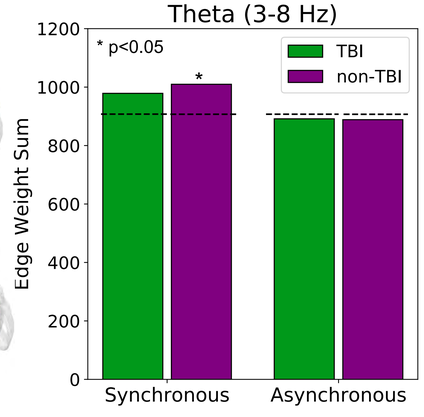


Logistic regression classifier to predict recall from power during encoding period. Same diagnostic ability in both groups (p=0.77)

Weaker theta connectivty during successful encoding in the TBI group

Both groups have an increase in whole-brain theta connectivity during successful encoding
Only the non-TBI group has significantly more synchronous connections than chance (p<.05)





Conclusions

- Biomarkers of local memory processing are generally conserved in those with a history of traumatic brain injury.
- Our ability to predict memory using spectral power information is similar in subjects with and without a history of TBI.
- Brain-wide theta synchrony was lower in the TBI group, but nonetheless aligned with prior results that theta synchrony increases during successful memory encoding.

References

Burke, J. F., Ramayya, A. G., & Kahana, M. J. (2015). Human intracranial high-frequency activity during memoryprocessing: neural oscillations or stochastic volatility?Current opinion in neurobiology,31, 104–110.

Solomon, E., Kragel, J., Sperling, M. R., Sharan, A., Worrell, G., Kucewicz, M., . . . others (2017). Widespread thetasynchrony and high-frequency desynchronization underlies enhanced cognition.Nature communications,8(1),1704.

Vakil, E. (in press). The mnemonic consequences of moderate-to-severe brain injury. In M. Kahana & A. Wagner(Eds.),Oxford handbook of human memory(chap. 9.6). Oxford, United Kingdom: Oxford University Press.