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► **To cite this version:**

Soheil Borhani, Xiaopeng Zhao, Michael O'Neil, Margaret R. Kelly, Katherine E. Snyder, et al.. Brainwave Profiles of Efficient Versus Inefficient Working Memory Retrievals in Healthy Older Adults. 42nd Annual Meeting of the Cognitive Science Society (CogSci 2020), Jul 2020, Toronto, Canada. hal-02966107

HAL Id: hal-02966107

<https://hal.science/hal-02966107>

Submitted on 13 Oct 2020

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Brainwave Profiles of Efficient Versus Inefficient Working Memory Retrievals in Healthy Older Adults

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Acknowledgements

- All Participants from U of Kentucky Alzheimer Disease Center
- NIH grants 1R56 AG 060608; P30 AG028383

INTRODUCTION

- General slowing of mental processing speed is the hallmark of brain and cognitive aging (Salthouse 2010).
- Attending to task-relevant information while ignoring task-irrelevant information facilitates accurately retrieving target matching objects held in working memory (WM) in monkey physiology (e.g. Miller et al. 1996).
- Human fMRI studies have shown frontal and parietal roles in WM retrieval (Jiang et al., 2000; Todd et al. 2011). Increased frontal-temporal, and parietal activity is associated with increased risk of Alzheimer's Disease (Jiang et al., 2016).
- PFC during a delayed-response WM task and found that fast older subjects showed greater DLPFC activation during memory retrieval than slow older subjects (Rypma and D'Esposito, 2000).
- Limited understanding in neural mechanisms underlying efficient versus inefficient memory performance within individual older adults.

OBJECTIVES

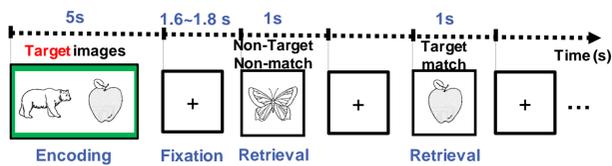
- To evaluate the predictive utility of resting-EEG on the working memory performance.
- To assess the validity of mobile EEG biomarkers in monitoring fast and "efficient" versus slow visual working memory retrieval.

HUMAN SUBJECTS & TASK

Participants: 17 normal aging participants from the University of Kentucky Alzheimer's Disease Center (UK-ADC).

Age (\pm SD): 80.4 \pm 6.5;

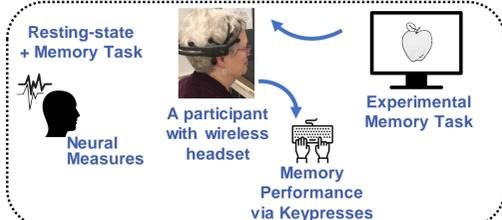
Sex: 65% Female



EEG outcome measures: EEG signals, Emotiv EPOC+ with 128 Hz sampling rate over AF3, F7, F3, FC5, T7, P7, O1, O2, T8, FC6, F4, F8, AF4

Resting-state EEG (rsEEG): 90 seconds eye-closed.

Bluegrass Short-term Memory Test: A modified delayed-match-to-sample (DMS) task to assess simultaneous visual matching ability and short-term visual recognition memory. With wireless eMotiv headset, participants responded by pressing a button indicating whether a test image is a match to one of the two memory targets (Borhani, 2019).

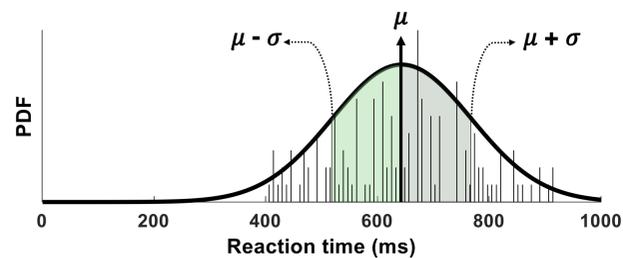


- 12 images were presented in each trial (6 *Target* images randomly interleaved with 6 *Non-Target* images). Image stimulus duration = 1s, ISI=1.6-1.8s.
- Participants were asked to respond by pressing different keys on the keyboard to *Target* and *Non-Target* stimuli.
- Key presses were counterbalanced between *Target* and *Non-Target* stimuli throughout the session.
- Each participant participated in 16 trials of short-term memory retrieval including 192 stimuli.
- Key-presses were counterbalanced throughout the trials.

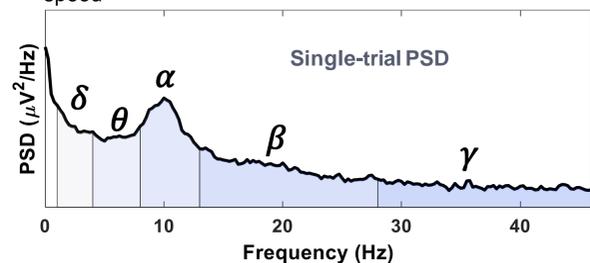
EEG METHODS

EEG preprocessing & feature extraction:

- High-pass filter @ 0.5 Hz to remove baseline drift
- Low-pass filter @ 46 Hz to remove powerline noise and unnecessary information
- Apply Artifact Subspace Reconstruction (ASR) algorithm to identify and reject "bad channels", remove/reconstruct occasional noise/artifacts in the signals (EEGLAB, *clean_rawdata* function).
- Interpolate removed channels using data of other channels ($<=2$ channels) using spherical method.
- Re-reference to the average EEG signals.
- PSD was estimated using Welch's method (Window size=4s, overlap=2s, hamming) for rsEEG
- Epoch memory-related EEG, onset to the *Target* and *Non-Target* stimuli, stratify individualized correct *faster* and *slower* than average epochs. Results are based on the analysis of all correct and *fast* and correct and *slow* stratified epochs.



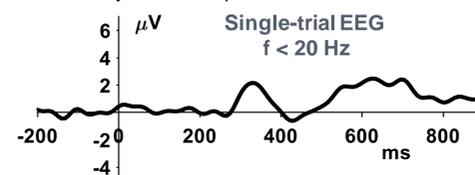
- Extract *task-related spectral features*, stratified by retrieval speed



$$\text{Total} = \text{Power}(\delta + \theta + \alpha + \beta + \gamma)$$

Spectral features: $\frac{\delta}{\text{Total}}$, $\frac{\theta}{\text{Total}}$, $\frac{\alpha}{\text{Total}}$, $\frac{\beta}{\text{Total}}$, $\frac{\gamma}{\text{Total}}$

- Extract *task-related temporal features* from single trial EEG, stratified by retrieval speed



Temporal features: MeanAmp, PeakAmp, PeakLat, Area from single trial memory-related potential

MeanAmp: Mean amplitude in [300, 900] ms single trial EEG,

PeakAmp: Peak amplitude in [300, 900] ms single trial EEG,

PeakLat: Latency of the peak in a range of in [300, 900] ms,

Area: Area under the curve in [300, 900] ms

RESULTS: rsEEG vs Mean reaction time

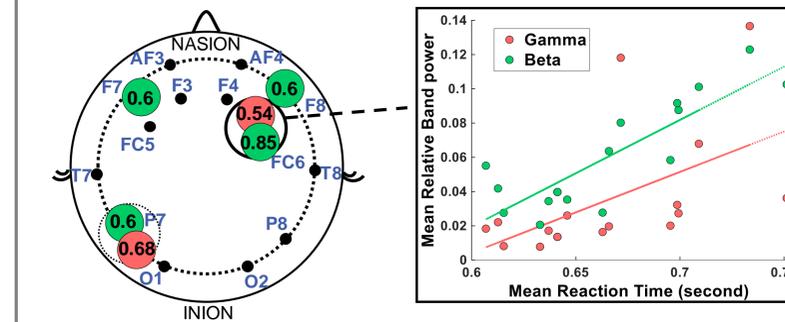


Figure 1. A significant positive correlation ($\rho(15) = 0.85$, $p < 1.6 \times 10^{-5}$) between resting-state Beta wave mostly over right frontal (F4), right fronto-central and left parietal ($\rho(15) = 0.6$, $p < 0.02$) sites and mean reaction time. A significant positive correlation ($\rho(15) = 0.68$, $p < 0.003$) of Gamma band activity over left parietal site (P7). We could not observe any significant correlation in Delta, Theta, and Alpha frequency bands in any EEG sites.

RESULTS: rsEEG vs Mean accuracy score

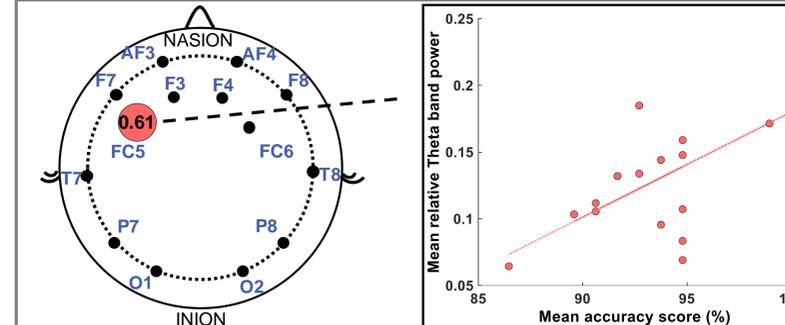


Figure 2. A significant positive correlation ($\rho(15) = 0.62$, $p < 0.01$) between resting-state Theta band mostly over left frontal (FC5), right parietal sites (O2, P8, T8) and accuracy score. No significant association were found in other frequency bands and other locations between rsEEG and accuracy score.

Group Results of Neuropsychological scores:

MMSE (\pm SD): 29 \pm 1.1
MoCA (\pm SD): 26.8 \pm 2.5

RESULTS: Task-related EEG

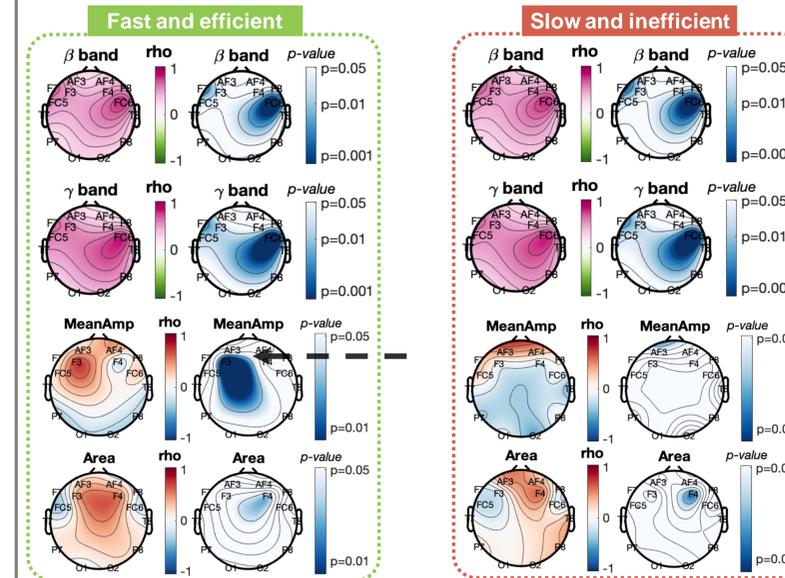


Figure 3. A significant positive correlation of the β and γ bands over right-frontal site (F4, FC6) in memory retrieval ($\rho(15) = 0.82$, $p < 1 \times 10^{-4}$). We did not observe significant correlation on any EEG site in Delta, Theta, and Alpha bands. Pace of memory retrieval does not clearly stratify the task-related spectral measures.

Fast memory retrieval has significant positive correlation ($\rho(15) = 0.73$, $p < 0.001$) with "MeanAmp" (mean amplitude) over **left-frontal site (F3)**, showing how left-frontal area compensate for faster reaction to object working memory retrieval. We also observed a significant positive correlation ($\rho(15) = 0.58$, $p < 0.02$) with the "Area" over right-frontal site (F4) with in both slow and fast memory retrieval. We did not observe significant correlation on any EEG site for "PeakLat" and "PeakAmp" features

CONCLUSION

- Beta and Gamma wave measured over *right frontal* and *left parietal* sites during *eyes-closed rsEEG* are strong predictive measures of WM *mean reaction time*. *Frontal theta* is highly correlated with WM *accuracy score*.
- While *right frontal* area is generally involved during *memory retrieval*, *faster* processing increased neural recruitment over *left frontal* and *left parietal* areas. *Mean amplitude* of late single trial brain response over *right frontal* is a good predictor of fast and efficient WM.
- Analysis of the *task-related spectral* data shows high positive correlation of *Beta* and *Gamma* bands over *right frontal* area. The left frontal Mean responses differentiated "Fast" vs. "Slow" trials.

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