Exploring Neuroplasticity in Acute Mild Traumatic Brain Injury

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BACKGROUND

- **mTBI:** affects mental state and possibly consciousness level
  - often underdiagnosed and untreated because of
  - lack of apparent external injuries and clear pathological findings
  - need for sensitive and objective test
- **EEG:**
  - noninvasive, readily available, and sensitive to brain function
  - may provide tests to detect mTBI
- **N-back paradigm:** behavioral task to measure working memory (WM).
- **fMRI findings:** WM impaired in mTBI patients.
- **Alpha power:**
  - increased work load associated with greater alpha desynchronization
  - Alpha power includes total power (Tp), non-phase-locked (induced) power (NPp), and phase-locked (evoked) power (Pp)
  - induced alpha increases during internally directed attention

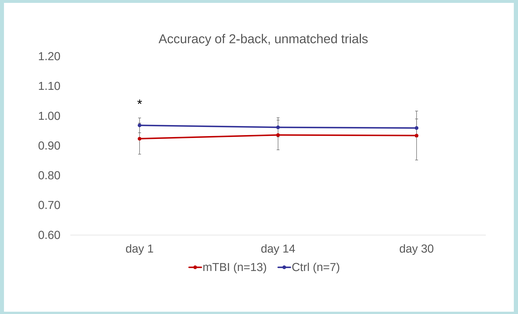
OBJECTIVE

Identify changes in evoked and induced alpha EEG activity in a visual n-back WM paradigm and compare the mTBI patients with controls

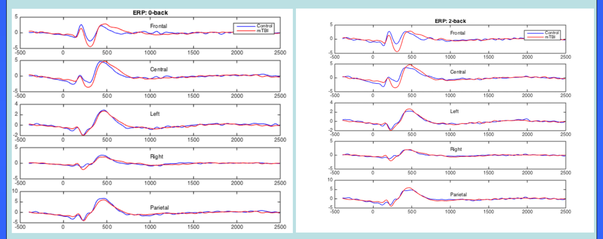
METHODS

- **Study participants:** 13 acute mTBI patients and 7 controls (non-head-trauma patients) recruited from the emergency department of Huntington Memorial Hospital in Pasadena, CA
  - Control and mTBI subjects matched on age, sex, education, and body mass index (BMI).
  - Three repeat sessions: within 1 week of injury, 14 days, and 30 days after injury
- **N-back task:** Stimuli consisted of 20 orthographically distinct uppercase consonants randomized and presented one at a time
  - Subjects asked to push a “target” button if the stimulus on the screen matched the stimulus N trials back, and a “non-target” button otherwise
- **EEG data** recorded using dry electrode headset (Quasar Wearable Sensing, DSI-24).
- **Time-Frequency Power Analysis:** EEG preprocessing included bandpass filtering (0.1–30 Hz), segmentation, and independent component analysis to remove “noisy” trials using Matlab, EEGlab, and in-house developed software
  - Individual trials were decomposed into their time-frequency representation via wavelet convolution performed in the frequency domain.
  - Power values were normalized to the average prestimulus baseline power at each frequency band.
  - The alpha power (8–15Hz) in the interval 200–800ms poststimulus was computed for all subjects, including Tp, NPp, and Pp
- **Statistics:** used the student t-test to compare the two groups, unless otherwise stated.

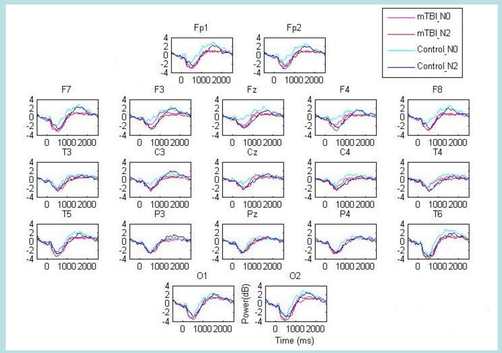
RESULTS



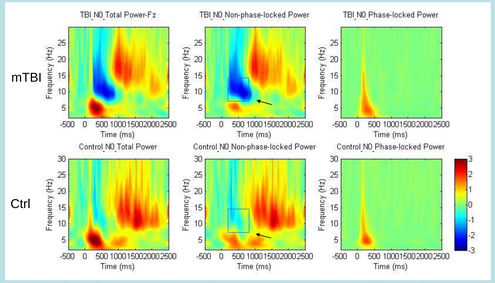
•***Figure 1:*** The behavioral n-back performance. The mTBIs’ performance slowly recovered. *, p<0.05.



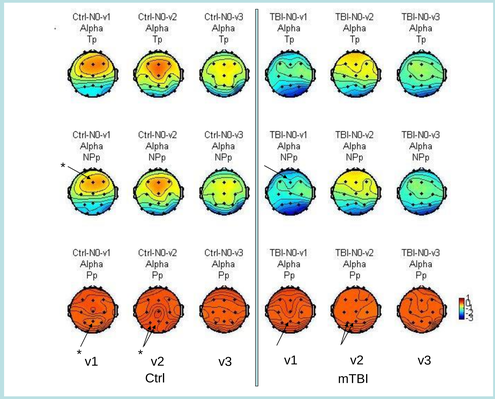
•***Figure 2:*** Average ERPs in the 0-back (left) and 2-back (right) test for controls (blue) and mTBI (red) subjects. MANOVA of P300 amplitude and latency across the 5 ROIs showed that mTBI and control groups were significantly different (F (10, 65) = 2.25, p = 0.0251 < 0.05); n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).



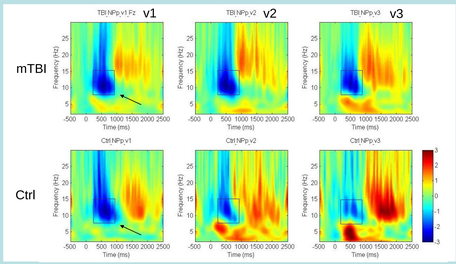
•***Figure 3:*** The plots of alpha power (non-phase-locked or induced power) from 0-back and 2-back (first visit) testing with time, on the mapped sensors. N0: 0-back; N2: 2-back; control: non-head trauma control group; mTBI: mild traumatic brain injury group. The alpha power (range 200-800ms, 8-15Hz) was extracted for later comparison between control and mTBI groups ; n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).



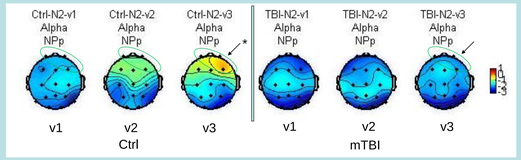
•***Figure 4:*** The time-frequency plots of averaged control and TBI study participants’ 0-back test, first visit. There were excessive alpha inhibition in the TBI group (rectangle and arrow) ; n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).



•***Figure 5:*** The topographic plots of alpha power (in dB) from 0-back test. Left of the vertical bar are control group, right of the vertical bar are the TBI group. When comparing control vs. TBI group: at the first visit, significant changes were at the NPp at Fz channel, Pp at Pz channel, p<0.05; and at the second visit, the Pp at P3 and Pz, p<0.05 (arrows). *, p<0.05. Tp: total power; NPp: non-phase-locked (induced) power; Pp: phase-locked power (Pp); N0: 0-back; Ctrl: non-head trauma control; TBI: traumatic brain injury; v1: first visit; v2: second visit; v3: third visit; n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).



•***Figure 6:*** The time-frequency plots of averaged control and TBI study participants’ 2-back test, non-phase-locked power (NPp) from Fz channel, three visits. The alpha inhibition became less in controls with visits, while it did not change in the TBI group (rectangle and arrow). Ctrl: non-head trauma control; TBI: traumatic brain injury; v1: first visit; v2: second visit; v3: third visit; n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).



•***Figure 7:*** The topographic plots of alpha non-phase-locked power (in dB) from the 2-back test. Left of the vertical bar is the control group, right of the vertical bar is the TBI group. The control group frontal alpha frequency wave become less inhibited at the third visit compared to their first and second visits (indicated by the ovals for the control group). However, the TBI group frontal alpha inhibition stays at the same level. When comparing control vs. TBI group at the third visit, the NPp at F4, Fp1, Fp2, and F8 channel differed in TBI from controls, p<0.05 (arrow and oval). *, p<0.05. NPp: non-phase-locked (induced) power; N2: 2-back; Ctrl: non-head trauma control; TBI: traumatic brain injury; v1: first visit; v2: second visit; v3: third visit; n=13~11 for mTBIs, n=7~5 for controls (some participants miss 1 or 2 visits).

SUMMARY & DISCUSSION

- mTBI patients performed significantly worse in the n-back test (within 5 days after injury) compared to controls; the mTBI time-frequency analysis showed significant differences from controls at the second and third visits when behavioral performance had recovered
- In the 0-back test, when behaviorally mTBI patients performed like controls, there was excessive alpha inhibition (non-phase-locked power) in the frontal lobe, indicating abnormal top-down control, as mTBI patients needed extra focus during a simple task
- In the 2-back test, at the third visit, the control group had less alpha inhibition (frontal non-phase-locked power) compared to the first visit, indicating a learning mechanism. However, the mTBI group still had, up to 30 days after injury, excessive alpha inhibition during the third visit, indicating a learning impairment
- The changes in frontal non-phase-locked (induced) alpha power suggest executive function impairment in mTBI patients
- Alpha inhibition in the n-back test can be a sensitive parameter that differentiates mTBI from non-head trauma controls

References

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Acknowledgements

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