THE USE OF FOUR CHANNEL MULTIVARIATE COHERENCE TRAINING ON MILD TRAUMATIC BRAIN INJURY:
A COMPARISON OF NEWLY CONCUSSED AND REMOTELY CONCUSSED INDIVIDUALS

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What is MTBI?
Epidemiology

EEG & Quantitative EEG Assessment

NFB Treatment

Coherence findings

Methods

Results

Discussion
MILD TRAUMATIC BRAIN INJURY (MTBI)

• Brain injury caused by acute trauma to the head
• Commonly known as a concussion
• Affects reaction time, memory, balance, and planning skills
• Associated with significant symptoms such as fatigue, headaches, memory loss, poor attention, sleep disturbances, seizures, and feelings of depression
ANATOMY OF A CONCUSSION

1. Initial Impact

2. Force of impact causes brain to strike the inner surface of the skull & rebound against opposite side.

3. As the brain rebounds it may twist.

4. The brain swells. In a severe injury it puts pressure on the brain stem, which controls breathing & other basic functions.

5. Get back in the game!
SIGN & SYMPTOMS

- Physical & Postural
  - Headache
  - Nausea/vomiting
  - Sensitivity to light/noise
  - Fatigue
  - Visual problems
  - Dazed
  - Dizzy

- Cognitive
  - Mental Fog
  - Feeling Slowed Down
  - Difficulty Concentrating
  - Forgetful
  - Repeating Questions
  - Drop in academic performance

- Emotion
  - Irritability
  - Sadness/Depression
  - Personality Change
  - Anxiety/Panic
  - More emotional
  - Apathy

- Sleep
  - Drowsiness
  - Sleeping more/less
  - Difficulty falling or staying asleep
PRIMARY EFFECTS OF CONCUSSION

Primary

- Rotational/Sheering
- Diffuse Axonal Injury
- Coup
- Contrecoup
- Contusions

Acceleration/De-acceleration
SECONDARY CHANGES TO HEAD TRAUMA

Secondary

- Hemorrhages
- Raised ICP / Hydrocephalus
- Wallerian Degeneration
- Edema
- Brain Shift / Herniation
- Biochemical / Neurochemical changes
CONCUSSIVE SYMPTOMS ASSOCIATED WITH NEUROANATOMICAL LOCATIONS
EPIDEMIOLOGY

• In the U.S., estimated 1.7 million traumatic brain injuries (TBI) a year accounting for 1.365 million emergency room visits and 275,000 hospitalizations

• After road trauma, second most common cause of TBI for 15-24 year olds is sport related events

• Mild/moderate TBIs often not reported so prevalence is underrepresented

• Almost 100,000 more concussions/year for 10-19 year olds in 2009 versus 2001

• Average of 19 concussions per NFL team per 100 games
CONCUSSION IN ATHLETES

• Estimated 3.8 million concussions occur each year, in the United States during a sporting event or practice.
• AND...it is estimated that 50% of concussions go unreported.
• Only 5-10% of sports related concussions are evaluated at the Emergency Room.
• Each year, U.S. emergency departments (EDs) treat an estimated 173,285 sports and recreation TBI's, including concussions, among children and adolescents, from birth to 19 years.
• During the last decade, ED visits for sports- and recreation-related TBIs, including concussions, among children and adolescents increased by 60%.
• Overall, the activities associated with the greatest number of TBI-related ED visits included bicycling, football, playground activities, basketball, and soccer.
• 2008-2010 rates of concussion 36% higher than 2005-2006 rates among high school football players
RATES OF COGNITIVE AND SYMPTOM RECOVERY

• There are measurable impairments in cognitive functioning after MTBI without LOC, PTA or focal neurological deficits.

• There are signs of measurable improvement within minutes to hours.

• The symptom profile, cognitive screening follows a gradual course to complete recovery within a week.

• NP recovery is also accelerated within a week and baseline will most often follow within 3 months.

• After 10 days of PCS, the course is described as a complex recovery. This usually accompanies headache, seizures and ongoing cognitive limitations.
DESCRIPTION OF NCAA CONCUSSION STUDY, CONCUSSION PREVENTION INITIATIVE AND PROJECT SIDELINE

• A combined effort study with the NCAA, Concussion Prevention Initiative, and Project Sideline. High School and college athletes (n=16,624).

• Male, late teens, and football were most prevalent independent variables

• Assessed through the Grades Symptoms Checklist (GSC), Balance Error Scoring System (BESS) and Standardized Assessment of Concussion (SAC) and neuropsychological test battery.
METHODOLOGY AND RESULTS

• Athletes were administered the FSC, SAC and BESS immediately, 2-3 hours and within a week of the injury.
• Subjects were administered NP tests 2 and 7 days post injury
• Headache was the symptom that lasted the longest.
• 85% of subject report full recovery within a week. Ninety seven percent rate a full recovery within a month.
• Conclusions suggested that concussion screening instruments were sensitive and specific in accurately detecting impairments during the acute phase, but lack sensitivity for detecting impairments post-injury phase
NEUROPSYCHOLOGICAL ASSESSMENT

- Reasoning
- Attention
- Concentration
- Memory
- Executive Functions
- Language

- Visuo-spatial
- Sensory-Perceptual
- Psycho-motor
- Academic Skills
- Mood/personality
SYMPTOM AND COGNITIVE RECOVERY IN MTBI

**Symptom Impairment (GSC)**
- Concussion
- Control

**Postural Stability Impairment (BESS)**
- Concussion
- Control

**Cognitive Impairment (SAC)**
- Concussion
- Control

**Cognitive Impairment (NP Battery)**
- Concussion
- Control

*Figure 3.* Percentage of concussion and control subjects classified as impaired based on symptoms, cognitive dysfunction, and postural stability problems from neuropsychological test battery. Assessment Points: D1, postinjury day 1; D2, postinjury day 2, etc. From McCrea et al. with permission.
RECOVERY OF NP SYMPTOMS

![Graph showing sensitivity levels for NP Testing and Brief Battery](image)

**Added Value of Neuropsychological Testing**

- **Sensitivity**: refers to probability of individual player abnormal on any measure (specificity > 84%)
- **Brief battery**: GSC, BESS, SAC
- **Neuropsychological Testing**: minimal increase (5%) in sensitivity over brief battery on day 2, but more than doubles sensitivity on day 7 (14% to 30%)
- **Neurocognitive Impairment**: delayed memory, processing speed, verbal fluency

*Figure 9.5: Incremental value of neuropsychological testing after sport-related MTBI. BESS, Balance Error Scoring System; NP Battery, neuropsychological test battery. Assessment Points: CC, time of concussion; PG, postgame/postpractice; D1, postinjury day 1; D2, postinjury day 2, etc. Adapted from McCrea et al. 24 with permission.*
ASSOCIATIONS WITH A COMPLICATED RECOVERY

• Psychological Variables
• Personality Variables
• Legal Variables
OPTIONS FOR ASSESSMENT: BEST PRACTICES APPROACH

• Sideline to Day 7, post-injury
• Neurological Assessment
• Symptom Checklists
• Balance Testing
• Brief mental status/cognitive testing
  • Paper/Pencil
  • Computerized, repeatable

• 1 week post-injury
• F/U Neurological
• F/U Cognitive Screening
• Neuropsychological Testing
  • More sensitive and specific for cognitive, functional and psychological deficits
PREDICTORS OF COMPLICATED RECOVERY

Age → Sex → ADHD/LD → Mood Disorder → Migraines → Previous Concussions

- Age
- Sex
- ADHD/LD
- Mood Disorder
- Migraines
- Previous Concussions
EEG AND QUANTITATIVE EEG ASSESSMENT
EEG CHANGES IN CONCUSSION
(HANEEF, Z, LEVIN, H., FROST, J., MIZRAHI, E., 2001)

• EEG may be more sensitive than a neurological exam in detecting head trauma.
• Post-concussion, 86% of patients will have an abnormal EEG
• Only 23% of those will have an abnormal neurological examination
• On occasion, resolution of EEG abnormalities may occur within 15 minutes
• PTA and unconsciousness predict longer EEG abnormalities
QEEG FINDINGS IN MTBI

Previous research supports:

✓ Reduced mean frequency in alpha
✓ Increased theta activity
✓ Reduced power in alpha and beta
✓ Increased frontal coherence

✓ Slowing in frontal and temporal regions
✓ Increased vulnerability in fronto-temporal regions
✓ Abnormality may last in excess of one year with persistent symptoms
✓ Decreased frontal to temporal coherence
EEG CHANGES FOLLOWING MTBI (HOURS TO WEEKS)

• Animal studies suggest that immediately following the event, epileptiform activity (high amplitude sharp waves/high frequency discharges),

• This is followed by diffuse suppression of cortical activity, usually lasting 1-2 minutes

• Followed by diffuse slowing of the EEG which returns to base line within 10 minutes to 1 hours.

• Half of a sample of 31 patients with mTBI did not demonstrate EEG changes within 24 hours.

• Within hours, there is attenuation of posterior alpha along with generalized/focal slowing, particularly noted over the temporal regions
EEG CHANGES FOLLOWING MTBI, WEEKS TO MONTHS

• Majority of EEG abnormalities resolve by 3 months and 90% by one year
• Within the first weeks, there is often a 1-2 Hz increase in posterior alpha activity
• Some suggestion that on going PCS, for more than a year, increase likelihood of epileptiform activity.
NEUROFEEDBACK AND THE TREATMENT OF MTBI
EEG NEUROFEEDBACK THERAPY: CAN IT ATTENUATE BRAIN CHANGES IN TBI?
(MUNIVENKATAPPA, ET AL., 2014)

- Case study of 2 patients; moderate head injury
- LOC: 1 hour; 1 week
- CT displayed diffuse axonal injury, blood in ears
- Moderately disabled according to Glasgow outcome score
- PCS
- <5th percentile on motor speed, mental speed, category fluency, visuospatial working memory, set shift, visual and verbal memory
- NFB and MRI completed one week before and one week after treatment
- 20 sessions of EEG NFB; 40 min/day; 3 days/week; protocol dependent on slow activity
EEG NEUROFEEDBACK THERAPY: CAN IT ATTENUATE BRAIN CHANGES IN TBI? CONT..

- Outcomes: Improvement in symptom reporting, NPE and MRI
  - Improvement in motor speed, mental speed, category fluency, working memory, mental shifting, encoding and memory.
  - Concussion symptoms
  - Significant decrease in theta, but not alpha excesses
  - Increased in cortical volume
  - Structural WM changes thalamocerebral connections, in WM tracts and cortical structures,
  - Improvement in functional connectivity-global and local efficiency
LITERATURE REVIEW

• Authors used Google Scholar, as it provided more citations than other search engines, such as Pub Med.

• 999 articles were identified, but after review only 22 were deemed worthy to be a part of the study.

• Of those, 8 were cohort designs.

TABLE 1

<table>
<thead>
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<th>Classification rubric for levels of evidence</th>
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<tr>
<td>1. Anecdotal evidence</td>
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<td>2. Uncontrolled case study</td>
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<td>3. Historical control</td>
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<td>4. Observational studies without randomization</td>
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<tr>
<td>5. Randomized wait-list or “intention to treat” controls</td>
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<td>6. Within-subject and intrasubject replication designs</td>
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<td>7. Single-blind, random assignment control design, either sham or active (behavioral, psychological, or pharmacologic) treatment controls</td>
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<td>9. Treatment equivalence or treatment superiority designs with placebo control</td>
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<td>10. Other designs, eg, double dummy, Solomon four-group</td>
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<td>Level of evidence</td>
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mTBI: mild traumatic brain injury; MVA: motor vehicle accident; NF: neurofeedback; RBANS: Repeatable Battery for the Assessment of Neuropsychological Status; QEEG: quantitative electroencephalogram; TBI: traumatic brain injury; WCST: Wisconsin Card Sorting Task.
Methods. Twenty-six patients with persistent post-traumatic symptoms (PTS) were seen by the first author 3 to 70 months after a MHI and had a quantitative EEG (qEEG). Neurofeedback therapy designed to normalize abnormal qEEG coherence scores was provided to determine the effectiveness of this approach. Five training sessions addressed each qEEG abnormality. Training continued until the patient, by self-report, indicated that significant improvement had occurred or until a total of 40 sessions were given. Results. Significant improvement (>50%) was noted in 88% of the patients (mean = 72.7%). All patients reported that they were able to return to work following the treatment, if they had been employed prior to the injury. On average, 19 sessions were required, less than the average of 38 sessions required using power training of Cz-Beta in our previous unpublished study. Jonathan E. Walker and Ronald K. Weber are affiliated with the Neuroscience Cen
A method of combining averaged psync values.

- 4 channels of EEG
- Each pair has a running psync calculation
- For each channel, the 3 pairs of psync values are computed, averaged and this is used as the output reward value
- If a raw channel is in artifact condition, the channel is not used in the averaging calculation

\[
\begin{align*}
A &= \frac{(AB + AC + AD)}{3} \\
B &= \frac{(BA + BC + BD)}{3} \\
C &= \frac{(CA + CB + CD)}{3} \\
D &= \frac{(DA + DB + DC)}{3} \\
\text{QPS Ave} &= \frac{(A + B + C + D)}{4}
\end{align*}
\]
### VARIABLES

<table>
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<th>Dependent</th>
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<td>o Months elapsed between initial evaluation and treatment.</td>
<td>o Global Coherence Change Scores</td>
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<tr>
<td>o Grouped into three groups</td>
<td>o Band Specific Coherence Change scores</td>
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<tr>
<td>o 0-1 Years</td>
<td>o Neuropsych Composite Index change scores</td>
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<td>o 1 to 5 Years</td>
<td>o Self Report Composite change scores</td>
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<td>o 10+ Years</td>
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<th>Z-Score</th>
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- Delta
- Theta
- Alpha
- Beta
- Total
There will be no statistically significant difference in coherence change scores and neuropsych change scores between time groups.

In other words: 4 CH multivariate coherence training improves functioning, no matter how long one waits to seek treatment.
Sample Demographics

- N=20
- Female=13
- Male=7
- Ages 18-65
- 100% Caucasian
- Treated for MTBI
- Received 4CH NFB
- Received Neuropsych testing
# GROUP MAKEUP

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<tr>
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<th>0-1 Years</th>
<th>1-5 Years</th>
<th>10+ Years</th>
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COHERENCE CHANGE SCORES

Global Z-score

PRE-POST=CHANGE SCORE

Band Scores

Total Scores
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<th>Composite NeuroPsych Index (Pre/Post)</th>
<th>Self Report Index (Pre/Post)</th>
<th>The Math</th>
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<td>o Includes:</td>
<td>o Depression</td>
<td>o The pre and post score represent the average of available scores</td>
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<tr>
<td>o Attention</td>
<td>o Anxiety</td>
<td>o The change score represents the post score subtracted from the pre score</td>
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<td>o Verbal Reasoning</td>
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...and here's a chart that shows what you might see if you looked at a mountain range through a tennis racket.
ANOVA Table

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ANOVA

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</tr>
<tr>
<td>Within Groups</td>
<td>12850.625</td>
<td>17</td>
<td>755.919</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13104.200</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ANOVA

<table>
<thead>
<tr>
<th>NeuroPsych_Change</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>53.132</td>
<td>2</td>
<td>26.566</td>
<td>.100</td>
<td>.906</td>
</tr>
<tr>
<td>Within Groups</td>
<td>3724.649</td>
<td>14</td>
<td>266.046</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3777.782</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The diagram shows a box plot for SelPReport_Change across different time groups: 0-1 Year, 1-5 Years, and 10+ Years. The box plot indicates the distribution of the data for each time group.

The ANOVA table provides statistical analysis for SelPReport_Change:

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>461.214</td>
<td>2</td>
<td>230.607</td>
<td>.761</td>
<td>.490</td>
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<tr>
<td>Within Groups</td>
<td>3334.431</td>
<td>11</td>
<td>303.130</td>
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</tr>
<tr>
<td>Total</td>
<td>3795.645</td>
<td>13</td>
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</tbody>
</table>
### Paired Samples Test

<table>
<thead>
<tr>
<th>Pair</th>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>NeuroPsych_Composite_P</td>
<td>-38.29570</td>
<td>15.36592</td>
<td>3.72678</td>
<td>-46.19612</td>
<td>-30.39528</td>
<td>-10.276</td>
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<tr>
<td></td>
<td>NeuroPsych_Composite_P</td>
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<td>63</td>
<td>54</td>
<td>84</td>
<td>105</td>
<td>115</td>
<td>125</td>
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<tr>
<td></td>
<td>SelfReport_Composite_P</td>
<td>70</td>
<td>73</td>
<td>65</td>
<td>90</td>
<td>110</td>
<td>130</td>
<td>150</td>
</tr>
</tbody>
</table>

**NeuroPsych Index Composite Pre/Post Score**

**Self Report Pre/Post Score**
Coherence Scores and Neuropsych Composite Scores Not * Predicted by:
- Time Group
- Age
- Gender
- Handedness
- Number of Head Injuries
- Psychoactive Medication
- Number of QEEG
- Months elapsed between Initial eval/Injury

*in most cases
EXCEPT:

- QEEG predicted change in EO Delta Change Score
  - This could be due to the patient getting better at controlling eye movements artifact related to delta.

- Gender predicts change in Self Report Composite Post Score and EC power
  - This could be reflective of the gender distribution of our sample group, however because of low sample size it’s hard to make solid assumptions about that.
Litigation and personality profiles were not predictors of NeuroPsych Score change.

This is important because many believe that....?
DISCUSSION
WHAT DOES IT MEAN?

• 4 channel multivariate coherence training can improve scores in coherence and neuropsych testing, even for those who wait to seek treatment.

• For each time group participants self reported less feelings of depression and anxiety.

• For each time group, participants scored higher on neuropsych testing, bringing them closer or into the normal functioning range.

• For each time group, participants saw a change in coherence scores that brought them closer to the norm.

• Factors such as litigation causing malingering or existing personality profiles were not predictors of neuropsych testing change.
LIMITATIONS

- Missing data
- Artifact
- Medications
- No information about treatments before initial eval.
- Increase N

Coherence score is based on average of averages, future studies could use ICA to look at source localization.

Could improve if a controlled study was used.
REFERENCES