Discover Your Brain Potential: Personalized Brain-Computer Interfaces with Machine Learning

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Outline

Brain-Computer Interfaces (BCI)

Clinical
- FEP patients vs health controls

Non-Clinical
- A new algorithm for EEG Classification
Brain-computer interface

A brain-computer interface means no touchpad, no keyboard, just pure thought. We look at cutting-edge research in neuroscience and computing in the quest to create a brain-machine interface.

Humans and technology 3 weeks

Facebook is making a bracelet that lets you control computers with your brain

The device would let you interact with Facebook’s upcoming augmented-reality glasses just by thinking.
FEP patients vs health controls

Clinical, non-invasive, wired

Electroencephalography (EEG)

Biomarkers, machine learning

Human cognitive tasks and mental states
<table>
<thead>
<tr>
<th>Variables</th>
<th>Controls (N=33)</th>
<th>Baseline Patients (N=20)</th>
<th>6m Follow-up Patients (N=18)</th>
<th>Statistics P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>22.91 (3.9)</td>
<td>22.7 (3.2)</td>
<td>23.39 (3.3)</td>
<td>F = 0.19</td>
</tr>
<tr>
<td>Females (count, %)</td>
<td>12 (36.36%)</td>
<td>7 (35.00%)</td>
<td>6 (33.33%)</td>
<td>p = 0.83</td>
</tr>
<tr>
<td>Education (years)</td>
<td>15.55 (1.7)</td>
<td>14.95 (1.6)</td>
<td>15.06 (1.6)</td>
<td>χ² = 0.05</td>
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<tr>
<td>UPSA total score</td>
<td>83.45 (8.3)</td>
<td>79.99 (10.9)</td>
<td>82.52 (12.0)</td>
<td>p = 0.98</td>
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<tr>
<td>MCAS total score</td>
<td>54.75 (0.6)</td>
<td>48.1 (5.8)</td>
<td>48.0 (6.2)</td>
<td>F = 0.58</td>
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<tr>
<td>MATRICS Neurocognitive Composite Score</td>
<td>50.45 (5.2)</td>
<td>46.21 (6.4)</td>
<td>48.63 (8.1)</td>
<td>p &lt; 0.0001</td>
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<tr>
<td>MATRICS Social Subscore</td>
<td>54.52 (6.6)</td>
<td>53.58 (11.5)</td>
<td>55.33 (13.8)</td>
<td>F = 2.70</td>
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<tr>
<td>TASIT</td>
<td>55.77 (4.5)</td>
<td>53.69 (6.4)</td>
<td>54.67 (5.2)</td>
<td>p = 0.13</td>
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<tr>
<td>PANSS positive</td>
<td>N/A</td>
<td>14.45 (6.8)</td>
<td>13.18 (5.4)</td>
<td>F = 0.579</td>
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<tr>
<td>PANSS negative</td>
<td>N/A</td>
<td>12.5 (3.8)</td>
<td>10.41 (3.5)</td>
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<td>PANSS general</td>
<td>N/A</td>
<td>30.6 (7.9)</td>
<td>26.70 (8.4)</td>
<td>t = 0.62</td>
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<td>PANSS total</td>
<td>N/A</td>
<td>57.55 (16.7)</td>
<td>50.29 (16.1)</td>
<td>p = 0.27</td>
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<tr>
<td>Chlorpromazine equivalents</td>
<td>N/A</td>
<td>226.51 (234.3)</td>
<td>292.45 (241.6)</td>
<td>t = 1.45</td>
</tr>
</tbody>
</table>

Means with standard deviations in parentheses unless specified otherwise; UPSA, UCSD Performance-based Skills Assessment; MCAS, Multnomah Community Ability Scale; MATRICS, Measurement and Treatment Research to Improve Cognition in Schizophrenia; TASIT, The Awareness of Social Inference Test; PANSS, Positive and Negative Syndrome Scale; CPZ, chlorpromazine equivalents.
Preprocess MMN
1. 0.01-20Hz Filter
2. Segmentation (S1: Standard; S2: Deviant)
3. Baseline Correction
4. Ocular Correction
5. Artifact Rejection

MMN Analyses

- Calculate averaged S2 – averaged S1 waveforms
- Calculate mean MMN amplitude (mean amplitude between 120-250 ms)
- Analyses of 24 frontocentral channels (see Figure 2)
- Exclude 0 outlier (>3SD)
- Run 4 clustering analyses:
  1. HC & Baseline FEP patients
  2. HC & Follow-up FEP patients
  3. Baseline FEP & Follow-up FEP patients
  4. MMN Change over time in FEP patients

Frequency Analyses

- Extract and export squared wavelet coefficients (μV²) of single trials response in the Delta, Theta, and Alpha frequency bands
- Calculate the AverageDifference index - sum of differences between the averaged S2 and S1 at evenly spaced timepoints between 0-280 ms for each frequency band
- Analyses of 24 frontocentral channels (see Figure 3)
- Focus on Delta frequency band (see Figure 5)
- Exclude 4 outliers (>3SD): 2 HC, 2 Follow-up FEP

Run 3 clustering analyses:
1. HC & Baseline FEP patients
2. HC & Follow-up FEP patients
3. Baseline FEP & Follow-up FEP patients

Clinical and functioning characterizations of clustering results
X axis: time (-100 ms to 280 ms)
Y axis: squared wavelet values

AF3  AFz  AF4
F5   F3   F1   F2   F4   F6
FC5  FC3  FC1  FC2  FC4  FC6
C5   C3   C1   C2   C4   C6
CP5  CP3  CP1  CP2  CP4  CP6
P9   P7   P5   P3   P2   P4   P6   P8   P10
Multi-Class Time Continuity Voting for EEG Classification

Non-Clinical, Non-invasive, wireless

Everyone can use it everyday

Human-In-The-Loop Machine Learning

Interpretable results
MUSE headband by InteraXon
Tasks

From Neuroscience:
learning, memory, behavior, perception, and consciousness

From four basic language skills:
listening, speaking, reading, and writing; [speaking -> noise]

What we have done:
reading, writing, typing, thinking, recalling, counting, drawing, solving math problems, and programming
<table>
<thead>
<tr>
<th>S/T</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>RB</td>
<td>BD</td>
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<tr>
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<td>BT</td>
<td>CR</td>
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<tr>
<td>6</td>
<td>TC</td>
<td>BR</td>
<td>DB</td>
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</tbody>
</table>

Fig. 2. Session (S) with Task (T) order shuffled

Fig. 3. 10-20 System, four electrodes used on Muse Headset were highlighted
Relative EEG bands for Subjects 1 and 2
Relative EEG bands for Subject 1
**Fig. 7.** Subject Difference

**Fig. 8.** Task Prediction Accuracy, average of all twelve subjects.
Recaption

- **Brain-Computer Interfaces (BCI)**
  - Clinical
    - FEP patients vs health controls
  - Non-Clinical
    - A new algorithm for EEG Classification
Questions?
Thank you so much!