Attentional Manipulations Can Enhance P300-based BCI Performance

DR Berry, CE Lakey, and EW Sellers

East Tennessee State University

EAST TENNESSEE STATE UNIVERSITY
Brain-Computer Interface Laboratory

We type with our brains, not our hands

INTRODUCTION

Though technical advances have improved P300-based BCI paradigms[1], user errors still exist. Given the attentional focus required for successful BCI performance, general lapses of attention and mind wandering represent one potential source of user errors. Would bolstering attentional resources improve user performance? To examine this possibility, we employed a Mindfulness Meditation and Induction (MMI) technique[2] to induce a heightened state of attentional awareness immediately prior to BCI use. We expected MMI to sustain attention to the target item, providing two important consequences for BCI users: 1) reduce distraction from non-targets and thereby increasing accuracy; 2) produce higher amplitude P300 responses: and reduce P300 response latencies.

METHODS

Subjects: 18 healthy (11 female) students (mean age = 22.5, age range = 18 - 53) recruited from ETSU psychology subject pool.

Paradigm: Subjects were assigned to either a 6-min MMI (N=9) or a non-MMI control group (STD; N=9). All subjects were presented with a 6x6 matrix of items on a computer monitor and were instructed to focus attention to a target item within the matrix and mentally note each time it flashed. Stimuli flashed in the form of an entire row or column (SOA 125 ms), and each target item flashed 26 times. Subjects were presented with a total of 35 items in which the first 21 items were used for classification of target responses, and the last 14 items. We used this data to perform a stepwise linear discriminant analysis, which we used on an additional 14 items where subjects received online feedback.

Data Acquisition and Analysis:
16-channel EEG was recorded (BCI2000, g.USBamp) using a right mastoid reference at 256 samples/sec and bandpass filtered (range = 0.05 to 30 Hz).
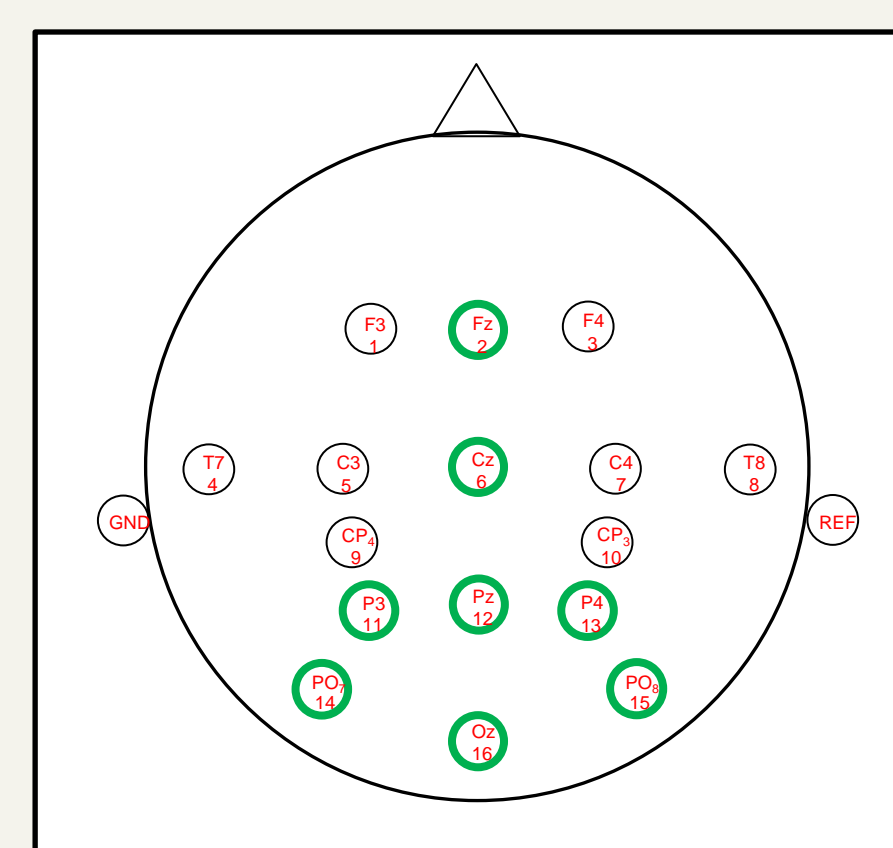

Figure 1. 16-Channel Montage. Channels circled in green were used for SWLDA input.

WAVEFORM ANALYSIS

Mindfulness   Standard
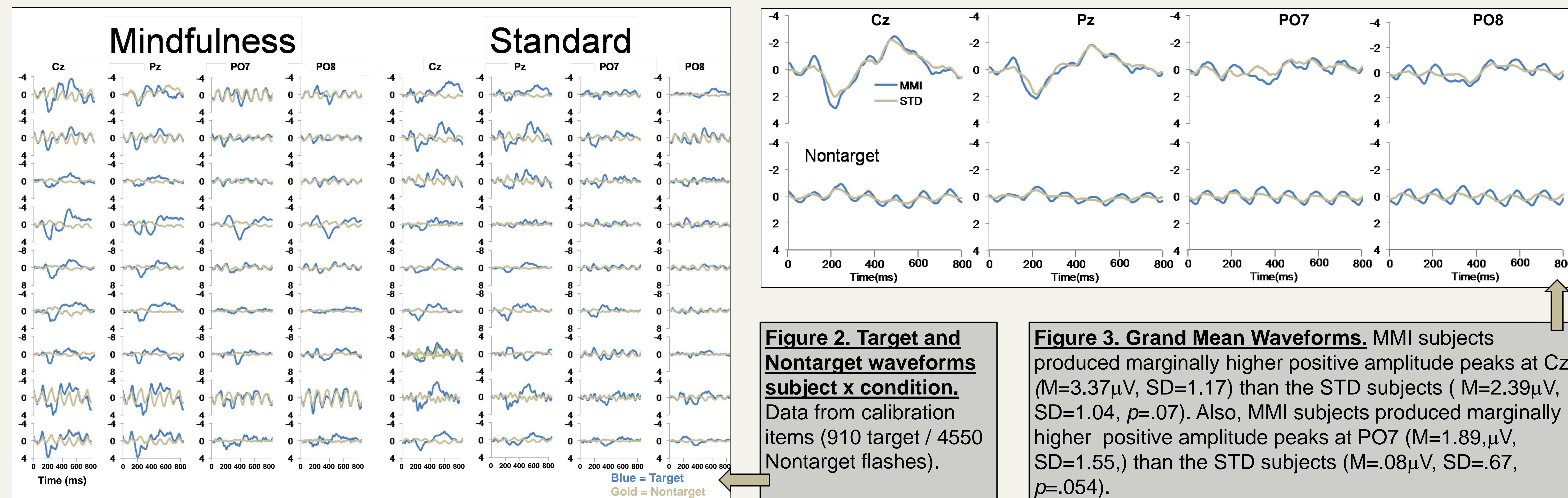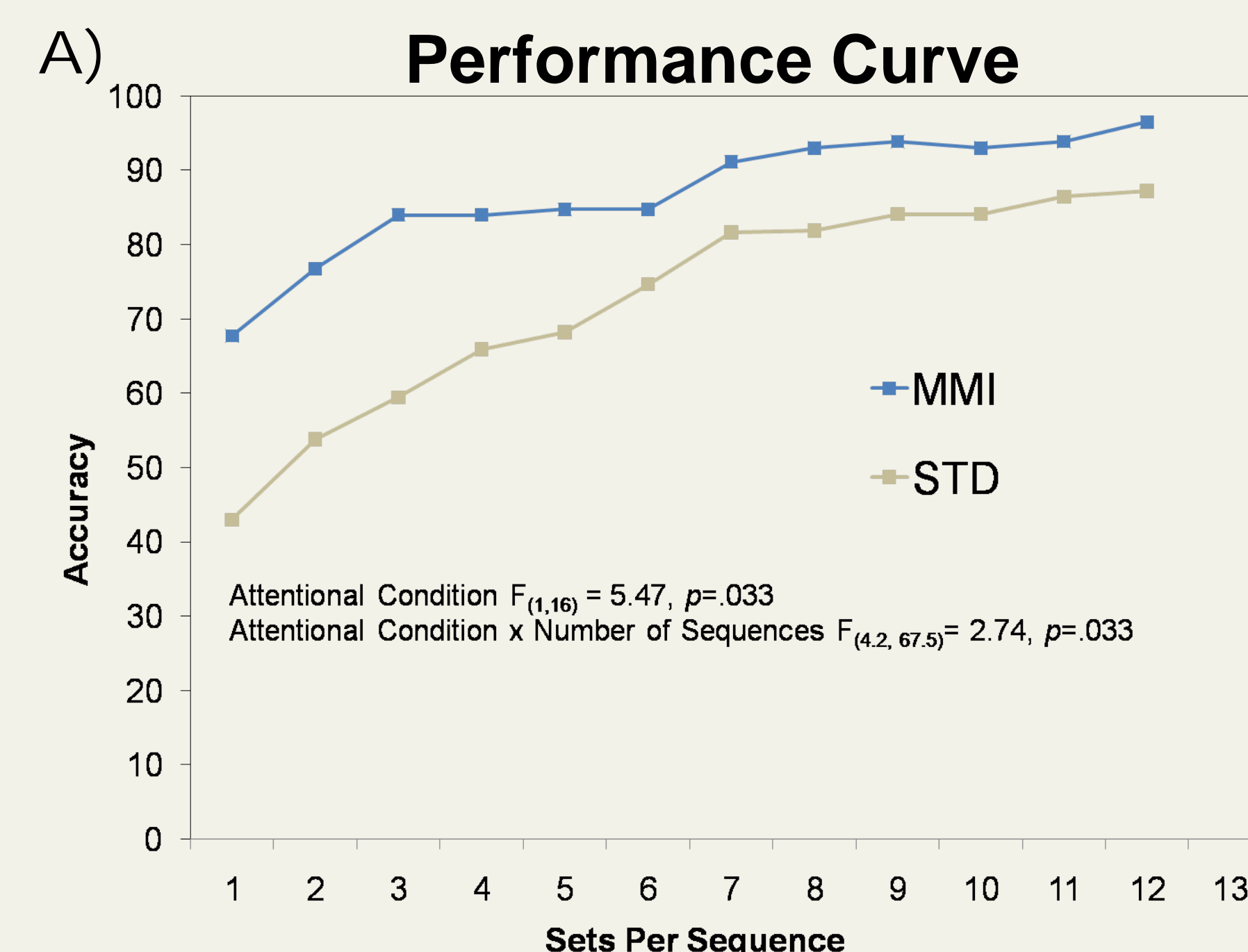
Blue = Target
Gold = Nontarget

Figure 2. Target and Nontarget waveforms subject x condition. Data from calibration items (910 target / 4550 Nontarget flashes).

Figure 3. Grand Mean Waveforms. MMI subjects produced marginally higher positive amplitude peaks at Cz (M=3.37μV, SD=1.17) than the STD subjects (M=2.39μV, SD=1.04, p=.07). Also, MMI subjects produced marginally higher positive amplitude peaks at PO7 (M=1.89,μV, SD=1.55,) than the STD subjects (M=.08μV, SD=.67, p=.054).

PERFORMANCE MEASURES

A) **Performance Curve**

Attentional Condition $F_{(1,16)}$ = 5.47, p=.033
Attentional Condition x Number of Sequences $F_{(4.2, 67.5)}$= 2.74, p=.033

* Each sequence is composed of two flashes.

B) **Accuracy Comparisons**

Subject	MMI Acc 3 SPS	STD Acc 3 SPS	MMI Acc 13 SPS	STD Acc 13 SPS
1	86	57	100	93
2	64	71	93	93
3	50	21	93	57
4	100	50	100	71
5	71	50	100	100
6	71	93	93	100
7	93	14	100	71
8	79	71	93	100
9	79	57	100	100
Mean	76.75	53.78	96.50	87.22
St Dev	15.18	24.59	3.69	16.43
St Err	5.36	8.69	1.30	5.81

Figure 4. **A)** Accuracy was analyzed using a 2 (Attentional Condition, MMI & STD) X 13 (Number of Sequences, 1 – 13) repeated measures factorial ANOVA. MMI produced higher accuracy than STD. Accuracy increased with more sequences. The interaction was also significant; accuracy in the MMI condition improves more rapidly than accuracy in STD over the first 6 sequences and then remains consistently higher. **B)** MMI achieves effective communication accuracy (>70%) at 3 sequences (76.8%), whereas STD requires 7 sequences to reach 70% accuracy (74.7%), thus twice as much time to make an item selection.

CONCLUSIONS

1. These data suggest that MMI leads to better P300 based BCI performance via increases in sustained attention than standard row/column presentation without MMI.

2. MMI may produce higher amplitude P300 responses and shorter target latencies on all channels with a larger cohort of subjects and a more rigorous MMI training protocol.

REFERENCES

1. Townsend, G., Lapallo, B. K., Boulay, C. B., Krusienski, D. J., Frye, G. E., Hauser, C. K., et al. (2010). A novel P300-based brain-computer interface stimulus presentation paradigm: Moving beyond rows and columns. *Clin Neurophysiol*

2. Kabat-Zinn, J. (1990). *Full Catastrophe living*, New York, NY: Dell.

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