A Longitudinal Analysis of the Synchronized Brainwave Dataset

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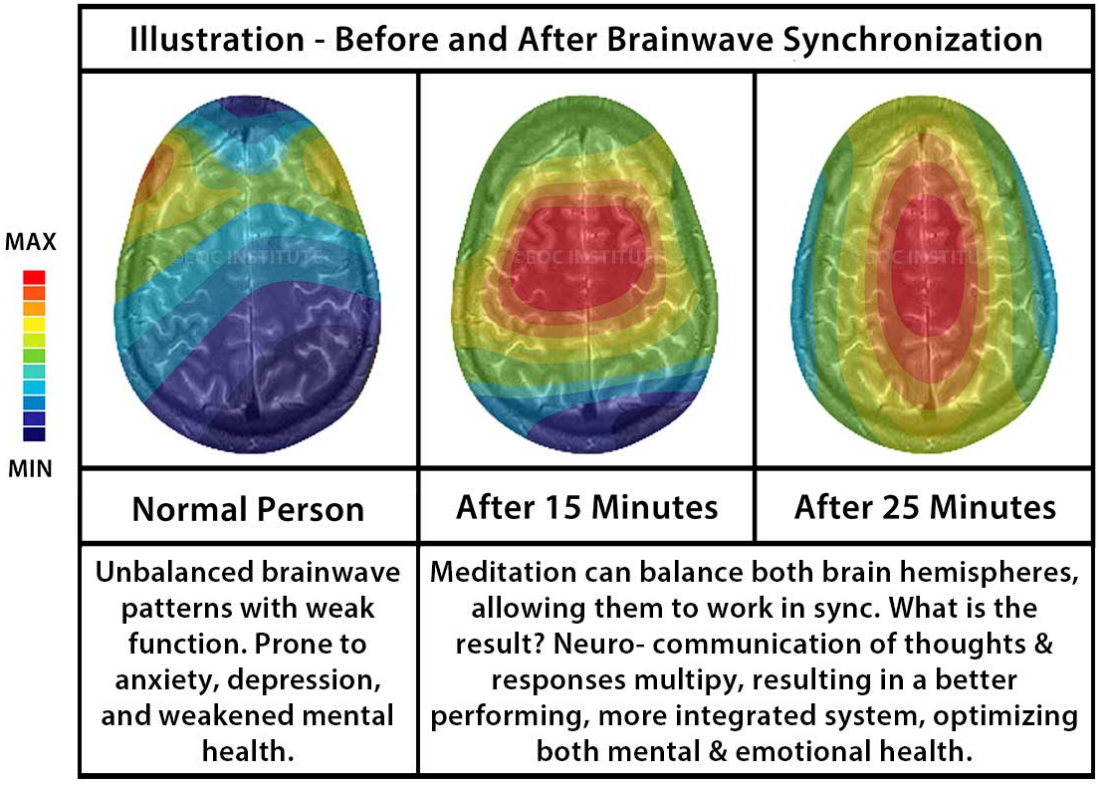
Inspiration

- Has been a growing interest over recent years to further understand the brain's ability to comprehend information at a faster rate
- Researchers at MIT performed an experiment on monkeys where they discovered that synchronized brain waves enable rapid learning (Trafton 2014)



Introduction

- As a next step, we thought it would be intriguing to explore this idea further by investigating how ones' brain waves can be manipulated to maintain a synchronized neurological state so that cognitive function is optimized
- To do this we analyzed EEG data collected on subjects exposed to different stimuli

Background

- Study involved 30 voluntary students from UC Berkeley (Chuang et al. 2015)
- Participants were randomly assigned to watch one of two stimulus videos (both videos 5:19 min)
- Everyone was hooked up to an Electroencephalography (EEG) headset which recorded electrical brain activity as they viewed the video and followed the instructions
- Frequency values for alpha, beta, delta, gamma, and theta waves were recorded approximately every .3 seconds so each individual had 1000 repeated measures on average
- Signal quality on the outputted values were also recorded (0 representing perfect signal quality)
- Decided to remove all values with signal quality larger than 128 since at that point it indicates the EEG headset is being worn incorrectly

Metadata

Summary statistics for *n* before data cleaning

```
summary(as.numeric(as.matrix(table(eeg$id))),
        digits=10)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
##   464.000   624.250 1067.000 1000.433 1266.750 1607.000
```

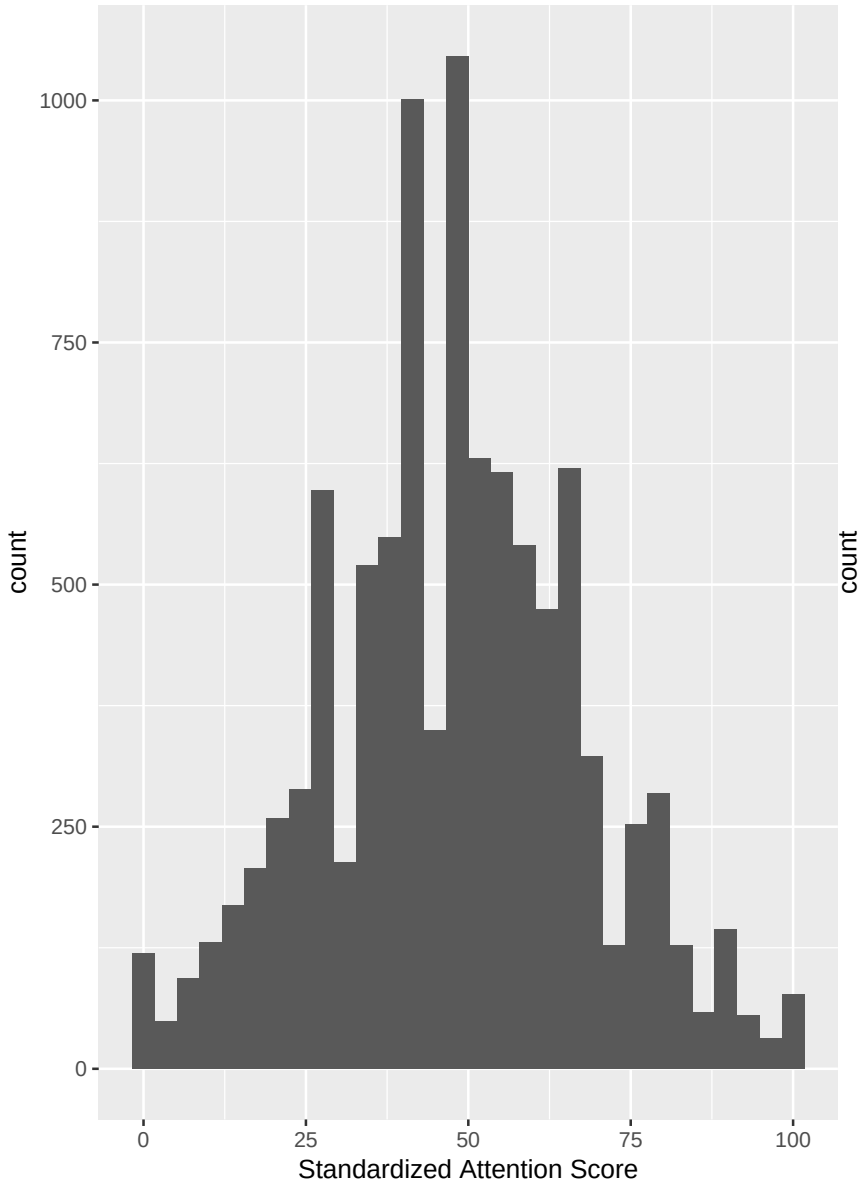
Summary statistics for *n* after data cleaning

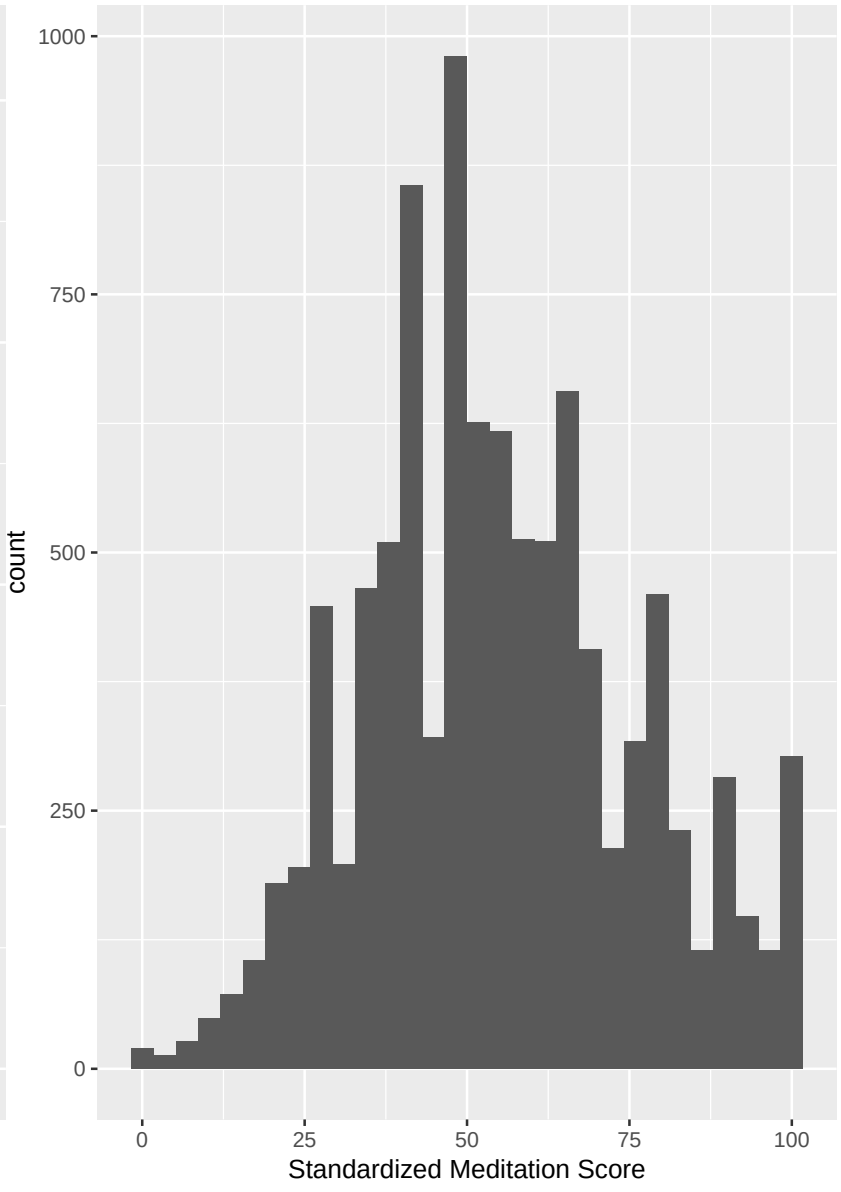
```
summary(as.numeric(as.matrix(table(eeg_clean$id))),
        digits=10)
```

```
##     Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   308.00  320.00  321.00  331.80  321.75  644.00
```

Smoothed Trajectories by Subject

Distribition of Responses





Univariate Models

$$\mathbf{Y_{1ij}} = \mathbf{X_{ij}}^T \beta_1 + \mathbf{Z_{ij}}^T \boldsymbol{b_{1i}} + \boldsymbol{\epsilon_{1ij}}$$

$$\mathbf{Y_{2ij}} = \mathbf{X_{ij}}^T \beta_2 + \mathbf{Z_{ij}}^T \boldsymbol{b_{2i}} + \boldsymbol{\epsilon_{2ij}}$$

- *Responses*: Attention, Meditation
- *Fixed Effects*: Intercept, Session, Gender, Color, Time, Hidden Icons, Previous Exposure to Ad
- *Random Effects*: Intercept

Attention Results

	Estimate	Std. Error	t value
(Intercept)	50.06	5.51	9.08
Genderm	-10.27	3.86	-2.66
Seen.video.before.y	10.38	4.00	2.60
Saw.icons.n	0.92	4.09	0.23
Saw.icons.smiley	-3.12	4.84	-0.65
Saw.icons.star	-0.67	8.18	-0.08
Chosen.colorg	-3.46	3.63	-0.95
Chosen.colorr	-8.20	3.95	-2.07
Chosen.colory	-5.03	7.35	-0.68
time	0.04	0.00	12.68
as.factor(Session)2	8.35	2.92	2.86
time:as.factor(Session)2	-0.04	0.00	-9.20

Meditation Results

	Estimate	Std. Error	t value
(Intercept)	62.99	5.29	11.90
Genderm	4.86	3.70	1.31
Seen.video.before.y	-9.74	3.83	-2.54
Saw.icons.n	-0.26	3.92	-0.07
Saw.icons.smiley	-5.40	4.64	-1.16
Saw.icons.star	-8.83	7.84	-1.13
Chosen.colorg	4.57	3.48	1.31
Chosen.colorr	2.08	3.79	0.55
Chosen.colory	-4.66	7.05	-0.66
time	-0.06	0.00	-21.71
as.factor(Session)2	-3.37	2.82	-1.20
time:as.factor(Session)2	0.02	0.00	5.45

Accounting for Correlation Between Responses

$$\begin{pmatrix} \mathbf{Y_{1ij}} \\ \mathbf{Y_{2ij}} \end{pmatrix} = \mathbf{X_{ij}}^T \begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} + \mathbf{Z_{ij}}^T \begin{pmatrix} \boldsymbol{b_{1i}} \\ \boldsymbol{b_{2i}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{\epsilon_{1ij}} \\ \boldsymbol{\epsilon_{2ij}} \end{pmatrix}$$

- *Responses*: Attention, Meditation
- *Fixed Effects*: Intercept, Session, Gender, Color, Time, Hidden Icons, Previous Exposure to Ad
- *Random Effects*: Intercept

Multivariate Results

	post.mean	l-95% CI	u-95% CI	eff.samp	pMCMC
traitattention_esense	-3682.76	-103776.73	121232.51	1500.00	0.93
traitmeditation_esense	1015.49	-111802.22	113646.04	1500.00	0.99
as.factor(Session)2	2.18	-2.75	7.49	1500.00	0.37
at.level(trait, 1):Genderf	3735.99	-121178.57	103829.74	1500.00	0.93
at.level(trait, 1):Genderm	3726.62	-121184.20	103818.52	1500.00	0.93
Genderf:at.level(trait, 2)	-955.42	-113585.39	111861.62	1500.00	0.99
Genderm:at.level(trait, 2)	-951.22	-113580.40	111862.34	1500.00	0.99
at.level(trait, 1):Seen.video.before.y	12.14	3.38	20.04	1374.57	0.01
at.level(trait, 2):Seen.video.before.y	-11.28	-19.73	-2.89	1500.00	0.01
at.level(trait, 1):Saw.icons.n	-0.92	-9.69	8.68	1778.60	0.79
at.level(trait, 1):Saw.icons.smiley	-4.00	-14.43	7.37	1500.00	0.48
at.level(trait, 1):Saw.icons.star	-4.41	-22.23	14.41	1500.00	0.63
at.level(trait, 2):Saw.icons.n	1.28	-7.04	10.00	1500.00	0.78
at.level(trait, 2):Saw.icons.smiley	-4.89	-15.61	4.73	1500.00	0.34
at.level(trait, 2):Saw.icons.star	-5.18	-20.67	12.88	1500.00	0.51
at.level(trait, 1):Chosen.colorg	-1.83	-10.28	6.22	1643.32	0.67
at.level(trait, 1):Chosen.colorr	-7.51	-16.88	1.45	1500.00	0.09
at.level(trait, 1):Chosen.colory	-7.30	-25.55	7.40	1500.00	0.37
at.level(trait, 2):Chosen.colorg	3.18	-4.33	11.14	1500.00	0.39
at.level(trait, 2):Chosen.colorr	1.48	-6.69	10.09	1500.00	0.72
at.level(trait, 2):Chosen.colory	-2.88	-19.74	12.34	1500.00	0.70
at.level(trait, 1):time	0.04	0.03	0.04	1500.00	0.00
at.level(trait, 2):time	-0.06	-0.07	-0.06	1500.00	0.00
at.level(trait, 1):time:as.factor(Session)2	-0.04	-0.04	-0.03	1500.00	0.00
at.level(trait, 2):time:as.factor(Session)2	0.02	0.01	0.03	1500.00	0.00

Conclusions and Future Work

Conclusions:

- In both the multivariate and univariate analyses, time and the interaction between time and stimuli are significant
- Evidence that Stimulus 1 was better at increasing attention level over time while Stimulus 2 was significantly better at increasing meditation level over time
- Most other covariates weren't significant (exception of gender for attention)

Future Work:

- Experiment with quadratic terms and/or more interactions
- Possibly add more responses (theta, gamma wave data)

References

Chuang, John, Nick Merrill, Thomas Maillart, and Students of the UC Berkeley Spring 2015 MIDS Immersion Class. 2015. "Synchronized Brainwave Recordings from a Group Presented with a Common Audio-Visual Stimulus."

Trafton, Anne. 2014. "Synchronized Brain Waves Enable Rapid Learning." *MIT NEWS on Campus and Around the World*.