# Analysis of Longitudinal Variations in Brain Oscillations for Breath-Focus and Mantra-Based Meditation

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## Overview

- Prior studies have primarily compared expert meditators with novices, leaving the progression of neural mechanisms as a result of daily meditation practice relatively unexplored.
- This study aims to compare the state difference, immediate effect, and longitudinal neuroplasticity changes, due to the regular practice of mantra-based meditation or breath-focused meditation over a six-week period.

## Background

- **Mantra-Based Meditation (MBM):** The form of MBM we are studying is Japa, in which specific sounds (mantras) [1] are repeated aloud or silently, as inner speech, for the purpose of improved concentration and relaxation.
- **Fitting Oscillations & One Over F (FOOOF) [2]:** Separating the $1/f$ aperiodic component is necessary to isolate and accurately measure the true periodic oscillations (See Figure 1).
- **Alpha & Cognition:** Studies show that alpha desynchronization, a decrease in Individual Alpha Power (IAP), indicates increased focus [3]. A higher Individual Alpha Frequency (IAF) is correlated with superior cognitive performance [4].

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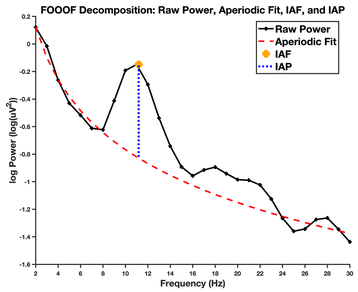


Figure 1: Power spectral density (PSD) decomposition using FOOOF. The raw power spectrum (black circles) is decomposed into an aperiodic component (red dashed line, $1/f$ background) and periodic oscillations. Individual Alpha Frequency (IAF, orange dot) and Individual Alpha Power (IAP, blue line) are extracted from the alpha band (8-13 Hz) peak.

## Methods

- **EEG Device:** 64 channel EEG wireless cap made by mBrainTrain was used to collect data with sampling rate of 250 Hz.
- **Techniques:** Three meditation techniques were used to form the groups: two MBMs using either the Hare Krishna (HK) or SaTaNaMa (SA) mantra, and one with Breath Focus (BF).
- **Spectral Metrics:** The analysis characterized brain activity using the following spectral parameters: IAF, IAP, and the Alpha Center of Gravity (CoG).

$$f_{CoG} = \frac{\sum_{f=a}^{b}(P(f)\cdot f)}{\sum_{f=a}^{b} P(f)}$$

## Acknowledgments

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- Thanks to our expert meditators, Devin O'Rourke and Sidharth Chhabra, from Harmony Collective, Ypsilanti, Michigan.

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## Methods (continued)

- **Cluster-Based Permutation Test:** A non-parametric method that controls for the multiple comparisons problem (i.e., Type I error inflation) by adjusting the statistical significance of spatio-temporal clusters of activity.
- **Participants:** EEG data was obtained from 30 pre-screened participants. Participants were divided into three groups (see Table 1).
- **Study Design:** The meditation program lasted for six weeks. Each group followed the pipeline outlined in Figure 2.

| Group | Hare Krishna | Sa Ta Na Ma | Breath Focus | Total |
|---|---|---|---|---|
| | M = 3 F = 9 | M = 3 F = 6 | M = 3 F = 6 | 30 |
| Age (years) | 22.0 ± 4.1 | 22.4 ± 3.0 | 22.4 ± 3.0 | 22.2± 3.2 |

Table 1: Information for three Groups (Avg ± Std). Male (M) and female (F) counts in each group are also shown.

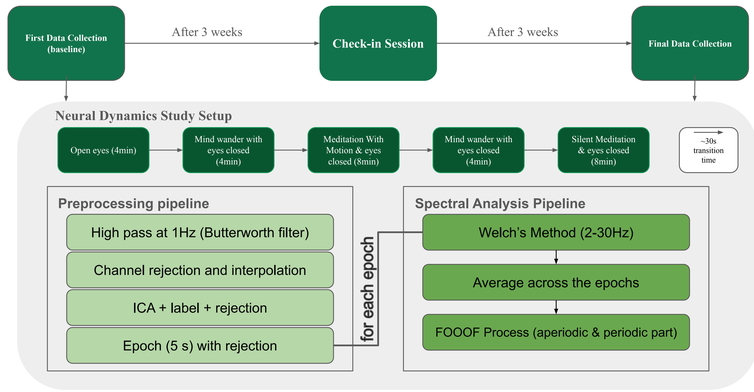
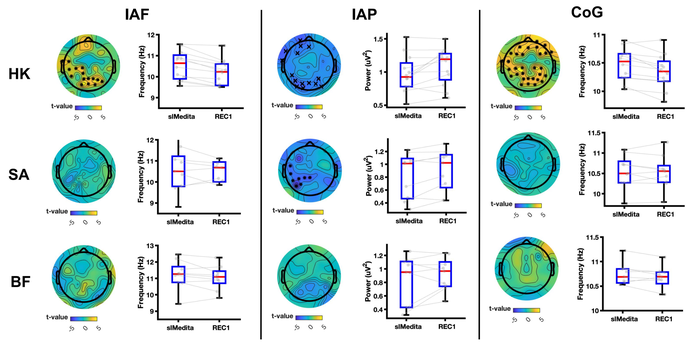



Figure 2: Pipeline for whole study setup.

## Results

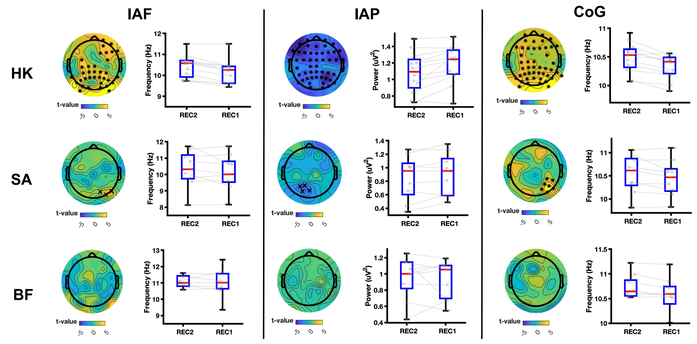
- **State Difference:** Comparing silent meditation state (M') vs. Resting (Eyes Closed) before meditation (REC1) state [5].
  - Data shown are from the pre-intervention phase.
  - While the HK and SA groups show some similar trends for metrics, the BF group does not show any significant results.



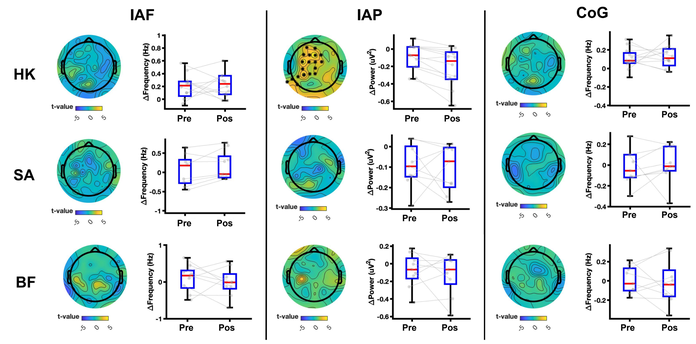

Boxplots show the average of significant channels (if found), or the average of all channels otherwise. Colors: yellow = larger t-value; blue = lower t-value. Significance: Asterisks ($p < .025$), 'x' ($p < .05$).

## Results (continued)

- **Immediate Effect (post-intervention):** Comparing resting state before (REC1) and after (REC2) meditation
  - Data shown are from the post-intervention phase, because a persistent effect of meditation is more likely following increased practice.
  - The HK group shows a significant difference for all three metrics i.e., IAF increase, IAP decrease, and CoG increase from REC1 to REC2. The SA group shows slight significant changes in the occipital region, while the BF group shows no significant change.




- **Long-term Neuroplasticity:** Comparing the difference of meditation and rest difference (M minus REC1) between pre-intervention and post-intervention.
  - The main significant difference was found in the HK group's IAP: As compared to before training, after six weeks, this group showed a greater alpha power reduction during meditation compared to resting. This suggests that more practice leads to enhanced attentional control.




## Discussion

- The Hare Krishna (HK) group and the SaTaNaMa (SA) group show a similar trend—lower IAP and faster IAF and CoG—compared to eyes-closed rest (presumably, mind-wandering). This suggests that Japa meditation may serve as a form of working memory training.
- Looking at the immediate effect, the HK group shows many more significant channels for all three metrics than the other groups. This may be because the HK mantra is longer and more difficult than the SA mantra, making it more cognitively demanding.
- The pre-post comparison for long-term neuroplasticity showed a greater IAP reduction between meditation and resting states. This suggests HK is an easier and more effective attentional focus training.

## Ongoing and Future Work

- Future research will utilize larger, age-matched samples to delve into the underlying mechanisms of meditation-induced cognitive improvements. We aim to establish robust brain-behavior correlations, connecting cognitive performance and EEG changes with objective enhancements.