

Understanding Longitudinal Effects of Mantra Meditation and Breath-focused Meditation using EEG

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Overview

- Prior studies have primarily compared expert meditators with novices, leaving the progression of neural mechanisms and cognitive changes during continuous meditation practice relatively unexplored.
- This study aims to compare the longitudinal cognitive ability changes, mental health, and neural dynamics associated with mantra-based meditation and breath-focused meditation over a period of regular practice.

Background

- **Types of Meditation [1]:** So far, most research has focused on the effects of four types of meditation (Figure 1).
- **Mantra-Based Meditation (MBM):** Involves repeating a specific word or sound (mantra) [2] for deep concentration and relaxation.
- **P300:** The P300 [3] event-related brain potential (Figure 2).
 - **Shorter latencies** are related to superior cognitive performance.

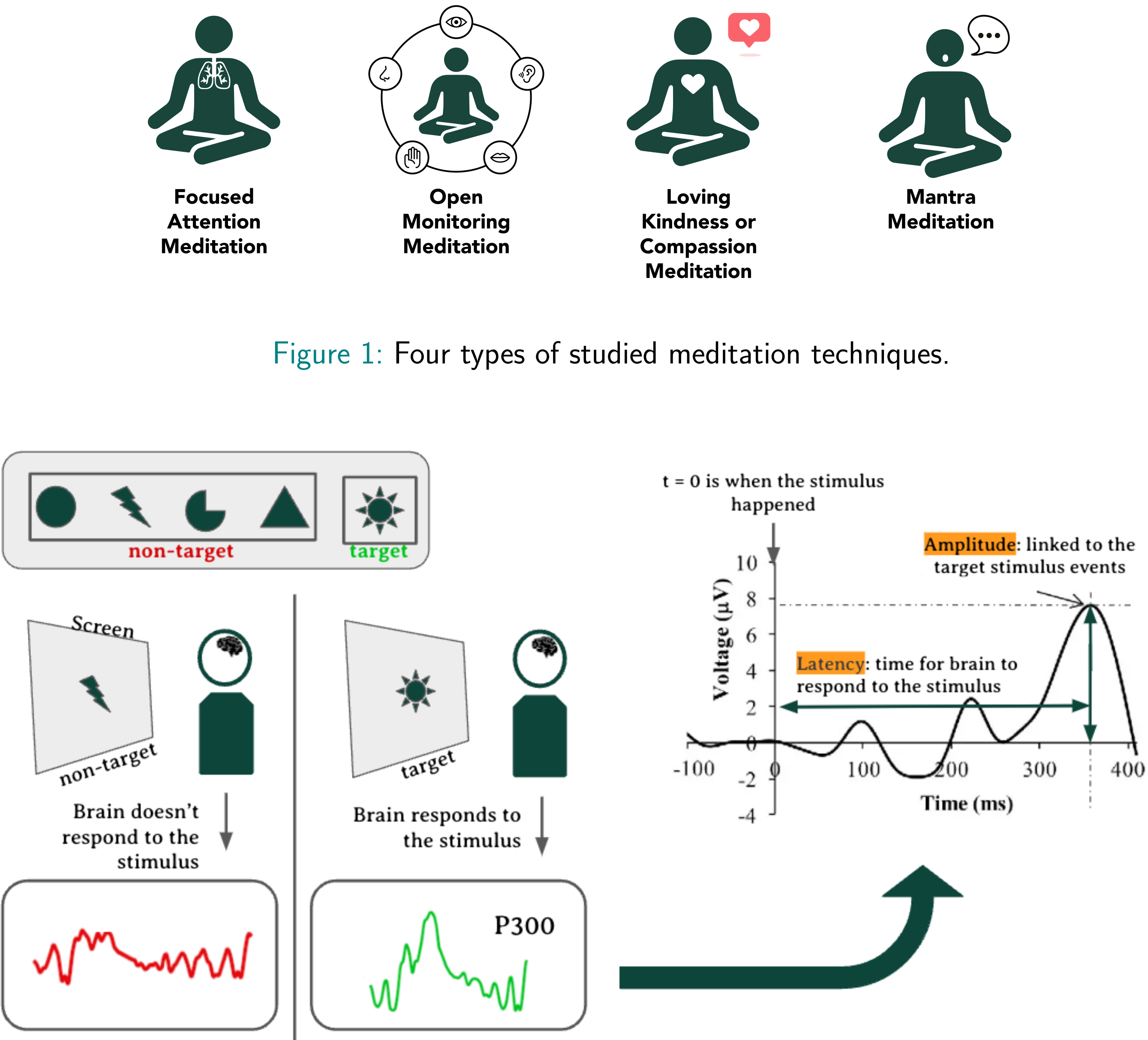


Figure 1: Four types of studied meditation techniques.

Figure 2: Generation of the P300 waveform.

Acknowledgments

- This research was funded in part by Brainwave Science, Inc., whose EEG headset and software were used in the study. The P300 results were collected by iCognitive instrumentation made by Brainwave Science, Inc.
- Thanks to our expert meditators, Devin O'Rourke and Sidharth Chhabra, from Harmony Collective, Ypsilanti.

References

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Methods

- **EEG Device:** EEG data for P300 task was collected using the AIKA health EEG headset (Brainwave Science, Inc.), with 8 electrodes. P300 results were processed through the company's software.
- **Participants:** EEG data was obtained from 24 pre-screened participants, all of whom signed IRB-approved consent forms. Participants were divided into three gender-balanced groups (see Table 1).
- **Procedures:** Three meditation techniques were used to form the groups: Hare Krishna (MBM), Sa Ta Na Ma (MBM), and Breath Focus (Focused Attention). Each group followed the pipeline outlined in Figure 3.
- **P300 Speller Test (Cognitive test):** The flowchart for this task is provided in Figure 3.
- **Neural Dynamics Study:** The test setup and preprocessing pipeline, including spectral analysis details are depicted in Figure 3.
- **Questionnaires:** FFMQ, MAIA-2, and PSS questionnaires were completed after the meditation sessions revealing changes in mindfulness, bodily awareness, and stress perception.

| Group | Hare Krishna | | Sa Ta Na Ma | | Breath Focus | | Total |
|-------------|--------------|-------|-------------|-------|--------------|-------|----------|
| | M = 5 | F = 3 | M = 6 | F = 2 | M = 6 | F = 2 | 24 |
| Age (years) | 27 ± 3.1 | | 29 ± 9 | | 28 ± 3.8 | | 28 ± 6.2 |

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

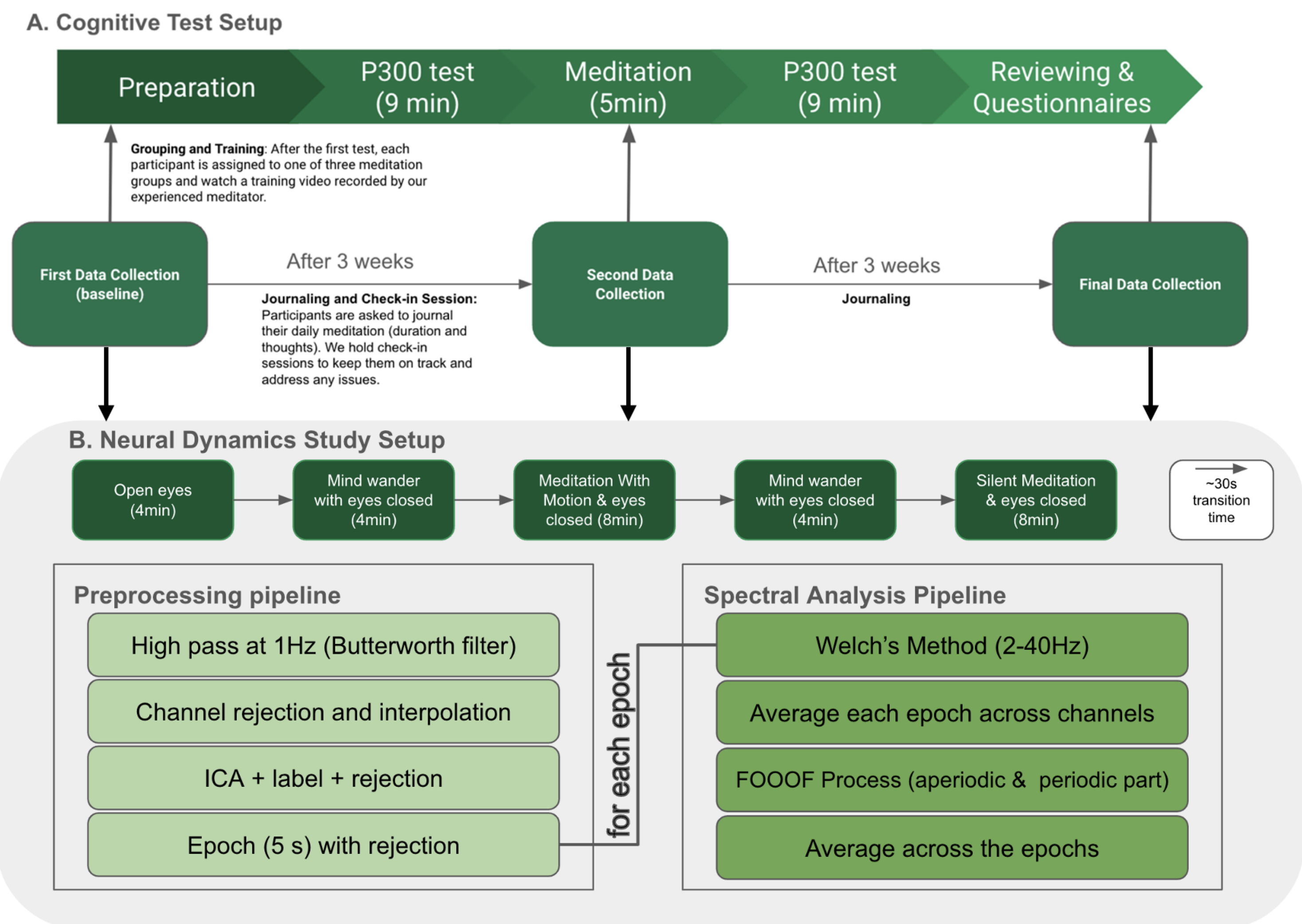


Figure 3: Pipeline for whole study setup with two main parts, A. cognitive study setup and B. neural dynamics study setup.

Results

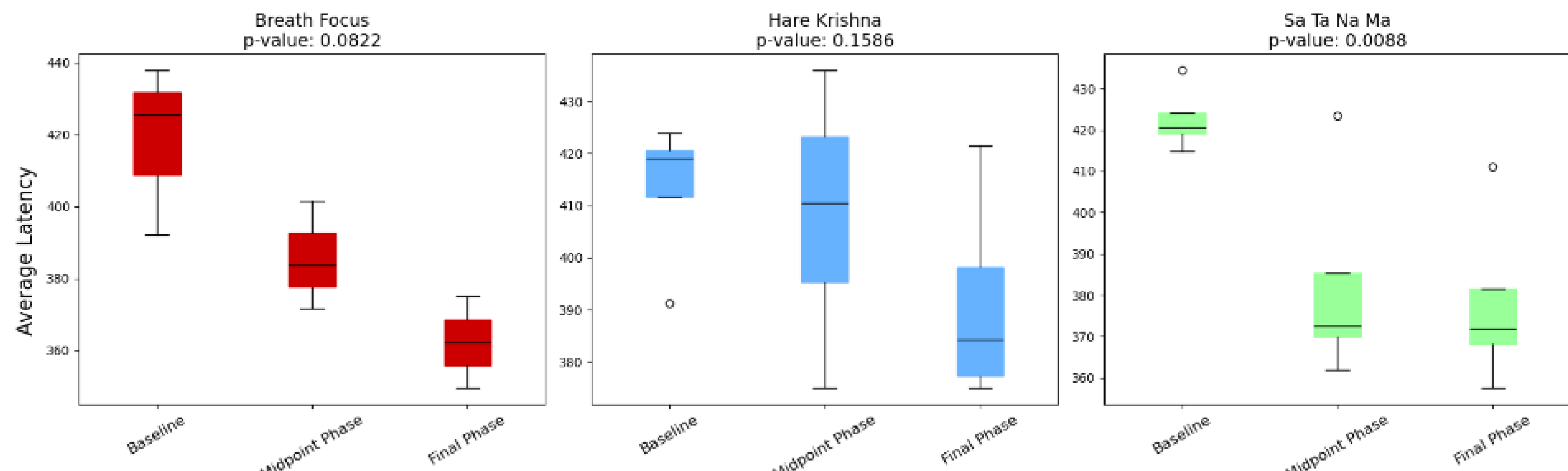


Figure 4: Latency comparison from P300 task across meditation groups, with p-values reported comparing the baseline and final phase.

Results Continued

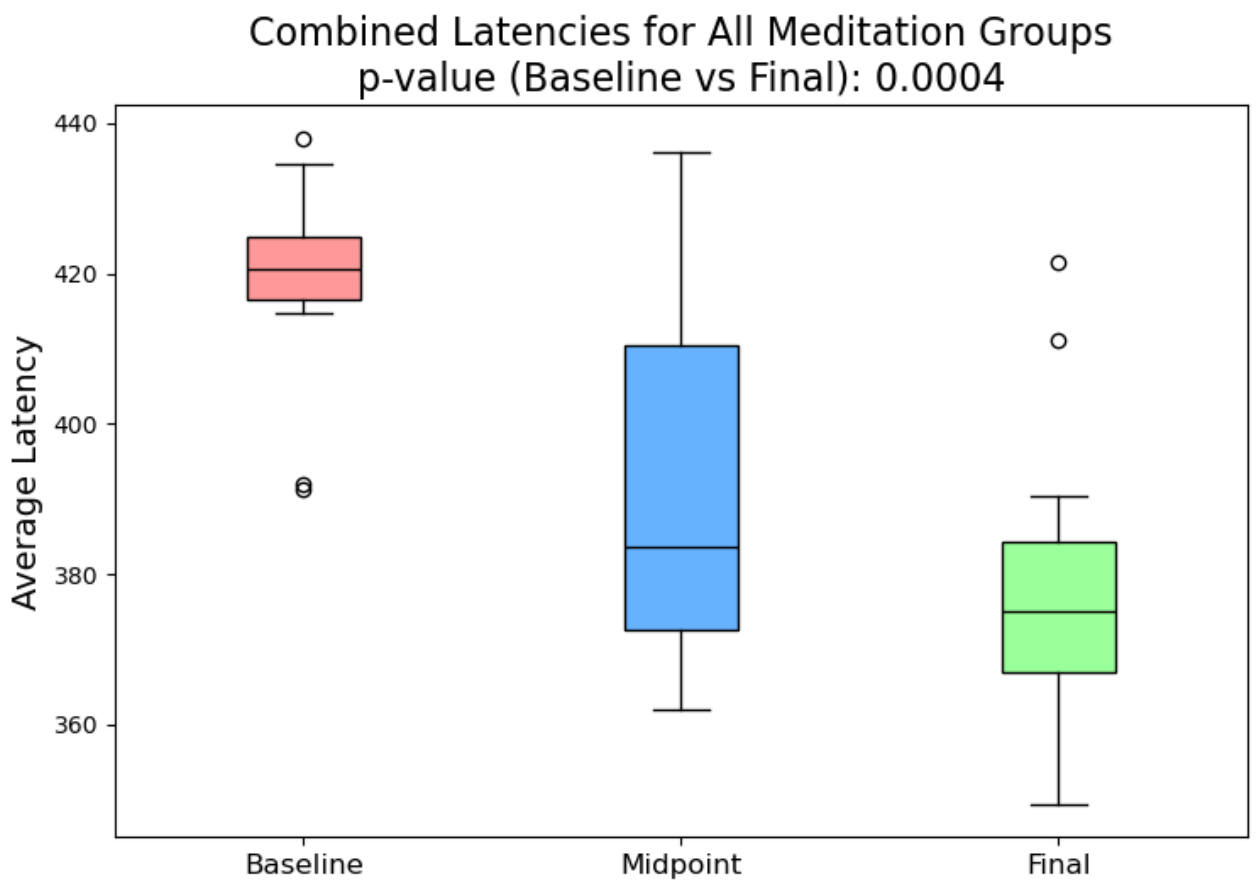


Figure 5: Latency comparison between each collection phase including all meditation groups.

| Group | MAIA-Attention Regulation ↑ | MAIA-Self Regulation ↑ | FFMQ-ActAware ↑ | FFMQ-NonJudge ↑ | PSS ↓ |
|-------------------------|-----------------------------|------------------------|-----------------|-----------------|--------------|
| Breath Focus (Baseline) | 3.23 ± 1.08 | 2.87 ± 0.90 | 18.67 ± 2.08 | 16.33 ± 4.04 | 19.0 ± 2.0 |
| Breath Focus (Final) | 3.60 ± 0.30 | 3.65 ± 0.85 | 19.50 ± 3.50 | 20.00 ± 1.00 | 9.5 ± 0.5 |
| Hare Krishna (Baseline) | 1.90 ± 1.26 | 1.75 ± 1.55 | 16.00 ± 5.16 | 17.50 ± 3.42 | 18.25 ± 6.29 |
| Hare Krishna (Final) | 3.33 ± 1.27 | 2.95 ± 1.79 | 17.00 ± 3.56 | 15.75 ± 4.57 | 14.00 ± 8.83 |
| Satanama (Baseline) | 2.78 ± 0.84 | 3.43 ± 0.63 | 15.75 ± 5.12 | 17.00 ± 3.46 | 18.25 ± 2.22 |
| Satanama (Final) | 3.20 ± 0.54 | 3.70 ± 0.81 | 17.50 ± 1.73 | 20.75 ± 3.20 | 17.00 ± 6.22 |

Table 2: Questionnaire data for meditation groups: Baseline and Final statistics (mean and standard deviation) shown.

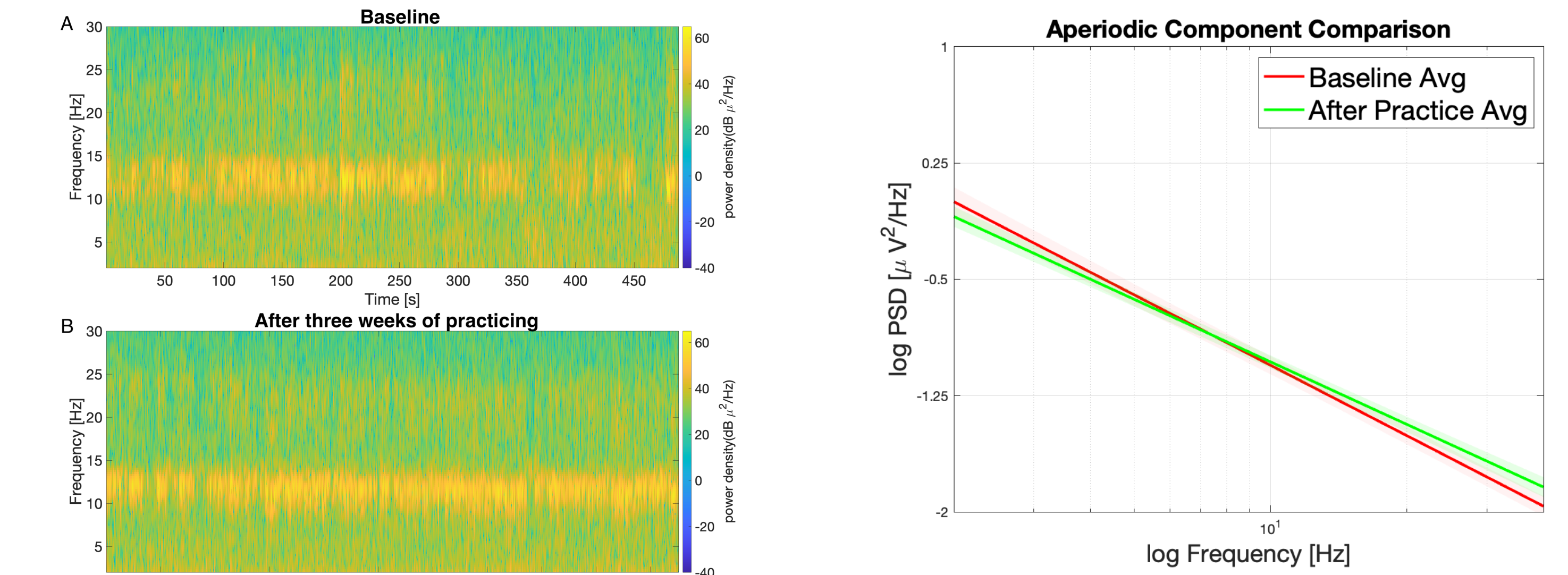


Figure 6: Time-frequency analysis for Sa Ta Na Ma meditation data (parietal channel was selected). (A): the baseline collection; (B): after 3 weeks of practice. We see focused power in alpha band after 3 weeks of meditation practice.

Figure 7: Log of power spectral density (PSD) displayed on y-axis with average power spectrum (solid line) and standard deviation (shaded) shown. 1/f trend (E1 ratio) for Sa Ta Na Ma group is shown. The slope became "flatter" after three weeks of regular practice reflecting increased cognitive load and/or arousal. A similar trend is observed for other groups.

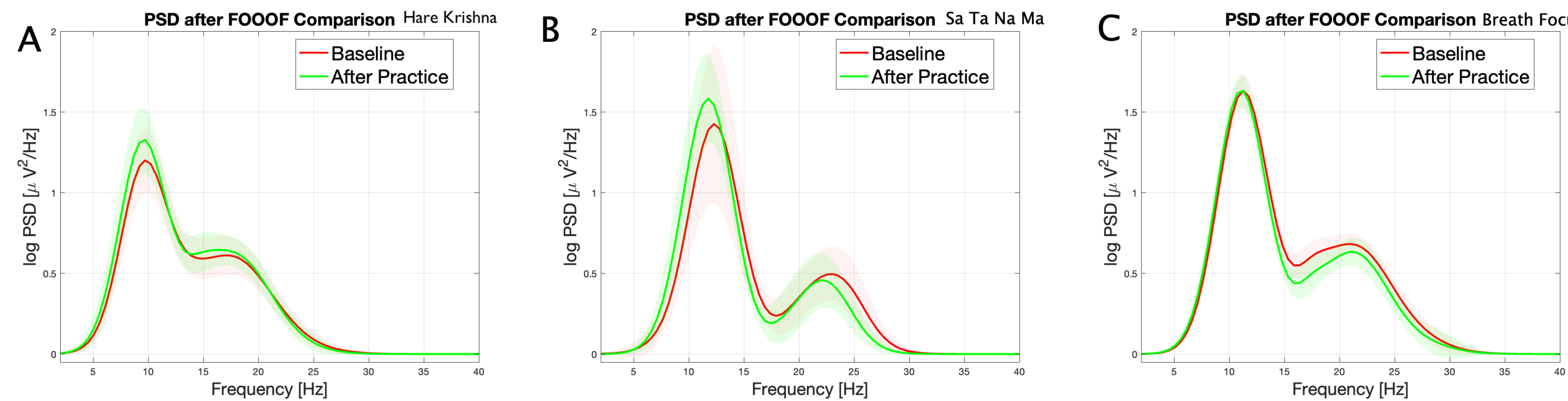


Figure 8: 2 MBM and 1 Focused Attention Meditation (FAM) power spectral density (PSD) plots are compared between baseline and after 3 weeks of practice. Average power spectrum (solid line) and standard deviation (shaded) (A): Hare Krishna meditation; (B): Sa Ta Na Ma meditation; (C): Breath Focus meditation. MBM shows increased alpha band energy after 3 weeks with Hare Krishna showing some increased lower beta band energy as well.

Discussion

- The reduction in latencies and the positive changes in the questionnaires over time suggest improved attentional focus from improved neural processing [4].
- Analysis of the PSD revealed distinct changes in the alpha band between MBM and FAM groups, with further beta band differences in the Hare Krishna and Sa Ta Na Ma subgroups.
- A flatter slope 1/f observed after three weeks of practice in all groups reflects increased cognitive load and/or arousal [5].
- Overall, after a period of meditation practice, positive changes were observed across all metrics, though the differences between the meditation techniques will require further analysis.

Ongoing and Future Work

- Our ongoing studies also include source localization. This research aims to differentiate the effects of different types of meditation techniques, contributing to the field of contemplative neuroscience.
- Future research will employ larger, age-matched samples, and include more measures for cognitive ability.