Final scientific report

Neuroscientific comparison of attentional resource allocation in different meditation traditions

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Principal investigator: Arnaud Delorme

Project summary and goals

One of the exciting developments in the cross-cultural study of human consciousness consists of studying non-classical conscious states such as self-induced transcendental states as produced by intensive meditation practices. Yet, despite decades of interest in this field and renewed interest over the past 10 years, a major current challenge in meditation research continues to be the delineation of distinct neural correlates to meditative experience across the varied meditative practice types. Various experimental methods have been used with different groups of meditators producing inconclusive results. A prime goal of the current research proposal is to assess how attention demanding and emotional stimuli are processed in a range of practices. Here, for the first time, the same protocol will be used to compare meditation practices.

In this report, one control group is compared to expert Vipassana practitioners, expert Isha meditation practitioners and expert practitioners in the Himalayan tradition. We are using EEG as well as peripheral autonomic nervous system recordings to characterize further brain dynamics associated with meditation modulation of external stimuli.

Data acquisition

As a result of the dedication of PhD student Claire Braboszcz, research technician Stephanie Pornin, research technician Pooja Badoni, post-doctoral fellow Yoni Levy and research technician Vinthia Wirantana, we have acquired high quality data from 94 subjects. We are presenting preliminary results from 18 control subjects compared to 18 age and gender matched meditators in the Himalaya meditation tradition, 18 meditators in the Vipassana meditation tradition and 18 meditators in the Isha tradition. All subjects gave written approval and were compensated a total of $10 each for participating in the experiment.

The tasks we are using involve auditory, visual, somato-sensory (tactile) and emotional tasks. Each subject performs 7 different experiments over a 4-

hour period. All recordings are performed in Rishikesh, India using a 64-channel EEG Biosemi system which have received ethical approval by both the University of San Diego California (IRB 090731) and a local Indian ethical committe. The outline of the experiment is indicated below.

Subjects began by filling out a series of questionnaires about their past meditation experiences. The experiment was divided into 2 sessions, one session where subjects were instructed to meditate and one session where they were instructed to perform a mind-wandering task, i.e. remembering past autobiographical memories. The order of the sessions was counterbalanced across subjects. A session started with 20 minutes of meditation or mind wandering, followed by 13 minutes of an auditory oddball task where subjects were instructed to continue to mind wander or meditate. This was followed by an additional 7 minutes of meditation/mind wandering. After the 40-minute session, subjects were presented with flashing stimuli for approximately 2 minutes. They were then presented with emotional images for about 12 minutes. Finally, at the very end of the experiment, subjects were given an active auditory oddball task. The detail of each experiment is given in each of the relevant section.

questionnaires

<table>
<tr><td colspan="3">passive</td><td>active</td><td rowspan="3">Rest Period</td></tr>
<tr><td>Spontaneous data collectoin - 20'</td><td>800 Stim Auditory Oddball - 13.2'</td><td></td><td>500 Stim Visual Oddball - 12.5'</td></tr>
<tr><td>10' breath focused meditation</td><td colspan="2">30' specific meditation practice</td><td>post-med cognitive engage</td></tr>
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<tr><td colspan="3">40' autobiographical mindwandering/default state</td><td>post-mindwander cognitive engage</td><td>post cognitive engagement</td></tr>
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Figure 1. Experimental setup.

Data preprocessing

With 72 subjects, and 9 files per subject, this amounts to a total of 648 files. Because pruning each individual data file manually would be too tedious, data was pruned of artifacts using an automated procedure that we designed specifically for this experiment and validated using manual rejections. The description of this method is outside the scope of this document.

Preliminary results on the meditation versus thinking period

We analyzed a time period ranging from 10 to 20 minutes after the beginning of the meditation and rest "mind-wandering" period. Results are shown in figure 1 in the 9-11 Hz frequency band for the different meditation traditions. The scalp maps represent the power in the meditation period minus the power in the mind-wandering period.

The power difference was negative in the control condition, and positive or neutral for all the meditation traditions. The power difference was highest in the Vipassana tradition.

Note that this does not necessarily mean that the Vipassana tradition is the best meditation technique. It simply shows that power difference is highest in this tradition in the alpha frequency band. We have not thoroughly investigated all of the differences, and it is possible and likely that other meditation traditions show characteristic patterns in the same and at other frequencies.

For controls, alpha power is lower during the meditation than during the rest period. One interpretation may be that subjects have to concentrate for performing the meditation breath counting task which is a new task never done by the subjects before. Alpha power has been shown to decrease during periods of concentrations.

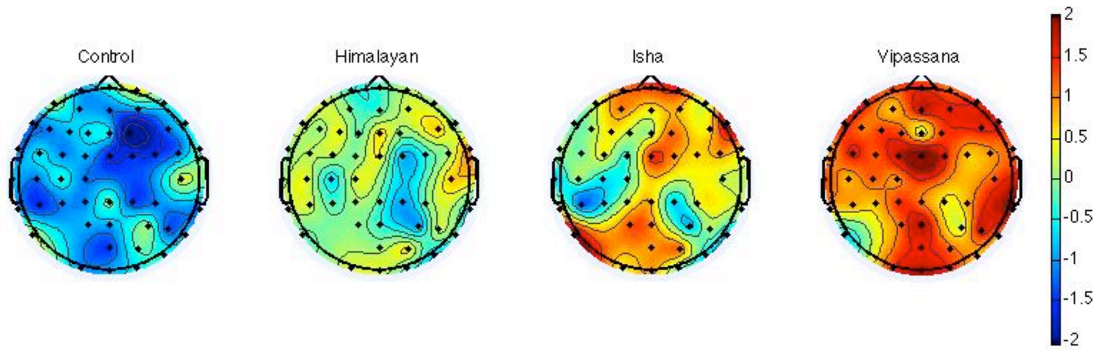

Figure 2. Scalp maps power difference in the 9-11 Hz frequency band between the meditation and the res "mind-wandering" condition is shown for the 3 meditation traditions and for the control group (average of 18 subjects in each group). Power is shown in dB.

Note that, in this preliminary qualitative analysis, we have not computed significance, which is complicated by the fact that some subjects are missing different sets of electrodes. We are planning to analyze differences in other frequency bands in more depth and compute significance in the scientific report we are preparing for publication.

Preliminary results for the SSVEP task

Rapid full screen white flashes at different frequencies were shown to each subject after the meditation period and after the rest "mind-wandering" period. For 30 seconds flashes were shows at 3.4Hz, then at 5.4Hz, 7.5Hz, 9.3Hz, 12.4Hz and 18.7 Hz. We used fractional frequencies since the exact flash frequency was a function of the computer screen refresh rate. Below we are showing spectral results in the 18.7 Hz frequency band. Scalp maps power difference between the meditation and the in the resting condition is shown for the 3 meditation traditions and for the control group (average of 18 subjects in each group). We observed that all the meditation traditions lead to higher power at 18.7 Hz in the resting condition compared to the meditation condition.

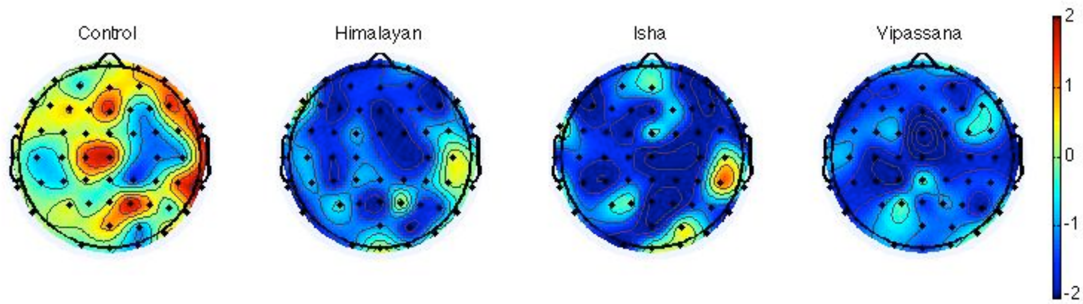

Figure 3. Scalp maps power difference at 18.7 Hz during SSVEP presentation between the SSVEP session following the meditation and the rest "mind-wandering" condition is shown for the 3 meditation traditions and for the control group (average of 18 subjects in each group). Power is shown in dB.

We can interpret higher power during rest in this frequency band as a potential internalization of mental resources during meditation. These resources are not available to process external stimuli in the way they are after the rest period. We are currently working on computing statistical significance to validate these results.

Preliminary results for the oddball task

We have started to analyze the data for the oddball paradigm. In this paradigm, subjects hear standard sound (500 Hz sound lasting for 0.1 second) that are more frequent that rare sounds (voice, pure noise or "oddball"). The oddball sound is 1000 Hz sound presented on 10 % of the trials.

We plotted event-related potentials (ERP) at electrode Cpz, which is located over the centro-parietal region. This region is known to be involved in the P3b ERP potential (P300). Figure 4 (red arrow) shows that the P300 peak is clearly visible for all groups in between 300 and 400 ms when the subjects are counting the target oddball sounds. It is not clearly visible in the passive oddball tasks when the subjects are meditating or mind wandering. However, the difference does not appear to be significant for this peak.

For the P200 peak (peak at 200 ms, blue arrow), there is however a clear difference at 200 ms between the controls and all the meditation groups. This peak reflect a difference in auditory processing between the control and the meditator groups. According to the relevant literature, it could represent larger allocation of attentional resources in control subjects compared to meditators.

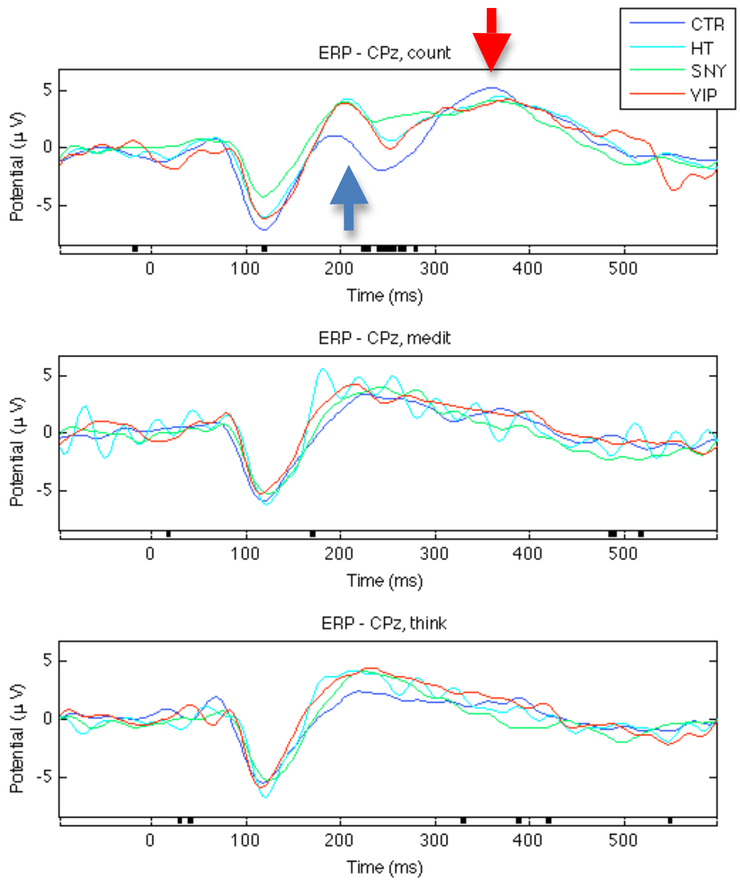

Figure 4. ERP analysis of oddball stimuli for the 4 groups of subject (CTR=control; HT=Himalayan tradition; VIP=Vipassana tradition; SNY=Isha tradition). Black rectangles above the abscissa indicate time region of significance using a 1-way parametric ANOVA procedure.

Preliminary results for the emotion task

In this task, subjects were shown emotional pictures (neutral; pleasant; unpleasant) every 4 seconds and asked to indicate which category the image belonged to (using a keypad). The number on the keypad associated with each category was counterbalanced for each subject. The valence, spatial frequency of images and color content was also balanced between the first and the second session (session following the meditation period or the meditation period). In figure 5, we computed the difference in the time range 300 to 500 ms between pleasant and unpleasant images following the mind-wandering period (the data following the meditation period is qualitatively similar). We chose this time range since it corresponds to late visual processing where differences about the emotional content of the stimuli are more likely to be visible. We can clearly see the difference between pleasant and unpleasant stimuli in control subjects. However, this difference between the two types of stimuli is of much lower amplitude for all groups of meditators.

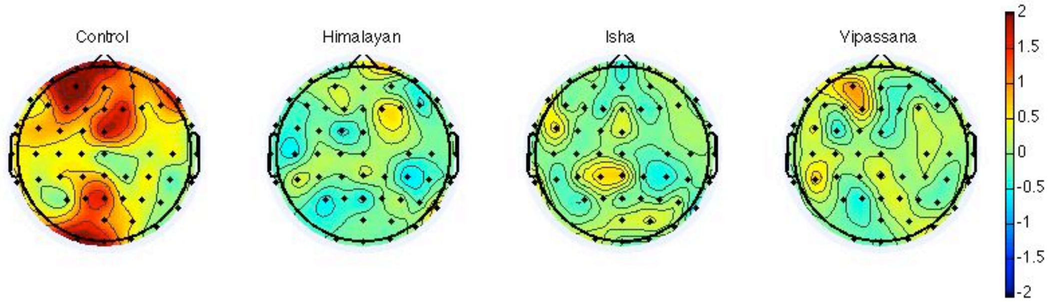

Figure 5. Scalp maps potential difference in the 300 to 500 time range between the pleasant and the unpleasant images following the rest “mind-wandering” condition is shown for the 3 meditation traditions and for the control group (average of 18 subjects in each group).

This result, which appears to be statistically significant so far (not shown), show that meditators are less affected by emotional stimuli than control subjects. This would be consistent with meditators having more equanimity than control subjects, thus being less affected by emotions.

Conclusion

We have successfully completed our ambitious plan of recording several meditation traditions and comparing the neural correlates between them. Our preliminary results suggest common neural correlates for the different meditation traditions that differentiates them from control subjects. These results reflect higher alpha power during meditation than during the resting state in meditators compared to control subjects in the alpha frequency band. Our results also show differential early (SSVEP) and late (P200 during oddball) perceptual processing differences between control subjects and meditators. These differences would appear to be a consequence of the intense training meditators undergo. Finally, it appears that meditators are less affected by emotional stimuli than control subjects (emotion task) which is consistent with the general idea that meditators have more equanimity.

For the first time we are comparing different meditation traditions and our results are consistent with what has been shown in current literature. It is important to emphasize that results presented here are preliminary and significance has not yet been formally assessed. Our results, although promising, will require more rigorous analysis, which we are planning to complete for the final publication.

This report constitutes the final scientific report for the BIAL foundation. We are grateful to the BIAL foundation for allowing us to conduct this ambitious project. The BIAL foundation will be acknowledge on the publication and on the web site where we plan to make the data available for public download.