# Comparing the EEG activity of Image Streaming, Mindfulness Meditation, and Non-Directive Meditation

*Jones, Aaron*

In the past decade or so, the practice of meditation has been gaining a significant amount of mainstream popularity. This is due to an ever-increasing body of data demonstrating meditations efficacy at decreasing stress and altering the structure and function of the brain. Though the various types of meditation may look similar to an outside observer, the subtle differences that exist between meditation styles can produce significantly different mental states and brain activity. Two of the most popular styles of meditation are mindfulness meditation and Transcendental Meditation™, both having large bodies of research examining the physiological effects of their immediate and prolonged practice. One of the main objectives of meditative practice (mindfulness in particular) is to increase ones "meta-awareness" both during and after the actual mediation session. Meta-awareness is the ability to be attentive to one's own thoughts and internal states without constantly becoming distracted/lost in the mental noise (Schooler et al., 2011). Meta-awareness (and the lack thereof) is proving to be closely related a series of brain structures (medial pre-frontal cortex, medial temporal lobes, anterior and posterior cingulate cortices, and other regions) known collectively as the "Default Mode Network" (DMN). The DMN is responsible for much of one's distracting resting-state mental activity: phenomena such as daydreaming, mental chatter, rumination, self-reflection, and various creative processes (Tryon et al., 2014). One of the brain regions that contributes to the DMN is the medial prefrontal cortex (mPFC), and it is found to have the greatest activity during one's baseline/resting state, decreasing in activity when attention is directed externally (Gusnard, Akbudak, Shulman and Raichle, 2001). This region is of great focus in meditation research and has been found in multiple studies to have decreased activity during meditation practice. It appears that overactivity of the DMN can hinder our ability to be meta-aware by amplifying distracting background mental activity and has been found to be implicated in mental illness (Fernandes Coutinho et al., 2016): especially those related to rumination, intrusive thoughts, and excessive self-reflection. Another mental technique exists that seems to utilize meta-awareness in parsing the stream of random mental activity flowing into our attentional field: this technique is known as Image Streaming. Image streaming is a

technique coined by Win Wenger Ph.D. 1996 in his book "*The Einstein Factor: A Proven New Method for Increasing Your Intelligence*" (Wenger and Poe, 1996 and involves actively observing and vocalizing the stream of visual stimuli flowing into our minds in as much detail as possible over a 10-30-minute session. Very little research on Image streaming exists, and the research that is out there is not incredibly academically rigorous in nature. Despite there being little research on Image Streaming, it seems to have much in common with meditation to the extent that it promotes the observation of mental activity (produced by the DMN) as it arises. It differs from conventional meditation in that it is about focusing solely on what is considered more of a distraction in the conventional forms of meditation.

---

**Mindfulness:**

The object of mindfulness meditation is to pay closer attention to the contents of consciousness, typically done by centering one's attention around what's known as an "object" of meditation. In mindfulness, this object is typically some bodily sensation such as the process of breathing, the feeling of one's feet making contact with the floor, the feeling of one's back-side making contact with the seat, the beating heart, etc. By diverting attention to one of these objects, one can notice all of the other stimuli (feelings, thoughts, sounds, smells, etc.) constantly popping into one's attentional field. Practice in mindfulness allows an individual to become more attentive to the present moment and more easily identify the distractions constantly stealing our attention in any given moment. Observing thoughts as they arise and viewing them more like an external stimulus than an internal one gives one the ability to not get as lost in them. Studies have been done that mindfulness meditation decreases activation of main DMN nodes, specifically the mPFC and posterior cingulate cortices (Brewer et al., 2011). Another study has demonstrated that mindfulness meditation results in reduced default mode network activity both during and after meditation

practice (Garrison et al., 2015). Overall, it seems the increased attention being diverted to the contents of consciousness decreases instances of mind-wandering, daydreaming, and mental noise.

**Transcendental Meditation/NDM:**

Transcendental meditation (TM) is a trademarked subset of the broader category of meditative practices known as "Non-directive meditation" (NDM). The purpose of NDM (specifically mantra based NDM such as TM) is to allow the wandering mind to "tire" itself out, allowing one to quickly and (nearly) effortlessly fall into a deep trance-like state in which almost all mind wandering ceases. This is also done using an object of meditation, but not in the way that mindfulness meditation uses objects. In mantra based NDM, one starts by chooses a "mantra", which is just some meaningless sound that lacks any subjective meaning to the individual (to avoid invoking any thoughts associated with a non-meaningless word). Once a mantra is selected, the individual starts repeating it to themselves (beginners typically start out-loud to get accustomed to how it's supposed to sound, but this isn't necessary for a more experienced practitioner), saying it progressively more quietly over time until the mantra is only being recited mentally. The goal from here is to effortlessly repeat the mantra in a manner similar to hearing an echo opposed to actively saying it (in the mind), allowing the mantra to change in volume, sound, or tempo naturally over time until it fades and eventually disappears. Once the mantra disappears, one may find themselves in a trance-like state in which almost all mental noise ceases but without any loss of consciousness. The most important aspect of NDM is the passive nature of its practice. One does not fight any distractions that may arise (they will almost constantly), simply notice the distracting stimuli in a manner similar to mindfulness meditation and then effortlessly recall the mantra to continue its mental repetition. Many studies have been done on the effects NDM has on the brain. One such study (Lagopoulos et al., 2009) demonstrated that twenty minutes of non-directive meditation increased theta-band oscillations across all brain regions, but mainly in the frontal and temporal regions. Alpha-band oscillations increased particularly in the posterior regions of the brain compared to frontal regions. Another study done (Brewer et al., 2011) demonstrates that NDM activates the default mode network and

areas associated with memory retrieval and emotional processing, which would make sense given the passive nature of NDM practice.

**Image streaming:**

Image streaming is a technique designed to increase one's mental visualization abilities and was popularized by the psychologist Wim Wenger in his book "The Einstein Factor". In Wenger's book, Image Streaming is presented as a method for increasing one's own IQ over many hours of practice. This is not what I am trying to examine in this experiment, rather, I would like to see how it affects neural activity compared to conventional meditation as well as a control. Image streaming is done by closing one's eyes, starting a tape recorder (this part isn't really necessary, its more for gauging progress), and vividly describing whatever mental activity is occurring in as much detail as possible, as quickly as possible. This technique promotes a sustained awareness of mental activity (as one must be paying attention to describe something), and it also promotes the mental activity itself. On its face, Image Streaming seems to just be controlled daydreaming/mind wandering. One study (Compton, Gearinger and Wild, 2019) demonstrates that mind wandering is characterized by increased alpha band frequency across various brain regions, however, this is also the case with both of the aforementioned styles of meditation practice.

I hypothesize that Image Streaming will produce an effect more closely resembling Nondirective meditation opposed to mindfulness. Based on the various studies on both mindfulness and NDM, though alpha band power increased in both groups, it has been demonstrated that NDM produced greater activation in default mode network regions compared to mindfulness meditation which only decreased the activation (lower frequency) of the default mode network. Mindfulness appears to be the opposite of daydreaming whereas nondirective meditation seems to use the random mental activity as a way to enter a deeper meditative state through "tiring out" the wandering mind. To validate my hypothesis, I must demonstrate that Image Streaming more closely represents nondirective meditation than mindfulness

meditation. My hypothesis will be verified if I demonstrate that Image streaming produces a greater percentage of theta band oscillations in the frontal and temporal lobes (as is found with NDM) compared to mindfulness. If Image Streaming turns out to be more like mindfulness, I would expect to see less theta and more alpha compared to NDM in the observed regions. I will examine the activity recorded from the AF7 and AF8 sensors, as these sensors correspond with the prefrontal cortex, as well as the TP9 and TP10 sensors, as these correspond with the temporal lobes.

---

**Participants:**

The participant included in this experiment was a 21-year old female. The mean age was 21 and the standard deviation was zero (as there was only one participant).

**Equipment:**

To record the cortical activity of the participants, I used the InteraXon Muse 2: Brain Sensing Headband, linking the output signal of the headband to iPhone application: Mind Monitor by James Clutterbuck. The Muse 2 contains four channels in addition to 3 reference sensors. The channels are (based on the 10-20 international standards) as follows TP9, AF7, AF8, TP10. The headband also contains 3 reference FpZ sensors.

**Procedure:**

The experimental procedure consisted of one preliminary practice session and three sessions for each of the three techniques, spread over the course of 3 days in total. For the preliminary practice session, the participant was taught how to perform Mindfulness meditation, Non-directive meditation, and Image Streaming. Each experimental session required the participant to sit stationary in a quiet room alone while engaging in the designated technique while having their EEG data recorded with the Muse 2 headband. Each session was performed at the participant's home, ensuring that they are in a comfortable and familiar environment. Once the sessions ended, the participant rated their meditative experience from 1-3(1: The session didn't feel productive at all, 2: I'm not sure, 3: I definitely felt as if the session was productive). The reasoning behind including this survey was that the participant was incredibly new to meditation practice and it typically takes a while to become proficient at these techniques. Having less data is preferable to having bad data from sessions the participant does not feel confident in, as improper technique would drastically affect the results. To account for this, I sessions rated as a 1 or a 2 from the data analysis section were excluded. Only the sessions that were rated as a 3 were included.

# Results

**Session Ranking**

Due to the participant only reporting Image Streaming session C, Mindfulness session B, and NDM session C, as satisfactory **(Table 1.)** and feeling as if the technique was performed successfully, these were the only sessions included in the data analysis.

**Hypothesis**

My hypothesis has three parts. A) The techniques will produce significantly different Alpha and Theta activities from one another. B) Image streaming will be less dissimilar to NDM compared to mindfulness. C) Image streaming will have greater theta activity in both frontal and temporal lobes compared to mindfulness. Alpha and Theta activity are quantified using the units muse chose to include in the .csv files produced.

**Data analysis**

*ANOVA*

One-way ANOVAs were conducted for each of the four sensors to determine if the differences in alpha waves were significant between techniques. There was a significant effect of meditative technique on alpha waves for each of the four sensors for each of the three conditions. The degrees of freedom, F-ratio, and p-value for AF7, AF8, TP9, and TP10 are respectfully as such: [ $F(2, 3654) = 30.32$, $p < 0.05$. ; $F(2, 3660) = 5.28$, $p < 0.05$. ; $F(2, 3654) = 81.81$, $p < 0.05$. ; $F(2, 3654) = 100.76$, $p < 0.05$. ]. (**Table 2,3,6,7)**

After the alpha waves were analyzed, one-way ANOVAs were also conducted for each of the four sensors to determine if the differences in theta waves were significant between meditation

groups. There was a significant effect of meditative technique on theta waves for each of the four sensors for each of the three conditions. The degrees of freedom, F-ratio, and p-value for AF7, AF8, TP9, and TP10 are respectfully as such: [ $F(2, 3654) = 62.80$, $p < 0.05$. ; $F(2, 3660) = 155.48$, $p < 0.05$. ; $F(2, 3654) = 59.10$, $p < 0.05$. ; $F(2, 3654) = 151.83$, $p < 0.05$. ]. (**Table 4,5,8,9)**

*T-Test*

Paired two sample t-tests were conducted for the both the alpha and theta activity for each sensor to test if the differences observed between Image streaming and either mindfulness or non-directive meditation (conducted for each) were significant.

In the paired samples t-test observing the **AF7** sensor, there was a significant difference in the amount of alpha activity between image streaming (M = -0.51, SD = 0.28 ) and mindfulness (M = -0.73, SD = 0.08 ), t and image streaming (M = -0.51, SD = 0.28 ) and NDM ( M =-0.45 , SD = 0.63), t(1220), {$p < 0.05$} ; as well as a significant differences in the amount of theta activity between image streaming ( M = -0.51, SD = 0.55) and mindfulness (M = -0.37, SD = 0.28), t(1220), {$p < 0.05$}; and image streaming(M = -0.51, SD = 0.55 ) and NDM( M = -0.22, SD = 0.78) , t(1220), {$p < 0.05$}; (**Table 10-11)**.

In the paired samples t-test observing the **AF8** sensor, there was a significant difference in the amount of alpha activity between image streaming (M = 0.01 , SD = 0.03 ) and mindfulness ( M = -0.03, SD = 0.13 ), t(1220), {$p < 0.05$} and image streaming ( M = 0.01, SD = 0.03 ) and NDM ( M =0.15 , SD = 0.05 ), t(1220), {$p < 0.05$} ; as well as a significant differences in the amount of theta activity between image streaming ( M = -0.74 , SD = 0.21 ) and mindfulness (M = -0.99 ,

SD = 0.22 ), t(1220), {p < 0.05} ; and image streaming( M = -0.74 , SD = 0.21 ) and NDM( M = -0.51 , SD = 0.003 ) , t(1220), {p < 0.05}; (**Table 10-11)**..

In the paired samples t-test observing the **TP9** sensor, there was a significant difference in the amount of alpha activity between image streaming ( M = 0.84 , SD = 0.32 ) and mindfulness ( M = 0.74 , SD = 0.01), t and image streaming (M = 0.84, SD = 0.32) and NDM (M = 0.89, SD = 0.05), t(1218) ; as well as a significant differences in the amount of theta activity between image streaming (M = 0.30 , SD = 0.29 ) and mindfulness (M = 0.19, SD = 0.20 ), t(1218), {p < 0.05} ; and image streaming( M = 0.30, SD = 0.19) and NDM (M = 0.21, SD = 0.20 ) , t(1218), {p < 0.05}; (**Table 10-11)**..

In the paired samples t-test observing the **TP10** sensor, there was a significant difference in the amount of alpha activity between image streaming (M = 0.86, SD = 0.34 ) and mindfulness ( M = 0.76, SD = 0.09 ), t(1218) and image streaming (M = 0.86, SD = 0.34 ) and NDM (M = 0.69, SD = 0.08 ), t(1218) ; as well as a significant differences in the amount of theta activity between image streaming (M = 0.29, SD = 0.37 ) and mindfulness (M = 0.28, SD = 0.28 ), t(1218), {p < 0.05}; and image streaming(M = 0.29, SD = 0.37) and NDM(M = 0.11, SD = 0.51) , t(1218), {p < 0.05} **(Table 10-11)**.

*Comparison of means*

For each sensor, the means of each frequency band (alpha or theta) were subtract between image streaming and each of the two other techniques (mindfulness and NDM). The differences were compared to find which difference was smaller, indicating which style of meditation image

streaming was closest to. For alpha activity, image streaming was more similar to NDM in the AF7 sensor (0.058 vs 0.222 for mindfulness) and the TP9 sensor (0.050 vs 0.101 for mindfulness). It was more similar to mindfulness in the AF8 sensor (0.047 vs 0.142 for NDM) and the TP10 sensor (0.10 vs 0.17 for NDM). For theta activity, image streaming was more similar to NDM in the AF7 sensor (0.06 vs 0.22 for mindfulness), AF8 sensor (0.23 vs 0.25 for mindfulness), and TP9 sensor (0.09 vs 0.11 for mindfulness). Image streaming was more similar to mindfulness in the TP10 sensor (0.01 vs 0.19). Overall, the differences were smaller (meaning they had greater similarity) between image streaming and NDM for five out of the eight sensors.

## Discussion

### Examining hypothesis

Addressing part-A of my hypothesis (That each technique would produce characteristic activity from one another), a one-way ANOVA was conducted to see if the mean spectral activity produced by each technique differed due to random chance (**Table 2-9)**. The ANOVA demonstrated that there was a significant effect of technique on spectral activity produced differences in EEG activity produced by image streaming, non-directive meditation, and mindfulness meditation were not due to random chance **(Table 2-9)**. Part-B of my hypothesis stated that the amounts of alpha and theta activity produced by image streaming would more closely resemble non-directive meditation compared to mindfulness meditation. The results of my comparative analysis of means showed that image streaming more closely resembled non-directive meditation in five out of the eight sensors examined (**Table 13**), discovered by comparing the differences in the mean power for each respective channel. When examining

alpha activity, image streaming proved to be more similar to NDM in the left frontal (AF7) and left temporal (TP9) sensors. For theta activity, image streaming was more similar to NDM in both frontal sensors (AF7 and AF8), as well as the right temporal sensor (TP10). Image streaming was only more similar to mindfulness in the right frontal (AF8) and right temporal (TP10) for alpha activity, as well as the right temporal (TF10) for theta activity. These results support part B-of my hypothesis, as the average activity recorded from the majority of the sensors during the image streaming trial matched NDM more closely than mindfulness. Part-C of my hypothesis stated that the image streaming would produce a greater amount of theta activity in all of the sensors (AF7,AF8,TP9,TP10) compared to mindfulness. The data collected **(Table 12-13)** supported this part of the hypothesis. Image streaming also produced more total theta activity than NDM did in both temporal sensors. For the frontal sensors, NDM produced the greatest amount of theta activity compared to both image streaming and mindfulness **(Table 12-13)**.

B) Comparing to past literature.

One study mentioned in the introduction (Lagopoulos et al., 2009) demonstrated that twenty minutes of non-directive meditation increased theta activity across all brain regions (primarily in the frontal and temporal regions) and increased alpha activity in the posterior regions of the brain compared to the frontal regions. These results were partially supported by the results of my experiment. Out of the three techniques, non-directive meditation resulted in the greatest amount of theta activity in the frontal lobes (AF7 and AF8), however, did not generate the most theta activity in the temporal lobes (TP9 and TP10) (Table 12). NDM actually generated the least theta activity in the right temporal sensor and was in between image streaming (greatest) and

mindfulness (least) for the TP9 sensor (Table 12). Another finding that supported the results of this study was the increased alpha activity from non-directive meditation. For NDM, alpha activity was greatest for all sensors except the TP10 sensor but was more powerful overall in the temporal sensors compared to the frontal ones (as demonstrated in the previous study (Lagopoulos et al., 2009)). Other studies referenced in the introduction incorporated fMRI to observe and quantify activity changes in default mode regions. Though it is possible to make parallels between increased amounts of spectral power in various regions and increase activity, I view my data as not being powerful enough to make such far reaching claims.

**Limitations of Study**

There were multiple design-flaws in this study that limited the quality and amount of data that could be collected. The primary design flaws were the small sample size, lack of experienced practitioners, small number of both practice and experimental sessions, and lack of an EEG device with more sensors to examine a wider range of brain regions. Firstly, the COVID-19 pandemic made it very difficult to find and recruit participants who would be willing to commit to multiple meditation practice sessions and recurring in-person meetings for data collection. As a remote student, most of the people that I would have included in this study were out of reach due to school restrictions on campus visitations, so I was limited to the immediate circle of people surrounding me. I had multiple recruits drop out of the study due to time restrictions or personal reasons involving unpleasant experiences meditating. I believe only having one participant performing three sessions (for each technique) does not allow for the actual differences between each technique to be properly identified. Secondly, for this study to have been conducted effectively, I believe subjects with more experience in each technique should

have been recruited. These techniques have an incredibly steep learning curve, so a few sessions worth of practice will not provide someone with enough experience to truly become proficient at the particular technique. Having a lack of proficiency in the technique prevents one from knowing whether or not they are actually doing the technique correctly. It is entirely possible that if recruited experienced meditators were recruited, the data would have been clearer (and more abundant due to having fewer faulty sessions). Many of the standard deviations obtained for each sensor were large compared to the means. I believe the lack of data clustering is due to only being able to use a single session for the statistical analysis. Finally, I view the EEG device's lack of sensors to be limiting in the ability to detect each technique's specific activity changes across the cerebral cortex. Luckily, much of the focus on the default mode network centers around the PFC and temporal regions (Gusnard, Akbudak, Shulman and Raichle, 2001). Despite this, the midline and posterior regions of the brain were left out of the analysis. It is entirely possible that some of the primary effects of image streaming could be seen in the visual areas of the cortex due to its emphasis on visualization, however, this would not be discoverable with only frontal and temporal sensors. Due to these limitations, I feel as if much of the data to be discovered was out of reach.

**Practical value of this research**

Developing a better understanding of meditative practices can give people a more diverse set of tools to use in the altering of our mental states and brain function. Many people are unaware of just how diverse the landscape of meditative practices actually is, potentially leading people to lump all forms of meditation together and overlook the individual benefits that each style possesses. Image streaming as a technique shows promise as a style of meditation similar in

nature to non-directive meditation, however, possessing less of a learning curve. Though NDM itself is not necessarily difficult, many beginners get discouraged when they notice themselves getting lost in distracting thoughts. Based on the results of this study, image streaming may serve as a way to produce similar levels of theta activity in the frontal and temporal lobes to NDM **(Table 13)** without the same fear of distraction (as the technique is basically observing and describing all of the distracting stimuli that exists in the mind at a given moment). Future studies would need to verify the efficacy of image streaming as an effective meditative practice, but if it is the case that it resembles NDM after more rigorous analysis, it could be an excellent meditation technique to get people started with meditation.

**Future Experiments**

For a future experiment, participants for both a mindfulness group and a non-directive meditation group should be recruited from established meditation practices to ensure that they have some formal training in each of the respective disciplines. Because there aren't any established image streaming organizations, each of the meditators in the mindfulness and NDM groups should be instructed on how to do the technique, and an image streaming group should be created from samples of both groups. Using both the mindfulness and NDM group for the image streaming group will allow intragroup differences in the characteristic spectral activity of image streaming to be observed. If those with training in both mindfulness and NDM consistently produce the same type of spectral activity while practicing image streaming, it will provide more supporting evidence for it being a distinguished practice of its own. Having a greater number of participants possessing a greater level of meditative ability would allow for more powerful statistical analyses to be performed. If each group contained a greater number of participants each highly

skilled in their respective techniques, the characteristic activity of each technique could be defined in greater detail and contrasted between that of the other techniques with greater ease. In addition to the modifications in the number and experience level of participants, instead of using the EEG device that was used in this experiment, an EEG device with sensors spanning the whole cerebral cortex should be used for measuring EEG data. With such a heavily visualization-based technique such as image streaming, I would like to see how some of the visual regions in occipital-lobe regions respond to its practice. Also, the experiment should consist of many more sessions (including more practice sessions) in order to have a larger dataset to analyze.

## Figures

| Session # | Image Streaming | Mindfulness | NDM |
|---|---|---|---|
| **A** | **1** | **2** | **2** |
| **B** | **2** | **3** | **2** |
| **C** | **3** | **2** | **3** |

*Table 1: Participant's ratings of each session from 1-3 (1 being the least confidence in performance and 3 being the most confidence in performance.)*

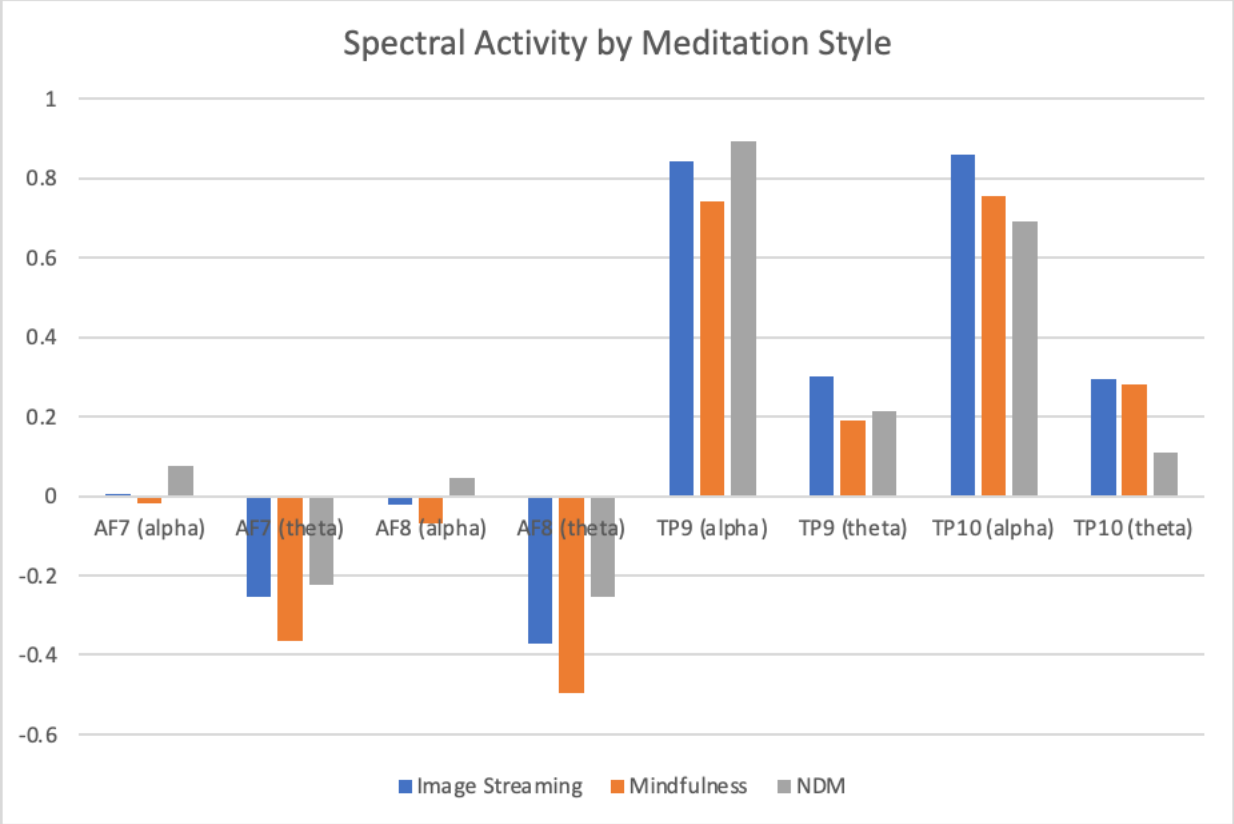


*Figure 1: Graph of mean values for each sensor. This graph represents the data found in table 12.*

## Supplemental Materials

### ANOVA

Anova: Single Factor (AF7 Alpha)

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Image Strea | 1219 | 7.607388787 | 0.00624068 | 0.091798006 |
| Mindfulness | 1219 | -21.342763 | -0.017508419 | 0.099197613 |
| NDM(Alpha_ | 1219 | 93.98690018 | 0.077101641 | 0.101259347 |

ANOVA

| *rce of Variat* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Gr | 5.90660719 | 2 | 2.953303594 | 30.31568942 | 8.74856E-14 | 2.998189668 |
| Within Grou | 355.966549 | 3654 | 0.097418322 | | | |
| Total | 361.873156 | 3656 | | | | |

*Table 2: ANOVA of alpha activity recorded AF7 for each technique*

Anova: Single Factor (AF8 alpha)

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Image Strea | 1221 | -50.75640419 | -0.041569537 | 0.636044838 |
| Mindfulness | 1221 | -164.2882898 | -0.134552244 | 5.646190023 |
| NDM(Alpha_ | 1221 | 111.03067 | 0.09093421 | 2.634749735 |

ANOVA

| rce of Variat | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Gr | 31.3581971 | 2 | 15.67909857 | 5.275022649 | 0.005156823 | 2.998185637 |
| Within Grou | 10878.7212 | 3660 | 2.972328198 | | | |
| Total | 10910.0794 | 3662 | | | | |

*Table 3: ANOVA of alpha activity recorded from AF8 for each technique.*

Anova: Single Factor (AF7 Theta)

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Image Strea | 1219 | -309.1799892 | -0.253634117 | 0.114877815 |
| Mindfulness | 1219 | -445.0681634 | -0.36510924 | 0.071461296 |
| NDM(Theta_ | 1219 | -273.9893051 | -0.224765632 | 0.133505109 |

ANOVA

| rce of Variat | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Gr | 13.3912923 | 2 | 6.695646143 | 62.80225556 | 0 | 2.998189668 |
| Within Grou | 389.57026 | 3654 | 0.10661474 | | | |
| Total | 402.961552 | 3656 | | | | |

*Table 4: ANOVA of theta activity recorded AF7 for each technique.*

Anova: Single Factor (AF8 Theta)

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Image Strea | 1219 | -452.0165652 | -0.370809323 | 0.120481563 |
| Mindfulness | 1219 | -603.4596094 | -0.495044798 | 0.079827487 |
| NDM(Theta_ | 1219 | -310.7058187 | -0.254885823 | 0.138973306 |

ANOVA

| rce of Variat | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Gr | 35.1677617 | 2 | 17.58388087 | 155.4800649 | 0 | 2.998189668 |
| Within Grou | 413.245908 | 3654 | 0.113094118 | | | |
| Total | 448.41367 | 3656 | | | | |

*Table 5: ANOVA of theta activity recorded from AF8 for each technique.*

Anova: Single Factor (TP9 Alpha)

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Image Streaming( Alpha_TP9 | 1219 | 1027.47069 | 0.84287998 | 0.06289912 |
| Mindfulness(Alpha_TP9) | 1219 | 903.994798 | 0.7415872 | 0.1210698 |
| NDM(Alpha_TP9) | 1219 | 1088.2953 | 0.89277711 | 0.08133324 |

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 14.4688558 | 2 | 7.23442788 | 81.8059049 | 0 | 2.99818967 |
| Within Groups | 323.138036 | 3654 | 0.08843405 | | | |
| Total | 337.606892 | 3656 | | | | |

*Table 6: ANOVA of alpha activity recorded from TP9 for each technique.*

| Anova: Single Factor (TP10 Alpha) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| SUMMARY | | | | | | |
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| Image Streaming(Alpha_TP10) | 1219 | 1046.16068 | 0.85821221 | 0.06472891 | | |
| Mindfulness(Alpha_TP10) | 1219 | 920.900649 | 0.75545582 | 0.10429537 | | |
| NDM(Alpha_TP10) | 1219 | 843.232803 | 0.69174143 | 0.08704144 | | |
| | | | | | | |
| | | | | | | |
| ANOVA | | | | | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 17.2004626 | 2 | 8.6002313 | 100.758095 | 0 | 2.99818967 |
| Within Groups | 311.888043 | 3654 | 0.08535524 | | | |
| | | | | | | |
| Total | 329.088506 | 3656 | | | | |

*Table 7: ANOVA of alpha activity recorded from TP10 for each technique.*

| Anova: Single Factor (TP9 Theta) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| SUMMARY | | | | | | |
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| Image Streaming(Theta_TP9) | 1219 | 368.945551 | 0.30266247 | 0.07879 | | |
| Mindfulness(Theta_TP9) | 1219 | 233.821448 | 0.19181415 | 0.05956684 | | |
| NDM(Theta_TP9) | 1219 | 260.366225 | 0.21359001 | 0.07508418 | | |
| | | | | | | |
| | | | | | | |
| ANOVA | | | | | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 8.40924762 | 2 | 4.20462381 | 59.097692 | 0 | 2.99818967 |
| Within Groups | 259.971158 | 3654 | 0.07114701 | | | |
| | | | | | | |
| Total | 268.380405 | 3656 | | | | |

*Table 8: ANOVA of Theta activity recorded from TP9 for each technique.*

| Anova: Single Factor (TP10 Theta) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| SUMMARY | | | | | | |
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| Image Streaming(Theta_TP10) | 1219 | 358.188189 | 0.29383773 | 0.08042962 | | |
| Mindfulness(Theta_TP10) | 1219 | 342.753534 | 0.28117599 | 0.09599084 | | |
| NDM(Theta_TP10) | 1219 | 132.771867 | 0.10891868 | 0.08060537 | | |
| | | | | | | |
| | | | | | | |
| ANOVA | | | | | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 26.0166932 | 2 | 13.0083466 | 151.833143 | 0 | 2.99818967 |
| Within Groups | 313.057464 | 3654 | 0.08567528 | | | |
| | | | | | | |
| Total | 339.074157 | 3656 | | | | |

*Table 9: ANOVA of Theta activity recorded from TP10 for each technique.*

| FRONTAL | | | | | |
|---|---|---|---|---|---|
| **ALPHA AF7** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | *Image Streaming (theta_AF7)* | *Mindfulness(Theta_AF7)* | | *Image Streaming (theta_AF7)* | *NDM(Theta_AF7)* |
| Mean | -0.506645055 | -0.729321405 | Mean | -0.506645055 | -0.448979014 |
| Variance | 78.27643632 | 162.0376066 | Variance | 78.27643632 | 61.51495954 |
| Observations | 1221 | 1221 | Observations | 1221 | 1221 |
| Pearson Correlation | 0.999070182 | | Pearson Correlation | 0.998004314 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1220 | | df | 1220 | |
| t Stat | 1.990577576 | | t Stat | -1.777233569 | |
| P(T<=t) one-tail | 0.023375077 | | P(T<=t) one-tail | 0.037889454 | |
| t Critical one-tail | 1.646103573 | | t Critical one-tail | 1.646103573 | |
| P(T<=t) two-tail | 0.046750154 | | P(T<=t) two-tail | 0.075778908 | |
| t Critical two-tail | 1.961910367 | | t Critical two-tail | 1.961910367 | |
| **ALPHA AF8** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | *Image Streaming(Alpha_AF7)* | *Mindfulness(Alpha_AF7)* | | *Image Streaming(Alpha_AF7)* | *NDM(Alpha_AF7)* |
| Mean | 0.012466026 | -0.03497382 | Mean | 0.012466026 | 0.154013843 |
| Variance | 0.138967299 | 0.471489116 | Variance | 0.138967299 | 7.323902735 |
| Observations | 1221 | 1221 | Observations | 1221 | 1221 |
| Pearson Correlation | -0.485393452 | | Pearson Correlation | 0.572774912 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1220 | | df | 1220 | |
| t Stat | 1.788615706 | | t Stat | -1.969442983 | |
| P(T<=t) one-tail | 0.036962388 | | P(T<=t) one-tail | 0.02456411 | |
| t Critical one-tail | 1.646103573 | | t Critical one-tail | 1.646103573 | |
| P(T<=t) two-tail | 0.073924777 | | P(T<=t) two-tail | 0.04912822 | |
| t Critical two-tail | 1.961910367 | | t Critical two-tail | 1.961910367 | |
| **THETA AF7** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | *Image Streaming (theta_AF7)* | *Mindfulness(Theta_AF7)* | | *Image Streaming (theta_AF7)* | *NDM(Theta_AF7)* |
| Mean | -0.506645055 | -0.729321405 | Mean | -0.506645055 | -0.448979014 |
| Variance | 78.27643632 | 162.0376066 | Variance | 78.27643632 | 61.51495954 |
| Observations | 1221 | 1221 | Observations | 1221 | 1221 |
| Pearson Correlation | 0.999070182 | | Pearson Correlation | 0.998004314 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1220 | | df | 1220 | |
| t Stat | 1.990577576 | | t Stat | -1.777233569 | |
| P(T<=t) one-tail | 0.023375077 | | P(T<=t) one-tail | 0.037889454 | |
| t Critical one-tail | 1.646103573 | | t Critical one-tail | 1.646103573 | |
| P(T<=t) two-tail | 0.046750154 | | P(T<=t) two-tail | 0.075778908 | |
| t Critical two-tail | 1.961910367 | | t Critical two-tail | 1.961910367 | |
| **THETA AF8** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | *Image Streaming (Theta_AF8)* | *Mindfulness(Theta_AF8)* | | *Image Streaming (Theta_AF8)* | *NDM(Theta_AF8)* |
| Mean | -0.740707567 | -0.988873271 | Mean | -0.740707567 | -0.509145392 |
| Variance | 167.183256 | 297.8407663 | Variance | 167.183256 | 79.07386563 |
| Observations | 1221 | 1221 | Observations | 1221 | 1221 |
| Pearson Correlation | 0.999520284 | | Pearson Correlation | 0.998755674 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1220 | | df | 1220 | |
| t Stat | 1.992195207 | | t Stat | -1.986667194 | |
| P(T<=t) one-tail | 0.023286102 | | P(T<=t) one-tail | 0.023591345 | |
| t Critical one-tail | 1.646103573 | | t Critical one-tail | 1.646103573 | |
| P(T<=t) two-tail | 0.046572203 | | P(T<=t) two-tail | 0.04718269 | |
| t Critical two-tail | 1.961910367 | | t Critical two-tail | 1.961910367 | |

*Table 10: paired two-sample t-test results for the frontal sensors. This table demonstrates that the differences we see between image streaming and either mindfulness or NDM are not due to random chance.*

| TEMPORAL | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **ALPHA TP9** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | | | | | |
| | *Image Streaming( Alpha_TP9)* | *Mindfulness(Alpha_TP9)* | | *Image Streaming( Alpha_TP9)* | *NDM(Alpha_TP9)* |
| Mean | 0.842879976 | 0.741587201 | Mean | 0.842879976 | 0.892777114 |
| Variance | 0.062899121 | 0.121069804 | Variance | 0.062899121 | 0.081333239 |
| Observations | 1219 | 1219 | Observations | 1219 | 1219 |
| Pearson Correlation | -0.04354422 | | Pearson Correlation | -0.00349459 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1218 | | df | 1218 | |
| t Stat | 8.080124399 | | t Stat | -4.579254913 | |
| P(T<=t) one-tail | 7.72776E-16 | | P(T<=t) one-tail | 2.57243E-06 | |
| t Critical one-tail | 1.646105627 | | t Critical one-tail | 1.646105627 | |
| P(T<=t) two-tail | 1.54555E-15 | | P(T<=t) two-tail | 5.14486E-06 | |
| t Critical two-tail | 1.961913566 | | t Critical two-tail | 1.961913566 | |
| **ALPHA TP10** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | | | | | |
| | *Image Streaming(Alpha_TP10)* | *Mindfulness(Alpha_TP10)* | | *Image Streaming(Alpha_TP10)* | *NDM(Alpha_TP10)* |
| Mean | 0.858212205 | 0.755455823 | Mean | 0.858212205 | 0.69174143 |
| Variance | 0.064728914 | 0.104295367 | Variance | 0.064728914 | 0.087041435 |
| Observations | 1219 | 1219 | Observations | 1219 | 1219 |
| Pearson Correlation | -0.146268091 | | Pearson Correlation | -0.072584245 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1218 | | df | 1218 | |
| t Stat | 8.165151506 | | t Stat | 14.41087696 | |
| P(T<=t) one-tail | 3.97502E-16 | | P(T<=t) one-tail | 6.84303E-44 | |
| t Critical one-tail | 1.646105627 | | t Critical one-tail | 1.646105627 | |
| P(T<=t) two-tail | 7.95003E-16 | | P(T<=t) two-tail | 1.36861E-43 | |
| t Critical two-tail | 1.961913566 | | t Critical two-tail | 1.961913566 | |
| **THETA TP9** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | | | | | |
| | *Image Streaming(Theta_TP9)* | *Mindfulness(Theta_TP9)* | | *Image Streaming(Theta_TP9)* | *NDM(Theta_TP9)* |
| Mean | 0.30266247 | 0.19181415 | Mean | 0.30266247 | 0.213590012 |
| Variance | 0.078789997 | 0.059566838 | Variance | 0.078789997 | 0.075084181 |
| Observations | 1219 | 1219 | Observations | 1219 | 1219 |
| Pearson Correlation | 0.03349412 | | Pearson Correlation | -0.122259432 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1218 | | df | 1218 | |
| t Stat | 10.5816998 | | t Stat | 7.483808178 | |
| P(T<=t) one-tail | 2.141E-25 | | P(T<=t) one-tail | 6.89478E-14 | |
| t Critical one-tail | 1.646105627 | | t Critical one-tail | 1.646105627 | |
| P(T<=t) two-tail | 4.28201E-25 | | P(T<=t) two-tail | 1.37896E-13 | |
| t Critical two-tail | 1.961913566 | | t Critical two-tail | 1.961913566 | |
| **THETA TP10** | | | | | |
| t-Test: Paired Two Sample for Means | | | t-Test: Paired Two Sample for Means | | |
| | | | | | |
| | *Image Streaming(Theta_TP10)* | *Mindfulness(Theta_TP10)* | | *Image Streaming(Theta_TP10)* | *NDM(Theta_TP10)* |
| Mean | 0.293837726 | 0.281175992 | Mean | 0.293837726 | 0.108918677 |
| Variance | 0.080429623 | 0.095990841 | Variance | 0.080429623 | 0.080605368 |
| Observations | 1219 | 1219 | Observations | 1219 | 1219 |
| Pearson Correlation | 0.011326147 | | Pearson Correlation | -0.161132129 | |
| Hypothesized Mean Difference | 0 | | Hypothesized Mean Difference | 0 | |
| df | 1218 | | df | 1218 | |
| t Stat | 1.05848413 | | t Stat | 14.9307827 | |
| P(T<=t) one-tail | 0.145022326 | | P(T<=t) one-tail | 1.01698E-46 | |
| t Critical one-tail | 1.646105627 | | t Critical one-tail | 1.646105627 | |
| P(T<=t) two-tail | 0.290044652 | | P(T<=t) two-tail | 2.03396E-46 | |
| t Critical two-tail | 1.961913566 | | t Critical two-tail | 1.961913566 | |

*Table 11: paired two-sample t-test results for the temporal sensors.*

| Sensor | Image Streaming | Mindfulness | NDM |
|---|---|---|---|
| AF7 (alpha) | 0.00624068 | -0.017508419 | 0.077101641 |
| AF7 (theta) | -0.253634117 | -0.36510924 | -0.224765632 |
| AF8 (alpha) | -0.020810334 | -0.067358872 | 0.04552303 |
| AF8 (theta) | -0.370809323 | -0.495044798 | -0.254885823 |
| TP9 (alpha) | 0.842879976 | 0.741587201 | 0.892777114 |
| TP9 (theta) | 0.30266247 | 0.19181415 | 0.213590012 |
| TP10 (alpha) | 0.858212205 | 0.755455823 | 0.69174143 |
| TP10 (theta) | 0.293837726 | 0.281175992 | 0.108918677 |

*Table 12: Mean values for each sensor. (muse units)*

| MEAN DIFFERENCES | | | |
|---|---|---|---|
| **AF7: ALPHA** | | **AF8: ALPHA** | |
| IMAGE-MINDFUL | 0.22267635 | IMAGE-MINDFUL | 0.047439847 |
| IMAGE-NDM | 0.05766604 | IMAGE-NDM | 0.141547816 |
| | | | |
| | | | |
| **AF7: THETA** | | **AF8: THETA** | |
| IMAGE-MINDFUL | 0.22267635 | IMAGE-MINDFUL | 0.248165703 |
| IMAGE-NDM | 0.05766604 | IMAGE-NDM | 0.231562176 |
| MEAN DIFFERENCES | | | |
| **TP9: ALPHA** | | **TP10: ALPHA** | |
| IMAGE-MINDFUL | 0.10129278 | IMAGE-MINDFUL | 0.102756382 |
| IMAGE-NDM | 0.04989714 | IMAGE-NDM | 0.166470775 |
| | | | |
| | | | |
| **TP9: THETA** | | **TP10: THETA** | |
| IMAGE-MINDFUL | 0.11084832 | IMAGE-MINDFUL | 0.012661734 |
| IMAGE-NDM | 0.08907246 | IMAGE-NDM | 0.18491905 |

*Table 13: Differences between Image streaming and 'X' technique. The smaller number is the technique image streaming was most similar to. The smaller values were highlighted for clarity.*

Citations


1. Tryon, W. W. (2014). Core Network Principles. *Cognitive Neuroscience and Psychotherapy*.

2. Fernandes Coutinho, J., Veiga Fernandes, S., Soares, J. M., Maia, L., Goncalves, O. F., Sampaio, A. (2016). Default mode network dissociation in depressive and anxiety states. *Brain*

3. Wenger, W. and Poe, R., n.d. *The Einstein Factor*.

4. Gusnard, D., Akbudak, E., Shulman, G. and Raichle, M., 2001. Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences*, 98(7), pp.4259-4264.

5. Brewer, J., Worhunsky, P., Gray, J., Tang, Y., Weber, J. and Kober, H., 2011. Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences*, 108(50), pp.20254-20259.

6. Garrison, K., Zeffiro, T., Scheinost, D., Constable, R. and Brewer, J., 2015. Meditation leads to reduced default mode network activity beyond an active task. *Cognitive, Affective, & Behavioral Neuroscience*, 15(3), pp.712-720.

7. Schooler, J., Smallwood, J., Christoff, K., Handy, T., Reichle, E. and Sayette, M., 2011. Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*,.

8. Compton, R., Gearinger, D. and Wild, H., 2019. The wandering mind oscillates: EEG alpha power is enhanced during moments of mind-wandering. *Cognitive, Affective, & Behavioral Neuroscience*, 19(5), pp.1184-1191.
9. Mohan, A., Roberto, A. J., Mohan, A., Lorenzo, A., Jones, K., Carney, M. J., Liogier-Weyback, L., Hwang, S., & Lapidus, K. A. (2016). The Significance of the Default Mode Network (DMN) in Neurological and Neuropsychiatric Disorders: A Review. *The Yale journal of biology and medicine*, *89*(1), 49–57.
10. Lagopoulos, J., Xu, J., Rasmussen, I., Vik, A., Malhi, G., Eliassen, C., Arntsen, I., Sæther, J., Hollup, S., Holen, A., Davanger, S. and Ellingsen, Ø., 2009. Increased Theta and Alpha EEG Activity During Nondirective Meditation. *The Journal of Alternative and Complementary Medicine*, 15(11), pp.1187-1192.