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Alexandria Hudeck  
ahudeck@bgsu.edu

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The effects of mindfulness meditation on electroencephalogram (EEG) asymmetry

Alexandria V. Hudeck

HONORS PROJECT

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\_\_\_\_\_, Advisor

Sherona Garrett-Ruffin, Psychology Department

\_\_\_\_\_, Advisor

Kei Nomaguchi, Sociology Department

### **Abstract**

This study examines the effects of a brief 20-minute single-session mindfulness meditation session on electroencephalogram (EEG) asymmetry, as well as the positive and negative affect scale (PANAS). It was hypothesized that mindfulness meditation would significantly decrease negative emotions through an increase of alpha band wavelengths to the right hemisphere and thereby resulting in greater left hemispheric activity. The results from the experiment using 10 Bowling Green State participants demonstrated that there was no significant difference between the mindfulness condition and the comparison condition in any of the dependent variables. Strengths and limitations of this study were discussed.

## **Introduction**

Clinical psychologists have developed a number of therapies to reduce stress and promote mental and physical health. Forms of emotional regulation are shown to help improve mental states (Yang et al., 2016)- This study is meant to help demonstrate the effects of a brief single mindfulness meditation session on a physiological measurement by assessing alpha band brain waves and self-reported emotion.

Using electroencephalogram (EEG) asymmetry and the Positive and Negative Affect Scale (PANAS), it is hypothesized that 1) mindfulness meditation will significantly decrease negative emotions through an increase of alpha band wavelengths in the right hemisphere (left hemispheric activity < right hemispheric activity) and 2) there will be a significant difference in positive and negative affect between the mindfulness and comparison conditions. Specifically, the positive affect score will increase and the negative affect will decrease for the mindfulness condition.

## **Electroencephalogram EEG**

Electroencephalogram (EEG) is designed to measure the electric currents in the brain through the use of electrodes and conductive gel (Teplan, 2002). Through EEG measurements, researchers are able to measure alpha (8-13 Hz), beta (13-30 Hz), theta (4-8 Hz), and delta (0.5-4 Hz) waves. Each wave corresponds to a particular brain and body experience. Alpha waves (8-13 Hz) activity occurs during relaxed, eyes closed conditions with an amplitude of about 50  $\mu$ V (Papousek, 2014). The increase of alpha waves in one hemisphere demonstrates that the other hemisphere is becoming more alert and aware compared to the other.

## **EEG asymmetry**

By using EEG, researchers can measure the amplitude of alpha waves in both the left and right hemispheres of the brain. Approach and stress regulation emotions correlate with more activity in the left hemisphere (Goodman et al., 2013; Coan & Allen, 2004). Papousek (2014) suggested that approach, or positive, emotions correlate with more activity in the left hemisphere, while avoidance, or negative, emotions correlate with more activity in the right hemisphere. Higher alpha wave amplitudes are indicative of lower activity in one hemisphere, as the function of alpha is primarily drowsiness and decreased awareness (Gollan et al., 2015). Because positive emotions are associated with activity in the left hemisphere, it can be assumed that there will be higher alpha wave amplitudes in the right hemisphere when a person is in a positive or attentive mood.

### **Mindfulness Meditation**

Mindfulness meditation is derived from Buddhism and involves keeping one's mind focused, being nonjudgmental, and removing one's mind from negative emotions and ideas (Ratanasiripong et al., 2015). Mindfulness meditation also is defined as when an individual focuses strongly on their body sensations and the way they are thinking and feeling (Hardy, 2015). Mindfulness meditation requires attentional and emotional self-regulation (Tang et al., 2015). Past researchers have shown that mindfulness meditation is strongly correlated with positive affect and decreasing stress (Aldao et al., 2010). Specifically, it has been linked to improvements in emotional regulation and a significant reduction of stress and anxiety (Fiore et al., 2013; Tang et al., 2015).

Mindfulness is meant to bring a participant's attention to their body and themselves. This is not meant to be a distraction or a mental mind task; mindfulness is meant to bring focus and emotional regulation to oneself in the present moment (Brown et al., 2003; Bueno et al., 2015).

Mindfulness is not a mere distraction but a form of deep concentration on oneself and their present emotions. For this reason, the comparison group for this study completed psychological questionnaires, a task that did not require deep concentration or focus on emotional regulation, but was still a mentally active task.

### **EEG and Mindfulness Meditation**

Mindfulness meditation and EEG asymmetry is a highly studied research topic. It can be assumed that mindfulness elicits changes in alpha wave amplitudes in the different hemispheres, contingent on feeling a particular emotion and being aware and attentive. Goodman (2013) concludes that emotional regulation during stress can be measured using EEG asymmetry, because of evidence supporting functional lateralization in affective processing, with the left frontal lobe involved in the management of the stress response and the right frontal lobe involved in sympathetic activation occurring during stress. This suggests that using EEG asymmetry can be used to measure stress levels.

Aldao et al. (2010) found that mindfulness promotes emotional regulation, as well as it improves the individual's emotional experience. This suggests that mindfulness in itself can create a positive emotional state that also involves being aware of the emotion. With this association between positive emotional awareness and mindfulness, Watford (2015) suggested that mindfulness can promote a more approach-related motivational stance and therefore result in a higher left brain activation over right brain activation.

Davidson et al. (2003) conducted one of the first experiments associating mindfulness meditation and EEG asymmetry. Davidson found a significant change in prefrontal asymmetry after intensive mindfulness. Davidson et al. (2003) and Barnhofer et al. (2010) also concluded

that there was a significant change in asymmetry, with increases in left-sided activation. This further demonstrates that mindfulness may facilitate approach tendencies.

Overall, previous researchers have significant relationships between EEG asymmetry, particularly increased alpha wave amplitudes in the right hemisphere and increased activity in the left hemisphere, and approach and positive emotions and mindfulness mediation.

### **Current Study**

As stated previously, mindfulness meditation can help decrease stress and promote positive affect in participants (Yang et al., 2016). The past research has been fairly consistent in the types of meditation used. This current study will add to the previous literature on the topic of mindfulness. In line with previous research, I studied the impact of mindfulness meditation on EEG asymmetry and self-reported mood. I modified my research by using a brief single mindfulness session and a novel comparison condition. The comparison condition involved participants completing a series of questionnaires. The comparison task required focus, but not necessarily on emotion and was a mentally active task. This makes my research original, as this particular study has never been done.

### **Participants**

The participants were individuals from Bowling Green, Ohio. I recruited 10 participants by using the Bowling Green State University (BGSU) SONA recruitment system, offering 2 SONA credits, or offering a \$15.00 electronic amazon gift card. Due to this limiting aspect of recruitment, majority of my participants were Caucasian, with the exception of two participants being African American. The age range of the participants was 18 to 23 ( $M_{\text{age}}=20$ ). There were 5 female participants and 5 male participants. Participants with a history of anxiety attacks, asthma/breathing related problems, or any skin sensitivities were excluded. Individuals were not

able to participate in the study if they were under the age of 18 or over the age of 65 or consumed nicotine/caffeine within 30 minutes or alcohol within 24 hours prior to the study. Each participant experienced both the experimental and control conditions. The conditions took place on the same day and because of the nature of the study, I counterbalanced the orders – i.e., because all subjects received both conditions, the order they received the conditions was interchanged. The university human subject review board approved the study and an informed consent form was signed and obtained from all participants.

## **Materials**

To measure the participants' EEG alpha amplitudes and eye blinks (potential artifacts in the EEG data), an electroencephalogram (EEG) and electrooculogram (EOG) signals were detected and amplified using a BiopacMP150 acquisition unit. A Dell desktop computer with Windows Vista as the operating system was used to display the data. Acknowledge 4.2 software was used to record and analyze the EEG and EOG data. The software was programmed with a 60 Hz notch filter to eliminate “noise,” such as that of electrical outlets. Recordings of EEG waves and eye blinks was obtained through the Biopac150 Acknowledge 4.2 acquisition unit and digitized at a sampling rate of 1,000 Hz. The raw EEG was band-pass filtered into the alpha (8-13 Hz) frequency band. The frequency band was segmented into 1-second epochs, with each epoch subject to Fast Fourier Transformation to derive absolute power data. Due to nonlinearity, all data was log transformed.

As a self-report measure, the participant was given the Positive and Negative Affect Scale (PANAS) (Figure 1). I gave the PANAS and manipulation check after each condition (See Appendix, Figure 1 & 2). Watson (1994) originally validated the PANAS scale and it has been used since as a reliable measure of positive versus negative affect with participants self-reporting



their emotion in response to the given condition. Each emotion was scored from 1-5, depending on the strength of the emotion, 1 being very slightly or not at all and 5 being extremely. The total scores range from 10-50 for both the positive and negative affect score, and the higher the score, the more positive or negative that affect was. I used the PANAS as a supplementary measure of emotion besides the EEG. A positive and negative affect score was computed for each participant after each of the two conditions (see the Procedure section below for more detail).

For the comparison condition, I gave participants the Interpersonal Reactivity Index (IRI), the Attentional Control Scale (ACS), the Behavioral Inhibition/Approach Scale (BIS/BAS), and the State-Trait Anxiety Inventory (STAI). These were not used as a measurement that was to be calculated, but rather as a condition that did not require any deep mindful emotional and bodily awareness.

The video used for the mindfulness meditation treatment stimulus was the Body Scan Mindfulness Meditation conducted by Gerry Mobbs (2015). Although not validated through any published research, I conducted a previous experiment with this video and found significant results in reduced stress (Hudeck, 2015). The video was approximately 24 minutes long.

## **Procedure**

The participants were first led into an empty room with dimmed lights with only I, the researcher, present. The participant read through the informed consent and I then verbally asked the participant if they had any questions about the form or if they had any questions about anything involving the form or the study. After the participant signed the informed consent, I began to set up the EEG. I started by identifying the EEG areas that the electrodes were placed on F3 and F4 (active) using the 10/20 international electrode placement system (Teplan, 2002), with linked ear references (Papousek 2014). Active electrodes were also placed above the

eyebrow (reference), below the eye (ground), and to the side of the eye (active) to measure eye blinks. I measured eye blinks so possible eye-blink artifacts could be removed.

Before placing the EEG electrodes, I abraded the skin to remove any dead skin cells from the head and ears to optimize the EEG reading. The reference electrodes were first placed on both ears, in order to have good connection and applying electro-gel to the sites. The cap with electrodes attached was secured to the participants' head, with active sites at F3 and F4, with linked ear references. Accordingly, electro-gel was inserted into the active sites, as well as the ground. The participant then attached a belt around their torso to clip the cap to. This was to ensure a strong and close connection with the electrodes and scalp.

Next I checked that the Biopac system was turned on and ready to conduct readings. After opening the software, I checked that all the leads were correctly attached to the proper channels, the sampling rate was 1,000 samples per second, and the EEG recording would be displayed. To determine the level of impedance, or resistance from the electrode connection, I conducted an electrode check. This check ensured that there was a good connection between the skin and electrodes. I aimed for the impedance to be under 10  $\Omega$ K. Every participant participated in both the mindfulness and comparison conditions, with counterbalancing to ensure internal validity and help eliminate carry over effects.

To begin and prepare the experimental condition, I pulled up the mindfulness meditation video (Mobbs, 2105) on the computer screen and prepared it to be played. For the comparison condition, I gave the participant the corresponding questionnaires and pen.

After I determined that I had prepared the treatments correctly, I started the EEG and EOG measurements again and began giving the appropriate treatment. For the mindfulness condition, I instructed the participant to follow the directions of the video without moving as

much as possible. For the comparison condition, I instructed the participant to fill out the questionnaires given to them, and if they completed them early to re-read them. I informed participants before both conditions that they would continue in the condition for about twenty minutes. The conditions both lasted twenty minutes because that was the duration of the mindfulness meditation video and I attempted to keep the comparison condition consistent with the treatment condition to eliminate a possible confound.

After each condition was complete, I conducted two minutes of EEG and EOG recording. Then I asked the participant to complete the PANAS and a self-report after each condition. I then removed the cap and EOG electrodes. After all the equipment was removed, the participant was free to leave after a debriefing.

### **Statistical Analysis**

The means and standard deviations of the alpha band wavelengths were determined for the positive and negative subscales of the PANAS, as well as the EEG asymmetry score.

EEG asymmetry scores were calculated for both right and left hemispheres using the Acknowledge 4.0 software. EEG wavelengths were first separated into individual wavelengths (alpha, beta, theta, etc.) using an algorithm from the software. The alpha waves were evaluated and both hemispheric scores were then transformed into a logarithm to assure the data would fall into a normal curve, based on the requirements of t-tests using an SPSS program. After the scores were transformed into log base 10, subtracting the left hemispheric score from the right hemispheric score ( $\text{Log [LH]} - \text{Log [RH]}$ ).

Using SPSS, three paired-sample t-tests were run. A t-test was run for each dependent variable. The dependent variables were positive affect, negative affect, and EEG asymmetry and the independent variable had two levels: the comparison and mindfulness conditions. I decreased

the *alpha* ( $\alpha$ ) value from ( $p = .05$ ) to ( $p = .0167$ ) because multiple t-tests were being conducted. Dividing a typical *alpha* value ( $p = .05$ ) by the number of tests being run (3) accounted for possible increased Type 1 error due to multiple tests that were run.

## Results

The results indicated that the hypotheses were not supported. A paired samples t-test was conducted to evaluate the impact of the mindfulness meditation on participants' positive affect scores. There was no statistically significant difference between the mindfulness group ( $M_{\text{meditation}} = 19.6$ ,  $SD = 5.06$ ) and the comparison group ( $M_{\text{comparison}} = 21.2$ ,  $SD = 4.211$ ),  $t(9) = -.979$ ,  $p = .353$  (two-tailed). Interestingly, the comparison group had higher levels of positive affect as compared to the mindfulness group. A paired samples t-test was conducted to evaluate the impact of the mindfulness meditation on participants' negative affect scores. There was no statistically significant difference between the mindfulness group ( $M_{\text{meditation}} = 11.3$ ,  $SD = 1.57$ ) and the comparison group ( $M_{\text{comparison}} = 11.5$ ,  $SD = 1.65$ ),  $t(9) = -.375$ ,  $p = .442$  (two-tailed). A paired samples t-test was conducted to evaluate the impact of the mindfulness meditation on participants' EEG asymmetry scores. There was no statistically significant difference between the mindfulness group ( $M_{\text{meditation}} = 0.506731$ ,  $SD = .534$ ) and the comparison group ( $M_{\text{comparison}} = 0.4024829$ ,  $SD = .447$ ),  $t(9) = -.375$ ,  $p = .442$  (two-tailed). Interestingly, the alpha amplitudes were greater in the left hemisphere of the mindfulness group, which is indicative of more right hemispheric activity and greater negative affect, which was contrary to my prediction.

## Discussion

The results of this study do not support the hypotheses and do not support the previous literature. There was no significant difference between the mindfulness and comparison condition in any of the dependent variables – EEG asymmetry, positive affect, and negative

affect. Furthermore, for two of the three variables, the scores actually went the opposite direction that was predicted. The second hypothesis was partially supported because the positive affect scores actually increased with the comparison condition (contrary to my hypothesis), but the negative affect scores decreased for the mindfulness condition. The lack of significant difference between the two conditions could be attributed to many factors.

The lack of statistical significance for all three measures may be explained by a weak manipulation. The mindfulness meditation used may not have actually been delivering mindfulness. Furthermore, this mindfulness protocol may have been too relaxing thereby creating a lethargic state. As alpha band wavelengths are typically increased during a drowsy state, this manipulation could have made a general increase in alpha waves across the whole brain, creating a ceiling effect and no significant differences across the two groups.

Another explanation for the lack of differences between the groups is the time of year. Because the experiment was done in the last few weeks of the semester, many of the students were extremely tired from midterms and final papers. This could have led to a ceiling effect as well, with the participants' alpha band wavelengths being so high the mindfulness meditation did not have enough strength to create a difference.

Moreover, this study was only made up of ten participants. This is an extremely small sample size and therefore it can be extremely hard to find significant effects, especially with EEG readings. There is tremendous variability in EEG readings that without more participants, it is extremely difficult to find trends in the data yielding significant results without an exceptionally strong manipulation. Additionally, this sample size was not very diverse, and therefore can only be generalized to Bowling Green State University students.

Lastly in terms of limitations, the PANAS scale emotions could have confused the participants. Many of the emotions listed were not seen as positive or negative, but rather neutral. For example, many people scored very highly on 'interested' and 'active' during the comparison group, as they were more physically active during the condition. These emotions, though seemingly neutral, were scored as a positive emotion on the PANAS. These high scores on certain positively scored emotions could attribute to the scores increasing in the opposite direction that was predicted.

Although this study had some limitations, there were also many pieces of this study that helped create a good experiment. For example, precautions were taken to ensure that the data that was being measured was truly EEG recordings. The EOG was used to eliminate eye blink artifacts, as well as the 60 Hz notch filter to eliminate potential artifacts from the electrical outlets in the room. I also used a well-validated measure of measure of positive and negative affect. Furthermore, every participant was treated exactly the same, specifically in terms of the mindfulness condition. A video was used to ensure that every participant received the exact same mindfulness to help ensure internal validity. Internal validity was also better established through the counterbalancing of the study to help eliminate any possible carry-over effects. I attempted to make sure that the mindfulness meditation was truly the only factor making any possible changes in the dependent variables.

Researchers build upon one another to help design better experiments and find significant results. A larger sample size and a stronger, or less sedentary, mindfulness condition, such as yoga, could also be used to improve this research. Ensuring that the essential elements of mindfulness (i.e. alertness, focus on oneself and emotional experience) might create alpha

wavelength difference between hemispheres consistent with positive affect. Additionally, a comparison between different mindfulness conditions could also be a very interesting study.

Overall, the hypotheses were not supported. The lack of significance can be attributed to many limitations; however the study had many strengths, as well. The results did not reflect previous literature; however the method used can be built upon to create a better and more influential study.

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**Figure 1****Questionnaire**

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you feel this way right now.

1	2	3	4	5
Very Slightly or Not at All	A Little	Moderately	Quite a Bit	Extremely

_____ 1. Interested	_____ 11. Irritable
_____ 2. Distressed	_____ 12. Alert
_____ 3. Excited	_____ 13. Ashamed
_____ 4. Upset	_____ 14. Inspired
_____ 5. Strong	_____ 15. Nervous
_____ 6. Guilty	_____ 16. Determined
_____ 7. Scared	_____ 17. Attentive
_____ 8. Hostile	_____ 18. Jittery
_____ 9. Enthusiastic	_____ 19. Active
_____ 10. Proud	_____ 20. Afraid

**Scoring Instructions:**

Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19.

Scores can range from 10 – 50, with higher scores representing higher levels of positive affect.

Mean Scores: Momentary \_ 29.7 ( *SD* \_ 7.9); Weekly \_ 33.3 ( *SD* \_ 7.2)

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20.

Scores can range from 10 – 50, with lower scores representing lower levels of negative affect.

Mean Score: Momentary \_ 14.8 ( *SD* \_ 5.4); Weekly \_ 17.4 ( *SD* \_ 6.2)