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The Relationship Between Time of Day, Mood, and
Electroencephalography (EEG) Asymmetry

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HONORS PROJECT

Submitted to the Honors College
Bowling Green State University in partial
Fulfillment of the requirements for graduating with

UNIVERSITY HONORS

May 2nd, 2016

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Abstract

Previous researchers have had success in finding a correlation between exercise and an increase in positive mood. Researchers have also found a correlation between time of day and mood. The current study will explore the relationship between time of day, mood, and electroencephalography (EEG) asymmetry. The study utilized a convenient sample of ten undergraduate students at Bowling Green State University. Participants had baseline EEG recordings taken, and then participated in moderate exercise, followed by another EEG recording. Participants' mood was assessed through a self-reported mood questionnaire before the condition as well as immediately after. Due to multiple statistical tests, the alpha level for rejection of the null hypothesis was set at .016. While no statistically significant differences were found, the difference between baseline EEG asymmetry and post-task EEG asymmetry approached significance. Specifically, there was greater left hemispheric activity post-task which is indicative of a more positive mood.

INTRODUCTION:

EEG asymmetry and Mood

The purpose of this review is to summarize the research on electroencephalogram (EEG) asymmetry and mood. Research presented in this review will help the reader understand the current knowledge on the subject.

An electroencephalogram (EEG) was used to measure electrical activity in the brain by attaching electrodes to the scalp to detect electrical activity. In regards to EEG asymmetry and mood, researchers have historically studied the alpha band (8-13 Hz). In the first recordings taken from the scalp by Berger in the 1920's, a wave around 10 cycles per second was observed and later named the alpha rhythm. This rhythm is used as an indirect measure of mood (Goldman et al. (2012)). Alpha activity (8-13 Hz) is linked to a wakeful, relaxed and alert state (Goldman et al. 2012). The highest alpha rhythm amplitude is seen when the eyes are closed and the participant is relaxed. Because of this, the loss of alpha rhythm is used to determine the first stages of sleep (Goldman et al. 2012). Asymmetry refers to the difference in electrical activity between the left and right hemispheres. Typically, to assess mood researchers measure the difference in alpha amplitude between the right and left hemispheres (Hall (2007); Schneider (2009); Aprea and Tantillo (2015)). A higher amount and amplitude of alpha activity is indicative of less brain activity, such that a high alpha reading in the right hemisphere means there is less activity in that area. In a study using PET scans, researchers found that the thalamus, visual cortex, and lateral geniculate are involved in generation of the alpha rhythm (Sadato et al. 1998).

To determine the meaning of alpha activity, research regarding alpha activity and mood was needed. Raymond et al. (2005) completed a neurofeedback study to investigate the role of the alpha rhythm on mood states. The participant received positive reinforcement when alpha wave amplitudes decreased in the left

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hemisphere. It was shown that those who received the positive feedback reported a significantly higher amount of energy than those who received mock feedback. Additionally, those who received real feedback showed an increase in positive mood, as indicated by the Profile of Mood States (POMS) questionnaire, and stated that they felt more composed, agreeable, elevated and confident after the trial. From this information, researchers inferred that less alpha rhythm activity in the left hemisphere correlates with a more positive mood state. Indeed, a robust finding in the literature is that positive mood is associated with greater left hemispheric activity (Raymond et al., 2005

Exercise and Mood

Researchers have found positive correlations between exercise and an individual's mood. Hall (2007) and Schneider (2009) completed experiments where the mood was predicted after various exercises based on hemispheric dominance. The researchers measured EEG asymmetry patterns prior to any exercise, and using those patterns predicted how participants would feel after moderate and vigorous exercise. The researchers used an electrocap to record from nine scalp locations. These locations were left, right, mid-frontal, central, and parietal. In order to reduce artifacts, Hall measured EOG (electro-oculogram) activity on both eyes. Both Hall (2007) and Schneider (2009) found a correlation between those who were left-brain dominant and a more positive mood following the exercise. The next step was to investigate specific regions of the brain and how activity within them differs with exercise.

EEG Asymmetry and Exercise

Schneider et al. (2009) conducted an experiment to test the correlation between frontal cortical asymmetry and response to exercise. The researchers found that, when moderate exercise was performed, a more positive affect was seen through more activity in the left hemisphere. Asymmetry was measured using EEG alpha activity, placing the electrodes at F3 and F4, P3 and P4 using the International 10-20 system. The researcher used a younger population (ages 14-16) because previous studies linking EEG asymmetry and mood were limited to adults. Their findings could then be generalized to adolescents, thereby extending the

relationship between EEG asymmetry and mood to a different population. The researchers, however, failed to test EEG asymmetry before each trial. Trials were about one week apart, and a lot may change for a high school student within a week. It seems that when they were tested and determined to have, for example, left hemisphere dominance at the first testing, this could have changed by the next week. The internal validity of the experiment may have been compromised, because the researchers did not eliminate the possibility that an outside variable was affecting the results. To help eliminate this, the trials could have been closer together, such as a day or two apart to help eliminate the possibility of an outside event-affecting mood.

In the studies discussed earlier in this review the researchers focused on mood changes in response to exercise among healthy individuals, which brings up the issue of whether exercise can be a treatment for individuals with certain mood disorders, such as depression and anxiety.

Another robust finding in the literature is that exercise reduces depression (Bercer, 1983, Brown et. al, 1978, Folkins, 1981, Klein et al., 1985, and Jasnoski et. al, 1988). These studies, however, are dated. More recent studies regarding the impact of exercise on mood related illnesses are needed. Furthermore, the researchers did not comment on the time of day that each trial took place. The time of day that the exercise was completed may mediate or moderate the relationship between EEG asymmetry and exercise.

Exercise, Mood and Time of Day

Maraki et al. (2005) investigated the effect of an exercise class on mood, which included investigating differences due to time of day. Subjects for the study included healthy females, aged 18-45 who did not take part in regular exercise. The design was a 2 (exercise) x2 (time of day) repeated measures, where each participants took part in each of the four trials. Trials included a morning control, morning exercise, evening control, and evening exercise. Control trials consisted of one hour of rest. Exercise trials consisted of a one-hour aerobic and muscle conditioning class. Mood was measured throughout the experiment using a Positive and Negative Affect Schedule (PANAS). Researchers found that an exercise class

caused an increase in positive affect and decrease in negative affect. There were no significant differences found in mood change from morning trials to evening trials. There is some controversy in the literature regarding whether the effects of exercise on mood depend on the time of day. Previous researchers (McMurray, Hill & Field (1990)) reported significant differences. However, Maraki et al. (2005) believe that the lack of interaction between exercise and time of day is due to differences in the mood scales used. More research is needed. Additionally, more experiments are needed to test the effect of time of day on mood, independent of exercise.

Researchers (Egloff et al. 1995) explored how the time of day, as well as day of the week altered one's positive mood. To examine this relationship, the researchers measured the participants' mood, using three different scales, three times a day over the course of 7 days. The first scale contained the words *active, attentive, inspired, and interested*. The second scale contained the *words balanced, content, at ease and happy.* The final scale contained the words *afraid, angry, disgusted, hostile, irritable, jittery, nervous, and shaky.* The first scale measured positive affect activation, while the second scale measured positive affect pleasantness. The final scale measured negative affect. The participants rated each word, on a scale of 1 to7, based on how they were feeling at the moment. A one denoted "not at all" and seven denoted "extremely". Researchers found that positive affect pleasantness was at its highest rating in the evening, and lowest in the morning. Egloff et al. (1995) also found that positive affect activation was highest in the afternoon. The results of the study indicate that more experiments are needed regarding the change in positive affect with respect to time of day, possibly using different scales.

Last semester, I completed a study on the effect of exercise on EEG asymmetry and mood, using various exercise levels and the Positive and Negative Affect Schedule (PANAS) (Aprea & Tantillo, 2015). The levels of exercise included no exercise, and vigorous exercise. After each condition, participants' EEG asymmetry and self-reported affect were measured. We found a statistically significant increase in positive affect following vigorous exercise. Participants also showed more alpha activity in the right hemisphere following more vigorous exercise, which is

indicative of greater left hemispheric activity. This finding was consistent with previous research linking greater left hemispheric activity with exercise. Surprisingly, there was no difference in self-reported mood between the groups. Drawing from my previous work and noting the gap in the literature, I sought to investigate whether time of day is related to EEG asymmetry. Given the robust finding that exercise elevates mood and increases left hemispheric activity, I made exercise a constant and had all participants engage in moderate exercise. Mood will be operationalized by self-report and EEG asymmetry. The proposed study is a modified replication of my previous work (Aprea and Tantillo, 2015).

Given the controversy in the literature regarding time of day and mood, I did not make a directional hypothesis regarding time of day, but instead sought to determine if there were differences in EEG asymmetry and self-reported mood between morning and evening exercise conditions.

METHODS

Participants

The sample was a convenient sample, recruited through word of mouth of the researcher and advisor. Research took place on the Bowling Green State University campus in Bowling Green, Ohio. Informed consent was obtained from each participant prior to starting the experiment. The participants consisted of ten Bowling Green State University undergraduate students. The ages ranged from 18-23, with a mean age of 20.2. All participants identified as Caucasian, with seven female and three male students tested. All ten participants were right-hand dominant. The human subject review board application for the study was approved. Participants were given an incentive for contributing their time. They were able to choose between two SONA credits and a fifteen-dollar gift card.

Materials

Positive and Negative Affect Schedule

The Positive And Negative Affect Schedule (PANAS) questionnaire developed by Watson, D., Clark, L. A., & Tellegan (1998), was used to gauge the mood of each participant at baseline and following the exercise condition. The PANAS

questionnaire consists of two columns of words such as "interested", "upset", "enthusiastic", and "nervous". Participants put a number 1 through 5, where 1 denotes "Very slightly or not at all" and 5 denotes "Extremely". The PANAS yields a positive affect score and a negative affect score. Scoring was done by taking the mean of all words reflecting positive affect, and the mean of all words reflecting negative affect for comparison. Watson (1998) provides a clear definition of positive affect versus negative affect, and how they differ from each other. A low positive affect does not reflect the same feelings as a negative affect. The researchers developed the scale by taking a large number of descriptive words, then testing the relevance of each word using analyses by Zevon and Tellegen (1982). John R. Crawford and Julie D. Henry (2004) tested the reliability of the PANAS questionnaire and found that, as measured by Cronbach's alpha, the positive affect is .89 and the negative affect is .85. This shows that the questionnaire is reliable. Waston and Clark (1988) found that the correlation between the positive affect and negative affect is -.12-.23, showing that the scales are independent. Convergent correlations were found to range from .89 to .95, and discriminant correlations ranged from -.02 to -.18 (Watson and Clark 1988).

Health screening questionnaire

A health-screening questionnaire made by the researcher was also used. This included questions such as gender, age, and dominant hand and general questions regarding their health. Questionnaires were not linked to a specific participant, but rather a number to ensure confidentiality.

Electroencephalogram (EEG)

To measure EEG asymmetry, an electroencephalogram (EEG) machine was used. BSL Pro 3.7.2 software with a Biopac acquisition unit MP 150 was used. A Gateway computer was used to run the program and take recordings. The sample rate for the acquisition unit is 1,000 Hz. The gel used on the electrodes was a Ten20 conductive gel. Nuprep gel was used to abrade the skin to make the best connection and obtain the best signal from person to electrode to computer. Light abrasion of the skin where the electrodes were to be placed was done to reduce impedance. Electrodes were placed using the International 10-20 scale. For each lead, a bipolar

montage will be used, with the active electrodes at F3 and F4, reference at Fz and two ground electrodes on the ears.

The alpha wave (8-13 Hz) was measured in the left and right hemispheres in each trial. The amplitude of alpha activity in the right hemisphere is compared to the amplitude of alpha activity measured in the left hemisphere after the manipulations. Data was log transformed to reduce skewness. The equation used to determine an asymmetry score is ln (right)- ln (left). EEG readings usually do not show a normal distribution, so the data is log transformed to meet assumptions for parametric statistical tests.

An impedance check for each lead was made prior to recording. Impedance levels were below 10 Kiloohms, with only a 1 to 2-kiloohm difference between the electrode leads. The experimenter visually inspected the data for artifacts using manual sliding window of 1 sec to remove amplitudes above 50 microvolts. Less than 1% of the data was removed due to artifacts.

Procedure

Prior to beginning the experiment, each participant was given a consent form to sign and return to the researcher. Those who agreed to and signed the consent form were then set up with the electro-cap and ground electrodes, and gel was applied in each. As the gel was let to sit, each participant was given a health-screening questionnaire to fill out. There was no time limit for filling out these papers, but participants were asked to stay in the room with the researchers for the duration. Participants were reminded that they could discontinue with the study at any time without penalty. A mixed between within design was used. The time of day conditions involved a between groups design.   A within-participant design was used for the EEG recording and mood assessment, where each participant had his or her baseline measured, and then measured again following moderate exercise. Participants came to the testing site on one occasion. After completing the consent forms and health questionnaires, participants' baseline EEG recording taken for two minutes. During the recording, participants were asked to focus on a piece of tape on the wall, and keep relaxed with their eyes open. Participants were told to blink if needed. Following the baseline recording, participants were asked to walk for 20

minutes along a predetermined path around the Psychology Building. After returning to the testing site 20 minutes later, participants has their EEG recorded again for two minutes, with the same instructions. Immediately following the recording, participants were again asked to fill out a PANAS questionnaire. They were also asked to fill out a manipulation check questionnaire made by the researcher.

Morning recordings were taken between 8 A.M. and 10 A.M. Night recordings were taken between 6 P.M. and 8 P.M.

Participants were reminded that they could leave the experiment at any point without penalty. Each participant was given a debriefing before leaving the testing area.

Results

EEG Asymmetry

Typically EEG data is very skewed. In order to reduce skewness and meet the assumptions of parametric tests, the EEG data was log transformed using the formula ln(right alpha)-ln(left alpha).

A mixed between-within subjects analysis of variance was conducted to assess the impact of time of day (morning vs. evening) on participants' EEG asymmetry, across two time periods (baseline and post-task).

There was no significant interaction between time periods and time of day, Wilks Lambda=.992, F (1,8)=.064, p=.806.

The difference between baseline (M=-1.0005, SD=.9458) and post-task (M=-.5735 SD=.6657), approached significance, Wilks Lambda=.673, F(1,8)=3.878, p=.084, at baseline there was more alpha activity in the left hemisphere , which is indicative of greater right hemispheric activity (i.e. more negative affect)

The difference between morning (M=-.815, SD=.355) and evening (M=-.764, SD=.355) was not significant, F(1, 8)=.011, p=.921, suggesting no differences between the morning and evening EEG asymmetry scores.

Positive Affect

A mixed between-within subjects analysis of variance was also used to assess the impact of time of day (morning vs. evening) on participants' positive PANAS score, across two time periods (baseline and post-task).

There was no significant interaction between the positive PANAS score and time of day. Wilks Lambda= .898, F (1,8)= .904, p=.370.

The difference between the positive PANAS score during baseline (M=27.5, SD= 5.34) and positive PANAS post task (M=26.5, SD=7.28) was not significant, F (1,8)= .226, Wilks Lambda= .973 p=.647, suggesting no differences between the baseline and post-task positive affect.

The difference between the positive PANAS score during the morning (M=24.7, SD=2.319) and positive PANAS score in the evening (M=29.3, SD= 2.319), F(1, 8)=1.967, p=.198 was not significant, suggesting no differences between the morning and evening positive PANAS scores.
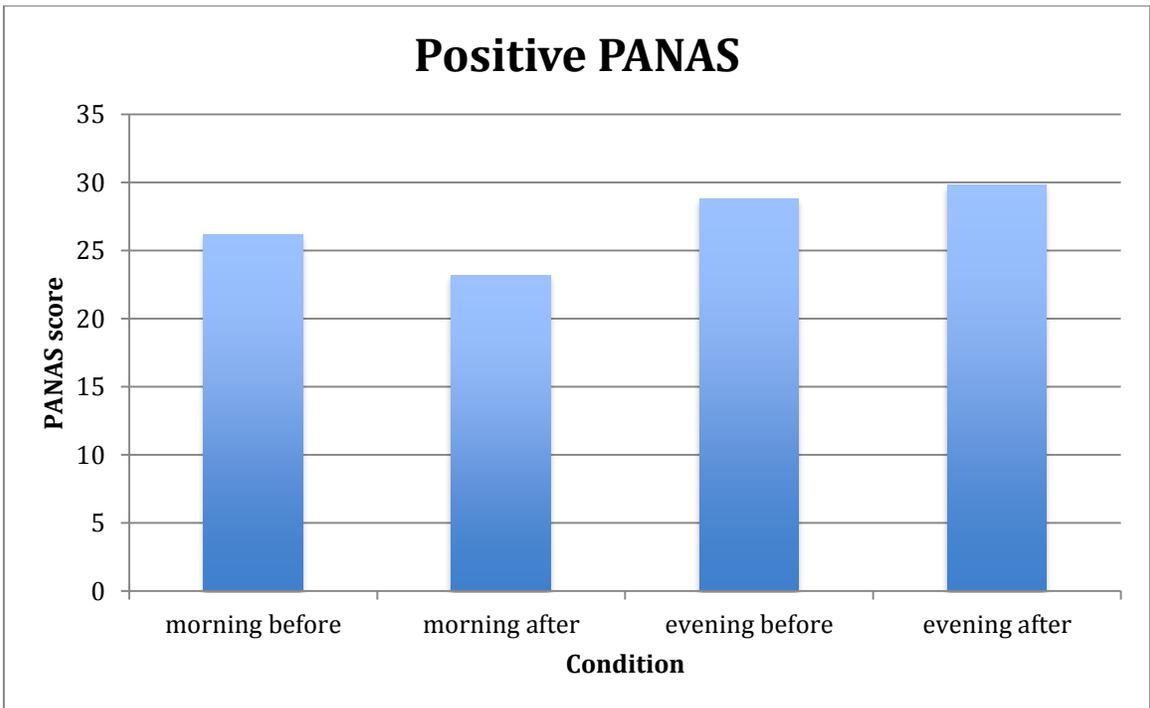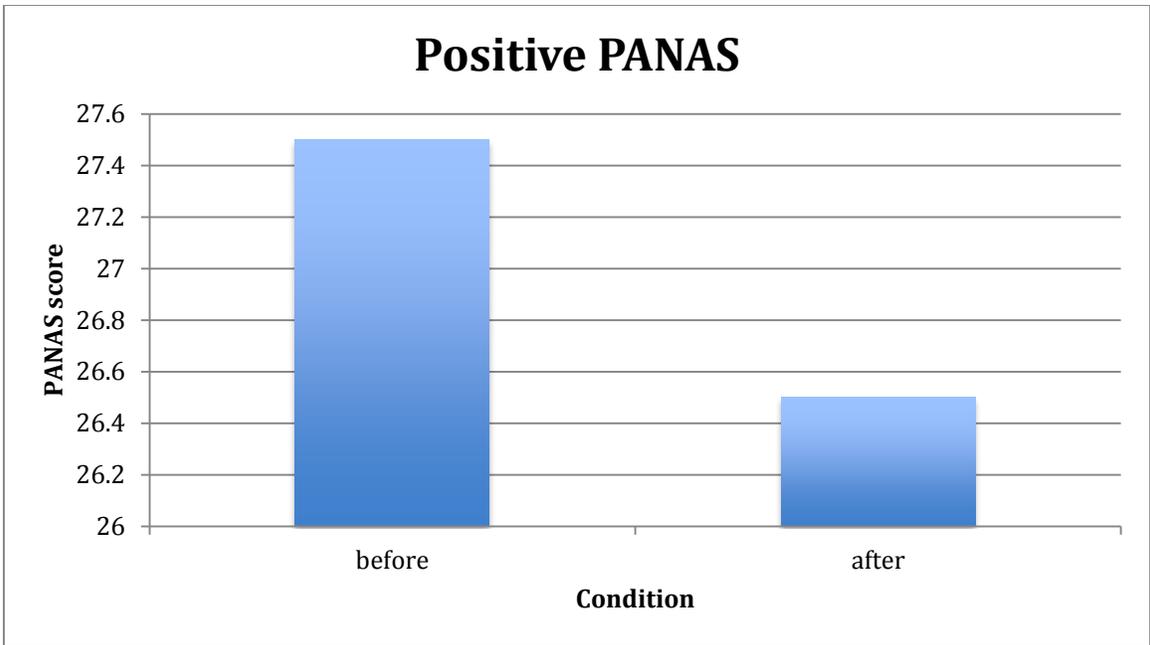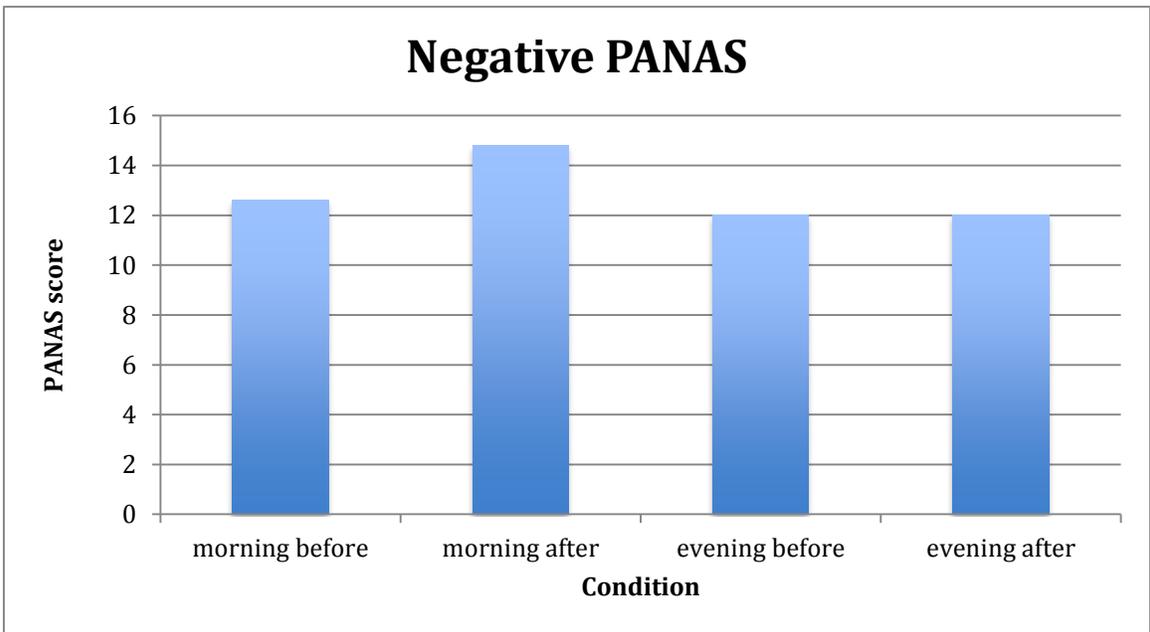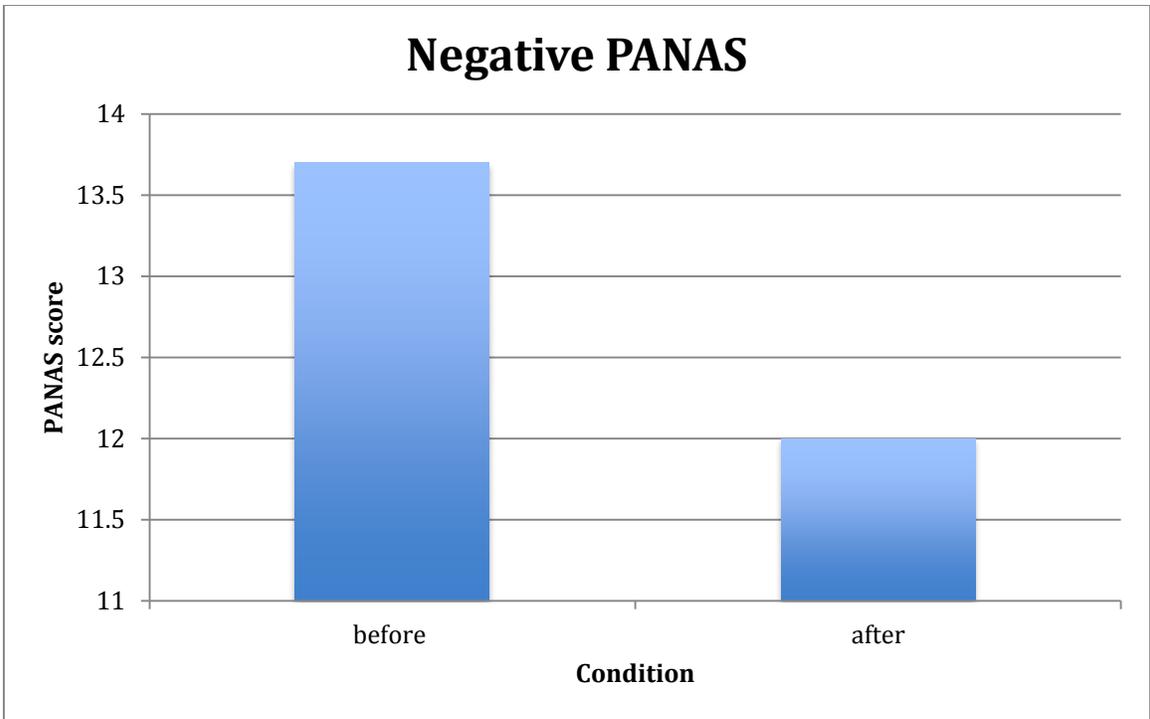
Negative Affect

A third mixed between-within subjects analysis of variance was used to assess the impact of time of day (morning vs. evening) on participants' negative PANAS score, across two time periods (baseline and post-task).

There was no significant interaction between the negative PANAS score and time of day. Wilks Lambda=.899, F(1,8)= .896 p=.371

The difference between the negative PANAS score during baseline (M= 13.7, SD=4.522) and negative PANAS post-task (M=12.00, SD=3.23) was not significant, Wilks Lambda=.789, F (1,8)= 2.141, p=.182, suggesting no differences between the baseline and post-task negative affect.

The difference between the negative PANAS score during the morning (M=12.2, SD=1.628) and negative PANAS score in the evening (M=13.4, SD= 1.628) was not significant, F(1,8)=.228, p=.646 suggesting no differences between the morning and evening negative PANAS scores.

Positive PANAS

Positive PANAS

Negative PANAS

Negative PANAS

EEG asymmetry baseline vs. post-test
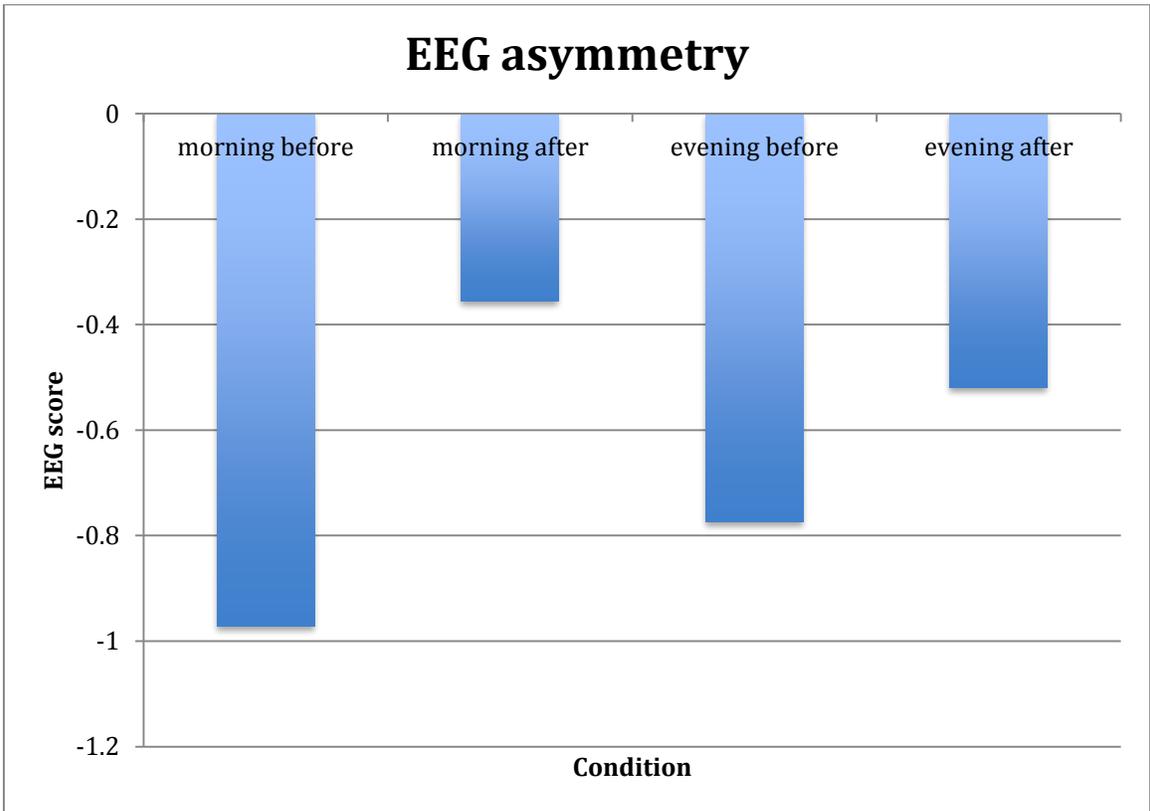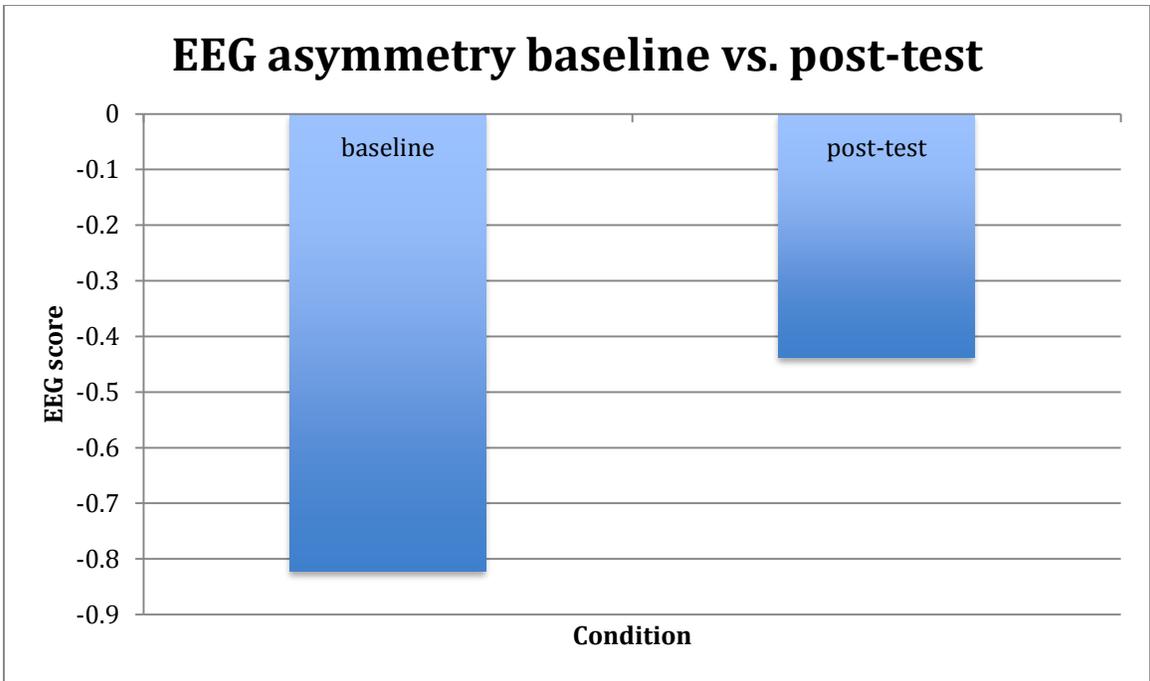
EEG asymmetry

Discussion

        The purpose of the research was to explore the effect of time of day on EEG asymmetry, positive affect and negative affect. There were no significant differences between time of day and the dependent measures. Interestingly, the difference between baseline and post-task EEG asymmetry approached significance. At baseline, there was more alpha activity in the left hemisphere, which is indicative of more right hemispheric activity, or more negative affect. This finding is consistent with the literature. However, there was no difference in self-reported affect between baseline and post-task.

        As with most research, there are strengths and weaknesses to this study. I will frame the discussion by talking about the four major validities: construct, internal, external and statistical.

Construct:

        EEG recordings were thoroughly analyzed and checked for artifacts. A manual sliding window of one second was utilized to capture signals above 50μV to remove artifacts. Less than 1% of the data was removed due to artifacts. The artifacting was done by the researcher to control for eye blinks, as well as any other outside signals that could've been picked up by the unit. Normally, measuring the eye blinks using an EOG (electrooculography) would be used to control for this. Because of the risk of damaging equipment, the decision was made to manually remove eye blink and other artifacts. Given that the amplitude readings were within the expected ranges and limited data was removed due to artifacts, I am confident of validity of the EEG measurements.

        The study had good construct validity for the PANAS, as it is a valid and reliable measure of affect. The study also had good construct validity in how the independent variable, time of day, was manipulated. Standard protocol was used. All morning trials took place between the hours of 8 A.M. and 10 A.M., and the evening trials took place between 6 P.M. and 8 P.M. A limitation and threat to the construct validity was the manipulation of exercise. The exercise task, which was a constant in the study, was meant to be moderately intense, yet the manipulation check showed that all participants found the task to be extremely low level instead.

<u>Internal:</u>

I sought to increase internal validity through random assignment, where five participants were part of the morning trials, and the other five were part of the evening trials. This was to help ensure groups would be as similar as possible. However, a major threat to the internal validity is that the experiment was a between subjects design, rather than a within subjects design. This leaves room for more significant differences across participants, which could alter the results found. One important variable that was controlled for within the study was handedness, where all participants were right-hand dominant. Many other variables were not controlled for, such as nicotine intake, caffeine intake, and history of psychological disorders.

<u>External:</u>

The study achieved external validity through a sample that accurately represents the population of interest. The participants were all between the ages of 18 and 23, which is representative of the majority of Bowling Green State University undergraduate students. Nevertheless, the results cannot be generalized to other populations outside of BGSU undergraduate students. Another threat to the external validity of the experiment is the artificial environment in which testing took place. In a more natural environment, such as having the participants exercise outdoors, may result in significant differences between morning and evening recordings.

<u>Statistical:</u>

As stated previously, there were no statistically significant differences. The reason for a null results could be due to the small sample size, the variables that were not controlled for, or too small of a range between morning and evening trials.

Further studies could utilize a larger sample in an effort to obtain significant results. The study could also alter the times of morning and night recordings, so that the morning is earlier and evening is much later. Altering the exercise to be sure that participants felt it was moderately intense could change results, as well as having them tested in a more natural environment, such as outdoors.

Conclusion

Overall, the results found in the current study are consistent with the literature, in that baseline EEG recordings showed more alpha activity in the left hemisphere, which is indicative of greater right hemispheric activity and more negative affect. Results of the effect of time of day were not supported, which may be due to factors that were not properly controlled for. The sample used and findings throughout the current experiment are representative of undergraduate Bowling Green State University students. Further studies should be completed to explore what was found, and strengthen some of the validities within the current experiment.

Worksheet 3.1   The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)

PANAS 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, that is, at the present moment *OR* indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure)**

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)

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