Effects of Relaxation under Alpha Wave Audio on Stimulus Response

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Abstract

Stress is common in the life of the average college student, and pressure of upcoming exams increases the amount of average stress. The increased physiological response produced by stressful situations can disrupt concentration. In an attempt to determine beneficial concentration techniques, this study was designed to analyze the effects of a common studying aid, meditative alpha wave audio, to determine if it does decrease the overall physiological response to an arousing stimulus. It was hypothesized that the experimental group listening to audio of alpha waves would have a decreased physiological response to an arousing visual stimulus. After recording and analyzing data from 21 participants, data showed that there was no significant difference in blood pressure, heart rate, or respiratory rate. While a significant difference in percent change of mean EDA occurred between intervals, it rejected the hypothesis. Future research using an electroencephalogram (EEG) may further elucidate the potential connection between alpha wave audio and decreased physiological response.

Introduction

University libraries today are filled with students studying, many with headphones plugged in. The increasing trend of college students who listen to music, or other audio, while completing their schoolwork raises the question: are music, meditative sound, or recordings of other inputs, such as alpha waves, beneficial to studying, or do they promote concentration? One study conducted by Morse used audio recordings of certain frequencies as a "Brain Wave Synchronizer (BWS)" to harmonize brainwaves with audio. People reported their subjective relaxation depth after listening to alpha waves was 75 percent or greater (Morse, 1993). The study went on to conclude that music has been shown to alleviate stress. In particular, alpha waves, oscillating between 8 to 13 Hz (Millbower 2000), are often associated with meditation and are known to induce calmness and relaxation. Additionally, there is recent evidence that alpha waves in the brain have the potential to suppress extraneous brain activity (Bonnefond, Jensen, 2012). Other evidence shows that while alpha waves play an important role in blocking distracting stimuli, they are also crucial in the act of processing information (Haegens, et al., 2012). Furthermore, music ranging from 50-80 beats per minute, matching the compositions of Baroque music, can also promote learning, memorization, and concentration by promoting the alpha wave brain state (Brewer, 1995). As noted by Millbower (2000), an alpha brain state induced by slow, minor key music is beneficial for evaluating and reviewing material, which is a desirable state for many college students preparing for exams. Millbower's research supplements our hypothesis, as the ability of music to control types of brain wave function is mentioned repeatedly throughout his book. Particularly relevant to this specific experiment is the ability of music to induce slow, alpha wave activity. This in turn, increases the role of the limbic system or emotional centers, allowing for an increased amount of information to be transmitted into long-term memory (Millbower 2000).

The aforementioned data correlating alpha waves and an induced meditative state raises the question of the role of alpha waves in attenuating stress responses, specifically by decreasing the physiological arousal of individuals. Alpha waves are known to calm subjects after exposure to a stimulus, but it is unknown if alpha waves prior to a stressful stimuli exposure perhaps dampen the body's response to it. As alpha waves are known to have an inverse effect on generalized cortical excitability (Wang, C, et al., 2016), our hypothesis follows that alpha waves also can effectively lower cortical response, and therefore general physiological excitability following an arousing stimulus. Furthermore, research from Mo Jue, et al. suggests that alpha waves may play an important role in both the occipital cortex upon exposure to visual stimuli, as well as in task-related attention (Jue, Mo, et al., 2011). Based on data like this, alpha waves may be further applicable to college students and their studying techniques, as data not only points to alpha waves inducing relaxation, but also to their potential role in focusing.

Materials

The blood pressure and heart rate of each volunteer were recorded using an Omron 10 series + automatic blood pressure monitor (model BP791IT, Omron Healthcare, INC. Lake Forest, IL, USA). Respiration measurements were obtained with a BSL Respiratory Effort Transducer (BIOPAC Systems, Inc. Goleta, CA. Model #SS5LB, SN 1602007571). Each volunteer's skin conductance response was recorded using the BSA EDA Finger Electrode Xdcr (BIOPAC Systems, Inc. Goleta, CA. Model #SS3LA, SN 1606004182) and Isotonic Recording Electrode Gel (BIOPAC Systems, Inc. Goleta, CA. Model #GEL101). Both respiratory rate and skin conductance were measured via BIOPAC software (BIOPAC Student Lab 4.0 with connected MP 36 unit from BIOPAC Systems, Inc.) connected to a computer. Over the ear headphones were given to each participant, which were either without audio (control group) or played alpha wave audio (experimental group). The chosen alpha wave video is called "Study Music Alpha Waves: Relaxing Studying Music, Brain Power, Focus Concentration Music" (https://www.youtube.com/watch?v=WPni755-Krg). The next video, or the "arousing" video, was chosen in order to produce a measurable physiological response in participants, specifically after their exposure to alpha wave audio or no audio. The selected video for this purpose is titled: "Felix Baumgartner Red Bull Stratos FULL SPACE JUMP VIDEO" (https://www.youtube.com/watch?v=E-w2_nTnunc). We hypothesized that the most physiological response would be induced based on participants' fear of heights, so specifically when the man leans out of his pod while in “outer space.” Right after this point, he begins his free fall to earth.

Methods

Participation

We enrolled 21 participants into our study, 10 male and 11 female, ages 20-22, from the Spring 2017 Physiology 435 class. The volunteers received no compensation for their participation in the study. For confidentiality purposes, each participant was assigned an ID number. Each participant was also given a modified consent form, which described their voluntary participation in the study (see Appendix A).

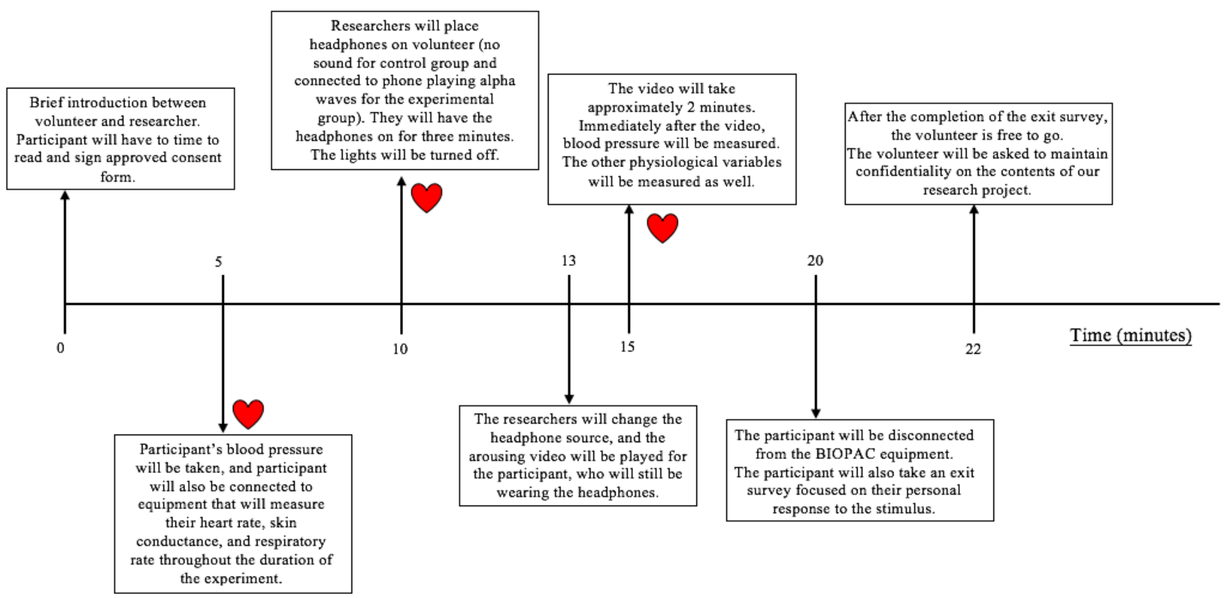

Figure 1. Volunteer Experience.
*The red hearts represent the time-points during which blood pressure and heart rate were taken during the experiment.

Experimental Procedure

The timeline specifically outlining each volunteer's study experience is documented in **Figure 1.** of this document. The experimental procedure for each participant was approximately 20 minutes total. Participants were assigned to the control group or the experimental group. Before starting the experiment, participants were given a brief overview of the physiological measurements that would be performed on them.

All of the participants had baseline measurements of heart rate, respiration rate, and skin conductance response taken. The blood pressure cuff was fastened above the elbow of the participant's left arm. The BSL Respiratory Transducer was fitted at axillary level around the participant's chest. The electrodermal sensors were fastened to the medial phalanx of the index and middle fingers of the right hand. An Isotonic Recording Electrode Gel was applied directly to the electrode, prior to the placement of the device on the index and middle fingers.

Each volunteer was given a pair of over-the-ear headphones and was given the instructions to relax. Prior to the relaxation period, lights in the room were turned off for the remainder of the experiment. The experimental group listened to the audio of alpha waves for a period of three minutes, whereas participants in the control group sat without audio playing for three minutes. The three minute period was chosen arbitrarily, as explained in the discussion. While the video description does not identify the specific wave frequency used, it states that it: "uses powerful Alpha Waves and Binaural Beats to boost concentration and brain power and is ideal relaxing music for stress relief." (Yellow Brick Cinema, 2014). Since alpha waves are defined as a rhythm that oscillates at a frequency of 8 to 13 Hz (Millbower 2000), as mentioned earlier, we operated on the assumption that this was the frequency range used in the video. After the three minute audio/no audio period, participants viewed the stimulus video, while continuing to listen to the alpha wave audio, or lack thereof. The participants were then given a final exit survey with questions mainly concerning if they had previously seen the video, if they have a fear of heights, and to rate how stressed they felt during the video, on a scale of 1 to 5 (See Appendix B). The survey was created using Qualtrics.com.

Data Analysis

The data sets from the four physiological measurements were calculated over different time intervals throughout the experiment. While respiratory rate and EDA were measured continuously throughout the experiment, blood pressure and heart rate were taken at three specific time points in the experimental process: (1) after the participant is initially connected to all of the equipment, but before the relaxation phase, (2) immediately following the three minute period of relaxation, with or without alpha wave audio, and (3) at the video climax of the visual stimulus. We defined the climax as the moment the man falls out of his capsule while high above the Earth in the stratosphere. We hypothesized this would be the moment of increased physiological response, due to a common fear of heights, and that watching a person free-falling would induce a stress response and increased skin conductance. Time points were marked during the video to facilitate measurement calculations of respiratory rate and EDA. Mean peak-to-peak values in mV were calculated as the ideal analysis for respiration rate, as they denote the average intensity of respiration over a given time interval. Mean EDA values in μS during each interval were calculated as the ideal measurement of arousal. Max, Min, and Mean values were recorded for each variable, but not considered, as individual variation and group outliers could obfuscate the rest of the data. To further ensure the accuracy of the data, percent changes between intervals were calculated individually and then averaged. This helped mitigate the shift caused by outliers, as well as individual variations in physiological response.

Data analysis proceeded as direct comparisons between the control (AW–) and experimental (AW+) groups at each interval via two-tailed t-test, unequal variance. A similar analysis was conducted on the change in physiological responses. Heart rate and blood pressure values from the three discrete time points were analyzed through direct comparison of average group heart rate and blood pressure data at the different time points and also through two-tailed t-tests, unequal variance, between the discrete time point measurements.

Results

Physiological data from one study participant is depicted in **Figure 2,** with the interval scheme overlying the graph. It shows trends we expected to see from our experiment. Study results for blood pressure, heart rate, and respiration rates yielded no significant differences between the AW– and AW+ groups; this data is represented in **Figures 3, 4** and **5**. The data set for mean EDA and percent change in mean EDA between intervals is depicted in box-plots, shown in **Figures 6** and **7.** Percent changes in mean EDA of AW– and AW+ groups were significantly different between the intervals for baseline and the entire video presentation (mean AW– = -31.99 and mean AW+ = -4.68; $p < 0.0089$), and they were significantly different between the intervals for relaxation and the entire video presentation (mean AW– = -6.55 and mean AW+ = 15.81; $p < 0.0222$). All physiological measurements were entered into box-and-whisker plots, each with inclusive medians and omitted outliers. Lower mean EDA values for arousal were observed within the control group. This can be seen visually in **Figure 6** and **Figure 7**; relaxation was, in general, higher (less aroused) in the control group versus the experimental group. Results of the exit survey analysis are displayed in **Figure 8.**

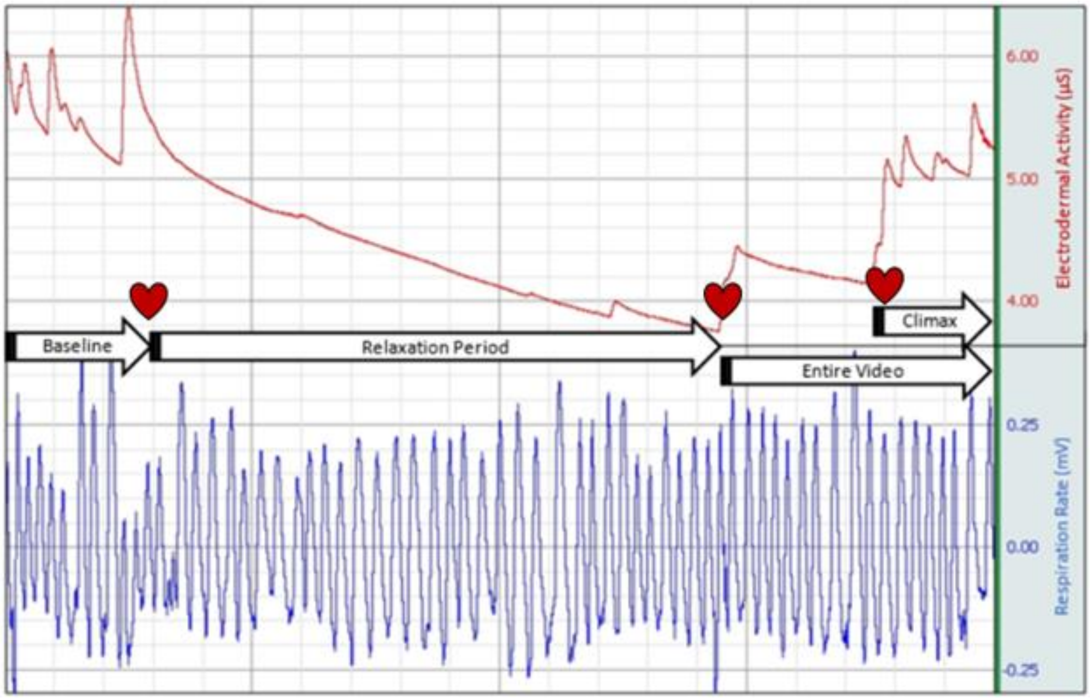

Figure 2. Screen capture from one study participant depicting expected EDA (top) and respiration (bottom) experimental data as processed by the accompanying software. Labeled arrows between the traces denote the intervals used for comparison. Data was calculated within each interval as the average µS value for EDA and the mean mV amplitude from peak to peak for respiration.

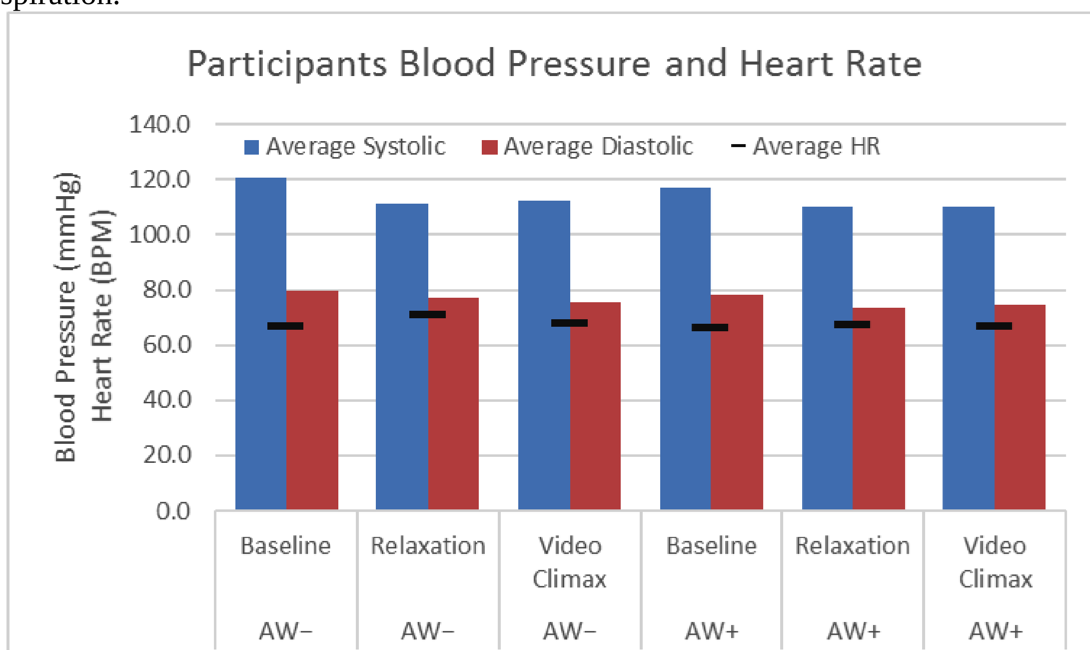

Figure 3. Participants blood pressure and heart rate were taken (1) Baseline, (2) after the Relaxation Period, and at the (4) Video Climax. Paired bars indicate systolic/diastolic pressure at the designated measurement interval for AW+/AW−. No observed for blood pressure or heart rate difference are reported between groups.

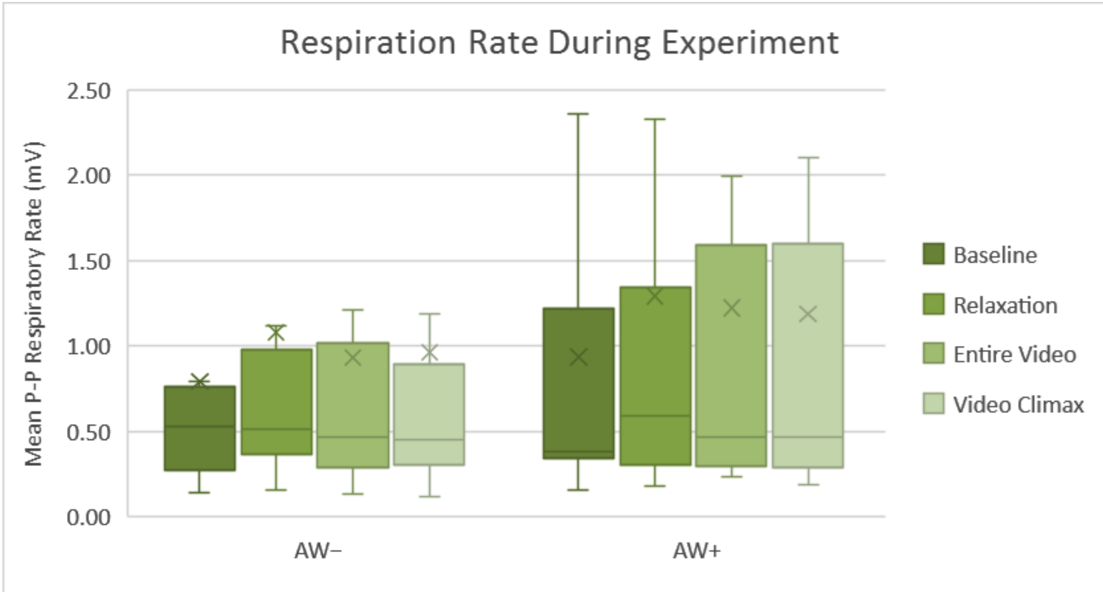

Figure 4. The average difference between the peaks and troughs of participants' breathing was measured in four intervals during the experiment. Comparison between the alpha wave group (AW+) with controls (AW−) yielded no significant difference. In the boxplot above, (×) denotes the mean and the solid line signifies the median (inclusive). Outliers falling outside Q1 or Q3 ± 1.5(IQR) were occluded from the figure.

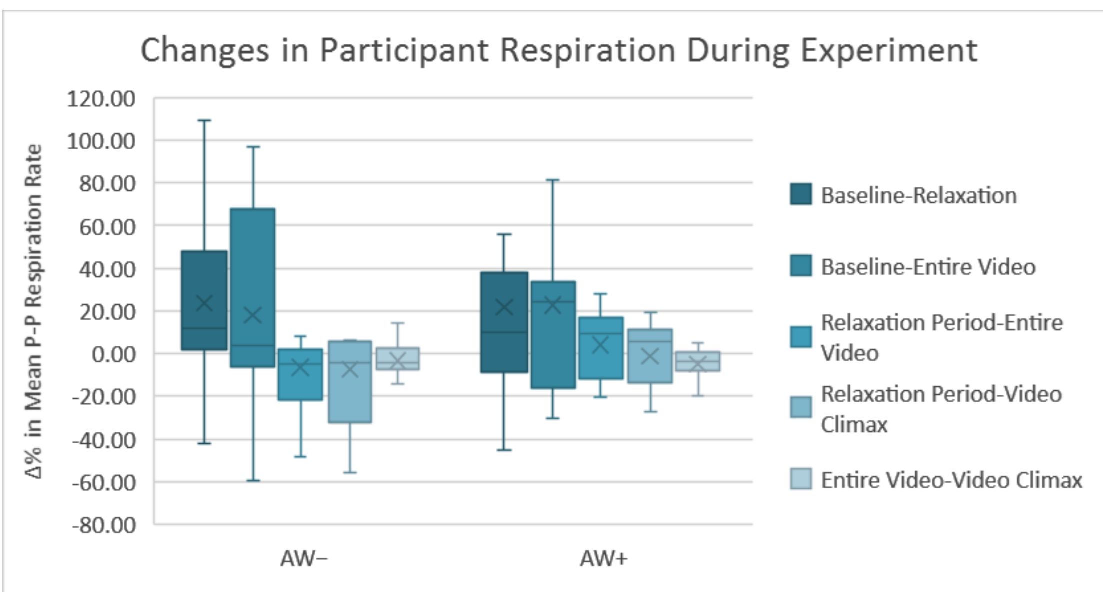

Figure 5. The percent change in mean peak to peak measurements of respiration between intervals were calculated for each participant and compared between AW+/AW−. In the boxplot above, (×) denotes the mean and the solid line signifies the median (inclusive). Outliers falling outside Q1 or Q3 ± 1.5(IQR) were occluded from the figure.

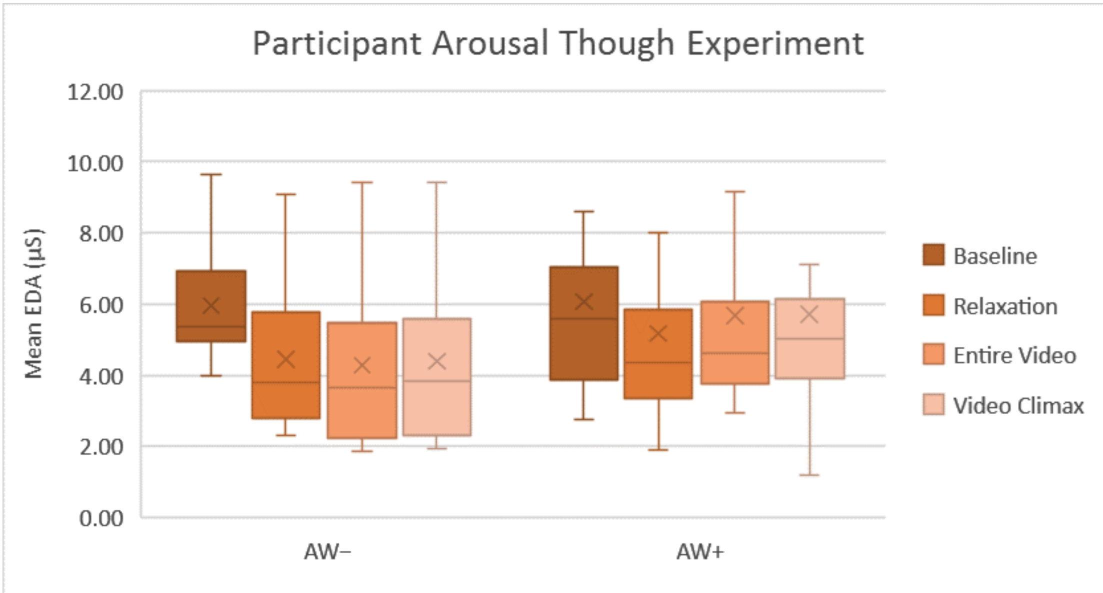

Figure 6. Participants' mean electrodermal activity was measured in four intervals during the experiment. Comparison between the alpha wave group (AW+) with controls (AW−) yielded no significant difference between group data during each interval. In the boxplot above, (×) denotes the mean and the solid line signifies the median (inclusive). Outliers falling outside Q1 or Q3 ± 1.5(IQR) were occluded from the figure.

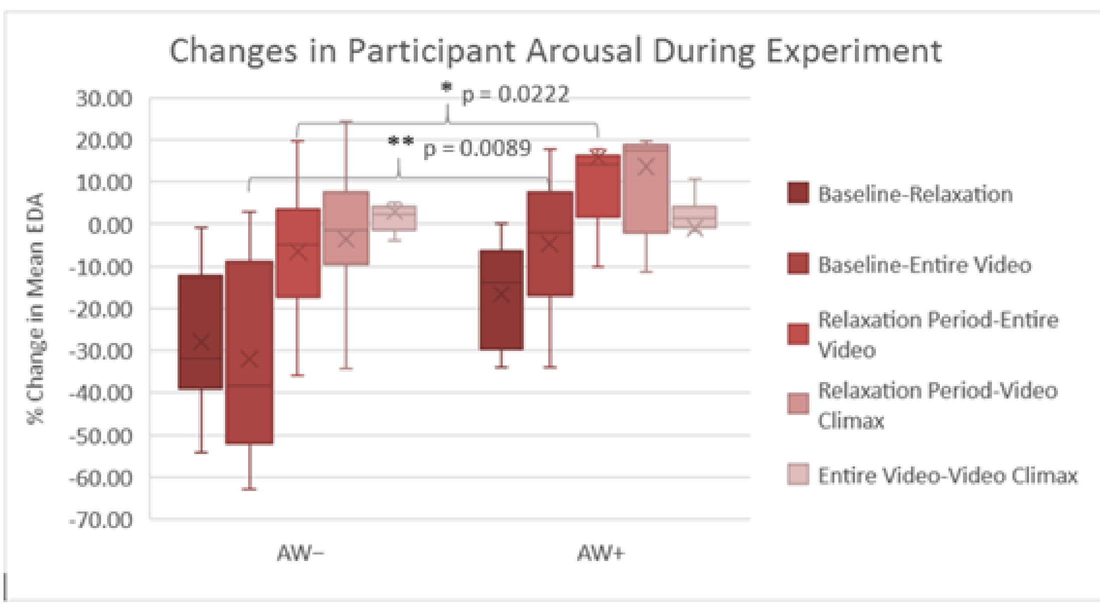

Figure 7. The percent changes in mean electrodermal activity between intervals were calculated for each participant and compared between AW+/AW−. Significant differences between AW+/AW− was observed and is denoted by * ($p < 0.05$) and ** ($p < 0.01$). In the boxplot above, (×) denotes the mean and the solid line signifies the median (inclusive). Outliers falling outside Q1 or Q3 ± 1.5(IQR) were occluded from the figure.

		Have you already watched the video that we showed you?			Do you have a fear of heights?		
		Yes	No	Total	Yes	No	Total
Was the subject exposed to alpha wave audio?	Yes	5	6	11	3	8	11
	No	3	7	10	0	10	10
	Total	8	13	21	3	18	21

Figure 8. A Cross Tabulation chart showing the totals of the answers shared in the exit survey. A Chi Squared test was run to test for an association between the experimental and the control groups. The Chi-squared value for the first section came to be 0.53 with 1 degree of freedom and a p value of 0.47. The second section Chi-squared value was 3.18 with 1 degree of freedom and had a p value of 0.07. Both of these data sets showed no significance that either of the results had an association with each other or being exposed to alpha wave audio.

Discussion

The proposed hypothesis that baseline physiological responses to a visual stimulus should be reduced after listening to meditative alpha wave recordings was rejected**.** The physiological measurements of blood pressure, heart rate, and respiratory rate showed no significant differences between groups. EDA measurements of percent change between time intervals did show a significant difference between control and experimental groups, but in the opposite direction as predicted by our hypothesis. Based on the mean EDA values throughout the experiment, the control group was shown to have lower skin conductance during each time interval, except during the interval spanning from the video climax to the conclusion of the experiment, as compared to the mean EDA of the experimental group. Although lacking statistical significance, the lower skin conductance measurement allowed us to hypothesize that there was less arousal, thus more relaxation, in the control group as compared to the experimental group. Although our hypothesis was not ultimately supported by our results, further studies could investigate this topic, while noting several aspects of our methods that could potentially be improved upon.

Various aspects of our experimental procedure could have influenced the accuracy of our results. Due to time and resource constraints, EEG recordings were not directly measured in conjunction with our other physiological measurements. Future studies would have to conduct research on the exact effect of alpha wave audio on brainwaves, in order to determine whether or not they actually would begin to mimic the audio. However, specific research by Wallace (1970) has already shown the connection between these specific measurements − decreased respiratory rate and heart rate, as well as increased skin resistance to specific measured EEG activity. Another study by Singh also underlines the connection between increased EDA, heart rate, and specific EEG activity in response to a stressful, arousing stimulus (Singh 2015). Additionally, previous research done by Meinicke, et al. found no significant decrease in physiological measurements in response to an audio recording used to stimulate alpha wave rhythms (Meinicke 2015). Instead of using alpha wave audio similar to that used in our experiment, they used only Binaural beats, which we suggested would still produce a change in physiological response.

The selection of a popular video as the visual stimulus introduces a confounding variable into the experiment that must be taken into account. As some of our participants already viewed the video, their physiological response may not have been as extreme upon watching it a second time. Additionally, there were participants that did not have a fear of heights, or were not bothered by videos depicting people falling from great heights. This presents another confounding variable, as our hypothesis assumed a physiological response based on the chosen visual stimulus. The exit survey asked if participants had seen the video before and also if they were afraid of heights. Analysis of survey data showed no significance, as based on p values calculated between questions asked and the participants' responses. If the study had used a larger sample size, it may have been notable that those participants who saw the video before, or don't have a fear of heights, may have had a milder response, if any at all. To combat these confounding variables, future studies could also implement a pre-study survey, in addition to the post-study survey, in order to screen those potential participants. Other error could have resulted from faulty equipment, especially from the electrodermal sensory equipment. The EDA recordings sometimes showed very little response. These potential inaccuracies in the EDA recordings could have been alleviated through the use of more consistent equipment. Methods for measuring blood pressure could be improved upon by using different equipment that could give a ongoing reading, as blood pressure varies throughout the different time intervals of relaxation and arousal. As individual blood pressure readings are sensitive to movement, a mean blood pressure over these time intervals would be a more reliable measurement.

The video introduces one other potential source of error. The video we used had an arousal period of 90 seconds. This could have been too long to collect the specific data points we needed. If the arousal moment had been limited to a few seconds, this could have made it easier to collect one data point of peak arousal. We compared measurements of the whole video as well as the video's climax to try to identify any effects of the video and to reduce the variability that the length of the video may have caused.

Some future research in this area could aim to determine if audio input relaxes people more, or less, than silence. We stated in our hypothesis that we believed audio input of alpha waves would relax a participant more than silence. However, we found through our results that EDA measurements suggested that participants relaxing in silence actually achieved greater levels of relaxation. The audio may induce stress if the participant has, for example, used it as a study tool, or a regular means of coping with a stressful or anxious situation. Someone who studies using alpha waves may associate it with being stressed out or worried, introducing another confounding variable. While our hypothesis was not confirmed, this introduces ideas for future studies in investigating the basis of relaxation, and the effect of an audio stimulus or silence in trying to help relax a subject.

Future research could also use more isolated controls. Factors such as a participant's individual ability to relax, preference to type of relaxation music, physical activity level prior to the study, and use of caffeine are all factors to consider in a more in-depth study. Prospective research would also benefit from using a larger sample size and allowing more time for the experiment. Originally the time we allotted for the relaxation phase was five minutes, but because of time restraints, the relaxation time was reduced to an arbitrary three minutes per person. Exposure of a participant to alpha waves for longer than three minutes may induce a more noticeable response. In the future, it would be worth studying how long a person must be exposed to alpha waves before they could "feel" the relaxing effects of the audio. This could be done by creating separate groups assigned to various time intervals in a similar experiment. Subsequent experiments on the topic of alpha waves relaxation should also use a control of "white noise" as the administered audio. This would create a good middle ground between silence and alpha wave audio. This would make a total of three groups per experiment: the white noise control, silence control and the experimental alpha wave group. Since white noise is not a rhythm, but just noise, it has the potential to cause more or less stress response. This would be an important contrast to alpha waves and pure silence.

While this is a complex endeavor, our initial foray into the specific effects of calming music on the studying mind lends itself to the generation of real-world applications for students throughout academia. This research introduces an interesting proposition that perhaps no audio at all may be more conducive to studying.

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