Effects of Audio Sensory and Cognitive Processing Stimuli on Alpha and Beta Brain Waves, Heart Rate, and Respiration

Physiology 435, Lab 603, Group 14
Robyn Goettelman, David Iranpour, Michael Peliska, Kelsey Shadel
May 14th, 2013

Key Words: Electroencephalography, Music, Audio Sensory, Cognitive Processing

Word Count: 3446

Abstract

High tempo music has previously been shown to have an excitatory effect on the body. We sought to determine the physiological effects of different types of auditory and cognitive stimuli by measuring 11 subjects' alpha and beta waves via an electroencephalogram, heart rate via a pulse oximeter, and respiration rate via visually confirming thoracic cavity expansions and compressions. We confirmed the significance of a high tempo audio sensory stimulus in causing an increase in heart rate and respiration, but found no novel significance of low tempo audio sensory stimulus producing a calming effect on physiological processes. The addition of math problems, as a cognitive processing stimulus, read aloud similarly produced no statistical significance, except on respiration rate where a significant increase occurred. Although EEG data produced no significant results of correlation to differential audio sensory and cognitive processing stimuli, the effect of musical stimuli on heart rate and respiration rate should be further investigated as a holistic therapy for disorders such as irregular cardiac activity, anxiety, depression, and movement disorders.

Introduction

Every day people use music as a tool to affect their mood. Some use it to relax, to "pump up" before exercise, or to help them focus. Many studies have been conducted to test the physiological effects that music can exhibit in the body. For example, Ellis and Brighouse (1952), designed an experiment to test the influence of music on both respiration and heart rate. They found that respiration rate increased with the onset of any audio sensory stimuli, with the music termed "vivid and dynamic" showing the greatest increases. An experiment performed by Bernardi *et al.* (2006) observed respiration rate and heart rate deviations with introduction of six types of musical stimuli. Their results showed highly significant correlations of both heart and respiration rate with the music, both increasing synchronously with a crescendo and both decreasing with a decrescendo. Others sought to observe how the brain is affected by music, whether cognitive processes are enhanced or diminished in the presence of audio sensory stimuli. Petsche *et al.* (1988) conducted an experiment in which an EEG was used to test if any significant differences were observed between brain waves at rest and with exposure to audio sensory stimuli. They found that while listening to music, subjects had a significant decrease in alpha wave power as well as an increase in beta wave power. Schaefer *et al.* (2011) also found a significant difference in alpha power when participants were "internally processing" audio sensory stimuli.

We, like the scientists before us, will employ an EEG in order to observe our subjects' brain activity. While the EEG is able to report about the frequencies of the many different characterized brainwaves, we are choosing to focus on the effects of audio sensory and cognitive processing stimulation on the alpha and beta brain waves. Alpha oscillations were the first EEG activity discovered, and the effects of mental and physical relaxation on alpha waves have long been studied (Niedermeyer and da Silva, 2004). They are typically present in the 8-14 Hz range, while the amplitude of the oscillations can be representative of the brain's level of cerebral cortex inhibition (Palva and Palva, 2007). The alpha rhythm is typically employed in sleep stage tests as an indicator of the onset of sleep (Ehrhart *et al.* 2000). Similarly, in response to auditory and painful stimulation, alpha waves have been found at different frequencies and amplitudes when compared between comatose patients and conscious patients (Iraqui, 1983). Normal alpha rhythms are attenuated by eye opening, audio stimuli, visual stimuli, and pain stimuli. Their oscillations have been observed to strengthen during internal mental tasks, and have shown a positive correlation with task difficulty (Palva and Palva, 2007).

Beta frequencies have been recorded typically at the 14-30 Hz band and have been categorized as indicators of cortical arousal (Rangaswamy *et al.* 2002). Beta waves correlate with an active mind and active motor senses. They have also been shown to be influenced by the thought of movement or the suppression of movement (Bressler *et al.* 2009). Whereas alpha waves are an indicator of mental relaxation, beta waves are implemented in mental and physical action. We will seek to engage beta waves through cognitive processing stimuli, in the form of an audio track of arithmetic problems that subjects will complete internally.

In addition to studying brain waves, respiration and heart rate will also be measured in response to audio sensory and cognitive processing stimuli. Respiration rate is defined as the number of breaths during a set period of time. This experiment will monitor breaths per minute and analyze the change during a presence of both types of stimuli. Next, we will use a pulse oximeter as a non-invasive way of measuring heart rates. Unfortunately, they do have their limitations. According to a study done by Ayers *et al.* (1991), deviations occurred between pulse oximeter and electrocardiogram readings when subjects' heart rates increase above 155 beats per minute. However, this should not be an issue in our study as we predict our subjects' heart rates will not rise to such an extent.

Having discussed previously conducted studies, we will now attempt to combine these research efforts and test for ourselves the physiological effect of music. The following hypothesis will be tested: Do audio sensory and cognitive processing stimuli exhibit a negative effect on EEG alpha waves and a positive effect on EEG beta waves, while positively affecting both heart rate and respiration rate?

We will collect a baseline negative control EEG from each participant with no addition of audio sensory or cognitive processing stimuli. We will use this for comparison, relating each individual's experimental EEG measurement to their baseline EEG. During soothing, low tempo audio sensory stimuli, we expect a decrease in beta waves and an increase in alpha waves because of an increase in mental relaxation. We also anticipate a slight decrease in heart rate and respiration rate in comparison with the baseline. During high tempo audio sensory stimuli we believe a decrease in alpha waves and an increase in heart rate, respiration rate, and beta waves will occur.

If significant changes are observed, music could possibly be used by doctors to non-invasively treat patients holistically; using certain songs and patterns to affect those with irregular cardiac activity, anxiety, depression, movement disorders, and many other psychosomatic ailments (Balsamo *et al.*, 2009; Lemmer, 2008; Bradt and Dileo, 2009).

Materials and Methods

Our data were collected from the student population of our University of Wisconsin- Madison Fundamentals of Human Physiology laboratory class. Our sample size was 11 students with 4 males and 7 females aged 20-22.

Electroencephalogram

For the EEG test, three electrodes were placed on the left side of the subject's scalp toward the ear, near the primary auditory cortex. The electrodes of the EEG measure voltage differences of different areas of the subjects' brains that are sensed during the summation of millions of neurons firing synchronously (Kubben *et al.* 2012). Electrodes were connected to the Biopac Unit for calculation of the area and mean of voltage differences in alpha and beta waves throughout the test.

Pulse Oximeter

To collect heart rate data, the pulse oximeter sensor was placed on the test subject's left index finger.

Audio Sensory Stimuli

Low-tempo music (*Weightless* by Marconi Union) was played first, followed by silence. Then high-tempo music (*Bulls Gone Ratchet* by Styles & Complete) was played, followed by silence again.

Cognitive Processing Stimuli

Finally, a recording of arithmetic problems was played, which subjects were instructed to complete internally.

Prior to the start of the test, subjects underwent a ten minute preparation for placement of the EEG electrodes and the pulse oximeter sensor. A swim cap was placed on the test subject's head in order to prevent the movement of the electrodes and wires during the duration of the test, and to ensure constant contact with the scalp for optimal electrode conductance. Monitoring respiration rate required the observation of the test subject's chest movements, so no preparation was needed. After written consent was received, subjects were seated in a dark room with over-the-ear headphones to limit external sound stimuli variables and create a calm environment.

Once the preparation was completed, the test began with sixty-seconds of silence. During the 60 second period, the subject's alpha waves, beta waves, heart rate and respiration rate were recorded. The results collected during this baseline period were used as the control to compare an individual's change in results through the subsequent presentation of various stimuli. After collecting the baseline data, intervals of 88 seconds of audio stimuli and 88 seconds of no audio stimuli were played for the test subjects. The subject's alpha and beta waves were continuously recorded for the entire length of the experiment. Heart rate was recorded every 22 seconds, and respiration rate counted as a whole number of breaths over each interval. These data were cross-analyzed between each interval and the baseline to demonstrate the effects of audio sensory and cognitive processing stimuli on alpha waves, beta waves, heart rate, and respiration rate.

Results

After subjecting each student to our audio sensory and cognitive processing stimulation tests, we collected the mean and area of alpha and beta waves from the EEG, the average heart rate, and the respiration rate over each treatment interval (low tempo music, high tempo music, mental mathematics). Starting with the initial 60 seconds of baseline data, we calculated a mean and standard deviation for all subjects. Then, means and standard deviations were similarly calculated for each treatment interval. From this, we standardized the data from each individual to create a Z-score by conducting a Z-test, to determine the amount of variance from baseline. These Z-scores were transformed to p-values to check for statistical significance of the results compared to the subjects' baseline ($p<.05$).

Electroencephalogram Results

The wave areas were collected in units of microvolt seconds (μV*s), the area under the curve over the entire 88-second interval. We collected this for alpha and beta waves. The baseline for the average of the eleven subjects' alpha wave area was 303μV*s (Table 1 & Figure 1a). For the low tempo music, high tempo music, and mental mathematics intervals, the average of alpha wave areas were 440μV*s, 330μV*s, and 456μV*s respectively (Table 1 & Figure 1a). The standard deviations, standard errors, and z-score statistics were then calculated to compute the p-values for the three intervals. The p-values for the low tempo music, high tempo music, and mental mathematics intervals compared to each subject's baseline values were 0.0375, 0.2451, and 0.0505 (Table 1). This suggests that the changes observed in the low tempo music intervals were statistically significant with respect to the baseline values which correlates to an increase in average alpha wave area. However, the changes seen in the high tempo music and mental mathematics intervals were not statistically significant.

The baseline for our eleven subjects' beta wave areas averaged to be 203μV*s (Table 2 & Figure 2a). For the low tempo music, high tempo music, and mental mathematics intervals, the beta wave areas averaged to be 275μV*s, 251μV*s, and 310μV*s respectively (Table 2 & Figure 2a). The standard deviations, standard errors, and z-score statistics were used to compute the p-values for the three intervals. The p-values for the low tempo music, high tempo music, and mental mathematics intervals with respect to each subject's baseline values were 0.0375, 0.0793, and 0.0359 respectively (Table 2). These data show that the changes seen in the low tempo music and mental mathematics intervals were statistically significant which correlates to an increase in average beta wave areas with introduction of the audio stimuli. However, these data also display that the changes seen in the high tempo music interval were not statistically significant.

The alpha and beta wave means were calculated using units of microvolts (μV), under each 88-second interval. The baseline for the average of the alpha wave mean was $2.2x10^{-3}$μV (Table 3 & Figure 3a). For the low tempo, high tempo, and mental mathematics intervals, the average of alpha wave areas were $3.4x10^{-}$

^{5}μV, -3.5x10^{-5}μV, and 1.7x10^{-5}μV respectively (Table 3 & Figure 3a). The p-values for the low tempo and high tempo intervals were too small to be calculated, while the p-value for the mental mathematics intervals with respect to each subject's baseline values was 0.0005 (Table 3). This suggests that the changes observed in the low tempo music, high tempo music, and mental mathematics intervals were highly statistically significant which correlates to an increase in alpha wave mean for each interval.

The baseline for the average of the eleven subjects' beta wave means was -6.3x10-4μV (Figure 4 & 4a). For the low tempo music, high tempo music, and mental mathematics intervals, the beta wave means were 1.3x10^{-4}μV, 7.1x10^{-5}μV, -3.1x10^{-4}μV (Table 4 & Figure 4a). The standard deviations, standard errors, and z score statistics were computed to calculate the p values for each interval. The low tempo music and high tempo music intervals had p-values extremely close to zero while the math interval had a p value of 0.1131 when being compared to each subject's baseline values (Table 4). This suggests that the low tempo music and high tempo music intervals are highly significant statistically and correlate to a decrease in the beta wave mean for these two intervals. Conversely, these data show that the mental mathematics interval has very low statistical significance and thus has no significant correlation.

Respiration Rate Results

Respiration rate was measured in number of chest falls per test interval. To standardize the experimental and baseline results, breaths per minute were calculated and an average rate was determined for the 11 subjects in each interval tested (Table 5 & Figure 5a). This produced an average baseline of 13.45 breaths per minute. The standard deviation from this baseline was computed for each interval's average breath rate (Table 5 & Figure 5a). On average respiration rates remained relatively constant throughout the low tempo music interval, with a statistically significant rise in rate during both the high tempo music and mental mathematics intervals. Calculated p-values were 0.0022 for the high tempo music interval and 0.0495 for the math section indicating a correlation between increase in respiration rate and listening to high tempo music or performing higher-order cognitive skills. (Table 5).

Heart Rate Results

Heart rate is reported as an average heart rate recorded over the entire 88-second interval. The baseline average heart rate was calculated as 75 beats per minute (Table 6 & Figure 6a). Generally, heart rates increased with the high tempo music and mental mathematics, and decreased with the low tempo music. The only p-value found to be statistically significant is the relationship between high tempo music and heart rate, at a value of 0.033, correlating to an increase in heart rate rate from listening to high tempo music (Table 6).

Discussion

Overall, we had originally hypothesised that audio sensory and cognitive processing stimuli would exhibit a negative effect on EEG alpha waves and a positive effect on EEG beta waves, while positively affecting both heart rate and respiration rate. Our results both support and refute different aspects of this claim. For instance, heart and respiration rates increased upon audio sensory stimuli, while the EEG results were conflicting. The following exemplifies this conclusion.

It has been shown that high tempo music is an arousing stimulus to the human body (Bernardi *et al.* 2006 and Balsamo *et al.* 2009), and therefore explains why high tempo music would produce an increase in heart rate, causing an increase in respiration rate. This supports part of our hypothesis that audio sensory stimuli would cause a general increase in heart rate and respiration rate. However, cognitive processing was only able to provoke a statistically significant difference in respiration rate, without significantly increasing heart rate. This could be due to variances in math skills across individuals, but physiologically, this seems flawed. Most likely, an increase in respiration rate should be correlated with an increase in heart rate, or vice versa, in order to accommodate the body's need for more oxygen and faster circulation of that oxygen. Perhaps the increase in respiration can account for those who were mentally stimulated by the arithmetic, but not made more alert or stressed by the work.

Furthermore, we hypothesized that low tempo music would have a calming effect on heart rate and respiration, but did not find statistically significant data to support this. Possibly this is because the application of any audio sensory stimuli, even if it has a slow tempo, will induce some sort of arousal when compared to silence. This has been shown to be the case in green monkey subjects (Hinds SB, 2007). When comparing the average heart rate and respiration only between low tempo and high tempo music, the high tempo music sample elicited both a higher heart rate and higher respiration rate.

As stated before, the EEG results displayed evidence that both supported and refuted the hypothesis. For example, beta waves had conflicting evidence with respect to the hypothesis, whereas alpha waves completely negated it. With regards to beta waves, the low tempo music interval displayed a significant increase in mean, but also exhibited a significant decrease in area. At this time, we are unable to account for this disparity or generate an explanation. Results also showed a decrease in mean during the high tempo music interval, disclaiming our hypothesis and indicating a decrease in cortical arousal. However, a significant increase in area during cognitive processing stimuli was seen. This evidence supported our hypothesis and indicated an increase in cortical arousal due to internal computations.

Conversely, the alpha wave results did not support our hypothesis that audio sensory stimuli have a negative effect. The experiment indicated a significant increase in alpha area while listening to low tempo music as well as a significant increase in alpha mean for all intervals tested. In retrospect, we should have hypothesised that alpha waves correlate to an increase in cortical activity due to all types of audio sensory and cognitive processing stimuli because any kind of stimuli will produce a greater effect than silence. Upon further research, we realized that we had misunderstood alpha wave function in the brain upon creating our hypothesis. We now understand that an increase in alpha wave area and mean should occur upon any audio sensory or cognitive processing stimuli, with a greater increase for the high tempo and mental mathematics intervals.

While obtaining these results, we encountered a few issues. One, issue is that different brain waves have different peaks of activity at different places in the brain, and because we are collecting data at only a small patch of the brain (3 electrodes positioned around the left ear) we will not be able to see all that occurs during the study. Also, to achieve more accurate results, the electrodes must be placed on precisely exact areas of the scalp, which leaves very little room for error in this experiment. Similarly, because we had minimal experience using an EEG before, significant truths demonstrated within our study may slip unnoticed to us due to how subtle the results of an EEG test can be.

Although a portion of our data was not determined to be statistically significant, it did produce general trends indicating that more extensive studies may show greater statistical significance. In light of this, if we could alter our experiment, there are three things we would have done differently. First, we would have presented a clearer set of instructions to each subject. A few instances occurred when subjects would misinterpret intervals of silence as errors in the study, and would try to communicate their confusion to us. These brief happenings may have led to data that did not accurately portray our measurements within the parameters of the experiment. Second, by recording measurements during the intervals of silence after the low tempo and high tempo intervals respectively, we reported a significant amount of data that we ended up not needing at all. In retrospect, we should have ignored the changes seen during these two intervals because we would have saved a significant amount of time. Finally, we would have learned the subtle differences between mean and area with respect to the EEG. For instance, beta area increased during the low tempo and mental mathematics intervals, but the beta mean actually decreased during both the low tempo and high tempo intervals. We still are unable to account for why our experiment induced these particular results, but if we knew how EEG mean and area relate to each other we may have been able to give an explanation to this phenomenon.

References

Ayers D, Iyriboz Y, Landry G, Morrow J, Powers S (1991). Accuracy of pulse oximeters in estimating heart rate at rest and during exercise. *British Journal of Sports Medicine*. Volume 25, Issue 3. 162-164.

Balsamo R, Bernardi L, Bernardi N, Casucci G, Fogari R, Porta C, Sleight P (2009). Dynamic Interaction Between Musical, Cardiovascular, and Cerebral Rhythms in Humans. *Circulation.* Volume 119, Issue 25. 3171-3180.

Bernardi L, Porta C, Sleight P (2006). Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians : the importance of silence. *Heart*. Volume 92, Issue 4. 445-452.

Bradt J, Dileo C (2009). Music for stress and anxiety reduction in coronary heart disease patients. *Cochrane Database of Systematic Reviews*. Volume 15, Issue 2.

Brand TM, Brand ME, Jay GD (2002). Enamel nail polish does not interfere with pulse oximetry among normoxic volunteers. *Journal of Clinical Monitoring and Computing.* Volume 17, Issue 2. 93-96.

Brismar T, Nikulin VV. Phase synchronization between alpha and beta oscillations in the human electroencephalogram. *Neuroscience*. Volume 137, Issue 2. 647-657.

Ellis DS, Brighouse G (1952). Effects of Music on Respiration-and Heart Rate. *The American Journal of Psychology*. Issue 65, Volume 1. 39-47.

Ehrhart J, Toussaint M, Simon C, Gronfier C, Luthringer R, Brandenberger G (2000). Alpha activity and cardiac correlates: three types of relationships during nocturnal sleep. *Clinical Neurophysiology.* Volume 111, Issue 5. 940–946.

Gruber G, Linder K, Petsche H, Rapplesberger P (1988). The EEG: An Adequate Method to Concretize Brain Processes Elicited by Music. Music Perception: An Interdisciplinary Journal. 133-159.

Hinds SB, Raimond S, Purcell BK (2007). The effect of harp music on heart rate, mean blood pressure, respiratory rate, and body temperature in the African green monkey. *Journal of Medical Primatology.* Volume 36, Issue 2. 95-100.

Iragui VJ, McCutchen CB (1983). Physiologic and prognostic significance of "alpha coma". *Journal of Neurology, Neurosurgery and Psychiatry*.

Kubben, Pieter L., and Nader Pouratian (2012). Abstract. *National Center for Biotechnology Information*. U.S. National Library of Medicine.

Lemmer, B (2008). Effects of music composed by Mozart and Ligeti on blood pressure and heart rate circadian rhythms in normotensive and hypertensive rats. *Chronobiology International.* Volume 25, Issue 6. 971-986.

Lew, S, Wolters, CH, Anwander A, Makeig S, MacLeod S (2009). Improved EEG source analysis using low-resolution conductivity estimation in a fourcompartment finite element head model. *Human Brain Mapping.* Volume 30, Issue 9. 2862-2878.

Niedermeyer E. and da Silva F.L. (2004). *Electroencephalography: Basic Principles, Clinical Applications, and Related Fields*. Lippincot Williams & Wilkins.

Palva JM, Palva S (2007). New vistas for α-frequency band oscillations. *Trends in Neuroscience*. Volume 30, Issue 4. 150-158.

Rangaswamy M, Porjesz B, Chorlian D, Wang K, Jones K, Bauer L, Rohrbaugh J, *et al* (2002). Beta power in the EEG of alcoholics. *Biological Psychiatry.* Volume 51. 831-842.

Schaefer RS, Vlek RJ, Desain P (2011). Music perception and imagery in EEG: alpha band effects of task and stimulus. *International Journal of Psychophysiology.* Volume 82, Issue 3. 254-259.

Zhang Y, Chen Y, Bressler SL, Ding M (2008). Response preparation and inhibition: the role of the cortical sensorimotor beta rhythm. *Neuroscience*. Volume 156. 238-246.

Acknowledgements

We would like to extend thanks to Dr. Andrew Lokuta for the assistance he gave us in formulating our experiments. We also would like to thank our teaching assistants and peer learning volunteers for teaching us how to operate the EEG, as well as other aspects of our experimental design. Finally, we would like to thank the University of Wisconsin-Madison for providing the equipment and available space to perform our experiment.

<u>**Tables & Figures**</u>

Alpha Wave Area Table

Audio Stimulus	Average (µV*s)	Standard Deviation	Standard Error	Z-Score	P-Value
Baseline	303	180	54	0.00	0
Calm	440	255	77	-1.79	0.0375
Upbeat	330	129	39	-0.69	0.2451
Math	456	309	93	-1.64	0.0505

Table 1: Table of alpha wave area averages, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

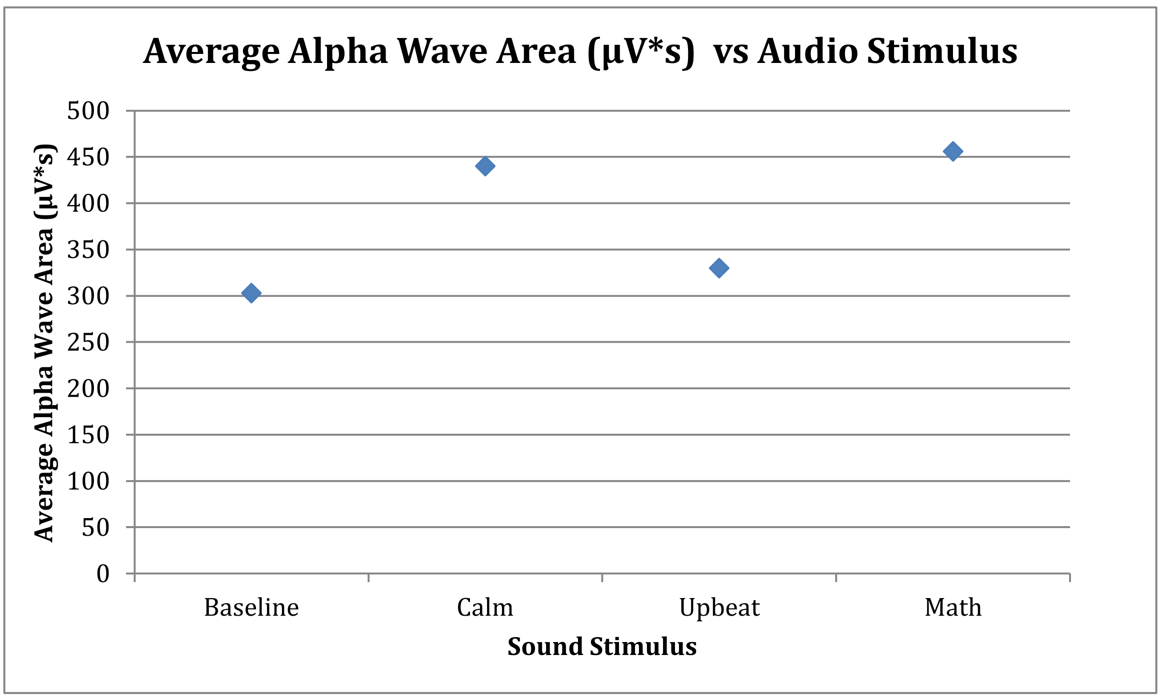

Figure 1a: Graph of average alpha wave area during various audio stimuli.

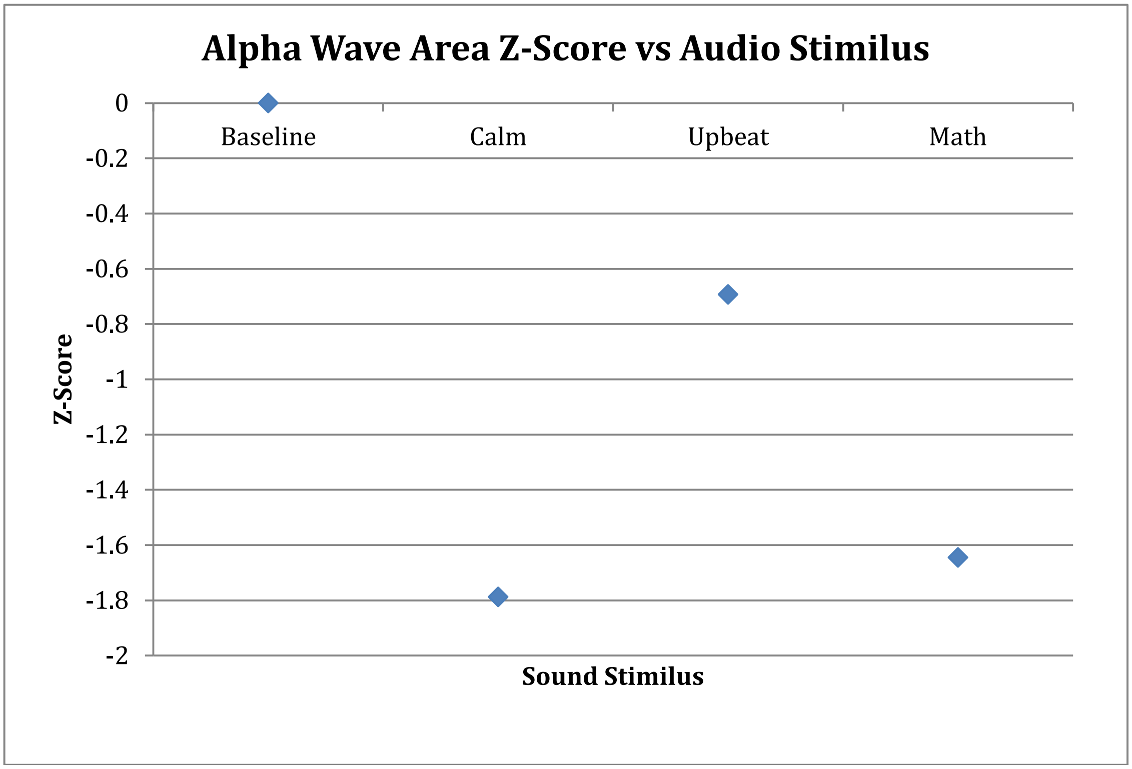

Figure 1b: Graph of alpha area z-scores during various audio stimuli in relation to the baseline.

Beta Wave Area Table

Audio Stimulus	Average (μV*s)	Standard Deviation	Standard Error	Z-Score	P-Value
Baseline	203	64	19	0.00	0
Calm	275	134	40	-1.78	0.0375
Upbeat	251	113	34	-1.41	0.0793
Math	310	199	60	-1.80	0.0359

Table 2: Table of average beta wave area, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

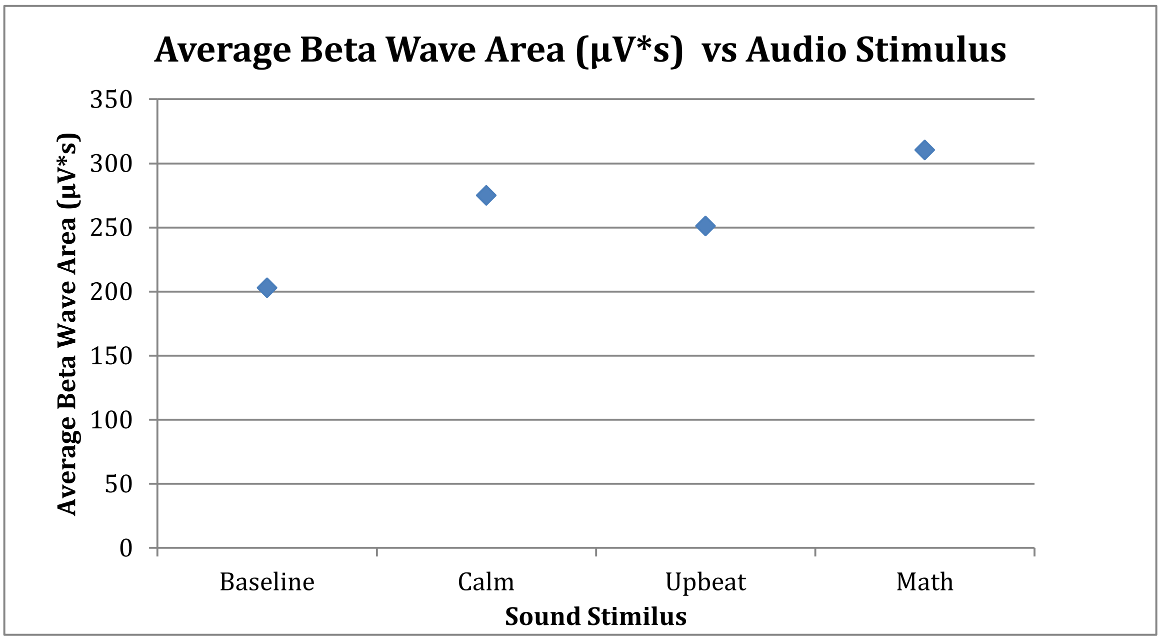

Figure 2a: Graph of average beta wave area during various audio stimuli.

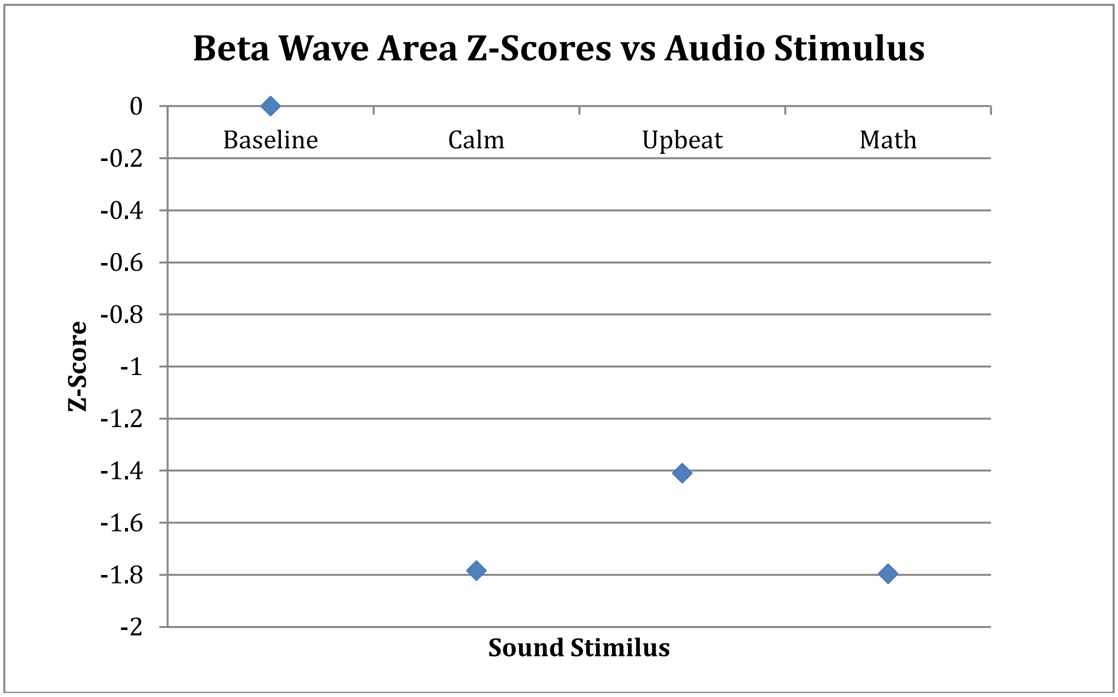

Figure 2b: Graph of beta wave area z-scores during various audio stimuli in relation to the baseline.

Alpha Wave Mean Table

Audio Stimulus	Average (µV)	Standard Deviation	Standard Error	Z-Score	P-Value
Baseline	$2.2x10^{-3}$	$6.0x10^{-3}$	$1.8x10^{-3}$	0.00	0
Calm	$3.4x10^{-5}$	$7.9x10^{-4}$	$2.4x10^{-3}$	9.26	0
Upbeat	$-3.5x10^{-5}$	$8.8x10^{-4}$	$2.6x10^{-3}$	8.61	0
Math	$1.7x10^{-5}$	$2.2x^{-3}$	$6.8x10^{-3}$	3.29	0.0005

Table 3: Table of alpha wave mean averages, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

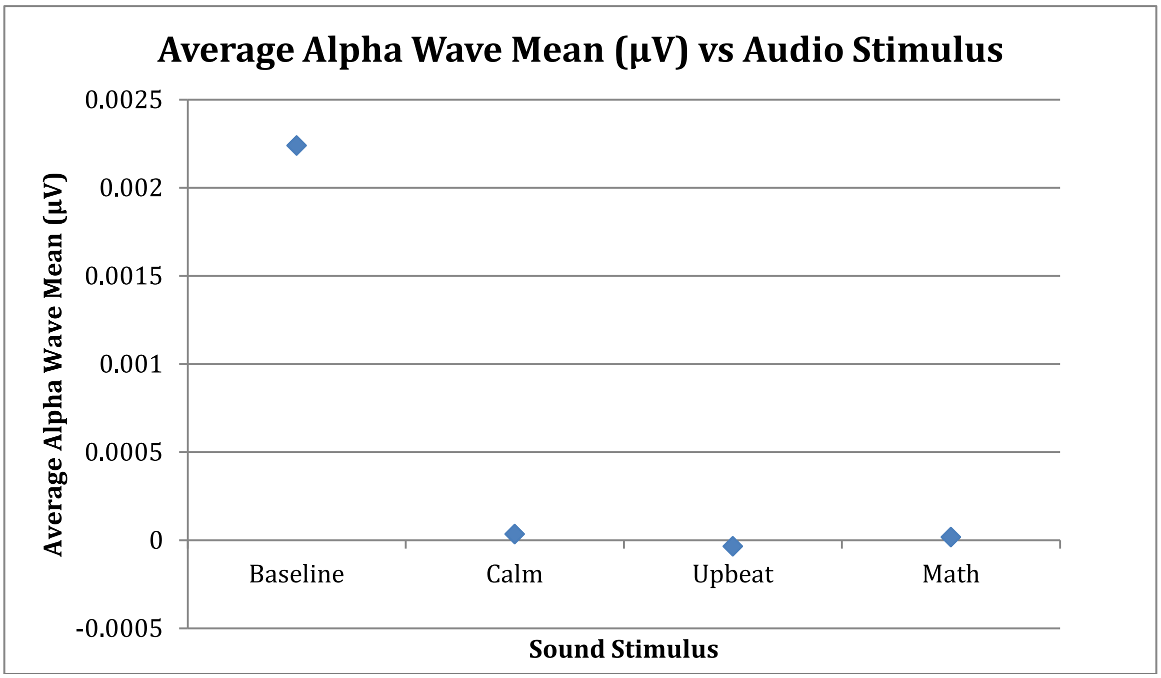

Figure 3a: Graph of average alpha wave mean during various audio stimuli.

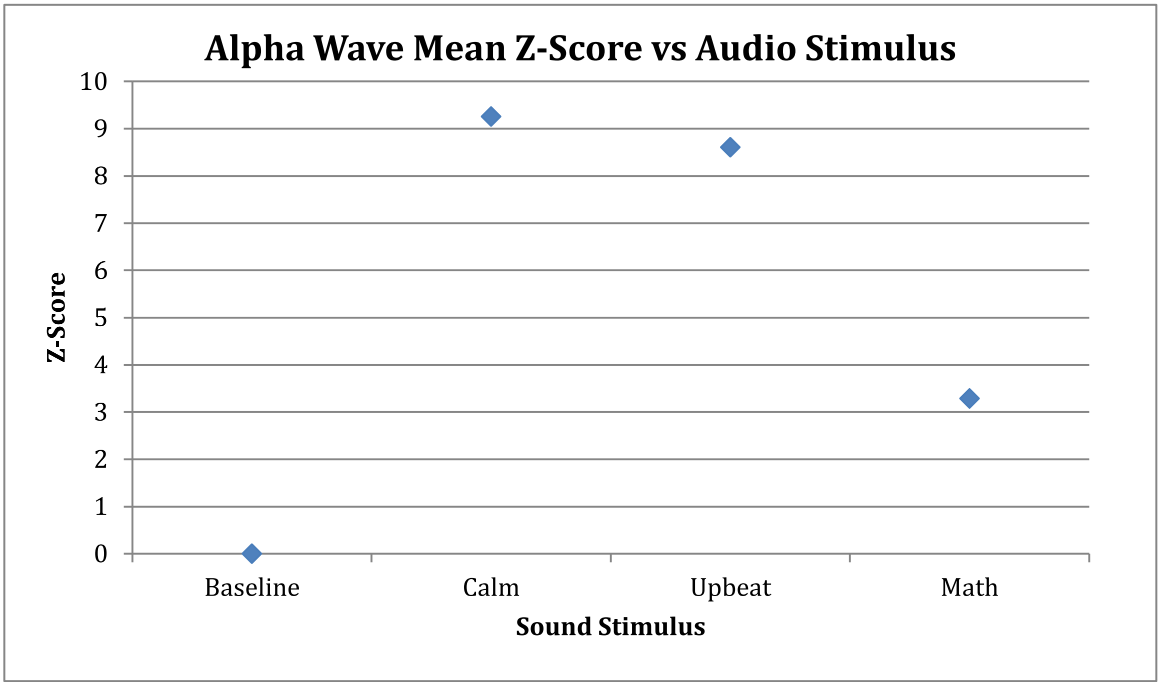

Figure 3b: Graph of alpha wave mean z-scores during various audio stimuli in relation to the baseline.

Beta Wave Mean Table

Audio Stimulus	Average (μV)	Standard Deviation	Standard Error	Z-Score	P-Value
Baseline	$-6.3x10^{-4}$	$1.2x10^{-3}$	$3.6x10^{-4}$	0.00	0
Calm	$1.3x10^{-4}$	$3.4x10^{-3}$	$1.0x10^{-4}$	-7.54	0
Upbeat	$7.1x10^{-5}$	$2.5x10^{-3}$	$7.0x10^{-5}$	-9.42	0
Math	$-3.1x10^{-4}$	$8.8x10^{-4}$	$2.7x10^{-4}$	-1.21	0.11

Table 4: Table of beta wave mean averages, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

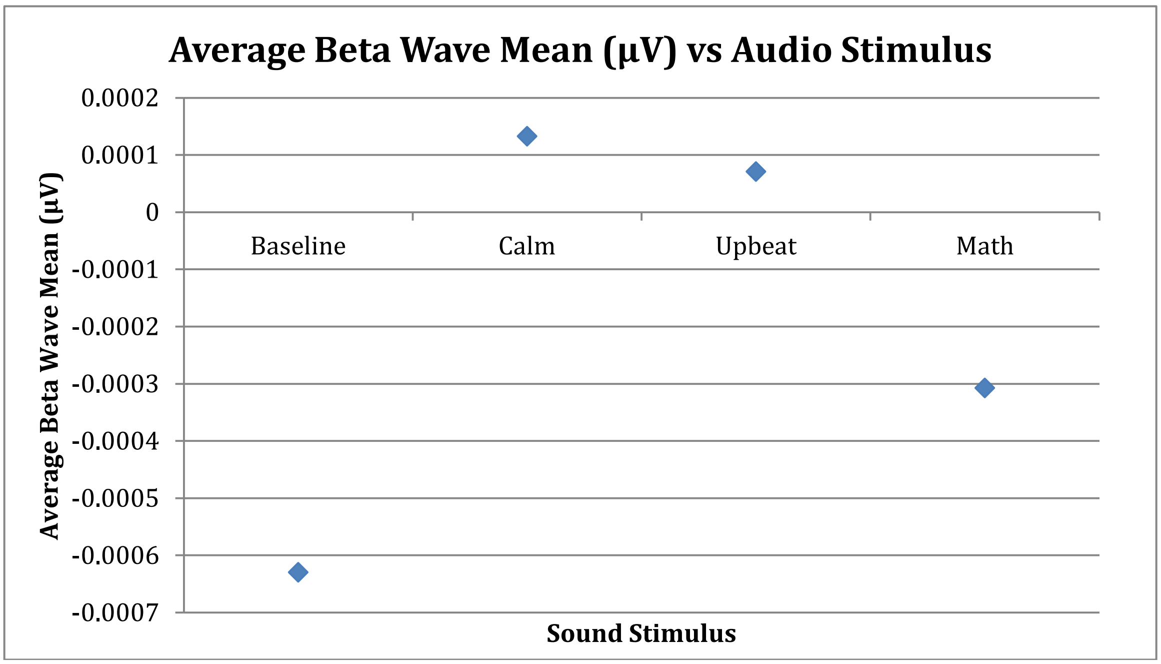

Figure 4a: Graph of average beta wave mean during various audio stimuli.

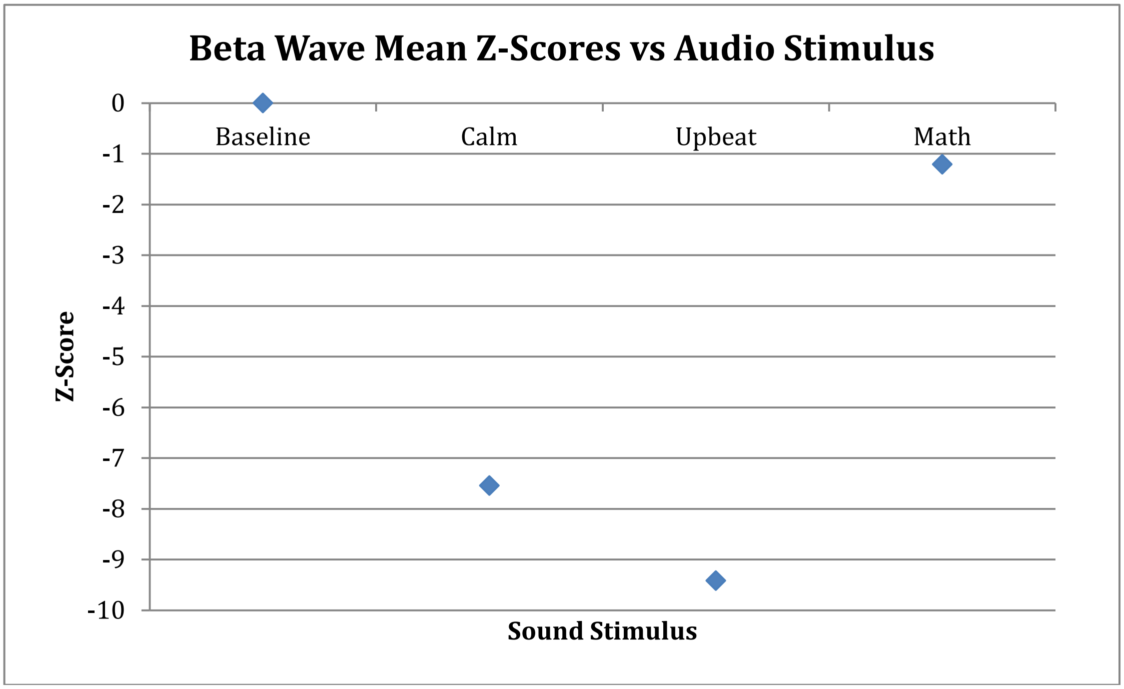

Figure 4b: Graph of beta wave mean z-scores during various audio stimuli in relation to the baseline.

Respiration Rate Table

Audio Stimulus	Average (breath/min)	Standard Deviation	Standard Error	Z-Score	P-Values
Baseline	13	3.3	1.0	0.00	0
Calm	13	3.6	1.1	0.46	0.3228
Upbeat	16	3.5	1.1	-2.85	0.0022
Math	15	3.0	0.9	-1.65	0.0495

Table 5: Table of respiration rate averages, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

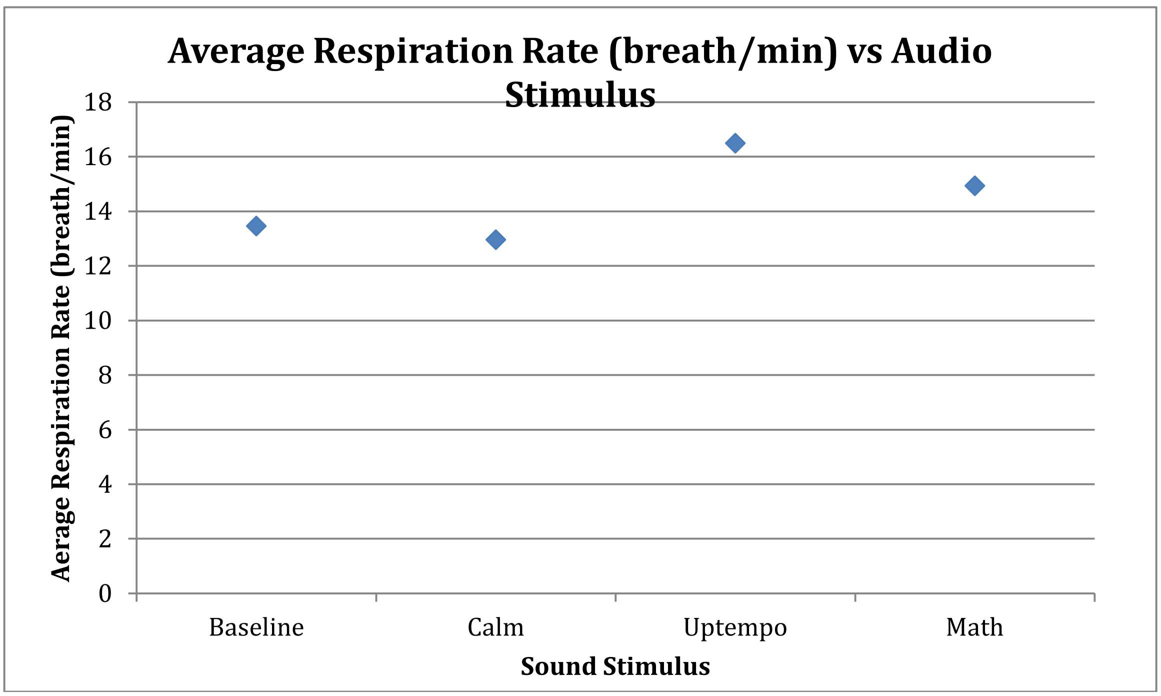

Figure 5a: Graph of average respiration rate during various audio stimuli.

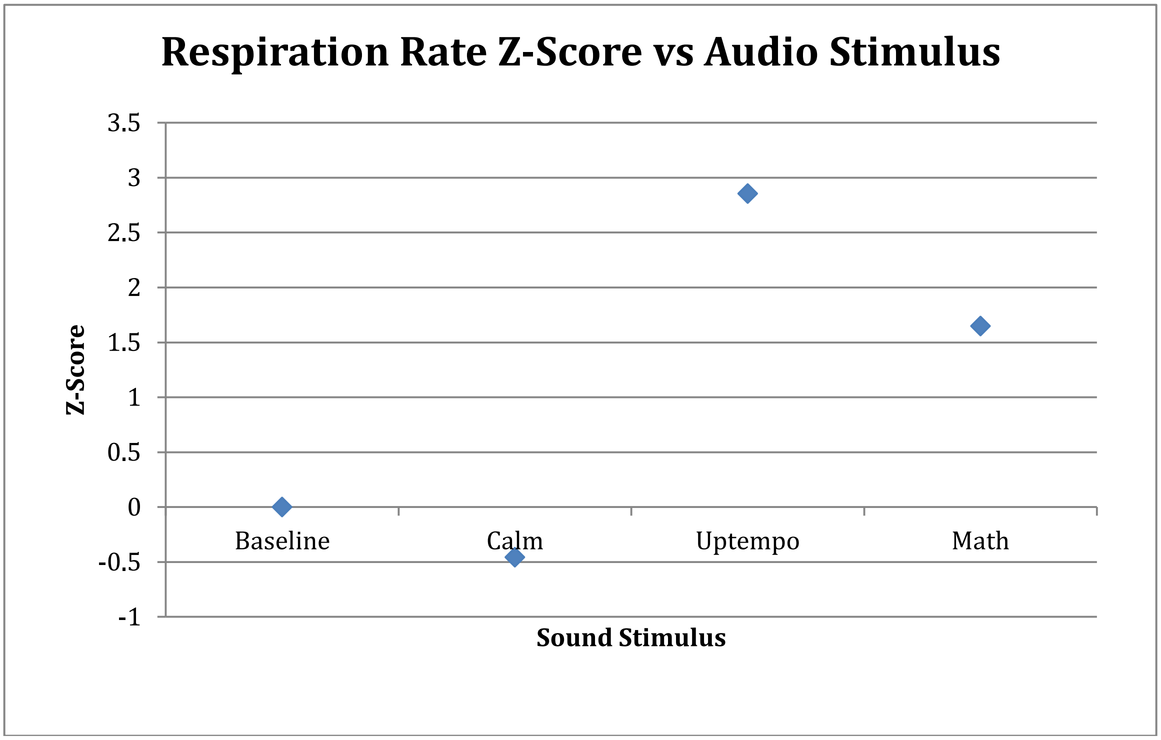

Figure 5b: Graph of respiration rate z-scores during various audio stimuli in relation to the baseline.

Heart Rate Table

Audio Stimulus	Average (bpm)	Standard Deviation	Standard Error	Z-Score	P-Value
Baseline	75	7.4	2.2	0.00	0
Calm	75	8.4	2.5	0.01	0.496
Upbeat	80	8.1	2.5	-1.84	0.0329
Math	78	12.8	3.9	-0.74	0.2266

Table 6: Table of heart averages, standard deviations, standard errors, z-scores, and p-values during various audio stimuli.

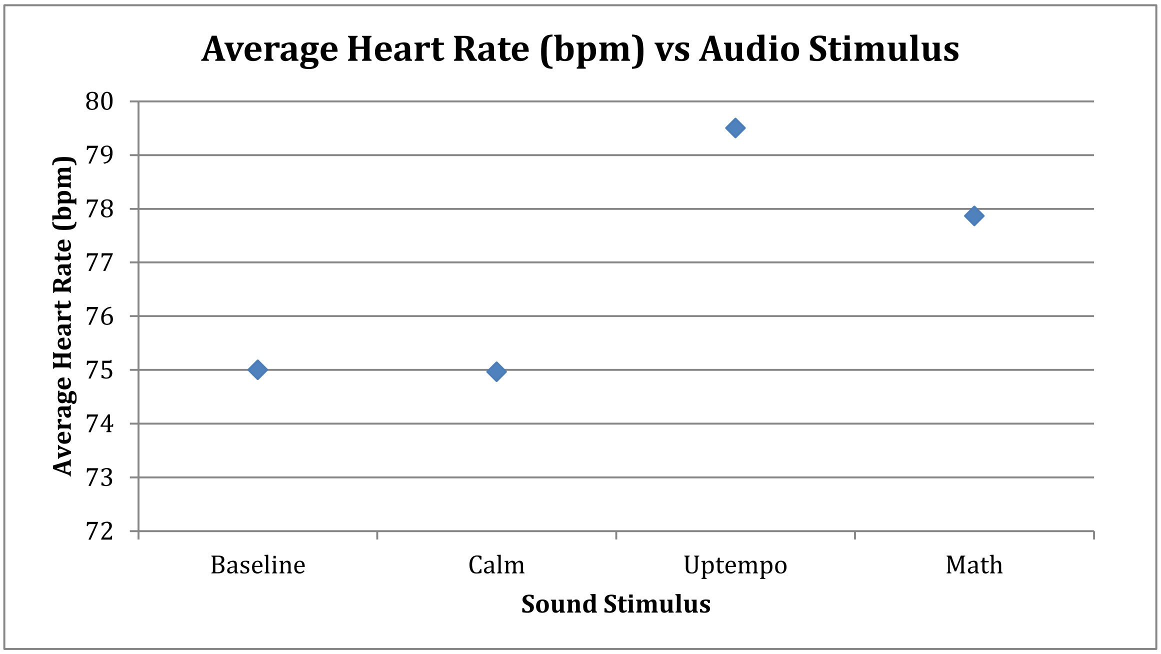

Figure 6a: Graph of average heart rate during various audio stimuli.

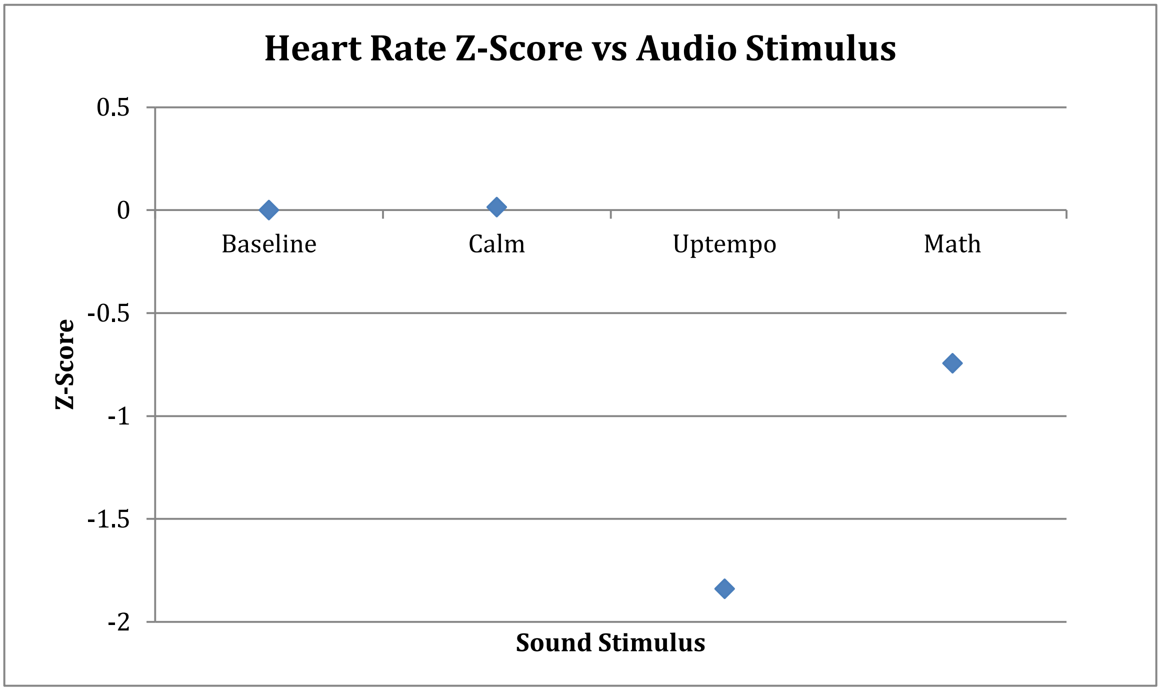

Figure 6b: Graph of heart rate z-scores during various audio stimuli in relation to the baseline.