Effects of music type on reading comprehension performance and other physiological factors

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Measuring the effects of classical music vs. dubstep music compared to a negative control of no music on cognitive performance as measured by a reading comprehension test as well as the effects on other physiological factors including changes in brain wave activity measured by EEG and heart rate measured by ECG.

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KEY POINTS SUMMARY

- The effects of listening to different types of music while taking a reading comprehension test were measured and compared to a negative control of no music
- Heart rate (beats per minute) was monitored by ECG and brain wave activity (frequency and wave mean) was monitored by EEG while the subject took three reading comprehension tests
- Effects on cognitive ability were measured by the subjects score on the reading comprehension tests out of 7 possible points
- While it seemed reading comprehension performance was positively affected by classical music and negatively affected by dubstep music, there did not seem to be any significant effect of dubstep vs. classical music on brain wave activity or heart rate
- Future studies related to this topic should include a larger sample size and the use of more advanced and modern EEG equipment to reduce error in data readings due to equipment malfunction

ABSTRACT

There are differing arguments as to whether listening to different genres of music is correlated with certain physiological effects. It was hypothesized that while listening to classical music, subjects would have a higher cognitive performance, lower beta wave activity, and a lower heart rate. On the other hand, it was hypothesized that while listening to dubstep music, subjects would have a lower cognitive performance, higher beta wave activity, and a higher heart rate. In order to measure these effects, the subjects were given three different comprehension tests. These tests were scored, the heart rate was recorded from an ECG system, and mean brain wave frequency as well as beta wave activity were recorded from an EEG system. Analysis of the data collected from the subjects (n=19) suggests that there is significant effect of music type on reading comprehension scores, however, effects on heart rate and brain wave activity were not significantly affected by music type. For future studies, a larger sample size and more advanced EEG system, such as the g.EEGcap®, would be beneficial as a broader range of data could be gathered with a higher degree of accuracy, clearly demonstrating if there is indeed a trend between the music genres and the physiological effects.

INTRODUCTION

Students of all ages use different study methods to maximize their studying, each preferring their own technique. Some students listen to a specific music type while studying, while others can only study if there is complete silence. According to a study done by Furnham and Bradley (2002), background music can have a negative effect on the performance of complex cognitive tasks. Further examining this idea, could the type of music have its own specific effect on a student's comprehension of material? Do different types of music have effects on other physiological variables, specifically heart rate and brain wave activity?

Studies examining the relationship between music and cognitive performance have shown that brain wave activity changes are heavily correlated with cognitive performance (Lundqvist *et al*, 2011). In particular, beta wave activity, a fast oscillation, is thought to be important in the attention processes (Benchenane *et al*, 2011) and has been linked with an important role in perception, cognition, consciousness, and the formation of mental representations (Medvedev, 2001). One study aimed to determine the effect of Mozart's music on brain activity. It was determined that subjects that listened to Mozart had less EEG activity and performed better when assigned cognitive tasks (Jaušovec *et al*, 2006). This is partially explained by the fact that the right frontal cortex is responsible for planning complex cognitive behavior and aiding in decision-making. As the right frontal cortex is more active, the beta wave activity decreases, finding less EEG activity should be mirrored by better performance on cognitive tasks (Howells *et al*, 2012).

In order to examine the questions dealing with a student's comprehension of material and different music types, we will study the effects of two genres of music (classical and dubstep) on reading comprehension performance and other physiological variables. Dubstep is a type of instrumental dance music characterized by a heavy bassline. Based on the previous studies mentioned, and assuming all classical music will have similar effects, we hypothesize that subjects will have higher cognitive performance, lower beta wave activity, and lower heart rates during exams taken while listening to classical music. On the other hand, while listening to dubstep, we hypothesize that subjects will have higher beta wave activity and will have higher heart rates, while scoring lower on the exams than they did while listening to classical music. Upon completion of this experiment, the music type did have significant effects on the reading comprehension performance of an individual, but further studies are needed to confidently determine if heart rate, and mean brain activity, and beta wave frequency were also significantly affected by music genre.

MATERIALS AND METHODS

Ethical Approval:

As this experiment was conducted on human volunteers, informed consent was obtained in writing. The studies conformed to the standards set by Dr. Andrew Lokuta, PhD and Physiology 435 lab guidelines and the procedures were approved by Professor Lokuta as well as the teaching assistants and peer-learning volunteers of this course.

General Procedure Overview:

In this study, volunteer participants took each of three reading comprehension tests while listening to classical music, dubstep music, and no music while their beta brain wave activity (frequency and wave mean) was measured using an electroencephalograph (EEG) and their heart rate (beats per minute) was monitored using an electrocardiograph (ECG). Their brain wave activity and heart rate were measured throughout the duration of each test taken and their raw scores (number of questions answered correctly) on the reading comprehension tests were recorded.

The equipment used for this experiment included the three different reading comprehension tests, EEG and ECG devices from BIOPAC Systems, Inc. software, headphones, and music. Student volunteers between the ages of 19-22 (n=19) were tested in this study and each individual signed a consent form agreeing to the terms of the study before the start of the experiment. The classical music used was "1st Piano Concerto" by Bach and the dubstep music used was "Kill Everybody" by Skrillex. The tempo was held constant between the two genres of music at 88 beats per minute, and the decibel level ranged from 60-70 dB for each subject. The tests used to measure cognitive ability were practice SAT reading comprehension tests obtained from MajorTests.com. The reading comprehension tests consisted of reading a passage and answering 7 questions pertaining to that reading, and each test was of similar level of difficulty and 10 minutes in duration. The participant was told to use all 10 minutes available to them for each test to eliminate erroneous beta brain wave activity due to speech or movement. The experiment was conducted in a silent room to ensure no background noise as well as to limit the distractions present while taking the reading comprehension tests.

Prior to participation in this experiment, the EEG and ECG electrodes were properly positioned on the subject's body as can be seen in the Figures 1 and 2 provided by the BIOPAC student handbook (BIOPAC Systems, Inc., 1998). The EEG and ECG systems were then calibrated to establish a baseline as well as to test proper positioning by having the subject sit comfortably for 5 minutes followed by a 10 second recording of brain wave activity and heart rate.

Provisional Test:

The provisional test required the individual to complete the first of three reading comprehension tests without listening to any music. This was intended to allow the individual to adjust to the experimental procedure. By performing this test first for each individual without randomization, it is understood that the data collected cannot be used as valid results. However, as the purpose of the study was to examine the difference in effects of classical music versus dubstep music, this provisional test is necessary. Brain activity was measured and recorded using the EEG device while heart rate was monitored using the ECG.

Experimental Tests:

The second and third reading comprehension tests served as the experimental tests for this study. These tests were taken by the subject while listening to either classical music or dubstep and again the EEG and ECG measurements were recorded. The order of the music type for the second and third tests (classical versus dubstep) was randomly chosen to eliminate any potential confounding variables cause by the order of the music. Also, it is important to note that not each reading comprehension test was given with the same music type (none, classical, or dubstep) to randomize and thus limit the effects of confounding variables.

Analyzing Experimental Data:

The data provided by the BIOPAC software on the computers was analyzed and the following values were recorded for each individual: overall mean brain wave frequency, mean beta wave activity, and mean heart rate. Analysis of Variance (ANOVA) was performed on each of the values listed above with the categories of control, classical, and dubstep. To examine and explain the the mean squared error from the ANOVA, scatter plots were created for each of the participant's values. A paired t-test, that takes into account two-tailed and equal variance data, was also preformed on the values measured for dubstep and classical music. The p-values obtained from these two tests showed whether or not the difference in the data between dubstep vs. classical was in fact due to the music playing during testing or if the difference occurred by random chance at a significance level of $\alpha=0.05$.

RESULTS

Effects of music type on reading comprehension exam scores:

From an ANOVA test performed on the effects of classical and dubstep music on reading comprehension performance, the mean squared error between groups was 15.1579 and within groups was 2.1696 (see Table 1). The mean value of the exam scores (out of a possible 7 maximum points) while listening to classical music was 4.2105 and while listening to dubstep music was 2.9474. The p-value from a paired t-test using the reading comprehension data for the two music types was found to be 0.0121.

Effects of music type on heart rate:

From an ANOVA test performed on the effects of classical and dubstep music on heart rate, the mean squared error between groups was 53.8118 and within groups was 127.6289 (see Table 2). The mean heart rate while listening to classical music was 74.6653 bpm and while listening to dubstep music was 77.0456 bpm. The p-value from a paired t-test using heart rate data from the two music types was found to be 0.5202.

Effects of music type on mean brain wave frequency:

From an ANOVA test performed on the effects of music type on mean brain wave values, the mean for classical music was found to be 0.0018 Hz and the mean for dubstep music was found to be 0.0017 Hz (see Table 3). The mean squared error values were too small to be calculated by ANOVA. The p-value from a paired t-test using mean brain wave frequency data from the two music types was found to be 0.1798.

Effects of music type on beta wave activity:

From the ANOVA test performed on the effects of music type on the beta wave activity, the mean for classical music was found to be -0.0002 uV and the mean for dubstep music was found to be 0.00006 uV (see Table 4). The mean squared error values were too small to be calculated by ANOVA. The p-value from a paired t-test using beta wave activity data from the two music types was found to be 0.9363.

DISCUSSION

This study attempted to answer the question of whether or not listening to different types of music will have an effect on a person's cognitive performance. Analysis of the data collected from the subjects suggests that there is significant effect of music type on reading comprehension test scores ($p=0.0121$). Effects on heart rate ($p=0.5202$), mean brain wave frequency ($p=0.1798$), and beta wave activity ($p=0.9363$), however, no evidence to support this claim ($p>\alpha=0.05$). Graphs for each variable tested were made to visually represent this data (see Graphs 1, 2, 3, and 4).

The one test we administered showing significance was the effect of music type on reading comprehension. Analysis of our data showed that music type had a significant effect on the subject's reading comprehension exam score with the p-value ($p=0.0152$) less than the significance level of $\alpha=0.05$. Again, no significance was found for the effects of music type on heart rate, mean brain frequency, and beta wave activity as the p-values for each was below the significance level of $\alpha=0.05$. Both the EEG and ECG data seemed sporadic and unreliable. There may be several factors contributing to this result.

While administering the tests it was clear that any time the test subject moved or talked a large spike in brain wave activity was observed. In order to mark answers for the reading comprehension exams the subjects had to make slight movements. Additionally, several subjects talked, coughed, or made some other verbal disturbances during the testing. Other issues with the EEG data may have been a result of the EEG machine itself. There were several issues connecting the electrodes to the test subjects' scalps, such as differing hairstyles and head shapes. There were also difficulties with placement of the swim cap onto the subject's heads without altering the position of the electrodes or having the electrodes touch one another. The EEG used was somewhat outdated and only had three electrodes components. A more accurate EEG system such as the g.EEGcap® may have provided more accurate data and eliminated several difficulties due to the fact that it has 65 electrodes with sockets that optimize the distance between the skin and the electrode, guaranteeing that the system works regardless of head shape or hair style.

The ECG was used to measure the test subjects' average cardiac beats per minute during each of the tests. As mentioned earlier, this data seemed to be very sporadic. Several times throughout the testing an electrode on a test subject's wrist or ankles became disconnected, skewing the data. Something as simple as putting a piece of tape over the electrode to secure it would have fixed this problem. Also pertaining to the ECG, it was crucial that each subject had ample time to bring their heart rates down to a normal resting rate before the start of the experimental procedure. However, if the subject didn't get enough time to do so they might have had a higher than normal heart rate due to the anxiety experienced when connected to a machine by strangers in a testing environment.

In conclusion, it seems as though more research and testing must be done to say for certain whether different music types have an effect on individuals reading comprehension. Also, a larger number of test subjects would more conclusively show the effects of the different types of music on reading comprehension and other physiological factors including heart rate and brain activity. Encouragingly, our initial data, though not strong, shows signs that an individual's reading comprehension performance is indeed effected by the music type they are listening to while taking the exam.

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AUTHOR CONTRIBUTIONS

All authors were involved in the conception and design of this experiment. The collection and analysis tasks were divided as follows: McDaniel was responsible for positioning the electrodes and properly connecting the leads on the subjects as well as proper swim cap placement; Jennifer was responsible for collecting consent, informing the subject of the experimental procedure, and handing the subjects their exam at the appropriate time; Lauren was responsible for running the computer connected to the ECG leads; Peter was responsible for running the computer connected to the EEG leads. All authors were involved in the drafting and critical revision of this article for important intellectual content. It is also confirmed that all authors approve of the final version of this manuscript.

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TABLES AND GRAPHS

Analysis of Variance (One-Way)

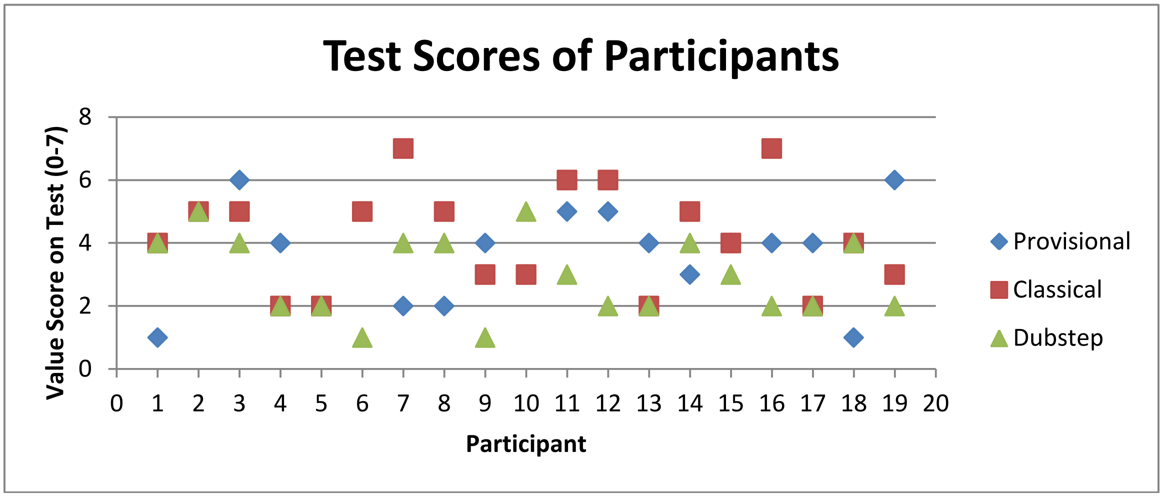
Summary

Groups	*Sample size*	*Sum*	*Mean*	*Variance*
Classical	19	80.	4.21053	2.73099
Dubstep	19	56.	2.94737	1.60819

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	15.15789	1	15.15789	6.98652	0.01208	4.11317
Within Groups	78.10526	36	2.16959			
Total	93.26316	37				

Table 1: This is a table showing the ANOVA output for the effects of classical and dubstep music on reading comprehension performance. Important to note from this table is the mean test score for classical music is higher than the mean test score for dubstep music, and the p-value shows significance. In regards to the mean squared error values, the smaller value for within groups (MS=2.16959) indicates smaller variance within each group, while the larger number for between groups (MS=15.15789) indicates larger variance between the two music types.



Graph 1: This is a graph of the test scores for each participant. From this graph, it is visually evident that the type of music playing while the subject was taking the exam has a significant effect on their test score.

Analysis of Variance (One-Way)

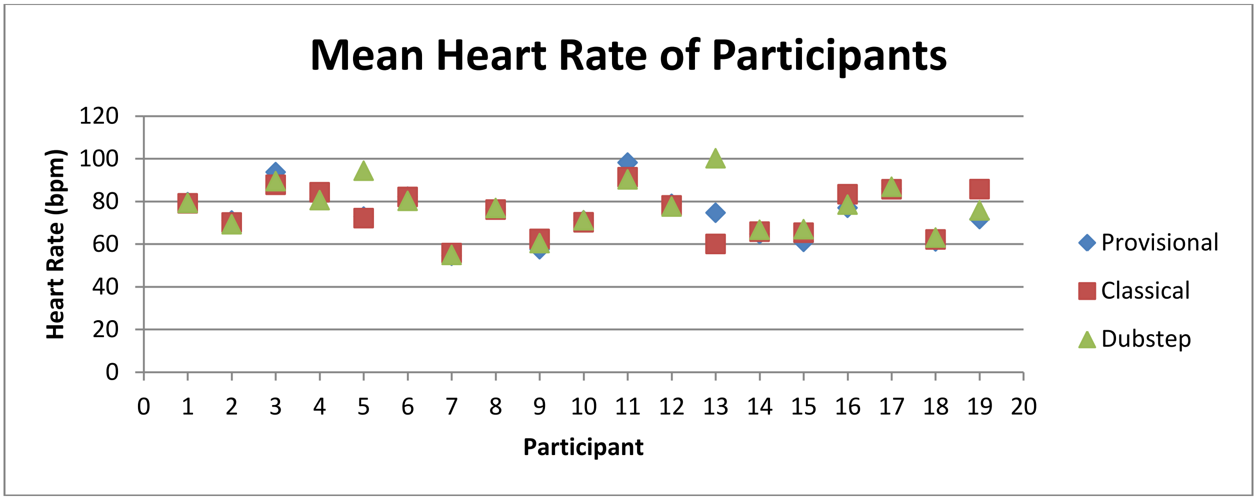
Summary

Groups	*Sample size*	*Sum*	*Mean*	*Variance*
Classical	19	1,418.64	74.66526	113.20258
Dubstep	19	1,463.86	77.04526	142.05514

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	53.8118	1	53.8118	0.42163	0.52025	4.11317
Within Groups	#########	36	127.62886			
Total	#########	37				

Table 2: This is a table of the ANOVA output for data from the effects of music type on mean heart rate. According to this table, the p-value of 0.52025 is much higher than the significance level of 0.05 indicating the data is not significant and there is no correlation between music type and mean heart rate. Also, the high mean square error values both within and between groups shows a lot of variance in the data and thus no trend.



Graph 2: This is a graph showing the mean heart rate of each participant for each music type. This visually indicates that while the mean heart rate is quite different from one subject to the next, each individual's mean heart rate is unaffected by the type of music being listened to.

Analysis of Variance (One-Way)

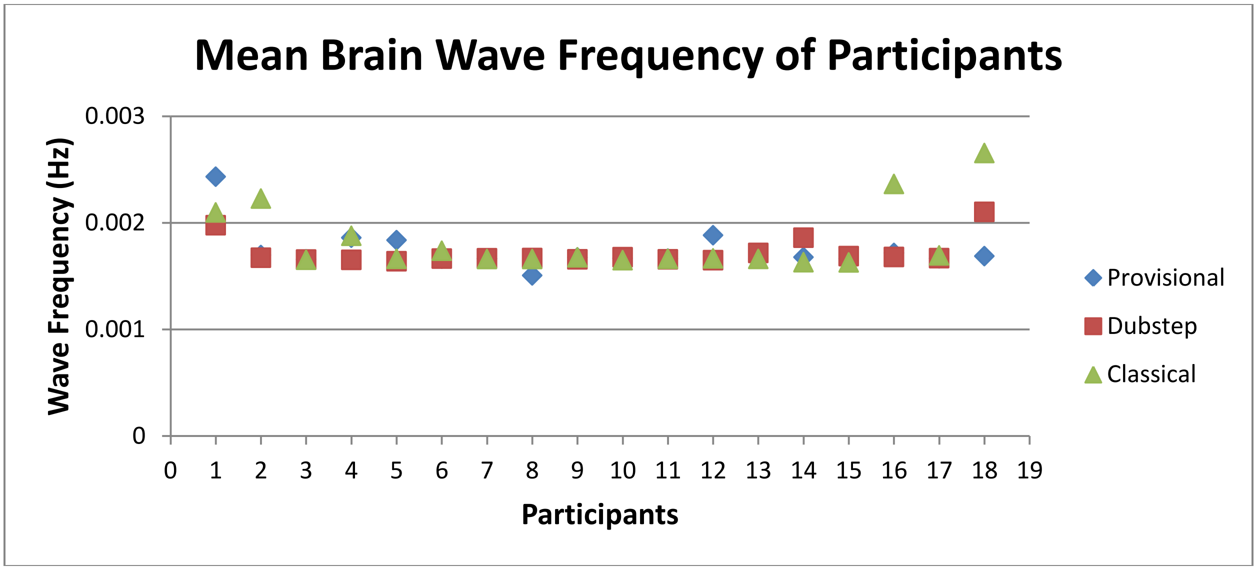
Summary

Groups	*Sample size*	*Sum*	*Mean*	*Variance*
Dubstep	18	0.03097	0.00172	0.
Classical	18	0.03288	0.00183	0.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	0.	1	0.	1.87613	0.17975	4.13002
Within Groups	0.	34	0.			
Total	0.	35				

Table 3: This is the table with the ANOVA output for the effects of music type on mean brain wave frequency. The p-value of 0.17975 is greater than the significance level of 0.05, showing that there is no significant effect of music type on mean brain wave frequency. For this data, because the numbers being analyzed were so small, the mean square error values could not be calculated as the variance was so small.



Graph 3: This is a graph showing the mean brain wave frequency of each participant while listening to the different types of music. It can be seen that there is very little variance both within each individual's frequency as well as between individuals of the group. This shows that the music type does not seem to have an effect on mean brain wave frequency.

Analysis of Variance (One-Way)

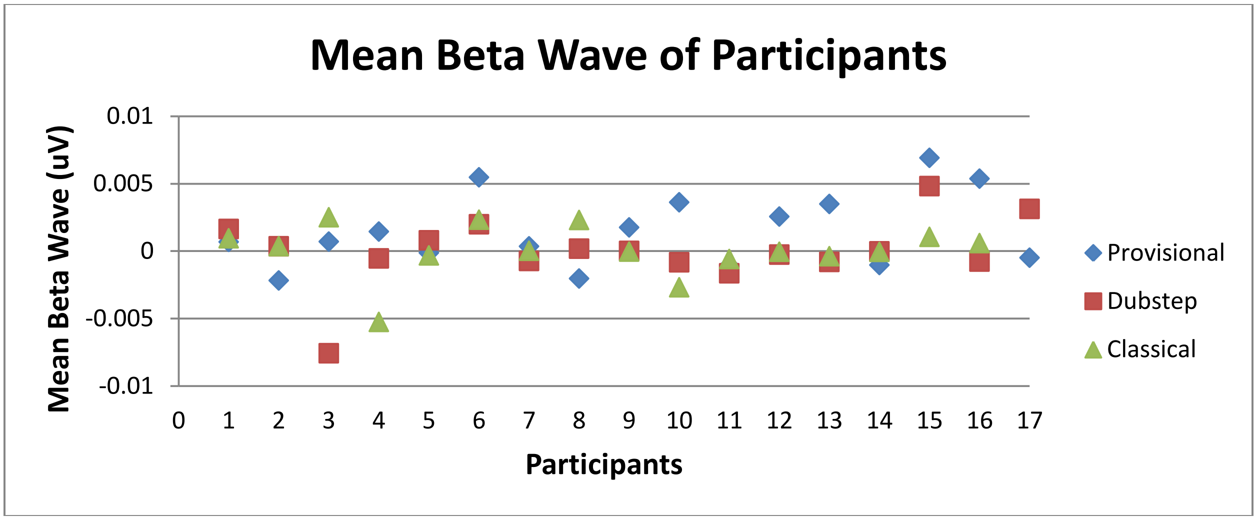
Summary

Groups	*Sample size*	*Sum*	*Mean*	*Variance*
Dubstep	16	- 0.00327	-0.0002	0.00001
Classical	16	0.00089	0.00006	0.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	0.	1	0.	0.10971	0.74277	4.17088
Within Groups	0.00015	30	0.			
Total	0.00015	31				

Table 4: This is the output from the ANOVA test run on the effects of music type on mean beta wave activity. The large p-value of 0.74277 is much greater than the significance level of 0.05, showing that there is no significant effect of music type on mean beta wave activity. For this data, because the numbers being analyzed were so small, the mean square error values could not be calculated as the variance was so small.



Graph 4: This is a graph showing the mean beta wave activity of each participant for the different music types. This graph shows that there is very little variance both within each individual's frequency as well as between individuals of the group. This shows that the type of music does not seem to have an effect on mean beta wave activity.

FIGURES

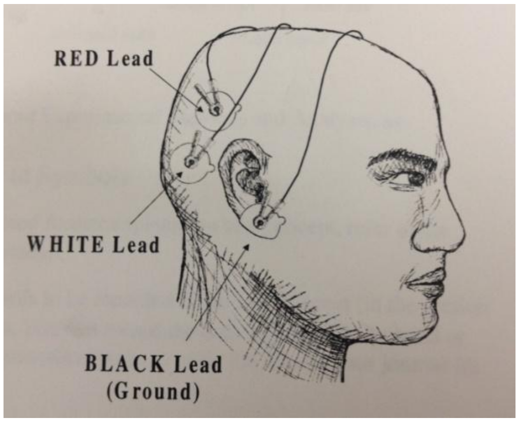


Figure 1: Location of electrodes for EEG.

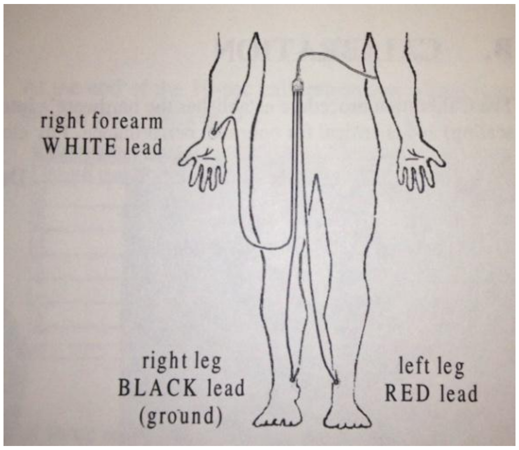


Figure 2: Location of electrodes for ECG.