THE USE OF BRAINWAVE MONITORING TECHNIQUES TO INVESTIGATE THE EFFECT OF AUDIO STIMULI ON STUDENT CONCENTRATION LEVELS IN A LEARNING ENVIRONMENT

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Abstract

The properties of audio stimuli, such as the frequency and strength of a sound/voice, can have both positive and negative impacts on audiences' cognitive processes. This is especially important for students who study in a learning environment where the information is mainly passed on through audio/voice communication, such as a traditional lecture. The brain goes through different neurological activities reflecting the positive and negative impacts. These activities can be monitored and analysed from their distinctive brainwave outputs using a special electroencephalographic device. In this study, the key properties of audio stimuli that may affect the student's concentration level were investigated. These include: (a) the frequency and strength of the main communicating voice and (b) the type and strength of background sounds behind the main voice. A special electroencephalograph device was used. This device places small non-invasive electrodes on a participant's head, picks up tiny amounts of electrical activity created by the brain, and interpolates the outputs into a *concentration level* (i.e., neurological attention values) measurable on a scale of 0-6.

The study was carried out by monitoring the participants' concentration level when they were listening to a selection of different voice clips presenting the same information. Effect of background sounds was investigated by playing different types of background sounds at various levels behind the same learning material. Results showed that the properties of the main voice can influence the audience's concentration level, some music that does not use predominantly sounds occupying the critical voice bandwidth can help to improve the concentration, and environmental noise, specifically vocal sounds (such as a distant argument or raised voices), can detract audience from the learning experience.

Introduction

The properties of audio stimuli, such as the frequency and strength of a sound/voice, can have great impacts on students' learning experience especially in an environment where the information is mainly passed on through audio/voice communication, such as a traditional lecture. These impacts can be positive or negative for an audience's cognitive processes depending on what neurological activities the brain goes through. Benefiting from the rapid developments of Electroencephalograph (EEG) techniques in recent years, these brain activities can be monitored and analysed from their distinctive brainwave outputs now.

When the brain goes through neurological activities, neurons are electrically charged by membrane transport proteins, which push ions across their membranes. As ions of similar charge repel each other, this causes a ripple effect across the brain. The EEG device places multiple small non-invasive electrodes on a participant's head. When this ripple reaches the electrodes on the scalp, it can be captured and measured by the EEG.

In this paper, the key properties of audio stimuli that may affect the student's concentration level will be investigated, including

- The frequency and strength of the main communicating voice.
- The type and strength of background sounds behind the main voice.

The participants' concentration level will be measured when they are listening to (a) a selection of different voice clips presenting the same information and (b) different types of background sounds at various levels behind the same learning material. An EEG device will be used to pick up tiny amounts of electrical activity created by the brain and interpolate the outputs into a "concentration level" (i.e., neurological attention values) measurable on a scale of 1-6.

Methodology

A selection of sound clips were created to carry out the test. They are designed to investigate how sound will influence the subject. A wide variety of psychoacoustically influenced sounds (Stoller-Conrad, 2012) were used in an attempt to influence audiences' concentration levels.

The Four Parts of the Test

The test includes four parts, each of which includes two listening stages. Between different stages the subjects take a five-minute break, listening to a song or watching a video, in order to prevent the test speeches from sounding too repetitive and adversely affecting the result.

Part 1

The subjects are required to listen to a brief speech made by a Scottish woman with a relatively high pitched speech range (Track A) and an English man with a very low voice (Track B), both using very different styles to present the speech. They will have 5 minutes break between the tracks. Voice A typically speaks in a soft, calming manner with slight traces of the Scottish accent, whereas Voice B uses a very loud, powerful manner of speech, but also speaks very clearly with an English non-descript accent. The speaker for Track A produces far more high frequency content than the speaker for Track B. The speech used for this test was Mary Schmich's Famous "Wear Sunscreen" speech.

Part 2

The subjects are required to listen to the same 2 speeches with a quiet piece of music playing along with the speeches. The music chosen was "The Heat" by Jungle, an upbeat, but soft and relaxed, synth-driven track.

Part 3

The subjects are required to listen to the same speech once again. But this time the music track in the background is "All the Kings' Horses" by Two Steps from Hell, a decisively more upbeat, intense and attention grabbing track.

Part 4

The subjects are required to listen to the same 2 speeches with intermittent sound effects in the background, including banal / common sounds (such as birds chirping and construction works noise) and more sudden and jolting sounds (such as distant gunfire or muffled shouting). This is to gauge the attentiveness and focus of the subjects when exposed to sudden unexpected sounds, and how well they return to focusing on the speech after these audio disturbances.

The Electroencephalograph (EEG) hardware used to pursue this study was a modified variant on a consumer "brain toy" with all unnecessary features and aesthetics removed. The output signal amplified and fed into an easy to read box, which uses the chipset developer's (Neurosky) own interpolation of Raw EEG values (eSense data), into easy to handle 0-100 values of Attention and Meditation. The EEG eSense data values will then be presented on the box by 6 Light emitting diodes (LEDs) representing the 6 consecutive levels.

The eSense data from the EEG electrodes are also sent to and recorded by a micro-computer, Arduino. The data can then be further process and analysed using "Arduino Brain Library" (Vidich & Yuditskaya, 2013).

Results

Due to a short time scale and a limited budget of this project, only four participants were found to undertake all the stages of in this study. However they covered an age range from 18 to 38 and both genders. These subjects who were able to participate will be referred to as Subject A, Subject B, Subject C, and Subject D here. The background of each subject is listed in Table 1 for the purpose of cross referencing any findings.

Table 1

Background of Each Subject

	Exposure to Commercial Media (Films, Television, Video Games, Radio)	Exposure to Professional Public Speakers (Lecturers/Teachers)	Profession	Physical Activity Levels/Lifestyle Factors
Subject A Age – 19 Gender – M	Daily exposure to films and videogames, some TV, little/no radio	Few times weekly, no exposure or interest outside of university	Student, Sport Coaching & Development	Very active, athletic
Subject B Age – 27 Gender - M	Infrequent exposure to films, and TV, daily exposure to radio in car & at place of work	Occasional "TED talk" and web based instructional videos	Carpenter & Carpentry Instructor	Sedentary, slightly overweight, infrequent exercise, smoker
Subject C Age – 18 Gender - F	Daily exposure to TV, common to film, infrequent videogames, no radio	Few times weekly, no exposure or interest outside of university	Student, Fashion Journalism	Overweight, smoker, motivated to get healthy.
Subject D Age – 38 Gender - F	Daily exposure to TV, infrequent film, rarely radio, no videogames	Regular attendee of conferences and presentations	Teacher, Modern Languages	Underweight, smoker, recreational drug user

Study Results

Subject A

Part 1

Subject A showed a measurable increase in attention towards Track A, over Track B. During Track A, the subject had a 2 on EEG activity and remained visually attentive and listening. However, during Track B, the EEG was constantly fluctuating, between 0 and 3 sporadically. The subject was noticeably paying less attention to the audio, as evident by considerably more fidgeting and other signs of boredom.

Part 2

During track A, Subject A displayed a relatively consistent level of attention throughout, noting that prior to the study the researcher was not aware that the subject was a fan of the music chosen for this part. With Part 2 Track B the subject displayed slightly more fluctuating attention levels and verbally described the speaker as “not being a good match for the music.”

Part 3

In track A, Subject A’s attention was not very focused and displayed erratic EEG activity, as opposed to Part 3 Track B, in which the subject’s attention remained on average consistent.

Part 4

The subject displayed a good level of attention to Track B, whilst still seeing similar fluctuations as Part 1. However, in Part 4 Track A the subject was distracted far more easily by the environmental sounds, specifically the distant sounds of two people arguing. The construction and traffic sounds caused some mild distraction, but did not distract anywhere near to the degree that the argument did.

Subject B

Part 1

Subject B showed on average a higher level of attention to Part 1 track A over Track B, with a consistent EEG level at 2. The subject also displayed a similar level of attention to Part 1 Track B on average, but with slightly more erratic spikes.

Part 2

During Track A, the subject was noticeably distracted, with EEG levels fluctuating much faster. The subject later described that his attention drifted more to the music over the speech, but found it difficult to focus on one or the other. He felt constantly being distracted, re-focused on one aspect, and then becoming distracted again. As Track B played the subject displayed much more consistent attention to the speech and was not distracted as much as Track A

Part 3

With Track A, subject B displayed an initially good attention level but soon became distracted by the music, specifically at stages where the speech was very mildly masked by the similar frequency content of the music track. The subject also displayed very similar results in Part 3 Track B to Track A.

Part 4

At the start of Track A, the subject was noticeably becoming bored of the same speech again, and EEG levels reflected this with noticeable changes to the average when the subject lost concentration or “phased out” as he described it. This was noticeably compounded by the environmental sounds, specifically in this case the repetitive 2kHz square wave “alarm” effect, which caused the subject’s attention to drop and then fluctuate. During Part 4 Track B, the subject displayed much more consistent attention levels and was not as easily distracted by any of the environmental sounds. The subject did still display some loss of concentration when exposed to the sounds of a distant argument, but not as much as with the alarm tone.

Subject C
Part 1
Subject C displayed a far more consistent level of attention to Track B over Track A, though the level of concentration on Track A was till at an acceptable level, averaging between 2 and 3.

Part 2
The subject was noticeably more attentive to Track B over Track A, verbally confirming that in Track A the music actively detracted from the delivery of the speech, whereas Track B was far clearer over the music.

Part 3
The subject displayed very erratic EEG activity, fluctuating from 1-3 during Track A, which indicated the subject was losing focus and trying to concentrate again. The fluctuation was less during Track B where the subject managed to concentrate more consistently on listening to the speech.

Part 4
Subject C showed a very similar response to the start of Track A as she did during Part 1, but she was easily distracted by the environmental effects. The subject identified that by this point of the study she was more interested in the distant argument sounds than hearing the speech again. Consistent EEG wave activity levels were showed when she was trying to focus on the speech. Erratic fluctuation appeared at the start of these sounds and subsequently when she was attempting to return focus towards the main speech after this section. Subject C displayed very similar results during Part 4 Track B as she did during Track A. However certain environmental sounds such as construction works and traffic did not affect the levels of attention as much as they did during Track A.

Subject D
Part 1
Subject D displayed a far higher level of attention during the duration of Track A over Track B, with EEG levels for the latter being more erratic than the relatively stable results of former.

Part 2
During Track A, the subject displayed a fairly consistent EEG wave level throughout, remaining relatively focused. With Track B the subject produced similar results, albeit with slightly more aberrations, but nothing to indicate anything less than a fair amount of attention paid throughout.

Part 3
During Track A the subject displayed very different results to the prior sections of the test, showing EEG wave fluctuations and a lack of concentration throughout. With Track B the results were similar to that of Track A, but less pronounced. In verbal feedback the subject described the music as too distracting in Track A, and not as bad in Track B.

Part 4
Subject D displayed similar attention levels to both Track A and B to begin with and was not easily distracted by a large majority of environmental noise. However, the distant argument sound caused the subject's EEG wave levels to rise, indicating less attention was paid to the speeches.

Discussion

Some Interesting points can be found from the data gathered from Part 1 of this test. Despite many modern techniques in public speaking pertaining to the idea that a powerful and deep voice is far better at capturing the attention of the listener (Dholakia n. d.), from the results found here, the subjects gave on average a stronger amount of concentration and focus to Track A. This may be due to a phenomenon described by Julian Treasure (Treasure, 2014) that an alternative technique of public speaking which requires the speaker to present the information in a calm, clean, and arguably too quiet vocal style is effective. The theory is that with the speaker talking more quietly the audience is then required to consciously listen more carefully and, unintentionally, pay far more attention.

The problem with this theory, as Part 4 of the test indicated, is that this technique only works well if there is (a) an audience who wants to listen (a common struggle in teaching younger students) and (b) no external audio interference or environmental disturbance. While the subjects' responses to Part 1 support Treasure's theory, the results from Part 4 highlight the problems with using this method of public speaking in a variety of environments. Subjects were found to be easily distracted by environmental noise, and distant voices detracted immensely from how well the information was delivered. The subjects' responses to Part 4 Track B, however, produced far more consistent levels of attention.

Part 2 of the test indicates some disparity with the results. Some subjects paid closer attention and concentration with Part A, and others indicated that Track B was better at capturing the listeners' focus. The point could be made that perhaps this is due to the similar crossover in frequency content between the music and the voice. Perhaps in Track A, the subjects were in fact paying more attention to the music, where in Track B the voice is louder and more forceful over a soft calming piece of music. This identifies a potential issue with the study's methodology. It is feasible that for Parts 2 and 3, the monitored attention levels of the subjects may not be entirely representative of the subjects' actual levels of concentration devoted to the speaker, and perhaps by this point (having already heard the speech a number of times) more attention was paid to the music. This is compounded by the results of Part 2 Track B, wherein most subjects displayed infrequent attention with some fluctuation. These fluctuations may well indicate where the subjects' concentration shifted focus from the speech, to the music and vice versa.

A study by Dr Nick Perham states: "We found that listening to liked or disliked music was exactly the same, and both were worse than the quiet control condition." According to Cutler (2013) "Perham asked his subjects how they think they performed when exposed to different tastes in music. Each reported performing much worse when listening to disliked music, although the study's results showed no difference."

Within Perham's study (Perham & Vizard, 2010), the results were gathered by evaluating subjects as they performed serial recall tasks, and he concluded that the control group performed better. His study (as well as from the results of Part 2 and Part 3 in this study) indicated that listening to music whilst aurally receiving information is fairly detrimental to the subjects' quality of learning. However, it should also be noted that Perham's study also found that listening to music *prior* to study, and during repetitive tasks, regardless of complexity, the preferred music very much did show a higher quality of results than disliked music.

A progressive route for further study here could be studying the EEG wave levels of subjects while listening to music subjects, such as music they do not like and music they are indifferent to, while they are sked to perform a variety of tasks, such as a serial recall task, a physical puzzle, etc.

Within Part 3 of the test, subjects displayed erratic EEG wave levels that made it clear they were having difficulty concentrating. This may be in part due to the far more intense style of the music, which contains a far wider dynamic range and higher amplitude than in Part 2. Judging from the results, it is apparent that Track A experienced some simultaneous masking over areas of commonly shared frequency content, whereas Track B had a higher dynamic range and the speaker spoke over the music (Haritaoglu, 1997). This may be attributable to the male speaker's lower fundamental speaking range.

Within Part 4 of the study the subjects found themselves easily distracted by some environmental sounds, but not to others. In particular, the sounds of a distant argument proved far more distracting than other common urban environmental effects like stereotypical traffic sounds, construction works, etc. The sounds of a car/fire alarm, a repeating 2kHz square wave, also distracted the subjects to a fair amount. It could be suggested that both of these points relate to a very human perception of sound, our biologically preferential response to the critical voice bandwidth (Kob, Henrich, Herzel, Howard, Tokuda, & Wolfe, 2011).

Conclusion

The subjects all displayed varying erratic attention levels during Part 2 and 3. This makes it apparent that while specifically listening to aurally presented data, having music play in the background was detrimental to the attention given to the speaker. This may well be because of the crossover of active frequency content between the music and the speaker. So with this in consideration, it can be surmised that if a public speaker were to use music as a background for enhancing the delivery of his/her speech/lecture, it would be far more conducive to the learning experience of using music with little or no specific focus on the critical voice frequency range. For example, a piece of music featuring acapella singing would detract far more than it would enhance the delivery of the information; likewise a piece of instrumental music, featuring woodwind instruments which characteristically produce a higher fundamental frequency (Clarinet, Oboe, Flute, or Piccolo), which occupies primarily a range of 1kHz to 8kHz, would be just as distracting. (IRN 2006)

From the results of this study, and as supported by previous studies, any music featuring predominantly frequency content occupying the critical voice frequency band can be more detrimental to a learning experience than music that does not, regardless of the method of learning. This is also supported by the results found in test Part 4, where the presence of audio in the critical voice range is more distracting when compared to the other sounds being heard (Assmann, 1996). All subjects were noticeably distracted by the sounds of an argument, therefore in summation; if a music bed is desired for a public speaking event or situation, music which is more rhythm based than melody, would be more appropriate.

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