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The effects of different kinds of music on brain activity: How change in brain activity caused by music affects short-term memory

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Outline

Introduction …..3-4
Background...4-6
Methods and Materials..6
Experiments and Results...7-11
Discussion...11-12
Conclusion...12-13
References...13

Please regard the extra excel file as our Appendix.

Introduction

The fact that music has an impact on the brain is little surprising: music is perceived, processed, memorized and enjoyed. However, there is more to music than just simple perception and processing. In 1993, Rauscher et al. claimed that listening to a particular piece of music by Mozart enhanced short-term memory performance and spatial learning. This effect was called the Mozart Effect. IQ scores would get as much as nine full points higher in the study done by Rauscher et al., in which subjects listened to Mozart's sonata for two pianos (K448) for ten minutes, before being asked to do small tests in the area of spatial learning. However, the effects of listening to Mozart's sonata did not last longer than ten to fifteen minutes.

Since 1993, many studies about the Mozart Effect have been done: some with no significant results, but numerous with a clear enhancement in subjects' skills. However, until today, these studies have merely looked at actual performance: subjects were exposed to ten minutes of Mozart, and then they were submitted to doing small tests like short IQ tests. The question that arises is: How come that listening to music brings on such surprising results in memory and spatial learning?

A way to answer this question is to look at the brain activity during the period of exposure to music, and see *which areas of the brain are stimulated*. It may very well turn out that the same areas that are stimulated by Mozart's sonata K448, play a role in short-term memory as well. In our research, we want to look not only at the effects of this particular sonata by Mozart, but also at different types of music, in order to see if they also have comparable effect. Therefore, our research question is:

"What are the effects of different kinds of music on brain activity and how does this change in brain activity affect the short-term memory?"

Background

Rauscher et al. discovered the 'Mozart effect' in 1993, although in their 1993 paper and subsequent research they did not refer to it as such. The name 'Mozart effect' was brought to life in 1991 (before the aforementioned study was conducted) by a French researcher called Alfred Tomatis, who believed that listening to Mozart's music promotes healing and development of the brain. The studies conducted by Rauscher et al. focused on measuring the short-term influence of Mozart's sonata on the Stanford-Binnet Intelligence Scale. What they found was that listening to Mozart's sonata for two piano's (K448) led to a short-term improvement on the spatial reasoning part of the formerly mentioned Intelligence Scale. This improvement only lasted for approximately 10-15 minutes. In further studies conducted by the same group of researchers (1995, 1998), the same results were found and slightly expanded to include more long-term effects. However, the results remained limited to improvements in spatial IQ.

While Rausher et al. continuously found results strengthening their hypothesis; other studies have tried to verify their study in the meantime. The results from these studies have been far from coherent (Cassity et al., 2007; Steele et al., 1999). While Steele et al. mainly failed to find any result similar to that of Rausher et al. (1999), Cassity et al. claimed that the Mozart effect is not limited to Mozart's music, but is more likely to be connected to the subjects' musical preference (2007). In their study, Cassity et al. indeed found a connection between subjects' musical taste and the degree of improvement in their spatial-reasoning IQ (2007). As a result of the social impact of the Mozart effect (which included parents having their babies listening to Mozart) and the resulting skepticism, there is a general distrust in the Mozart effect.

Concluding on the previous research conducted on the effect of music on the brain and learning, one can assert that the Mozart effect has, as of yet, not nearly found its way to academic agreement. The Mozart effect has provoked many debates in the academia, for while some groups of researches have found consistent results, repetition of the same experiment by others has led to greatly differing results.

There are various reasons that we think exemplify why there is still a research gap (that we attempt to fill with our research). Some of them and the alternatives we offer are as follows: Most of the studies we have looked at have used children as subjects. We intend to use students as subjects for our research project because we believe the inconveniences that can be caused by the subjects, in case they are students, are less. Apart from this, we would like to focus less on intelligence and more on memory. Jaušovec et al. have set a significant step in this direction, but while they claim to be focusing on learning, their primary focus still lies in the alleged spatial-reasoning improvement.

Methods and Materials

For our experiment, we used Emotive EPOC headsets that are available in the Beta Lab at Amsterdam University College. These are wireless EEG devices that are available to the public, and therefore, available to us as students. You can see how exactly they look in the picture below. The EEG device contains one main band and two arms equipped with 18 fingers in total. The semicircular band contains the battery, Wi-Fi transmitter/receiver and a gyroscope (orientation sensor). Two of the sensors are reference sensors, which are used to measure the base resistance of the skin and skull of the subject. This helps to adjust the device's measurements to an individual subject, and to cancel out some of the environmental noise. The two sensors pointing downwards that look different are dummies and reserved as alternate reference locations. So, there are in total 14 sensors to deliver actual EEG measurements All the signals we collected were transformed by Fourier analysis into weight functions. How does this 'sensoring' exactly happen? Before inserting the cups and pads into the headset, we need to moisten them with saline solution. Saline solution is a sterile, but very conductive fluid, which is necessary to pick up minute brain signals. Test subjects had to prepare themselves as well. They had to remove metal objects because many metal objects interfere with electric fields, thus would have created noise, which would have made the sensor readings worthless. For every test subject we had one of these devices that was on the subjects' heads while they were listening to the music samples.

Experiments and Results

a. Experimental setup

We conducted our experiment on around 10 subjects, all AUC students (so around same age), with an equal sex distribution (five females and five males).

The experimental setup is as follows: We played 10 minutes of certain type of music, for all types of music we chose. In order to conduct our experiment, we first decided on the exact number of types of music we are going to play to our subjects. There were four pod casts made for the tests; a classical, pop, silence, and K448 sonata pod cast. The duration of every pod cast is ten minutes. The subject listened to one of these pod casts (the order of which was allocated randomly) per time. While listening, the subject's brain activity was measured by the EEG. After this, we gave our subjects one minute time to memorize a list of around ten words in an unfamiliar language. To avoid bias of giving the subjects words in different languages that are personally unfamiliar to each of them, we decided to choose a single language that is unfamiliar to all the subjects, because some languages are more difficult to be learnt. The language that we chose to test our subjects on is Finish because none of our subjects has any knowledge of Finish. We gave our test subjects a new, different combination of words after each type of music. We tried to choose words with equal difficulty for every set, so that the complexity of the words will not affect our results.

Immediately after the subjects tried to memorize the words, we asked them to write the words down. We measured the brain activity both at the times the subjects' brains were exposed to music, and the times our subjects were memorizing the word list. The purpose of this is, as already mentioned previously, to find a possible relation between the brain area responsible for short-term memorization and the brain area responding to musical stimulation. We repeated the same process four times (with all the kinds of music we chose), which altogether took on average one hour. We used the results to see how different kinds of music affected the subjects' short-term memory (ability to memorize the word list) and whether there is a relation between the two brain areas aforementioned.

b. Experimental limitations faced

There are several issues that came up while doing our experiments. In the following text you can see how we think they can affect our conclusion. First of all listening to music or even silence for around an hour appeared to be tougher than we initially thought. Consequently, we did take into consideration that this might affect our study results: the time subjects spent on listening the music (about an hour) might have decreased their concentration and thus learning abilities, especially when taking into account that a subject only had one minute to learn words which is not much when your concentration is relatively low. However, the actual results point out whether this assumption is refutable or not.

Another moderately important difficulty in our research was the noise which was caused during our experiment sometimes. Although this is not of great influence during the time the subjects were listening to music, we think that having noise in the same room where the subject is, while learning the words in one minute could be a remarkable distraction. This also may as a result have decreased the learning abilities and capacities of our subjects.

Apart from this, we also experienced some technical difficulties. One of them was the fact that an EEG device may react upon mobile phone signals heavily; therefore we had to turn off our phones, while we also needed a timer for the one minute of learning. However, we improvised on this by using the time option on the computers in the Beta Lab. A somewhat more difficult problem was the many EEGs that were used: they could interact, thus influenced each other in such a way that the EEGs did not work properly at times. However, we managed to move some computers to another room and with that distribute the EEGs, which solved the problem.

Lastly, some members of our group had to collect and make the lists of Finnish words, but they were not allowed to remember these words, as otherwise this would influence their learning capabilities while doing the research. However, someone from our group knew a Finnish student who selected four different combinations of ten Finnish words, which relieved us from having to collect and read the words ourselves. The only task we, in our group, had to perform was to print and cut out the lists. However, we all agreed that this did not influence our familiarity of the words significantly.

c. Results

After having conducted our experiment, we looked at the data collected. We took EEG measurements for the whole 10 minutes during which subjects had to listen to one of the music genres or silence, so this yielded us a large amount of data. Before we started analyzing the data, we still had to take out some small parts. One of the subjects had to redo a few of the genres, so the data of the first few minutes of the unfinished test could be taken out. Apart from that, we did not change our dataset in any other way.

Since one of purposes of our experiment is to test the Mozart effect, we wanted to see if there is any difference in brain activity between Mozart's sonata and the different conditions. We did not do the usual procedure of subtracting EEG response of one condition from the other to see significant differences, but we tried to predict on the basis of EEG what genre subjects were listening to. The main factor that stands out when observing our data, without any kind of visualization or classification, is that the *brain activity during silence is much lower than brain activity in any of the other cases*. This, of course, makes sense because the brain is not processing any sound in the silence class. To find out if there is any significant difference between the other three genres; cases can be predicted with a reasonable accuracy.

There are a few different ways to investigate this. Firstly, we combined all our data into one single file. Then we removed one of our subject's data values, since he did not complete the entire experiment. Now having a reliable dataset, we first ran a k-nearest neighbor classifier over our data. We ran this test over the whole dataset, trying to see whether there would be a difference between any of the brainwaves in general. We found the biggest accuracy at k=4, so we used this in a 75% split. This means that the first 75% of our data was analyzed and used to predict the remaining 25%. In the end, this yielded a prediction accuracy of 64%. Given that we have a total of 4 attributes, this is a reasonable statistic, though far from ground breaking. Recall that there were 4 different conditions for our subjects: Silence, Mozart, Pop and

Classical. If we would have to predict only 2 of these attributes on the basis of 75% of our data, 64% would not be impressive, since it is fairly close to the expected 50% (since there would be just two attributes). In our case though, the program had to predict one out of 4 attributes, which makes 64% accuracy a more significant number. There is, however, still the fact that since silence was so easily predicted, this has also affected the accuracy. When we ran the

AVERAGES	
Average SAMPLE 1	6,48
Average SAMPLE 2	6,42
Average SAMPLE 3	6,67
Average SAMPLE 4	5,87

Table 1 shows the 'difficulty-factor' of the sets of words.

Same test on our dataset without the silence attribute, we reached an accuracy of 67%.

We did not find any difference between different brainwaves. However, we found a general difference between all of the brainwaves in the different conditions. Apart from the k-nearest-neighbor model, the decision tree model also yielded us an acceptable accuracy: 62%. This, again, had the purpose of seeing whether a computer could detect a general difference between any of the different attributes. Without our silence-group, we, again, reached an accuracy of 67%, which surely makes our result more reliable.

Apart from the results from the EEG, we also analyzed the results of the actual tests our subjects had to do. There was one assumption we forgot about: the difficulty of the different word samples. Since the language was chosen on the basis that nobody would be able to understand it, it was not possible to say anything about the difficulty. In order to test that all the words were equally difficult, a second research had to be conducted. This we chose not to do.

We compensated for the possible difference in difficulty between different words sets by doing the following: First, we took the averages of all the subjects corresponding to a specific sample set. By doing this, we found that certain sample sets were slightly ‘easier’ than others. Secondly, we divided every single result by the ‘difficulty-factor’ of the set. This gave us the absolute data, corrected to the difficulty of the concerning sets.

Finally, we took the averages to give us a sound basis for our conclusion.

Most evidently, there was one disadvantage to this all: the loss of comprehensibility. At first, the results were rather clear: the numbers represented the correct words out of a set of ten words. After the correction, however, the comprehensibility of the values was lost: they were changed into values between 0, 8 and 1,4. Again, we immediately noticed a clear distinction between silence and the other attributes. It surprised us, however, that the silence condition yielded worse results than the rest. We expected that silence would enable our subjects to excel in learning the words, although, as we'll discuss later, there was still a fair amount of noise during the supposed silence.

Discussion

In hindsight, our research and data collection went rather well. Of course, there were several problems that we encountered during our data collection that may have influenced our results.

AVERAGES CD	
Average SILENCE	0,84
Average POP	1,05
Average MOZART	1,00
Average CLASSICAL	1,10

Table 2 show the averages of the absolute, corrected data

Also, some factors that we initially thought might be problems for our data collection turned out to have little, if any effect. As it turns out, listening to different types of music and studying words over the course of an hour did not have worse outcomes after more time had passed. In the table of results (see Appendix I), it is visible that the fourth test was not done significantly better, or worse, by any of the test subjects, thus enabling us to conclude that the passing of time had no particular influence on our test results. However, distractions in the test room or in the hallway that were audible to the test subjects may definitely have influenced our results. Especially one of our subjects complained that while she was trying to study the words, people were talking in the room and the door to the hallway was open. Therefore, she could not focus on the words very well, which has negatively affected her results in the word test. Also, in another subject's test, after he listened to silence for 10 minutes, the experiment wizard program crashed, making it impossible for us to save his EEG data. We therefore left his test for silence out of our calculations for the averages, but having less data to average of course gives a less reliable representation of the results, especially in such a small sample.

In analyzing the EEG data, the first problem we encountered was that WEKA, the processing program for EEG data that we used, did not seem to work on our own computers at first. However, after having overcome this technical difficulty, we managed to see some correlation, as described in the Results section.

The only big problem we encountered in analyzing our data, was that initially we wanted to see which brain areas were ‘more’ active, and see if these were the same as those that are active in short term memory. However, short-term memory is situated very deep inside the brain and was therefore hard to localize with the Emotiv Headset. Also, the EEG data don’t really show the level of activity, just correlations between different areas of the brain, which was not exactly what we were looking for. Therefore, in the end we had to limit our research to these correlations, and see how the music that we used in our data collection had different effects on the brain and on the short-term memory.

Conclusion

Concluding on what music has to do with the brain, we first go back to our research question *“What are the effects of different kinds of music on brain activity and how does this change in brain activity affect the short-term memory?”* It was exemplified that studies conducted before ours tried to answer similar question(s). Some of them were considered to be on a good way to finding out 'the truth', whereas others had contradictory results. We tried working out what went wrong with past studies, and created a distinct experiment on our own.

Using EEG emotiv devices we collected data from ten test subjects and analyzed the results. The most important issue at hand is to answer how our results are different from the studies done before on the same subject. In other words, what can we conclude on the basis of our results? The answer to this question is as follows: our results enable us to quite surely state that listening to music enhanced our subjects in learning words. However, the line between the different genres is less clear-cut. From the data we have gathered, we cannot identify a significant distinction between any of the three genres in which subjects listened to music. This would certainly underestimate the possibility of existence of a Mozart effect. However, to say anything reliable about this, further research will be necessary.

References

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