Improvement of Concentration of Numeracy by Mozart Effect

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ABSTRACT

It is commonly believed that task performance is improved by listening to Mozart's music. Although this so-called Mozart effect is not often discussed in scientific literatures, those psychological experiments that have addressed it tend to confirm its existence. For example, college students who listed to Mozart's Sonata $KV.448$ scored 8 to 9 points higher on the IQ test than students who had listened to a relaxation tape or listened to no music at all. In another recent study, students who solved a simple visual task while listening to Mozart's music displayed more coherent brain activity. The goal of the present study is to investigate the influence of different types of music on task performance - as measured by error rate and reaction time on a bank of arithmetic questions - and on brain activity as measured with electroencephalography (EEG). Each musical segment is divided across high- and low-frequencies, so as to test the hypothesis that the observed performance enhancements are driven by a particular frequency range. In particular, eight minutes of Mozart's $KV.216$ (1st mov.) was segmented into high- and low-frequency ranges according to multiple division models. In general, we hypothesized that music would positively influence task performance during a learning phase, when participants become familiarized with the task, and during a subsequent test phase. We also predicted that this benefit would be further reflected in the EEG patterns. Finally, we expected brain activity patterns during the test phase to be similar to those observed in high performing individuals.

Keywords

Morzart Effect, Frequency, Arithmetic Questions, Electroencephalography

1. INTRODUCTION

One type of study for analyzing the effect of listening to music to characterize any improvement in performance is by exploring the Mozart effect [1–7]. Mozart effect is a phenomenon that the task efficiency is upgraded if the subject listened to classic music Mozart composed. Although this so-called Mozart effect is not often discussed in scientific literatures, those psychological experiments that have addressed it tend to confirm its existence. For example, college students who listed to Mozart's Sonata $KV.448$ scored 8 to 9 points higher on the IQ test than students who had listened to a relaxation tape or listened to no music at all [1,2]. In another recent study, students who solved a simple visual task while listening to Mozart's music displayed more coherent brain activity [3]. In particular, a paper [5] reported that the *gamma* wave component of brain activity was increased wile listening to Mozart's music. In addition, another paper reported that listening to Mozart's music enhanced efficiency for spatial rotation task [4].

In this paper, we investigate the influence of Mozart's music on task performance as measured by error rate and reaction time on a bank of arithmetic questions and on brain activity as measured with electroencephalography (EEG). For the experiment, a piece of Mozart's music was divided into high frequency and low frequency components. We monitored the performance of error rate, reaction time and EEG on arithmetic questions before and after when subject listened to each music. In particular, eight minutes of Mozart's $KV.216$ (1st mov.) was segmented into high- and low-frequency ranges according to multiple division models. In general, we hypothesized that music would positively influence task performance during a learning phase, when participants become familiarized with the task, and during a subsequent test phase. We also predicted that this benefit would be further reflected in the EEG patterns. Finally, we expected brain activity patterns during the test phase to be similar to those observed in high performing individuals.

2. ANALYSIS PROCESS OF MOZART EFFECT

We selected the Mozart concerto for violin No.3 F major ($KV.216$) "Strasbourg" in order to analyze Mozart effect. To divide into high frequency and low frequency for the Mozart concerto, we extracted the music in the power spectral density function with Fast Fourier Transformation(FFT). To explore effects of different frequency components of the mu-

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sic for the Mozart effect, we defined several different ways to divide the frequency components of the music into low frequenciy and high frequency components. These seven ways are listed below.

AVE : Average of power spectral distribution

MED : Median of maximum frequency and minimum frequency

MNP : Median of normalized power spectrum

MODE : Frequency of maximum power spectrum

C_1 : Median of AVE and MED

C_2 : Median of MED and MNP

O : Frequency of octave boundary value

The indexes of AVE, MED, and MNP are defined as follows;

$$AVE = \frac{\sum_i f_i p_i}{\sum_i p_i} \quad (1)$$

$$MED = \frac{f_{min} + f_{max}}{2} \quad (2)$$

$$MNP = \min_i \left| \frac{p_i}{\sum_i p_i} - 0.5 \right| \quad (3)$$

where, f_i shows the i-th frequency, and p_i is the power spectrum of f_i.

In addition, we defined the indexes of C_1, C_2 and O which show the median of AVE and MED, the median of MED and MNP, and the octave boundary frequency, respectively. The indexes C_1 and C_2 are defined as follows;

$$C_1 = \frac{AVE + MED}{2} \quad (4)$$

$$C_2 = \frac{MED + MNP}{2}. \quad (5)$$

Figure 1 shows the division frequency to divide into upper register and lower register for the Mozart concerto. The result became the order of $MODE$, MNP, C_2, O, MED, C_1, and AVE in ascending order of the frequency.

In this paper, we consider that the music have to be divided into two halves, one with lower frequency compoents and one with higher frequency componets. Several ways were tried to determine the particular value of frequency that separated the two halves. We find a best division frequency from these division ways, which is decided by evaluation of subjects for listening to a piece of music divided by each frequency. Specifically, as the first step, subjects listen to a piece of music which is divided into fourteen kinds of frequencies with upper and lower registers of Mozart concerto, and evaluate points by "the most difference between upper register and lower register, and that is similar to the original music." The evaluation is assumed five answers, which are 1:Not absolutely, 2:No, 3:Not decide, 4:Yes, and 5:Absolutely yes.

The initial evaluation of what method to divide the music into higher and lower frequencies did show that the dividing method resulted in different user perceptions of the music as AVE : 62.2%, MED : 68.4%, MNP : 62.2%, $MODE$: 61.3%, C_1 : 76.8%, C_2 : 77.2%, O : 73.4%. In addition,

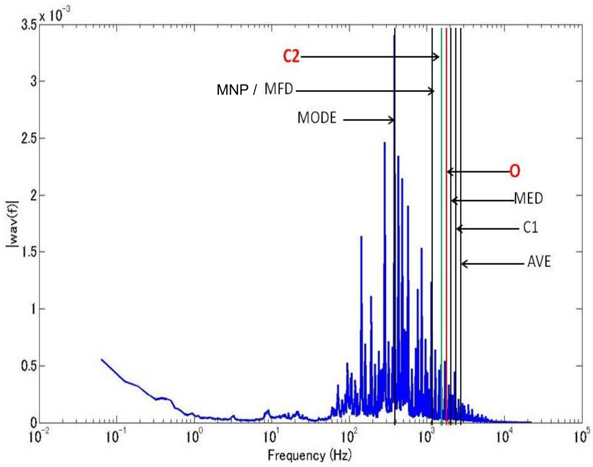

Figure 1: Division of Music Frequency

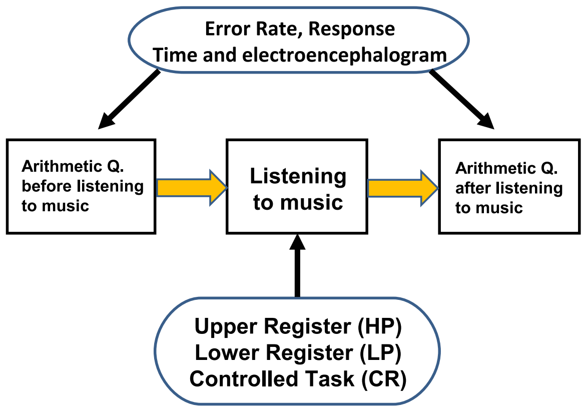

Figure 2: Process of Experiments

the evaluation to be most similar to the original piece of music was C_2 whose average was 3.03 and standard deviation was 0.83, and the second evaluation was O whose average was 2.96. By these results, we assumed indexes of C_2 ($1536.1Hz$) and O ($1569.6Hz$) the experiment sound source of the Mozart effect from seven kinds of methods.

3. EXPERIMENTS AND DISCUSSION

The Mozart effect is analyzed using the error rate and reaction time of the arithmetic questions on the web site, and signal of electroencephalographic measurement. Figure 2 shows the process of experiment. The questions used in the study were based on arithmetic questions at the elementary level. The problems presented to the subjects in this study were the reverse problem: to cipher the missing value from the answer. Figure 3) shows an example of such a question. We monitored the performance of error rate and reaction

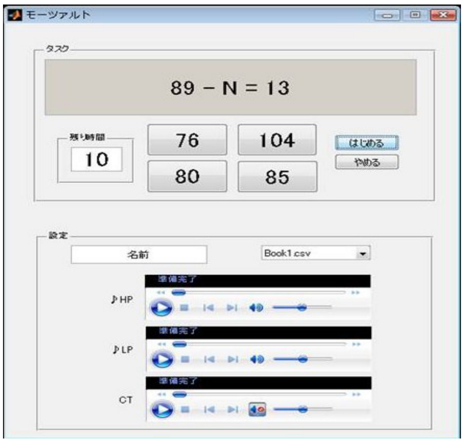

Figure 3: Numerical Task

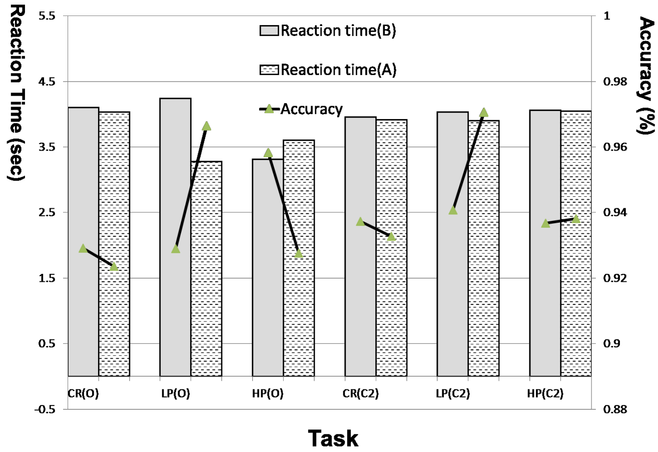

Figure 5: Task Performance by Mozart's Music

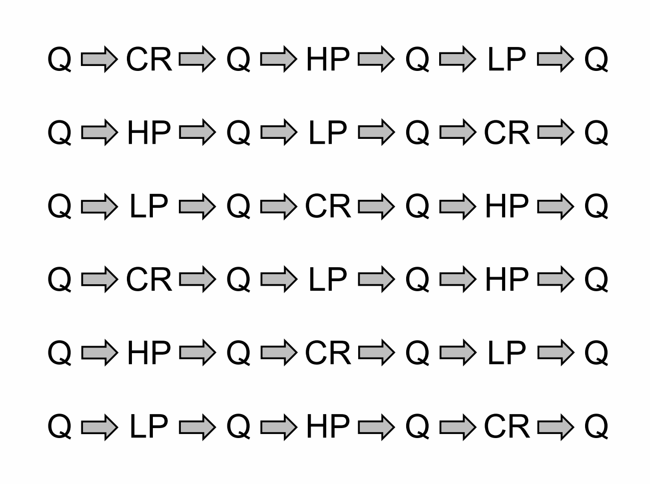

Figure 4: Sequence of Audition Experiment

time on arithmetic questions before and after when subject listened to the piece of music.

Simultaneously, we monitored the EEG of subjects with the instrument of TEAC Corporation, $PolymateII\ AP216$ (sampling frequency : $200Hz$). The electroencephalogram is monitored by the international 10-20 method at ten places of electrode positions of subjects.

Subjects listen to a piece of music divided by upper and lower registers of C_2 ($1536.1Hz$) and O ($1569.6Hz$), and subjects then answer the arithmetic questions(Q). In the experiment, a subject listens to the original Mozart concerto ($K.216$) for one minute, and then listens to the upper register (HP) and lower register (LP) for one minute, respectively. In addition, the subject listens to the original piece of Mozart concerto again for one minute whenever the subject listens to a new sound. For the controlled task (CR), the subject listens to nothing during the resting period. The order of the music to be listened to (LP, HP, CR) was shuffled for preventing the strong dependency of order of experiments. The order of pieces of music shows in Figure 4.

By combining of sound sources which are upper register (HP), lower register (LP) and controlled task (CR), and two kinds of indexes which are C_2 and O, all experiments are 12 orders. We gave 21 subjects 12 orders, and we measured correct rate, answer time, and electroencephalographic signal. The results of correct rate and answer time are shown in Figure 5. The bar graph shows reaction time on arithmetic questions before and after subject's listening to the piece of music for each division method of frequency. In addition, the line segment shows the performance of accuracy rate. If the reaction time after listening to the music at a division frequency is shorter than the reaction time before listening to the music, the division frequency shows Mozart effect most. In addition, if the line segment is increasing, the division frequency shows Mozart effect most. It was the lower register of the O method that the correct rate was improved most after of subject's listening to the piece of music. After listening to the sound source, 0.04 point is improved, and 0.04 point is higher than the controlled task. As a result, we should notice that subject increased the degree of concentration by listening to the sound of the lower register divided by the O method. In addition, it was the lower register of the O method that answer time was improved most for 3.3 seconds from 4.2 seconds at average answer time, and it was faster than the controlled task for 0.76 seconds. Similarly, we should notice that the lower register divided by the O method increases the concentration degree.

On the other hand, the big difference of electroencephalogram after listening to the piece of music was detected at electrodes of FP_1, FP_2 and O. Figure 6 shows examples of electroencephalogram. We should notice that a power spectrum of δ wave ($1Hz-3Hz$) of FP_2 increased after listening the piece of sound divided by the O method. In particular, it was activated with the right frontal lobe more. The relationship between the increase of δ wave at the right frontal lobe and the degree of concentration is unknown, but we are interested in further investigating such a possible relationship in future studies.

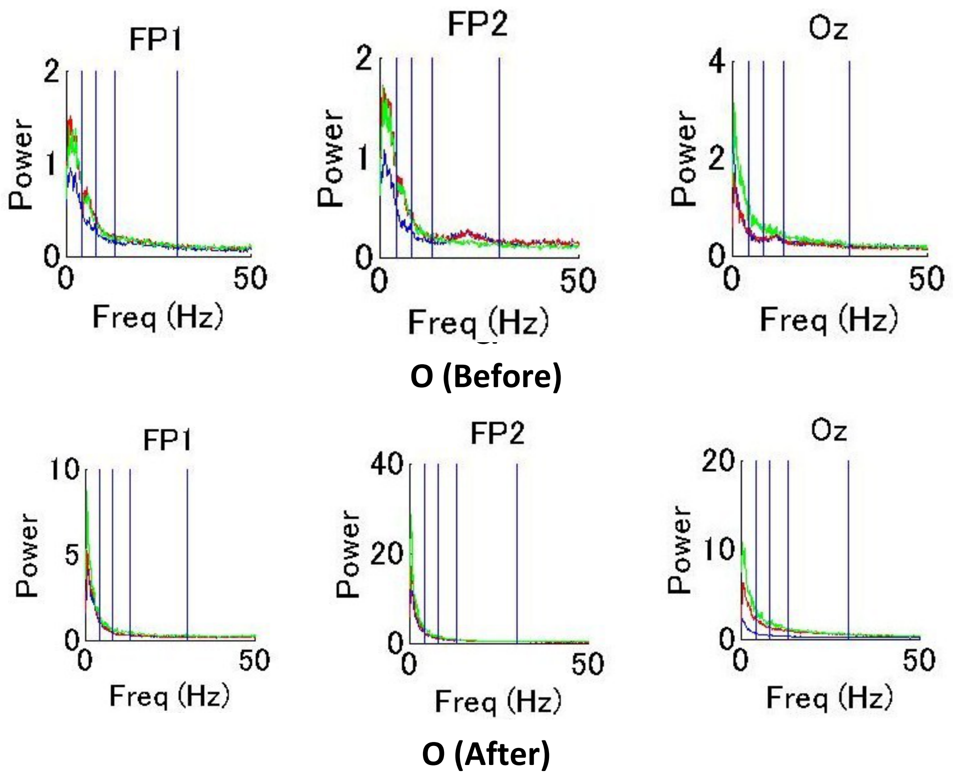

Figure 6: Brain Activity Measured with EEG

4. CONCLUSION

In this study, we divided a muscial piece (Mozart concerto) by frequency domain into upper and lower registers. Then we measured error rate, reaction time and EEG signal before and after the subject listened to the piece of music.

In this paper, we designed an experiment changed an order for listening to music to reduce the long-lasting effect. In other studies, we have already investigated any similar Mozart effect that may be induced by other kinds of music. In future studies, we should investigate further the division of music into frequency components in more specific detail.

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