Brain Responses while Imaging Music: Comparison between Known and Unknown Music

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Abstract: This paper describes an electroencephalogram (EEG) response while imaging music with and without listening to it. It is reported that, by performing actions (such as singing, imaging, etc.) in synchronization with music, we can feel more pleasant than when not performing these actions. We think that emotions (such as pleasantness, sadness, etc.) may be different between imaging music with and without listening to it. Taking these issues into consideration, we investigate activated parts of the brain while listening or not listening to known and unknown music to explore the source of emotions evoked by past experiences. As a result, the visual cortex is activated while listening to known music, but it is not activated while listening to unknown music. In conclusion, we know that the subjects tend to perceive known music more visually when imaging music with listening than when doing without listening to it. This may suggest that the activation of visual cortex is related to the emotions evoked by past experiences.

Keywords: Music-Imaging, EEG, Brain-Information Analysis

1. INTRODUCTION

Recently, portable audio players have become widely used and opportunities to enjoy listening to music have been increasing. We enjoy listening to music in various ways, e.g., we sing, image, and tap with listening to music.

In theoretical studies of music, Meyer [3] and Swanwick [4] suggested that movement of body was responsible for sensibility affair of music. Furthermore, in recent study, it is reported that, by tapping thumbs in synchronization with music, we can feel more pleasant than when not performing this action [6]. In addition, Yamamoto et al. [6] reported that, when the subjects listened to music, they tended to perceive music more visually.

On the other hand, we often image music either when we listen or when we do not listen to it. For example, in the case of listening to music, we may call up melodies (such as sounds, lyrics, melody line, etc) or rhythm. In the case of not listening to music, we may also call up melodies or rhythm. Even as listening and not listening to music, it is thought that the music imaging stimulates brain activities by thinking positive, relieving tedium, etc. In addition, another point that attracts interest in terms of kansei research is that emotions (such as pleasantness, sadness, etc.) may be different between imaging music with and without listening to it.

Taking these issues into consideration, in early studies, we compared brain responses while imaging known music between with and without listening to it [2, 5]. These studies suggested that, when imaging music while listening to it, the subjects tended to perceive known music more visually than when imaging it while not listening to it. Furthermore, these papers suggested that the area that took charge of memory was activated. By this experiment, it is assumed to be possible that the memorized music in the brain many years ago was stimulated to be reactivated. Taking these issues into consideration, we compare brain responses between while listening to known music and while listening to unknown music.

So, this paper describes an electroencephalogram response while imaging music with and without listening to it. And, we compare the activated parts between while listening to known music and while listening to unknown music to explore the source of emotions evoked by past experiences.

2. EXPERIMENTAL CONDITIONS

This time, we conducted first-stage experiments using a small number of subjects.
2.1 Subjects

A total of 2 male university students in their 20’s participated in the experiments as subjects. We surveyed both subjects’ answers about the following questionnaire items after the experiments ended: “What do you image when you listen to music every day?”, “Do you like singing?”, “Do you know the music presented first?”, and “Do you know the music presented last?” Reported results about subject attributes are shown in Table 1.

2.2 Music Imaging

We enjoy listening to music in various ways, e.g. we sing, image, and tap with listening to music. Emotions (such as pleasantness, sadness, etc.) may be different between imaging music with and without listening to it. This paper describes “melodies (such as sounds, lyrics, melody lines, etc.) called up” as “music imaging”. And, taking these issues into consideration, we conducted experiments in which EEG data were recorded as brain responses while imaging music between with and without listening to it.

3. METHODS

3.1 10-20 International System [1, 6]

EEG data were recorded at 11 electrode locations (Fp1, Fp2, Fz, T3, T4, C3, C4, T5, T6, O1, O2) according to the international 10-20 electrode placement system. The international 10-20 electrode placement system and 11 electrode locations, to measure brain waves while imaging music with or without listening to it, are shown in Figure 1. Alphabets with suffixes shown in Figure 1 mean the following: “A” is “Ear lobe”, “Fp” is “Frontal polar”, “Fz” is “Frontal midline lobe”, “T” is “Temporal lobe”, “C” is “Central lobe”, and “O” is “Occipital lobe”. Furthermore, additional electrodes are placed on the nose, and left and right ear lobes (A1, A2).

Frontal areas (Fp1, Fp2, Fz) have the following function: imagination, prediction, consideration, etc. The muscle basis of moving was directed by this area. Furthermore, the following functions (such as thinking, configuration, resolve, etc.) were decided by this area. Temporary areas (T3, T4, T5, T6) have such functions as receptive, explanation, cognition, etc. for language, music, sounds, etc. Information about feelings from body was integrated, analyzed, and cognized by central area (C3, C4). Occipital areas (O1, O2) have such functions as receptive, explanation, cognition, etc. for movement of target. Furthermore, cognition of various patterns was carried out in this area.

3.2 Imaging Experiment

3.2.1 Composition of Experiment

Because we compare the activated electrode locations between while listening to known music and while listening to unknown music, experiments were conducted divided into two sessions. (1) An experiment in which EEG data are recorded to measure brain response while imaging known music with and without listening to it. (2) An experiment through which we explore activated parts of the brain while listening or not listening to unknown music.

3.2.2 Composition of Each Session

Each session’s experiments consist of four tasks. Time schedule of experiment was shown in Figure 2. Each task lasts 1 minute. Each session’s experiment was carried out as follow: (1) for the first task, the subject sat on a seat deeply, relaxed, and closed his/her eyes, (2) for the second task, the subject opened his/her eyes and listened to music, (3) for the third task, the subject closed his/her eyes again, and imaged music that he/her had listened immediately before, (4) for the last task, the subject opened his/her eyes, and imaged music while listening to it.
3.2.3 Experimental Environment
This experiment was carried out in a magnetically-shielded room (blocking effect: 60dB, cutoff frequency: 500kHz–60MHz). The experimenter asks the subject to keep sitting on a seat deeply, and the experiment was done keeping the room dimly lit. The environment of this experiment is shown in Figure 3. The parameters of the EEG measurement are shown in Table 2.

3.3 EEG Data Separation
After EEG-data recording, in order to compare brain response while imaging music between with and without listening to it, a total of 48,000 sample EEG data (= 4 minutes) were separated into four tasks, and these separated data were named as following: 1. “eyes closing”, 2. “music listening”, 3. “imaging only”, 4. “music imaging while listening to it”. Furthermore, each task was divided into 24 intervals and the squared EEG data were averaged over 500 sample (= 2 minutes and 30 seconds).

4. RESULTS AND DISCUSSIONS
The averages of the squared EEG data for “eyes-closing” task were compared with those of other tasks. For example, Figure 4 shows the results of comparison between imaging music with or without listening to it. In this paper, statistical-test results are denoted as “+” if the two mean values are significantly different at the 5% level, and as “++” if they are significantly different at the 1% level. Activated points in Figures 4-7 are shown by gray levels as follows: white locations denote that the data are not significantly different, pale-gray-colored locations denote that the data differ significantly at the 5% level, and deep-gray-colored locations denote that the data differ significantly at the 1% level.

4.1 Test Results about Subject A
The results of comparison between the data in the case of listening to known music and those in the case of not listening are shown in Figure 4, and those between the data in the case of listening to unknown music and not listening are shown in Figure 5.

Table 2: Parameters of EEG measurement

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC filtering frequency</td>
<td>50Hz</td>
</tr>
<tr>
<td>Reference impedance</td>
<td>10kΩ</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>200Hz</td>
</tr>
<tr>
<td>Time constant</td>
<td>0.30sec.</td>
</tr>
<tr>
<td>Cutoff frequency (High pass filter)</td>
<td>60Hz</td>
</tr>
<tr>
<td>Cutoff frequency (Low pass filter)</td>
<td>0.53Hz</td>
</tr>
</tbody>
</table>

Figure 2: Time schedules of experiment.

Figure 3: Experimental environment about imaging music.
4.1.1 Discussion on brain responses to known music

The subject answered the following: (1) he wholly listened to known music without regard for lyrics and melodies, and (2) he imaged focusing on lyrics when imaging known music.

In Figure 4, the left temporal area (T3) and the right frontal area (Fp2) were both activated at each task. Especially, the activation of the temporal area suggested that the memory of the music to which the subject was listening was remaining in the next task “imaging only”.

The left occipital area (O1) was only activated at “music-imaging while listening to it” task. This area has such functions as receptive, explanation, cognition, etc. for movement of target. On the other hand, frontal area has function including imagination and prediction. This result suggests the following: (1) because he knew this music, he was imaging or listening to music while predicting it, (2) when imaging music while listening to it, he tended to perceive known music more visually while predicting it.

4.1.2 Discussion on brain responses to unknown music

The subject answered the following: (1) he wholly listened to unknown music without regard for lyrics and melodies, and (2) he imaged focusing on lyrics when imaging unknown music.

In Figure 5, when the EEG measurement was carried out in “music-listening” and “music-imaging while listening to it” task, the frontal areas (Fp1, Fp2, Fz) and the occipital areas (O1, O2) was activated in both task. On the other hand, when the EEG measurement was carried out in listening to music with and without imaging (left and right figure in Figure 5), this experiments resulted the following in addition to the frontal-area and the occipital-area activation: (1) when listening to unknown music, the temporary areas (T3, T4, T5, T6) were activated, (2) when imaging music, the left of the central area (C3) was activated, (3) when imaging unknown music while listening to it, a part of the temporary area (T5) and both of the central areas (C3, C4) were activated.

These results suggested that he was remembering melodies and lyrics prior to understanding them when imaging unknown music while listening to it. In addition, these results suggested that unknown music was stimulated visually more than known music was. On the other hand, we obtained that the frontal area was activated in each task. The frontal area has functions including imagination and prediction. Because he was going to remember unknown music, these results suggested that unknown music always activated the frontal area.

4.2 Test Results about Subject B

The results of comparison between the data in the case of listening to known music and those in the case of not listening are shown in Figure 6, and those between the
data in the case of listening to unknown music and not
listening are shown in Figure 7.

4.2.1 Discussion on brain responses to known music
The subject answered the following: (1) he wholly
listened to known music without regard for lyrics and
melodies, and (2) he imaged focusing on lyrics when
imaging known music.

In Figure 6, the central areas (C3, C4) and the right
temporally areas (T4, T6) were activated when “imaging
only” and “music-imaging while listening to it” tasks
were given. The activation of the temporal area suggested
that the memory of the music to which the subject was
imaging was remaining in the next task “music-imaging
while listening to it”.

The occipital area was activated when “music-listening
(only O1)” and “imaging only (only O2)” tasks were
given. The frontal area was activated when “music-
listening (only Fp2)” and “imaging only (only Fp1)”
tasks were given. When “music-listening” and “imaging
only” tasks were given, the activation of these locations
suggested that he was imaging or listening to music
while predicting it because he knew this music. Since
neither of the both occipital areas were activated when
“music-imaging when listening to it” task was given, this
experiments suggested that he was only predicting
music.

4.2.2 Discussion on brain responses to unknown music
The subject answered the following: (1) he wholly
listened to unknown music without regard for lyrics and
melodies, and (2) he imaged focusing on melodies when
imaging unknown music.

In Figure 7, when “music-listening” task was given, all
electrodes were activated. However, the both occipital
areas were less activated than other electrodes. The
weaker activation of these points suggested that he was
predicting unknown music prior to imaging it visually. In
addition, when “music-imaging while listening to it” task
was given, all electrodes except the left occipital area
(O1) were activated. This suggests that the memory of the
unknown music which the subject had been imaging
immediately before was remaining in the next task
“music-imaging while listening to it”. However, since the
occipital areas were not activated or less activated than
the other areas when the “music-imaging while listening
to it” task was given, this experimental result suggested
that he was predicting music prior to imaging music.

Comparing between brain responses while listening to
known music and those while listening to unknown music,
the experimental results showed that unknown music ac-
tivated the brain more than known music. Especially, the
occipital areas were activated while imaging and listening
to unknown music more than known music. Furthermore,
by comparing between the activated points when “imaging

Figure 6: Activated electrodes while listening to known music (subject B).
(Left: music-listening, center: imaging only, right: music-imaging while listening to it)

Figure 5: Activated electrodes while listening to unknown music (subject B).
(Left: music-listening, center: imaging only, right: music-imaging while listening to it)
only” tasks were given and those when “music-imaging while listening to it” tasks were given, we knew that the “music imaging while listening to it” tasks stimulated brain activities more than the “imaging only” tasks.

5. CONCLUSION

We have compared brain responses while imaging known music between with and without listening to it. Furthermore, we have conducted experiments through which we explore activated parts of the brain while listening or not listening to known music, and compare the activated parts between while listening to known music and while listening to unknown music.

By comparing between brain responses while listening to known music and while listening to known music, the analysis results have shown the following: (1) with regard for known and unknown music, both subjects have imaged music while predicting it, (2) occipital areas have been activated while imaging and listening to unknown music more than known music, (3) music imaging while listening to it has stimulated brain activation more than imaging only.

In these experiments, we have known that the subjects tend to perceive known music more visually when imagining music with listening than when doing without listening to it. This may suggest that the activation of visual cortex is related to the emotions evoked by past experiences.

Future studies will be to conduct experiments through which we explore activated parts of the brain while listening to various music in the absence of vocal (such as “off-vocal” version of music that has been used in this paper, jazz, classic, etc.). In addition, because this paper has described first-stage experiments, further experiments must be conducted using more subjects in order to strengthen the obtained results.

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