Brain Activity During Listening to And Imagining Music: Does Imagining Music Provide a Similar Effect as Listening to Music?

Yusuke Mitani*, Yuya Chiba†, Kenji Moriya‡, Takuya Kubo†, Yoshiko Maruyama‡, Masahiro Nakagawa||

Abstract: We hypothesized imagining music that is one of our mundane action also provides us a relaxation effect as listening to music. The effects of imagining music as a relaxation task after studying compared with the effects of listening to music were investigated in terms of prefrontal activity. We defined accuracy of imagining music determined from questionnaire the imagining accuracy (IA). Brain activities were investigated in three types of music (i.e., uplifting song, relaxing song, and classical music) when both subjects listened to music and imagined its music. In uplifting song and relaxing song which were selected subject’s selves, listening to and imagining music provided same or slightly greater relaxing effect than that of resting. However, listening to classical music provide greater relaxation, whereas relaxing effect from imagining classical music was significantly smaller. This result indicates that the music that is easy to image, i.e., having high IA value, might provide certain level of relaxation by just imagining. More details of the relationship between the IA and the level of relaxing needs to be investigated in the next step.

Keywords: Brain Activity, Relaxation, Imagining Music, Imagining Accuracy (IA)

1. Introduction
Concentrations is required and important factor for effective and positive results on various tasks such as study, sports, and works. The relationship between emotions and brain activity has been investigated by electroencephalogram[1][2]. More recently, blood flow of the frontal lobe has been determined using near infrared spectroscopy (NIRS), representing a comparatively simple and easier method of measuring brain activity[3].

We have focused on the relaxation effect during a short break between learnings in terms of brain activity, and have investigated what kind of relaxation task is better for students. In the previous study, we suggested listening to music could be the one of the effective relaxation techniques to ensure better rest. For example, classical music such as having 1/f fluctuations (e.g., Mozart) is well known as relaxation music[4]. In addition, previous study found the uplifting music which is subject’s favorite music provide positive relaxation regardless its tempo and key (i.e., major key or minor key)[4].

Thought we often listen to the music in order to have fun or as background music, we also occasionally imagine music in our heads and/or with humming unconsciously. If imagining music provides similar effect as actual listening to music, we can rest easier without music player regardless locations. Therefore, we attempted to elucidate the difference of relaxation effects between listening to music and imagining music by measurement of brain activities.

2. Experimental Methods
2.1 Experimental Procedure We quantitatively evaluated brain activity during relaxation tasks (i.e., listening to music and imagining music) after a study task. Instead, of a study task, subjects were given a mental calculation. Three tasks were selected for the relaxation tasks: (1) listening to music; (2) imagining music; (3) resting (as the control); three types of music were selected when listening to music and imagining music: (1) uplifting song (selected by each subject); (2) relaxing song (selected by each subject); (3) classical music (Johann Pachelbel’s “Canon”). Apparently, uplifting and relaxing songs are easy to imagine because these songs are listened to often by the subjects. Conversely, it seems that classical music is difficult to imagine because the music has no lyrics. However, the effect of imagining...
Music cannot be investigated if the subjects cannot imagine at all. Therefore, Johann Pachelbel’s “Canon,” which is famous classical music, was selected. Additionally, the accuracy of imagining was estimated from VAS questionnaire. Fig. 1 shows the examples of the study task (i.e., a mental calculation) and the questionnaire using VAS.

The experimental procedure is shown in Fig. 2. The first 30 s of the procedure consisted of a rest period. The duration of the study task was 1 min. The duration of each relaxation task as 1 min. The subjects then completed a 1-min study task and then completed several 1-min relaxation tasks. The subjects repeated this procedure with the different three types of music at adequate time intervals. This experimental procedure was conducted three times each on separate days by each person. During the experiment, the subjects were sitting on a chair and looking at a PC screen. Instructions for each task and mental calculation problems were displayed on the PC screen. The subjects were instructed to keep their eyes closed during the relaxation task.

Noise-canceling headphones (QC25 noise canceling headphones, Bose Corporation, LLC.) were used while they listened to the music.

2.2 Imagining Accuracy We conducted questionnaire about “How accurate did you image the song?”. The visual analog scale (VAS) is used for the questionnaire in order to subjects answered more subjectively. The accuracy of imagining was estimated from a level of 0 to 100 using a VAS, such as that shown in Fig. 1 after the experiment. Here we defined this index as the imagining accuracy (IA). Assuming that 0 is a state that cannot be imagined and 100 as a state that can be completely imagined, the subjects specified how accurately music could be imagined by indicating a position along a continuous line between two end points when responding to the VAS[6].

2.3 Analysis of Brain Activity Brain activity in the prefrontal area was measured by changes in oxy-Hb and deoxy-Hb concentrations as determined by 10-channel (CH)-wearable optical topography system (WOT-100, Hitachi High Technologies, Ltd.) with near-infrared spectroscopy (NIRS) at a sampling frequency of 5 Hz[1][4]–[6]. When a near-infrared ray passes through hemoglobin, the intensity of the near-infrared ray changes and results differences in the absorption spectra of oxy-Hb and deoxy-Hb. By measuring this change, oxy-Hb and deoxy-Hb concentration changes can be calculated. If oxy-Hb increased and deoxy-Hb decreased, this indicated that the corresponding region in the prefrontal area was active compared with the previous condition. When oxy-Hb decreased and deoxy-Hb increased, prefrontal activity was inactive (summarized in Table 1). In this study, if Hb in the regions surrounding the CHs used for the study task changed during the relaxation task according to the above definition of inactivity, we proposed that the subjects were relaxed during the current task compared with during the previous task.

The correlation between the measurement region in the prefrontal area and each CH is shown in Fig. 3. In this study, two analyses were performed: (1) average Hb changes during rest and average Hb changes during the study task after rest were compared to investigate which regions of the prefrontal area became active during the study task; (2) average Hb changes during each relaxation task after the study task and average Hb changes during each study tasks were compared to investigate the rates of prefrontal inactivity and amount of prefrontal inactivity during the relaxation task. Considering the influence of sudden changes, analyses were performed except for 10 s at the beginning and 5 s at the ending during each task. The remaining 45 s were divided into three sections of 15 s, and the Hb changes were analyzed in detail using the respective average value.

3. Results and Discussion

Measurements of blood flow in the prefrontal cortex were conducted on five subjects (healthy male students who were 19–21 years of age); therefore, 45 data in total were obtained because the experiments were performed three times for three types of music per person. We investigated which regions in the prefrontal area became active during the study task. The results indicated that active rates in CH 9, CH 12, and CH 15 of the prefrontal cortices, respectively, were higher than those in other channels. Considering the individual differences among subjects, we focused on prefrontal activity around high activation rate.

| Table 1: Brain activities determined from changes of oxy-Hb and deoxy-Hb |
|-----------------------------|-----------------------------|-----------------------------|
| Change of oxy-Hb | Change of deoxy-Hb | Brain Activity |
| : increase | : decrease |  |
| : : increase | : decrease | Active |
| : : inactive | : inactive | Inactive |

Figure 1: Example of mental calculation and VAS

Figure 2: Experimental procedure

Figure 3: Measurement channel (CH) in the prefrontal area
Brain Activity During Listening to And Imagining Music: Does Imagining Music Provide a Similar Effect as Listening to Music?

Figure 4: Percent activation rated during the study task for each channel (CH) of the prefrontal area. The listed values indicate the rates at which each area became active per total number of measurements (n = 45).

Figure 5: Subject A: An example of the changing amounts of average Hb concentration for CH 9.

CHs (i.e., CHs 7, 9, 10, 12, 13, 15, and 16) when investigating effective relaxation after the study task.

We calculated the changing amount of average Hb concentration during the task compared to the average Hb concentration change during the previous task. Fig. 5 shows an example of the changing amounts of average Hb concentration change for CH 9 (Subject A). The vertical axis shows how much average Hb concentration changed during the task compared to that during the previous task. When the brain activity was active, the background was red, and when it was inactive, it was blue. This indicated that when changes in the oxy-Hb were low and when the changes in the deoxy-Hb were high, the prefrontal area was more inactive.

We calculated the individual rates of prefrontal inactivity for the three types of music during the three relaxation tasks performed after the study task as shown in Fig. 6. Colored bars represent the three relaxation tasks: listening to music, imagining music, and rest. This result shows that the tendency of prefrontal inactivity easily moves to a relaxation state during each relaxation tasks for each music type. The prefrontal area tended to be inactive while the subject was imagining music compared with listening to music and during rest for the uplifting and relaxing songs. However, rates of inactivity were not significantly different among the various relaxation tasks for the uplifting and relaxing songs (P > 0.05). However, there was significant difference between listening to music and imagining music in regards to classical music (P < 0.05). The relaxation effect while the subject was listening to music was higher than while imagining classical music.

Next, we focused on the IA measured by VAS, which was performed after the experiment. Table 2 shows each average value of IA for the three types of music. The value of IA for the classical music was lower than the IA for the uplifting and relaxing songs. This means that classical music could not be imagined accurately by the subjects compared with the uplifting and relaxing songs. Consequently, it suggested that there was no difference in the relaxation effect between listening to music and imagining music when the IA value was high. However, the amount was lower in the case of imagining music than in the case of listening to music when the IA value was low. Therefore, these results indicate that imagining music may have the same effect as listening to music, if the music can be accurately imagined in the person’s head. Additionally, we suggest that if the IA value increases (i.e., the person is accustomed to imagining music), the relaxation effect also increases.
4. Conclusions

We examined the difference in prefrontal activity between listening to music and imagining music as a relaxation task after a study task in terms of changes in blood flow. Prefrontal activity was determined by changes in the oxy-Hb and deoxy-Hb concentrations. In this study, the accuracy of imagining music was estimated by VAS and was defined as the IA. The mental calculation, which was used as the study task, activated prefrontal activity near CHs 9, 12 and 15. Rates of inactivity after the study task in the prefrontal area were not significantly different among all three relaxation tasks (listening to music, imagining music, and resting) and for the three types of music (uplifting song, relaxing song, and classical music). In uplifting song and relaxing song which were selected subject’ selves, listening to and imagining music provided same or slightly greater relaxing effect than that of resting. However, listening to classical music provide greater relaxation, whereas relaxing effect from imagining classical music was significantly smaller. The IAs of imagining uplifting song and relaxation song were 78.6 and 79, respectively, whereas that of classical music was low value of 53.4. This result indicates that the music that is easy to image, i.e., having high IA value, might provide certain level of relaxation by just imagining. Low IA indicates possibility that subject attempted to remember the music/song, in other words, subject’s brain is active to remember. Of course, although imagining favorite song also need brain activity, it might be light load for the brain than that of remembering load. There is a possibility that IA is an important factor for the relaxation effect. This hypothesis suggests new problem that whether the relaxation effect (i.e., brain inactive) correlates with IA. For example, to repeat listening and imagine the music may stepwisely increase IA. In addition, autonomic nervous system activities need to measure simultaneously for supporting analysis of the level of relaxation effect. This experiment was conducted in healthy students who were 19–21 years old (i.e., young adults). Different results may be found among older people or those from different cultures.

Additional Statement

This research was approved as making adequate provisions for the safety and privacy of subjects by the Life Ethics Committee of National Institute of Technology, Hakodate College.

Acknowledgment

A part of this study was supported by a grant from Nagaoaka University of Technology for collaborative research with National Institute of Technology (2017, 2018).

Table 2: Average value of IA during listening to the three types of music (N=45)

<table>
<thead>
<tr>
<th></th>
<th>Uplifting song</th>
<th>Relaxing song</th>
<th>Classical music</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>78.6</td>
<td>79.0</td>
<td>53.4</td>
</tr>
</tbody>
</table>

References


Yusuke Miyani (Non-member) received a Bachelor degree in electronic and electronics engineering from National Institute of Technology, Hakodate College in 2018. He is working at MIRUC OPTICAL CO., LTD. as an engineer.

Takuya Kubo (Non-member) received an Associated degree in production systems engineering (electrical and electronics field) from National Institute of Technology, Hakodate College in 2017, and is presently a Student of Computer Science and Information Technology, Faculty of Engineering, Hokkaido University.

Yuya Chiba (Non-member) received an Associated degree in electrical and electronics engineering from National Institute of Technology, Hakodate College in 2012, and is presently a technical officer at NIT, Hakodate College.
Brain Activity During Listening to And Imagining Music: Does Imagining Music Provide a Similar Effect as Listening to Music?

Yoshiko Maruyama (Member) received a Ph.D. degree in engineers from Kyoto Sangyo Univ. in 2013, and is presently an Assistant professor at National Institute of Technology, Hakodate College since 2016. She has worked on electrophysiology and bio-measurement engineering.

Kenji Moriya (Member) received a Ph.D. degree in engineers from Muroran Institute of Technology in 2001, and is presently a Professor at National Institute of Technology, Hakodate College since 2016. He has worked on bio-measurement engineering and signal processing. He is a member of IIAE, JSWE, JSEE and IEICE.

Masahiro Nakagawa (Non-member) received Ph.D. degree from Nagoya University in 1988, and is presently Professor of the department of science of technology innovation and the director of information processing center at Nagaoka University of Technology. His major discipline is concerned with non-linear phenomena in physical and physiological systems, e.g. chaos, fractal and neural networks, related to the brain function analysis focusing on the state-of-the-art in sensibility information engineering field. He is also a member of JPS, JSAP, JNNS, JLCS and IEICE et al.