Analyzing the effect of music therapy based on cerebral function analysis

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Abstract
The purpose of this research is to propose the optimal presentation method of the music therapy effecting on the activation level of brain. The relation between how to experience a music therapy and activation level of cerebral function was investigated in listening to the music or singing. In addition to this, the new effectiveness evaluation index regarding the music therapy was proposed. The activation level of cerebral function was quantified in terms of the fluctuation of oxygenated hemoglobin (oxyHb). Additionally, the Cardiac Sympathetic Index (CSI) of the sympathetic nerve and the Cardiac Vagal Index (CVI) of the parasympathetic nerve were used for the quantification. The result of experiment showed that making the parasympathetic nerve predominates by listening to music to enjoy the music after making the sympathetic nerve activated by singing music is effective for increasing the level of oxyHb. In addition to this, it was observed that the effectiveness of music therapy was increased when the parasympathetic nerve was activated efficiently.

Keywords: Music therapy, Dementia, Cerebral function, Activation level of cerebral function, Autonomic nerve

1. Introduction
The evaluations of "musical therapy" in terms of the improvement of the mental disease by presenting music were reported in precedence researches [1][2]. In those researches, it was reported that the music has effect on the active level of cerebral function [1] and that the music has effect on improving the mental condition and behavior of the patients [2]. Based on those reports, the researches which utilize music in dairy life were reported.

However, there are very few reports which analyzed the mechanism that the music has effect on a human body, in terms of the cerebral blood flow and the fluctuation of autonomic nerves system. In this research, the activation level of cerebral function and the autonomic nerves system were investigated, for the analysis of the effectiveness of music therapy. Based on the results, the presentation method of music aiming at improving cerebral activation was proposed.

In addition to this, a method which quantifies the activation level of cerebral function was proposed to clarify the effectiveness of the method. In this study, the absolute value of the oxygenated hemoglobin (oxyHb) and its differential value meaning the fluctuation of oxyHb were analyzed as the state variables which quantify the activation level of cerebral function.

2. Effect of music on cerebral function
The way of experiencing music therapy is singing music and listening to the music. Therefore the difference of the effects on a cerebral function during listening to the music and a singing music were clarified. In this experiment, we investigated the fluctuation of the oxyHb and the fluctuation of R-R interval (RRI) of heart rate, regarding the sequence of singing music or listening to the music. Based on the results, the correlation between the level of oxyHb and the RRI was evaluated.

2.1 Experimental sequences
The sequences of experiments are shown in Fig. 1. "Rest" represents a status of rest without presenting music. In this study, singing music and listening to music are called "Music tasks". The participants performed Music tasks after the Rest, and experienced the sequence twice. The music during the task of singing and the music during the task of listening to music were same.

2.2 Evaluation indexes
2.2.1 Fluctuation of cerebral blood flow
In this study, the oxyHb was analyzed as the evaluation index of the fluctuation of cerebral blood flow. The oxyHb was investigated at the sixteen measuring points on the forehead, using the near infrared spectroscopy (NIRS). The noise removal was conducted on the results of oxyHb by the Discrete Wavelet Transform. In addition to this, for the normalization of the test results, the z-score conversion was performed on the results. The formula regarding z-score conversion is shown below.

\[ z \text{ score} = \frac{\text{Measured score} - \text{Average score}}{\text{Standard Deviation}} \]

2.2.2 Fluctuation of R-R Interval
The activation level of human body was quantified by focusing on the autonomic nerves system (the sympathetic nerve and the parasympathetic nerve). The state variables like the CVI, CSI were used as the
2.3 Type of music and participants

The type of music that satisfies the following conditions was prepared by the participants. It was about 4 minutes for one experimental trial. The selection criteria of music are described below.

- The palatability is matched to the participant.
- The participant feels the exaltation.
- The participant can sing easily.

The presentation of music was performed by use of acoustic speakers.

The participants were ten male students (average age: 22 years old) who got the informed consent enough in advance.

2.4 Effectiveness of singing music and listening to music

(1) Fluctuation of cerebral blood flow

The fluctuation of the oxyHb in the experimental results is shown in Fig. 3 (a). The Fig. 3 (a) shows that the oxyHb decreased at the start time of singing and the oxyHb increased at the time of taking the Rest after singing. The oxyHb decreased at the start time of listening to the music and the oxyHb increased at the time of taking the Rest after listening to the music. Based on those results, it is suggested that the oxyHb decreased during singing or listening to the music. The statistical t-test for clarifying the difference of these results between each task was carried out (Table 1). The time span of the t-test was 1 minutes before and after starting and ending of Music tasks. The same kind of tendency showing a significant difference was confirmed in eight participants among ten participants.

| Participant | Experiment I | | Experiment II |
|-------------|--------------||--------------|
| A           | ↑            | | ↑            |
| B           | ↑            | | ↑            |
| C           | ↑            | | ↑            |
| D           | ↑            | | ↑            |
| E           | ↑            | | ↑            |
| F           | ↑            | | ↑            |
| G           | ↑            | | ↑            |
| H           | ↑            | | ↑            |
| I           | ↑            | | ↑            |
| J           | ↑            | | ↑            |

The fluctuation of oxyHb was carried out (Table 1). The fluctuation of oxyHb in terms of the evaluation index (Experiment II)
(2) Fluctuation of R-R Interval
The state variable like CSI was focused on. The activation level of autonomic nervous system was classified into two tendencys.

One of the tendencies is that the sympathetic nerve is predominant at the time of the Music tasks. One of the experimental results is shown in Fig. 3 (b). The Fig. 3 (b) shows that the CSI increased. Therefore it turns out that the sympathetic nerve is predominant at the time of singing. The CSI decreased after the Music tasks. Therefore, it turns out that the parasympathetic nerve was predominant after the Music tasks. The same kind of tendency showing a significant difference was confirmed in six participants among ten participants.

The other tendency is that the parasympathetic nerve is predominant at the time of the Music tasks. The CSI decreased at the time of listening. Therefore, it turns out that the parasympathetic nerve is predominant at the time of singing. The same kind of tendency showing a significant difference was confirmed in four participants among ten participants.

3. Quantitative analyzing the activation level of cerebral function
We focused on the results regarding fluctuation of oxyHb which was analyzed in Chapter 2. It was confirmed that the oxyHb was decreased during the Music tasks. In the previous study, it was said that the cerebral function becomes active during music therapy. Therefore, we think that the increase and decrease of the oxyHb are dominant factor on the cerebral function. Therefore, we proposed the quantitative analyzing method regarding the activation level of cerebral function.

The oxyHb was analyzed quantitatively in terms of the absolute value of oxyHb and differential value of oxyHb[3]. This is a method which evaluates the activation of cerebral function. In this research, we analyzed the distance from a center-of-gravity point to the trajectory (Fig. 4). The trajectory was drawn based on the absolute value of oxyHb (the horizontal axis) and the differential value of oxyHb (the vertical axis).

Based on this methodology, it was confirmed the activation level of cerebral function increases when the distance from a center-of-gravity point becomes long.

4. Effect of the relaxation level on the activation level of cerebral function
In Chapter 2, the activation of cerebral function was confirmed when the participants felt relaxed atmosphere after the activation of the body. In this chapter, the effectiveness of presenting music on the cerebral function after singing was investigated. Based on the investigation results, the effectiveness of presenting music after singing was evaluated. The fluctuation of the oxyHb and the autonomic nervous system was analyzed as same as the experiment of Chapter 2.

4.1 Experimental sequence
A sequence of the experiment is shown in Fig. 5. The participants experienced the condition of “listening to music” after singing. Based on this result, the difference between the results of Experiment II and III was evaluated. "Rest" represents a rest without presenting music as same as the experiment of Chapter 2.

<table>
<thead>
<tr>
<th>Time[min]</th>
<th>Rest</th>
<th>about 4</th>
<th>about 4</th>
<th>3</th>
<th>about 4</th>
<th>about 4</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Singing</td>
<td>Listening</td>
<td>Rest</td>
<td>Singing</td>
<td>Listening</td>
<td>Rest</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5 Experimental sequence verifying the effectiveness of listening to music after singing (Experiment III)

4.2 Evaluation index
In this chapter, the evaluation indexes that used in Chapter 2 are used. In addition to this, the methodology to evaluate the activation level of cerebral function which was proposed in Chapter 3 is used.

4.3 Type of music and participants
The type of the music is same with that in Chapter 2. It was about 4 minutes per music.

The participants were ten male students (average age: 22 years old) who got the informed consent enough before the experiment.

4.4 Results
(1) Fluctuation of cerebral blood flow
The decrease of oxyHb was confirmed at the time of singing in the experiment II and the experiment III. This tendency was the same as tendency in Chapter 2.

In the experiment III, it was clarified that there were cases where the oxyHb decreased and the oxyHb increased after singing. The former case is the same tendency with the results of Chapter 2. The latter case, it was clarified that the oxyHb continued to be decreased. This case suggested that the participants concentrated in listening to music after singing. In order to evaluate the fluctuation of each index quantitatively, the t-test was carried out (Table 2). The t-test was used in the same manner as in Chapter 2.

(2) Fluctuation of R-R Interval
The activation level of autonomic nervous system was investigated in terms of focusing on the fluctuation of CSI. The tendency that the CSI increased at the time of singing was clarified in the experiment III. This
tendency was the same as tendency in Chapter 2. The
different tendency was confirmed concerning the
fluctuation of CSI during listening to music after
singing.

In the experiment III, it was clarified that the CSI
increased at the time of starting to sing and the CSI
decreased at the time of the Rest after singing. In
addition to this, the different tendency was clarified that
the CSI decreased after singing. This tendency was
shown in four participants among ten participants. In this
case, it was suggested that the CSI continued to be
increased, because the participants were also exciting
during listening to music.

Table 2 t-test to clarify the fluctuation of Experiment III

<table>
<thead>
<tr>
<th>Participant</th>
<th>oxyHb</th>
<th>CSI</th>
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<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
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<td>C</td>
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<td>I</td>
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<tr>
<td>J</td>
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</tr>
</tbody>
</table>

\(\text{start}: \text{start of Music task}
\text{end}: \text{end of Music task}
\)

\(\star \star : P < 0.01 \quad \text{N.S. (Not Significant):} 0.05 < P\)

(3) Activation level of cerebral function

The comparison between presenting music and not
presenting music in terms of the effectiveness of
fluctuation level of oxyHb was carried out. The average
of a distance from the center-of-gravity point
investigated in the results regarding the oxyHb of all
participants is shown in Fig. 6. Fig. 6 shows the two
tendencies regarding activation level of cerebral
function.

One of the tendencies is that the activation level of
cerebral function becomes high during the Experiment
II. This tendency was observed in six participants
among ten participants. The five participants among six
participants showed that the CSI was lower during the
experiment I.

The other tendency is that the activation level of
cerebral function becomes high during the Experiment
III. This tendency was observed in four participants
among ten participants. The three participants among
four participants showed that the CSI was lower during the
experiment II.

Therefore, it was suggested that the difference
regarding activation level of cerebral function was
affected by the mental attitude during listening to music.

5. Conclusion

In this research, the effectiveness of presenting music
on the cerebral function was investigated. The
experiments were constructed with the tasks of "Singing
music", "Listening to music" and "Rest". Each of the
experiment was investigated with ten participants. The
state variables like CVI, CSI were quantified for the
evaluation.

In this study, the decrease of oxyHb was observed
during the human body was activated. And the increase
of oxyHb was suggested during the participants felt
relaxed atmosphere in listening to music after singing
music.

In addition to this, for quantifying the activation level
of cerebral function, the distance from a center-of-
gravity point to the trajectory in terms of the absolute
value of the oxyHb and differential value of the oxyHb
were analyzed. In this analysis, it was shown the two
tendencies. The tendencies were that the activation level
of cerebral function became higher during the
parasympathetic nerve was predominant after the
sympathetic nerve was predominant. Therefore, it was
suggested that the parasympathetic nerve become
predominant efficiently after the sympathetic nerve
become predominant is one of the dominant factor for
the effective activation of cerebral function.

We have three future items to be studied. We will
clarify the effect of music therapy on cerebral function
in terms of the type of music. The In addition, we will
clarify the weighting value regarding oxyHb of absolute
value and its differential value. Moreover, we will
clarify the relationship between a music therapy and
activation level of cerebral function.

6. References

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