Effectiveness of music therapy on the activation level of cerebral function

Katsutoshi Tadokoro , Koh Inoue , Keisuke Suzuki

Kagawa University

Abstract

The effectiveness of the musical therapy on cerebral function and cerebral blood flow is not clearly investigated. In this research, the relation between how to enjoy the music and activity level of cerebral function when listening to music or singing music was investigated. Based on the investigation results, the optimal presentation method of the music effecting on the activity level of the brain was proposed. In this study, the activity level of cerebral function was quantified in terms of the fluctuation of oxygenated hemoglobin (oxyHb). The fluctuation of the oxyHb and the RRI of heart rate were observed during each experiment. The Cardiac Sympathetic Index (CSI) of the sympathetic nerve and the Cardiac Vagal Index (CVI) of the parasympathetic nerve were used for the investigation. It was observed that making the level of CVI higher by listening to music after making the level of CSI higher by singing music is effective for increasing the level of oxyHb.

Key words: *Music therapy, Dementia, Cerebral function, Cerebral blood flow, Autonomic nerve system*

1. Introduction

The effect analysis of "musical therapy" aiming at the improvement of the mental disease by presenting music was reported in precedence researches [(1) (2)]. By those researches, it was reported that the music has effect on the activity level of cerebral function [(1)] and that the music has effect on improving the mental condition and behavior of the patient [(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 activity level of cerebral function and the autonomic nerves system were investigated, for the analysis of the effectiveness of music therapy. Based on the investigation results, the presentation method of music aiming at improving cerebral activity was proposed.

In addition to this, a method which quantifies the activity level of the 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 were analyzed as the state variables which quantify the activity level of cerebral function.

2. Effectiveness of music on cerebral function

2.1 Experimental outline

The presentation methods of music were singing music and listening to music. In this experiment, we investigated the fluctuation of the oxyHb and the fluctuation of R-R interval (RRI) of heart rate, regarding the order of singing and listening to music. Based on the results, the correlation between the level of oxyHb and the RRI was discussed.

The flow of experiment is shown in Fig.1. "Rest" represents a rest without presenting music. The test subjects experienced listening to music after singing, and singing after listening to music. The music used during the task of singing and the music used during the task of listening to music was same. And the presentation order of the music was same in each task. The test subjects responded to a questionnaire regarding mental condition by use of POMS before and after the experiment.

2.2 Evaluation indexes

2.2.1 Value of cerebral blood flow

The evaluation index of the fluctuation of cerebral blood flow was the oxyHb. We used the oxyHb as an index for quantifying the fluctuation of cerebral blood flow. The oxyHb was investigated at the point of sixteen channels on the forehead, using near infrared spectroscopy (NIRS). The noise removal was conducted on the results of oxyHb by the Discrete Wavelet Transform. In addition to this, in order to carrying out quantitative comparison, the Z-score conversion was performed on the results.

2.2.2 Fluctuation of R-R Interval

The activity level of the 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, LF/HF, and HF/ (LF+HF) were used as the index of the autonomic nervous system. The CVI (the index of parasympathetic nerve) and the CSI (the index of sympathetic nerve) were analyzed by carrying out the Lorentz conversion of the RRI (Fig.2 (a)). When the level of parasympathetic nerve is higher, the data plots are scattered and the CVI increases (Fig.2 (b)). When the level of sympathetic nerve is higher, the data is plotted near the line of x=y and the CSI increases (Fig.2 (c)).

2.3 Type of music

The music that satisfies following conditions was prepared by the test subjects. It was about 8 minutes for one experimental trial. The selection criteria of music were described is described below.

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

The presentation of music was performed by use of acoustic speakers (Companion 2 series II Black : BOSE).

2.4 Test subjects

The test subjects were ten male students (average age: 22.7 years old, SD: ±1.42 years old) who got the informed consent enough in advance.

2.5 Results

(1) Fluctuation of cerebral blood flow

The fluctuation of the oxyHb in the results is shown in Fig.3(a). Fig.3(a) shows that the oxyHb decreased at the start time of singing and the oxyHb increased at the time of listening to music after singing. It is suggested that the oxyHb decreased during singing because the oxygen was consumed after singing by the brain. Then, it is thought that the oxyHb increased for filling up the oxygen which is lacked during singing. The t-test for clarifyint the difference of these results between each task was carried out (Table 1). The time span of the t-test was

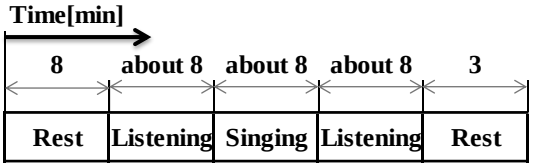
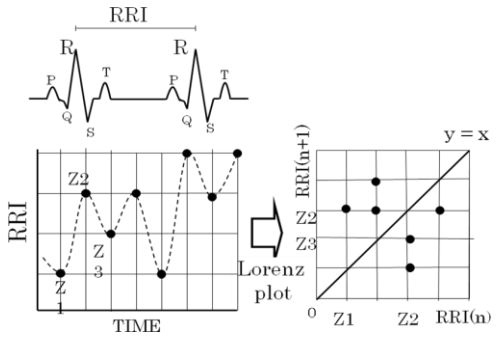
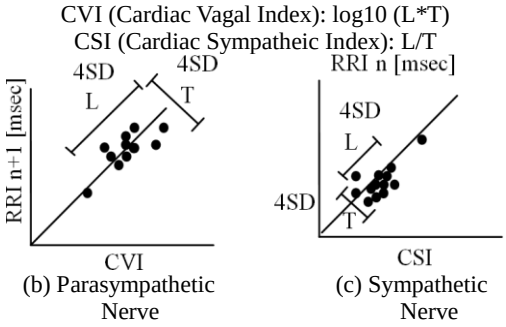


Fig.1 Experimental sequence verifying the effectiveness of music on cerebral function



(a) Lorentz transformation



(b) Parasympathetic Nerve

(c) Sympathetic Nerve

Fig.2 Calculation method of CVI and CSI

5 minutes before and after of the starting and ending of singing. The same kind of tendency showing a significant difference was confirmed by 6 test subjects among 10 test subjects.

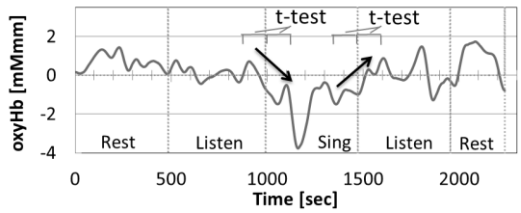
(2) Fluctuation of R-R Interval

The state variables like CSI, LF/HF, and HF/(LF+HF) were focused on. The activity level of the autonomic nervous system was classified into two tendencies.

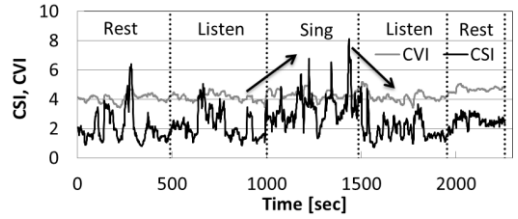
One of the tendencies is that the sympathetic nerve is predominant at the time of singing. One of the experimental results is shown in Fig.3(b)(c). The Fig.3(b)(c) shows that the CSI and LF/HF increased and the HF/(LF+HF) decreased at the time of singing. Therefore it turns out that the sympathetic nerve is predominant at the time of singing. The CSI and LF/HF decreased after singing and the HF/(LF+HF) increased after singing. Therefore, it turns out that the parasympathetic nerve was predominant after singing.

The other tendency is that the parasympathetic nerve is predominant at the time of singing. The CSI and LH/HF decreased at the time of singing, and the HF/(LF+HF) increased at the time of singing.

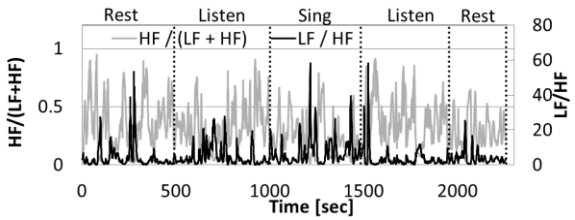
Therefore, it turns out that the parasympathetic nerve is predominant at the time of singing. Two test subjects showed this tendency. Their answer of the subjective assessment regarding the palatability of singing music showed extremely high score. This means these two subjects like singing and don't feel any hesitation. Therefore, it can be concluded that the test subjects were relaxed and the parasympathetic nerve was predominant at the time of singing.



(a) Fluctuation of oxyHb



(b) Fluctuation of CSI and CVI



(c) Fluctuation of HF/(LF+HF) and LF/HF

Fig.3 Fluctuation of the presentation method of music in terms of the index

2.6 Influence of presentation of music on each index

In Table 1, a tendency that the oxyHb increased was confirmed in listening to music and decreased after singing in 6 test subjects among 10 test subjects. In these 6 test subjects, it is suggested that the sympathetic nerve is predominant at the time of singing. And it is suggested that the parasympathetic nerve becomes predominant at the time of listening to music after singing.

Therefore, it is suggested that the oxyHb decreased during the activation of human body and the oxyHb increased during the test subject felt relaxed atmosphere in listening to music.

3. Effectiveness of presenting music after singing

3.1 Experimental outline

In chapter 2, the activation of cerebral function was confirmed when the test subjects felt relaxed atmosphere after the activation of the body. Therefore, the effectiveness of presenting music on the cerebral blood flow 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.

A sequence of the experiment is shown in Fig.4. The test subjects experienced the condition of "listening to music" after singing. In the different condition, the test subjects experienced "rest" after singing. "Rest" represents a rest without presenting music as same as the experiment of Chapter 2.

3.2 Evaluation index

We focus on the evaluation index which was used in Chapter 2. The oxyHb was analyzed quantitatively in terms of the absolute value of oxyHb and differential value of oxyHb [(3)].This is a

Table 1 The t-test to clarify the fluctuation of each index between after singing and before singing

Test subject	oxyHb		CSI		HF/(LF+HF)		LF/HF	
	start	end	start	end	start	end	start	end
A	* * ↓	* * ↓	* ↑	* * ↑	* * ↓	* * ↓	N. S.	* * ↑
B	* * ↓	* * ↑	* * ↓	* * ↑	* * ↑	* * ↓	* * ↑	* ↑
C	* * ↓	* * ↑	* * ↑	* * ↓	* * ↓	* * ↑	* * ↓	N. S.
D	* * ↓	* * ↑	* * ↑	* * ↓	* * ↓	* * ↑	* * ↑	* * ↓
E	* * ↓	* * ↑	* * ↓	* * ↑	* * ↓	* * ↑	* * ↓	N. S.
F	* * ↑	N. S.	N. S.	N. S.	* * ↑	* * ↑	* * ↓	* * ↑
G	* * ↑	* * ↑	* * ↑	* * ↓	* * ↑	N. S.	* * ↑	* * ↓
H	* * ↑	* * ↑	* * ↓	* * ↑	* * ↑	* * ↓	* * ↑	* * ↓
I	* * ↓	* * ↑	* * ↑	* * ↓	* * ↓	* * ↑	* * ↑	* * ↓
J	* * ↓	* * ↑	* * ↑	* * ↓	* * ↓	* * ↑	* * ↑	* * ↓

The dashed under line represents the results that was discussed in chapter 2.

* * : P < 0.01 ↓ : average is decreased N .S. (Not Significant) : 0.05 < P

* : 0.01 < P < 0.05 ↑ : average is increased start : start of singing end : end of singing

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.5). The trajectory was drawn in terms of the absolute value of oxyHb (the horizontal axis) and the differential value of oxyHb (the vertical axis).

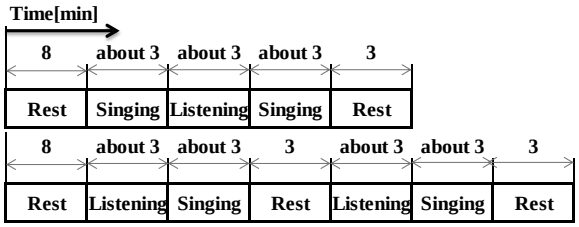


Fig.4 Experimental sequence verifying the effectiveness of listening to music after singing

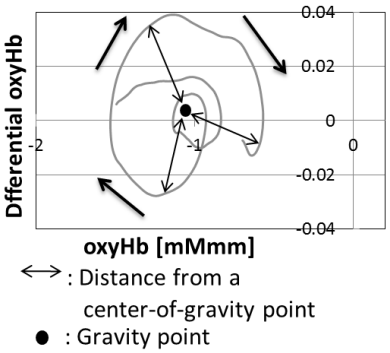


Fig.5 Transitions in terms of the absolute value and the differential value of oxyHb

3.3 Type of music

The characteristics of the music are same with that was used in the experiment of Chapter 2. It was about 3 minutes per one music.

3.4 Test subjects

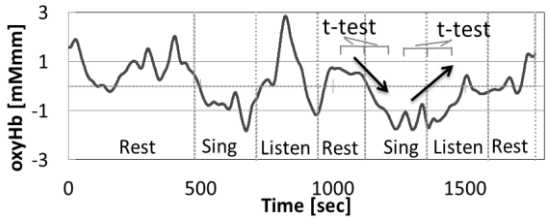
The test subjects were ten male students (average age: 22.8 years old, SD: ±0.45 years old) who got the informed consent enough in advance.

3.5 Results

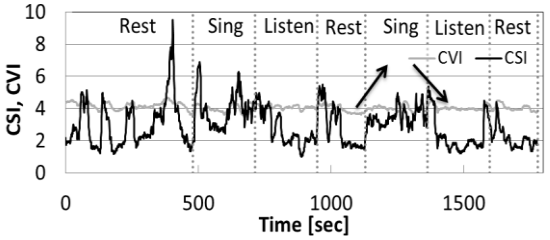
(1) Fluctuation of cerebral blood flow

One of the experimental results in time series data during listening to music after singing (experiment II) is shown in Fig.6. And the result of the experiment during the rest after singing (experiment III) is shown in Fig.7. From Fig.6 (a) and Fig.7 (a), the decrease of oxyHb was confirmed at the time of singing in the experiment II and the experiment III. The different tendency was clarified concerning the fluctuation of oxyHb after singing in each experimental condition.

In the experiment II, it was clarified that there is a case where the oxyHb decreased and the oxyHb increased after singing. An example showing that the oxyHb decreased after the singing is presented in Fig.8. The former case is the same tendency with the results of Chapter 2. The latter case, it was suggested that the oxyHb continued to decrease, because the test subjects were concentrated in listening to music after singing.

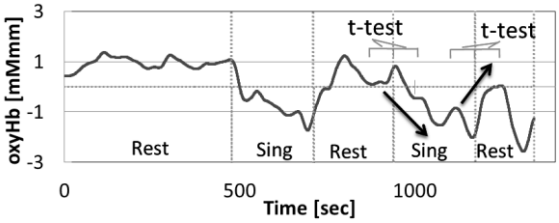


(a) Fluctuation of oxyHb

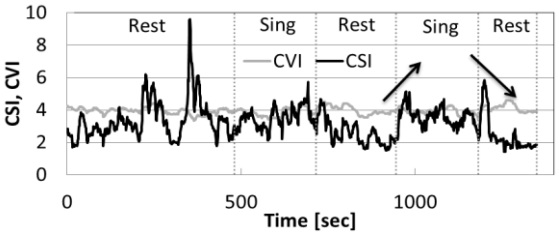


(b) Fluctuation of CSI and CVI

Fig.6 Fluctuation of the index in the case of listening to music after singing



(a) Fluctuation of oxyHb



(b) Fluctuation of CSI and CVI

Fig.7 Fluctuation of the index in the case of the rest after singing

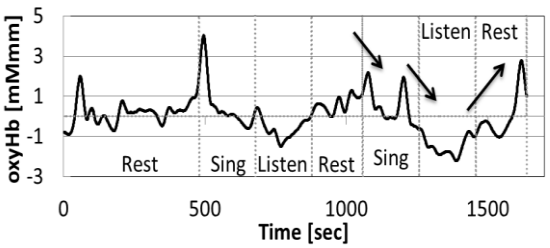


Fig.8 Example of a test result that the oxyHb was decreased by listening to music after singing

In the experiment III, it was clarified that there is a case where the oxyHb increased after singing. It was suggested that the oxyHb increased because the cerebral function was activated when the test subjects felt relaxed atmosphere.

(2) Fluctuation of R-R Interval

The activity level of the autonomic nervous system was investigated in terms of focusing on the fluctuation of CSI. From Fig.6 (b) and Fig7 (b), the tendency of CSI increased at the time of singing was clarified in the experiment II and in the experiment III. The different tendencies were confirmed concerning the fluctuation of CSI after singing in each experimental condition.

In the experiment II, 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 (Fig.5 (b)). The different tendenciy was also clarified that the CSI decreased after singing (Fig.7). In this case, it was suggested that the CSI continued to increase, because the test subjects were also exciting during listening to music.

In the experiment III as same as the experiment II, it was clarified that the CSI increased at the time of starting to sing and CSI decreased at the time of the rest after singing (Fig.7 (b)).

3.6 Various influences on each index in terms of presentation method of music

In order to evaluate the fluctuation of each index quantitatively, the t-test was carried out (Table 2). The time span of t-test was 90 seconds before and after of the starting and ending of singing. In the experiment II, it is suggested by 6 test subjects among 10 test subjects that the oxyHb continued to decrease because the test subjects felt the elation in listening to music after singing. In the experiment III, it is suggested by 4 test subjects among 10 test subjects that the oxyHb increased at the time of active state and the oxyHb decreased at the time of relaxed rest.

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 acquired in the results regarding the oxyHb of all test subjects is shown in Fig.9. In Fig.9, it is suggested that the fluctuation level of oxyHb is higher during listening to music than that during the rest after singing.

The effectiveness of the fluctuation of oxyHb on preventing the progress of dementia is not clarified. Therefore, it is one of the future items to be investigated in the future studies.

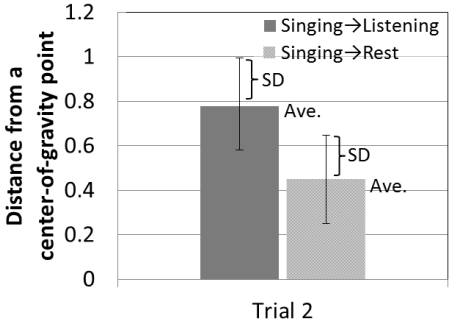


Fig.9 Predominance of carrying out listening to music after singing in terms of the oxyHb trajectory

4. 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 10 test subjects. The state variables like CVI, CSI, LF/HF, and HF/(LF+HF) which evaluate the fluctuation of the autonomic nervous system were analyzed. In addition to this, the oxyHb which evaluates the

Table 2 The t-test on fluctuation of index in presenting music after singing

Test subject	Experiment II								Experiment III							
	oxyHb		CSI		HF/(LF+HF)		LF/HF		oxyHb		CSI		HF/(LF+HF)		LF/HF	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end	start	end
K	**↓	**↓	**↑	**↓	**↓	**↑	**↑	*↓	**↓	**↑	**↑	**↓	**↓	**↑	**↑	**↓
L	**↓	**↑	**↑	**↓	**↓	**↑	*↑	**↓	**↓	**↑	**↑	**↓	**↓	**↑	**↑	**↓
M	**↓	N. S.	**↑	**↓	**↓	N. S.	**↑	**↓	**↓	**↑	**↓	**↑	**↑	**↓	**↓	**↑
N	**↓	**↓	**↑	N. S.	**↓	**↑	**↑	**↓	**↑	N. S.	N. S.	**↑	**↑	**↓	**↓	N. S.
O	**↓	**↓	**↑	**↓	**↓	**↑	**↑	**↓	**↓	*↑	**↑	**↓	**↓	**↑	**↓	**↓
P	**↓	**↑	**↓	**↑	N. S.	**↓	**↓	**↑	**↓	**↑	**↓	**↑	**↓	**↓	N. S.	**↑
Q	**↓	**↓	**↑	*↑	**↑	N. S.	**↓	**↓	**↓	**↑	**↓	**↑	**↑	**↓	**↑	**↑
R	**↓	**↓	N. S.	**↑	**↓	N. S.	**↑	**↓	**↓	**↑	**↑	**↓	**↓	**↑	**↑	**↑
S	**↑	N. S.	**↑	**↓	**↓	**↑	**↑	**↓	**↓	**↓	**↓	**↑	**↓	**↑	**↑	**↓
T	**↓	**↓	N. S.	**↑	N. S.	**↓	N. S.	**↑	**↓	**↑	**↓	**↑	*↑	**↓	*↓	**↑

The dashed under line represents the results that was discussed in chapter 3.

** : P < 0.01 ↓ : average is decreased N .S. (Not Significant) : 0.05 < P

* : 0.01 < P < 0.05 ↑ : average is increased start : start of singing end : end of singing

fluctuation of cerebral blood flow was analyzed. It was clarified that the sympathetic nerve became predominant and the oxyHb decreased during singing. It was clarified that the parasympathetic nerve became predominant and the oxyHb increased at the time of rest after singing. Therefore, the decrease of oxyHb was suggested during the activation of the human body. And the increase of oxyHb was suggested during the test subject felts relaxed atmosphere in listening to music after singing music.

For quantifying the activity 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, the activation of cerebral function was clarified in listening to music after singing. It was suggested that the fluctuation level of oxyHb was higher during listening to music than at the time of rest after singing.

We have two future items to be studied. We will clarify the mechanism that the oxyHb increases during the sympathetic nerve become predominant. We will clarify the effectiveness of music therapy on the prevention of dementia.

5. References

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