Individual Differences in Brain Activities When Human Wishes to Listen to Music Continuously Using Near-Infrared Spectroscopy

Shin-ichi Ito, Momoyo Ito, Minoru Fukumi

Abstract*: This paper introduces an individual difference in the activities of the prefrontal cortex when a person wants to listen to music using near-infrared spectroscopy. The individual differences are confirmed by visualizing the variation in oxygenated hemoglobin level. The sensing positions used to record the brain activities are around the prefrontal cortex. The existence of individual differences was verified by experiments. The experiment results show that active positions while feeling a wish to listen to music are different in each subject, and an oxygenated hemoglobin level is different in each subject compared to its value when a subject does not feel the wish to listen to music. The experiment results show that it is possible to detect a wish to listen to the music based on changes in the oxygenated hemoglobin level. Also, these results suggest that active positions are different in each subject because the sensitivities and how to feel on stimulus are different. Lastly, the results suggest that it is possible to express the individual differences as differences in active positions.

***Keywords* : individual differences, near-infrared spectroscopy , wish to listen to music, prefrontal cortex activity, music therapy**

I. INTRODUCTION

Music therapy and music refresh methods are to control human mental state and be enjoyed by human lives. There two kinds of music therapy, passive music therapy and active music therapy. In active music therapy, the instrument such as a guitar, piano, or drums are played, which should bring happiness and joy to one person who is plating the instrument. By enjoying the music, the person's mental state is controlled, and it becomes stable. However, a person should play an instrument with a music therapist, and it is not easy to perform active music therapy. Moreover, the music played for music therapists cannot be easily specified because people have different preferences and different feelings about music. On the other hand, in passive music therapy, a person listens to music, and controls his mental. The passive music therapy can be conducted easily because a person only listens to music. However, it is not easy to specify effective music for a particular person. The music to be listened to is selected based on the facts whether a person likes it, whether it matches the person's mood, whether the person knows it, and whether the person wants to listen to it continuously, respectively. However, these factors are difficult to be determined. Once they are determined, effective music to control a person's mental health can be specified easily.

This paper uses the brain activity analysis technique to detect the aforementioned factors because these factors are created in the human brain. Although all the factors to select the music are important, this paper focuses on the factor of whether a person wants to listen to specific music continuously because the influence of the music that a person wants to listen to, has a strong influence on the person's mental state. At present, there are many techniques for brain activity analysis, such as electroencephalogram (EEG) analysis [1][2], functional near-infrared light imaging/functional near-infrared spectroscopy (fNIRS) analysis [3]-[21], functional magnetic resonance imaging analysis, and many others. However, this paper employs the fNIRS to analyze the brain activities related to the factors to select the music to listen to. The fNIRS measures the activities of the brain by sensing variation in both the oxygenated hemoglobin (oxy Hb) and the deoxygenated hemoglobin (deoxy Hb). Then, the prefrontal cortex activities are studied because these activities relate to the person's emotions, sensibility, and KANSEI. Here, brain activity analysis shows an individual difference. Particularly, the brain activities related to the person's emotion, sensibility, KANSEI, and decision-making with emotion, have a large individual difference. In this paper, it is assumed that the individual difference expresses the differences in activation positions in the brain and activation actions of each sensing position. Accordingly, this paper analyzes the individual difference.

The individual differences in brain activities while feeling a wish to listen to music continuously are confirmed and analyzed by experiments.

II. RELATED WORKS

There have been many studies related to brain activity analysis using fNIRS. By analyzing the prefrontal cortex activities, Pinti et al. [3] showed that fNIRS and thermal infrared imaging had strong coherence for low-frequency components. The task was a cognitive task. Yennu et al. [4] introduced a method for the

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evaluation of abnormal activities of the prefrontal cortex. The task was the Stroop task. Ho et al. [5] introduced a method to classify the stress levels related to the mental workload levels. The proposed method employed the principal component analysis and convolutional neural networks. This method achieved average recognition accuracy higher than 65%. Minematsu et al. [6] introduced a method to evaluate human preference on foods and drinks. The results of experiments showed that the pleasantness of foods and drinks could be determined using the changes in the oxy Hb level. Tanveer et al. [7] proposed a method to detect drowsiness using deep neural networks, and the mean recognition accuracy of more than 99% was achieved. Foy et al. [8] introduced a method to investigate the higher accident risk in young drivers. Their experimental results showed that the prefrontal cortex activities of young drivers became low compared with those of old drivers when tasks were the one-following and four-overtaking tasks.

From the analysis of prefrontal cortex activities using the auditory stimulus, Jeong et al. [9] developed a new method or auditory attention deficits when an analyzed position was left dorsolateral prefrontal cortex. The experimental results suggested that the proposed mechanism served as a bio-marker. Balconi et al. [11] introduced a method to evaluate human emotions using visual and auditory stimulus. The experimental results proved the method's effectiveness for both left and right prefrontal cortex activities.

The fNIRS analysis is employed to evaluate brain activities, mental workload levels, preference, and other related factors. Therefore, mental changes can be determined by fNIRS through the analysis of prefrontal cortex activities. Although human brain activities related to emotions, sensibility, and KANSEI have shown individual differences, to the best of the authors' knowledge, there has been no study that discusses the individual differences in prefrontal cortex activities related to the emotions, sensibility, and KANSEI.

III. EXPERIMENTS

In order to confirm the individual differences in prefrontal cortex activities while the subject wants to listen to music continuously, the experiments were conducted. In the experiments, six healthy persons with the mean age of 22.5 years, were included. The OMM-3000 device made by Shimazu corporation in Japan was employed to record the prefrontal cortex activities, and it is shown in Fig. 1. The OMM-3000 sensed the variation in both the oxy Hb and the deoxy Hb because the absorption rates of the near-infrared light of oxy Hb and deoxy Hb were different. The sensing positions were in the frontal cortex, as shown in Fig. 2. In Fig. 2, the red circles denote the probes for the entrance of the near-infrared light, and blue circles denote the light-receiving probes. The measurement positions of oxy Hb and deoxy Hb are denoted from 1 to 24 in Fig. 2. In the experiments, the subjects were sat on the chair and had the OMM-3000 probes attached to their heads, while sensing the oxy and deoxy Hb. The time course consisted of four intervals: rest time that lasted for 15 seconds, task time that lasted for 15 seconds, time for answering the questionnaire that lasted for 15 seconds, and deep-breathing time that lasted for 1 second and was used as a set. During the rest time, the subjects were asked to count in their minds without speaking. During the task time, the subjects listened to music. During the time for answering the questionnaire, the subject answered the questionnaire that included the following three questions: "Do you want to listen to music continuously?"; "Do you let music pass?"; "Do you skip music?" During the deep-breathing time, the subjects steadied their breathing. The subjects conducted ten sets per day. Also, the music for listening to was prepared by the participants.

The target positions for analyzing the brain activities were 7, 9, 10, 12, 18, 20, 21 and 23 (refer to Fig. 2), which were positions around the prefrontal poles that are related to emotion, sensibility, KANSEI and decision-making with emotions and are free of noise influence caused by hair.

Fig. 1. The image of the OMM-3000 device used to record brain activities.

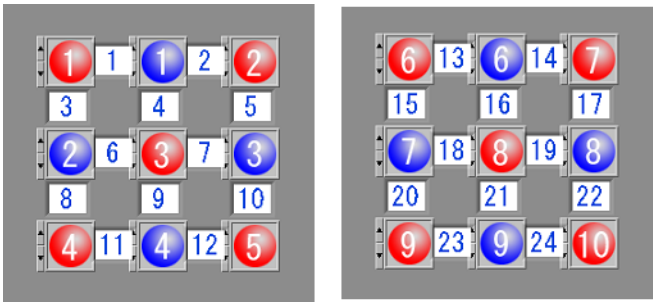

Fig. 2. Positions to the record brain activities of the prefrontal cortex. Blue and red circles denote probe positions (blue: 1- 9, red: 1-10). Blue numbers 1-24 denote measurement positions.

IV. RESULTS AND DISCUSSIONS

The sample results of variation in oxy and deoxy Hb on the subjects A-F are presented in Figs. 3-8, respectively. In Figs. 3 and 4, the changes in oxy Hb in positions 7, 9, 10, 12, 18, 20, 21, 23 were unique selected when the subject would like to listen to the

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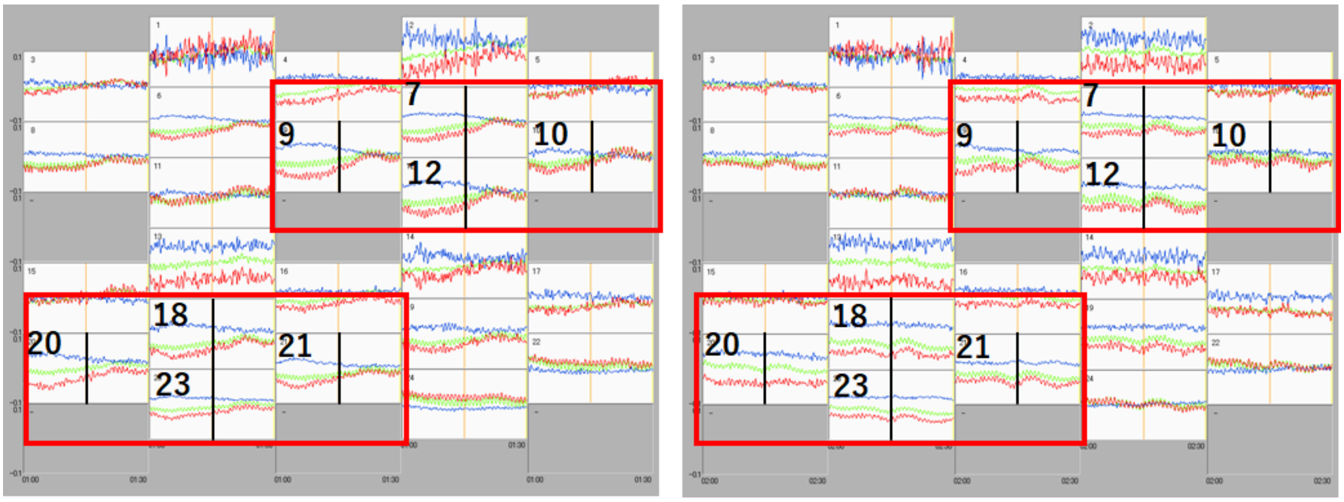
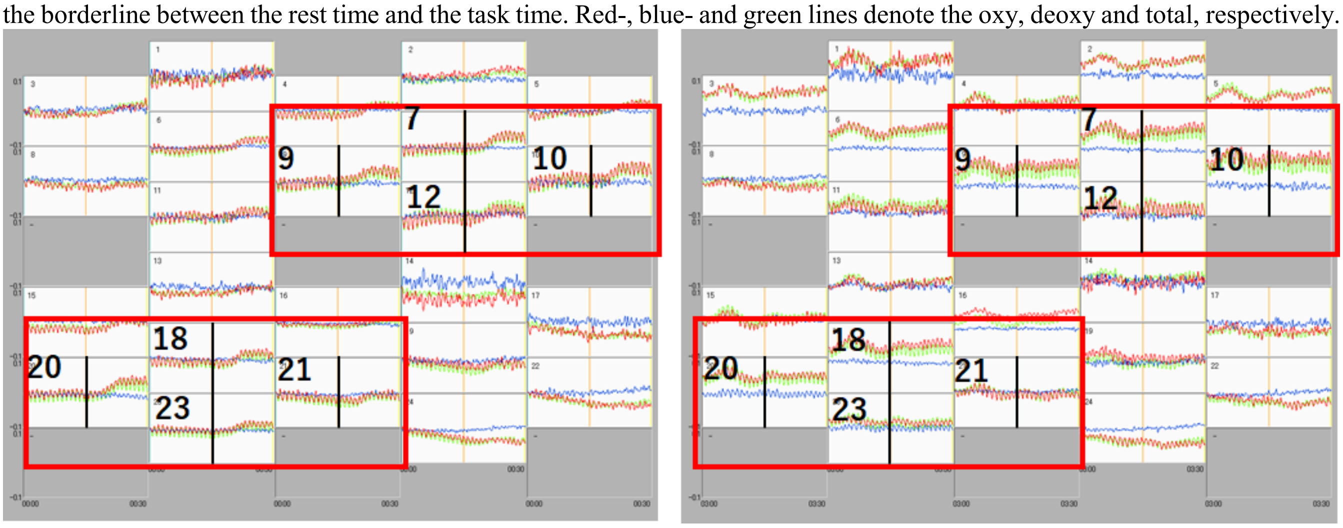


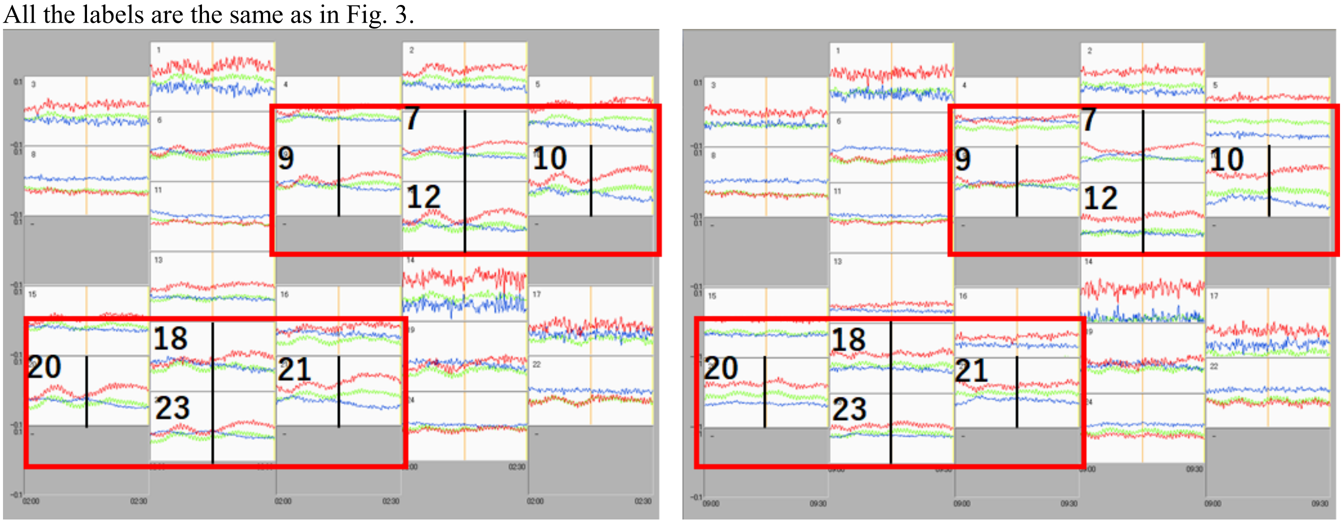
(a) (b)

Fig. 3. Samples of variation in the oxy and deoxy Hb levels of subject A when the subject (a) wanted and (b) did not want to listen to the music continuously. Red squares denote target positions used for analyzing the brain activities. Black line denotes the borderline between the rest time and the task time. Red-, blue- and green lines denote the oxy, deoxy and total, respectively.



(a) (b)

Fig. 4. Samples of variation for subject B when the subject (a) wanted and (b) did not want to listen to the music continuously. All the labels are the same as in Fig. 3.



(a) (b)

Fig. 5. Samples of variation for subject C when the subject (a) wanted and (b) did not want to listen to the music continuously. All the labels are the same as in Fig. 3.

music continuously. Although the changes of oxy Hb from the rest time to the task time in Figs. 3 and 4(b) were fewer, the changes in Figs. 3 and 4(a) were a lot, and the oxy Hb increased f or all the measurement positions. These results suggest that it was possible to detect a wish to listen to the music by confirming the changes in oxy Hb level. The positions 7, 9, 10, and 12

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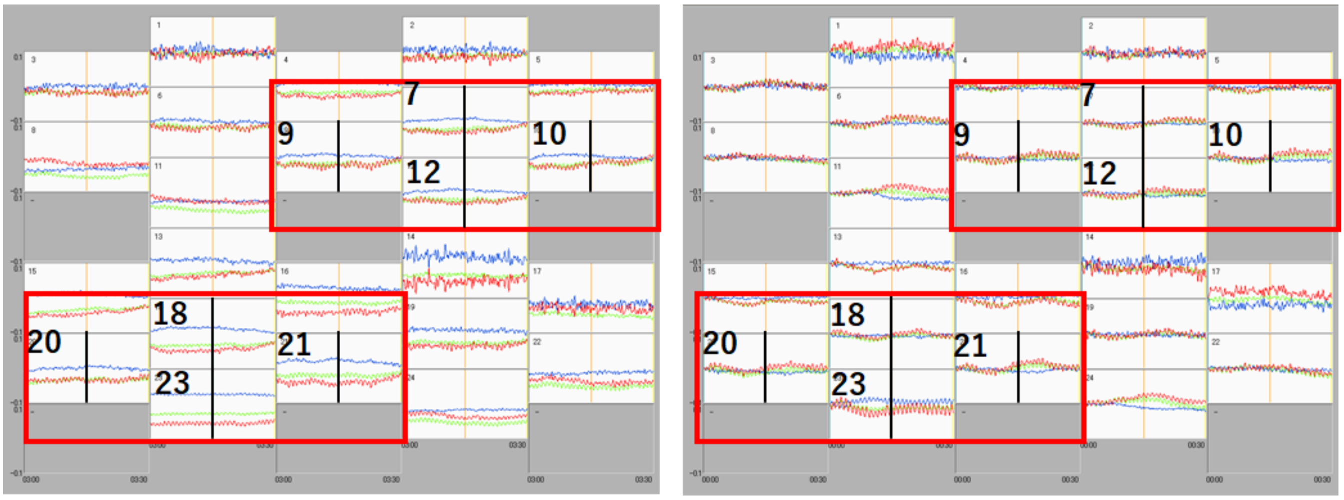
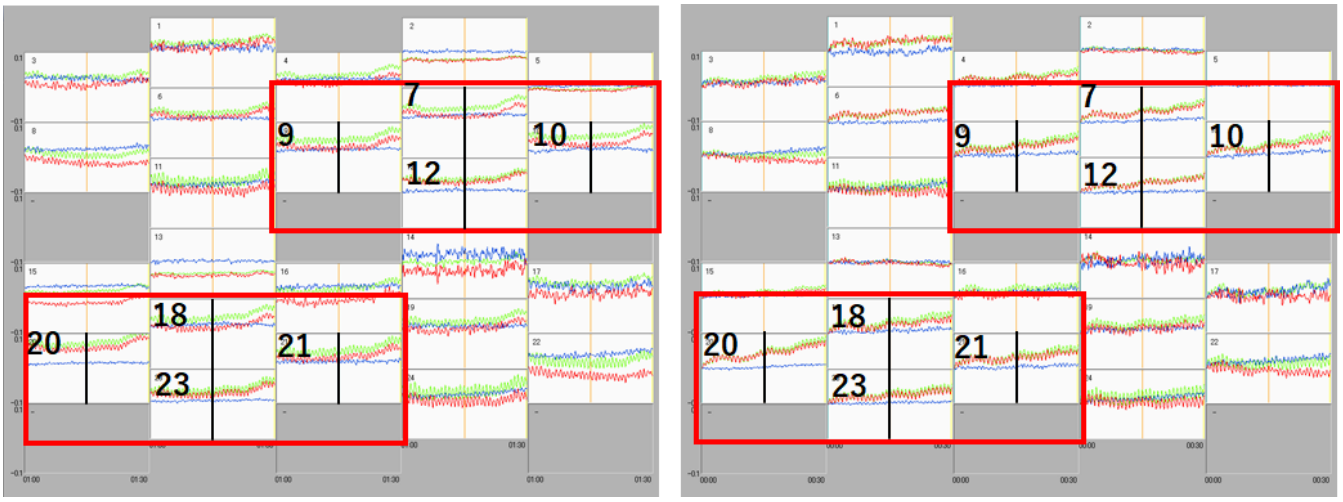


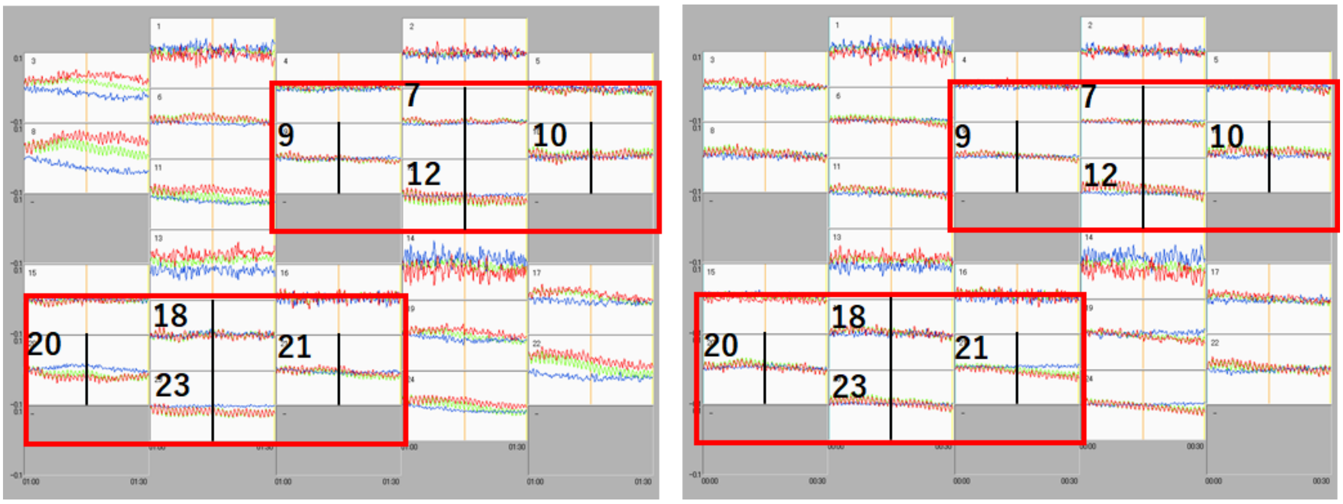
(a) (b)

Fig. 6. Samples of variation for subject D when the subject (a) wanted and (b) did not want to listen to the music continuously. All the labels are the same as in Fig. 3.



(a) (b)

Fig. 7. Samples of variation for subject E when the subject (a) wanted and (b) did not want to listen to the music continuously. All the labels are the same as in Fig. 3.



(a) (b)

Fig. 8. Samples of variation for subject F when the subject (a) wanted and (b) did not want to listen to the music continuously. All the labels are the same as in Fig. 3.

corresponded to the right prefrontal cortex, while positions 18, 20, 21, and 23 corresponded to the left prefrontal cortex. The experimental results suggest that the right and left prefrontal cortex of subjects A and B became active when these subjects had positive emotion on the music they

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were listening to.

In Fig. 5, the changes in the oxy Hb level in positions 18, 20, 21, 23 were unique when the subject would like to listen to the music continuously (Fig. 5(a)). Although the changes in the oxy Hb level from the rest time to the task time in Fig. 5(b) were fewer, while there were a lot of changes in oxy Hb increased on the left prefrontal cortex, as shown in Fig. 5(a). According to the obtained results, it was possible to detect a wish to listen to the music by confirming the changes in the oxy Hb on the left prefrontal cortex. Also, the experimental results suggested that the left prefrontal cortex of subject C became active when the subject has positive emotion on the music he was listening to. In Fig. 6, the changes in oxy Hb in positions 18, 21 were unique, which was when the subject would like to listen to the music continuously (Fig. 6(a)). Although the changes in oxy Hb from the rest time to the task time were fewer in Fig. 6(b), the changes in Fig. 6(a) were numerous, and oxy Hb increased in part corresponding to the left prefrontal cortex. These results suggest that it was possible to detect a wish to listen to the music by confirming the changes in oxy Hb in the left prefrontal cortex. Further, the experimental results suggest that the left prefrontal cortex of subject D became active when the subject had positive emotion on the music he was listening to. In Fig. 7, the differences between the changes in oxy Hb at the rest time and task time were a few, and both of them increased. In Fig. 8, the differences between the changes in oxy Hb at the rest time and the task time were a few, and both of them decreased. These results suggest that the differences feel the effect of conditions of listening to music and information, which the subject E and F wanted to listen to the music continuously, was buried in information, which the subject E and F listened to the music.

The difference between the changes in oxy Hb of the rest time and the task time of each subject were as follows. For subjects A and B, the difference became apparent in positions 7, 9, 10, 12, 18, 20, 21, and 23; for subject C, the difference became apparent in positions 18, 20, 21, and 23; for subject D, the difference became apparent in positions 18 and 21; and lastly, for subjects E and F, it could not be possible to confirm information whether these subjects wanted to listen to music continuously. The active positions were different on each subject. These results suggested that the active positions were different for each subject because the subject sensitivity and the way how the subjects feel on the stimulus were different. Consequently, it can be concluded that it is possible to express the individual differences as the differences in the active positions.

V. CONCLUSIONS

This paper introduced the individual difference in the prefrontal cortex activities obtained using fNIRS when the subjects would and would not like to listen to music. The individual differences were confirmed by visualizing the changes in oxy Hb. The sensing positions to record the brain activities were around the prefrontal cortex. The experiments were conducted to confirm individual differences. The experimental results showed that the oxy Hb in active positions, when the subject would like to continuously listen to music, was different from the case when the subject would not like to listen to music, for each of the subjects. These results suggested that it was possible to detect a wish to listen to the music by confirming the changes in oxy Hb. Also, these results suggested that the differences between the subjects were caused by their differences in sensitivity and how they feel on stimulus.

The results presented in this work confirm that it is possible to express the individual differences as differences in the active positions. In our future work, we will develop a method to detect the information that the subject would like to consciously listen to music.

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