Cerebral blood oxygenation changes during a hearing music task in measurement with fNIRS

Makoto MISUMI ^{a,*}, Hideaki ORII ^a, Tanjina SHARMIN ^a, Kenji MISHIMA ^a, Ko NISHIHARA ^b

^a Faculty of Engineering, Fukuoka University, 8-19-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, JAPAN

^b Faculty of Economics, Fukuoka University, 8-19-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, JAPAN

*Corresponding Author: mmisumi@fukuoka-u.ac.jp

Abstract

Functional near-infrared spectroscopy (fNIRS) was used to study the changes in cerebral blood oxygenation during a hearing music task. Three right-handed male volunteers were matched on demographic variables and hearing two kinds of music, which bring the emotion of relaxation or restlessness in the study. Subjects were performed the task of listening to two different music for 4 minutes. Significant responses were observed in the right prefrontal cortex, the superior frontal gyrus.

Keywords: Cerebral Blood Oxygenation, Measurement, Near-Infrared Spectroscopy.

1. Introduction

In these days, functional near-infrared spectroscopy (fNIRS) is receiving the special attention in the region of research of the brain function. In our study, functional near-infrared spectroscopy (fNIRS) was used to investigate changes in cerebral blood oxygenation to monitor brain activation. This equipment is based on measuring the transmitted and received near-infrared light in multiple wavelengths and calculating relative concentrations of oxy-Hb and deoxy-Hb using modified Beer-Lambert approach [1]. The alternations in [oxy-Hb] and [deoxy-Hb] have been shown to reflect cortical activation [2, 3]. fNIRS is one of the more recently available functional brain imaging techniques, because it enables measurement in a simple setting as compared other functional brain imaging techniques, such as single-photon emission computed tomography (SPECT), and functional magnetic resonance imaging (fMRI). The advantages of fNIRS are known that its complete non-invasiveness enabling repeated measurements, and a high

time resolution of 0.1 s, even using commercially available NIRS apparatuses, enabling a detailed clarification of temporal changes in cerebral blood volume. These advantages of fNIRS make it possible to examine higher brain functions under more natural conditions. Therefore, fNIRS is expected to use clinical studies, schizophrenia [4], depression [5], panic disorder [6], and attention-deficit/hyperactivity disorder [7]. These characteristics of fNIRS make also it possible the investigation of subjective delicate experiences in healthy subjects such as developing brain function [8] and taste-related higher cognitive brain functions [9].

The most frequently used tasks in fNIRS studies are the verbal fluency task and verbal memory task as conventional neuro-psychological measurement of language production and memory. Verbal fluency and memory tasks are easy to perform, and induce large signals. During the verbal fluency task, task-induced brain activation has usually been observed in the frontal region of healthy subjects by means of various methods such as fMRI [10], regional cerebral blood flow measurements [11], and NIRS [12]. But the verbal fluency task and verbal memory task are still lower level of activities in the frontal region of the brain.

Therefore, the purpose of this work was to investigate the effect of listening to music in more high-level activities of the brain by monitoring the changes in cerebral blood oxygenation. In this experiment, a music task was used to listen during the verbal fluency period, which is expected to induce emotion of relaxation or restlessness.

2. Methods

2.1 Participants

Three right-handed healthy native Japanese speaking

Fig. 1. Attachment example of the flexible adjustable surface holder.

subjects participated in the experiment (males, mean age 22, ranging from 21 to 23) having no history of neurological, medical and psychiatric disorders. None were taking medication at the time of measurement. Subjects were seated in a chair in a daylight room with their eyes open throughout the measurement. The distance from eyes to monitor was about 50 cm. Strength of sound of a speaker was 45-60 dB and the distance from the speaker to subjects was 1.5 m.

2.2 fNIRS Data acquisition

In the present study, cerebral oxygenation changes were sampled by a Shimazu functional near-infrared spectroscopy (fNIRS, FORIE-3000, Shimazu Co., Japan). The fNIRS is a continuous wave device which measures changes in attenuation at 3 wavelengths (780, 830 and 805nm, $\pm$ nm) and hence allows for the differentiation of two dynamic absorbers ([oxy-Hb] and [deoxy-Hb]). Concentration changes in [oxy-Hb] and [deoxy-Hb] were calculated based on a modified Beer-Lambert approach [1]. Flexible, adjustable surface holder (FLASH) is attached to the forehead (Fig. 1). Fig. 2 illustrates the arrangement of optical-fiber units (3 x 7 matrix, 32 channels). The numbers between the light-emitting fiber unit and the light-receiving fiber unit denote the measurement channels; measurements were performed through a total 32 channels.

2.3 Verbal fluency task and verbal memory task

The verbal fluency task was done for the training of hearing, prior to the hearing music task. The verbal fluency task consisted of a 30-s pre-task baseline, a 60-s verbal fluency period, and a 30-s post-task baseline. During the verbal fluency period, the subjects were instructed to produce as many words as possible that fall into specific categories (e.g. animals or flowers). These three initial

Fig. 2. The arrangement of the optical fiber.

syllables were employed in the above-mentioned, order and changed every 20 s during the 60-s verbal fluency period to reduce the time during which the subjects remained silent. The number of words generated during the verbal fluency period was determined as a measure of task performance. During the pre-task and post-task baseline periods, the subjects were instructed to repeat the syllables /a/, /i/, /u/, /e/, and /o/ as the Japanese counterparts of A, B, and C in English.

During the verbal fluency task, two dynamic absorbers ([oxy-Hb] and [deoxy-Hb]) was measured by the fNIRS and the concentration changes in [oxy-Hb] and [deoxy-Hb] were calculated based on a modified Beer-Lambert approach.

2.4 Hearing music task

The hearing music task is done after the verbal fluency task and 5 min rest time. The hearing two different types of music (melodious for relaxation and noise for restlessness) music task consisted of a 30-s pre-task baseline, a 60-s verbal fluency period, and a 30-s post-task baseline. During the verbal fluency period, the subjects hear the music sitting on the chair.

Fig. 3. Cerebral blood flow measurement results during the verbal fluency task

Fig. 4a. Cerebral blood flow measurement results of the prefrontal cortex.

Fig. 4b. Cerebral blood flow measurement results of the prefrontal cortex. (Ch. 14)

3. Results and discussion

Fig. 3 shows the amount of change of [oxy-Hb], [deoxy-

Hb], and [total-Hb] during the verbal fluency task of . Clear the amounts of [oxy-Hb] and [total-Hb] increase were observed during the task period. Fig. 4a shows the measurement results of all channels of brain blood flow in the prefrontal cortex at the time of listening to music. Fig. 3 shows the change in blood flow during music listening in the prefrontal cortex. Because, the value of oxyHb, deoxyHb and totalHb have changed by listening to music.

Fig. 4b is an enlarged view of a channel 14 of the measurement results. The relative value of oxyHb and totalHb increased with the start of both music listening task, and then gradually decreased. In other words, the brain activity of the prefrontal cortex once was activated by hearing to music, are then suppressed. In the modeled Ferreri et al study⁽¹³⁾ oxyHb changed at the time of percussion music listening, in the melodious and noise music, brain activity of the prefrontal cortex has been suppressed after activation. The experimental results of Fig. 4 shows the results similar to Ferreri et al.

Fig. 5a and Fig. 5b are a mapping of prefrontal entire blood volume at the time of hearing relaxation music and restlessness music. Focusing on total Hb of Fig. 5a and Fig.

Fig. 5. Blood flow mapping of the prefrontal cortex when a hearing music task.

5b, cerebral blood flow is decreased in the prefrontal cortex midline during melodious music hearing. This phenomenon can be explained by the previous studies of Katayose et al⁽¹⁴⁾, where the high/immense concentration to the music decreased blood flow in the prefrontal cortex midline, it was also stated that the listener tends to easily devoted to music if the music was preferred. Two tracks were used in this experiment, although the melodies were different, both music were preferred by a subject and therefore, because of this preference of music the subject the immersion can be measured.

4. Conclusions

In this paper, fNIRS was used to investigate changes in the effect of listening to music in cerebral blood oxygenation to monitor brain activation. Three right-handed male volunteers matched on demographic variables and hearing two different kinds of music, which bring the emotion of relaxation or restlessness in the study. Subjects were performed the task of listening to two music during 4 minutes. Significant responses were observed in the right prefrontal cortex, superior frontal gyrus.

Acknowledgment

This research was partially supported by a Grant-in-Aid

for Scientific Research (Grant Nos. 26420770 and 23560913). The authors gratefully acknowledge the Japan Food Chemical Research Foundation (2015).

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