EFFECTS OF EMOTIONALLY INDUCED SOUNDS TO THE LANGUAGE AREA OF THE BRAIN

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ABSTRACT Emotion plays an important role in language comprehension that is essentials to establish smooth communication and good personal relationships. The objective of this research is to understand how emotional context in language sounds can affect the language areas of the brain. A survey with 30 Japanese students aged 18 to 22 years was conducted to prepare the recording of language sounds to be used in a NIRS experiment. The language sounds are Japanese declarative sentences expressed with and without emotional intonations, and they were then reversed by using an audio editor. The subjects chose one of five emotions; happiness, sadness, anger, surprise and fear given in a questionnaire after they listened to each sentence, and we chose the sound recording with more than 80% accuracy for the NIRS experiment. In the experiment, 21 subjects who were native speakers of Japanese listened to the language sounds while their brain activities were recorded by a NIRS system. The NIRS data obtained from the prefrontal cortex and left hemisphere of the brain indicated that the rates of changes in oxyhemoglobin concentration for Broca's area were more significant while the subjects were listening to the sentences with emotion compared to non-emotional language sounds.

1. INTRODUCTION

Although physically the left and right hemispheres have more or less the same shape and size, each hemisphere has some functional specializations. Nobel laureate Roger W. Sperry, who contributed greatly to the discovery of brain lateralization, suggested that speech production and language comprehension are conduct by the left hemisphere of the brain. Further studies have shown that the left hemisphere tends to control analytical and logical processing while the right hemisphere carries out the spatial recognition, emotion processing (Schirmer et al., 2006). However recent studies demonstrate that these two hemispheres do not operate in isolation (Singh et al., 2004). Thus, despite knowing that the right hemisphere is specialized for emotion processing, we decided to investigate whether emotional context in language sounds affect the activities of the left hemisphere of the brain.

In the left hemisphere, there are two areas which are the keys to language comprehension; Broca's area and Wernicke's area. The Broca's area, which is situated in the lower region of the frontal lobe, is associated with the production of language or language outputs. Meanwhile, the language input or language processing is done by Wernicke's area in the temporal lobe (Yokoyama, 2010). In this study, we focused on reactions in the left hemisphere, specifically on both the linguistic areas mentioned above during emotion processing.

We conducted an experiment to study the effect of emotional context in language sounds to the Broca's area and Wernicke's area of the brain. The language sounds or as mentioned in the title, the emotionally induced sounds are referring to the six recordings of reversed-Japanese sentences: three of them were expressed with emotion and the other three were without emotion. To further explain these, a declarative sentence delivered with emotion was recorded and then reversed. The same declarative sentence expressed without emotional intonations was again recorded and reversed. These processes were repeated with another two declarative sentences which make up a total of 6 recordings. While listening to the language sounds, the subject's brain activities were recorded by a Near-Infrared Spectroscopy (NIRS) system. The NIRS system measured the relative changes in oxygenated hemoglobin and deoxygenated hemoglobin concentration. The subjects were later given a set of questions to be answered after listening to the language sounds.

This future direction of this research is to provide additional data in developing the treatment for individual suffering from neurological disorder particularly the dementia patients. Although their symptoms of deterioration in memory and thinking can be control by existed medicine or treatment, there is still no cure for them. As emotion has significant affect to human memory (Cahill et al., 1995), this study would perhaps able to provide some help in finding the cure for dementia patients.

2. EXPERIMENT

2.1 Pre-test survey

A pre-test was needed to be done to select the language sound to be used in the NIRS experiment. Fifteen sentences expressed with 3 of the six basic emotional tones (Batty et al., 2003), happiness, sadness and anger, were recorded and reversed. The recorded sounds were reversed by using an audio editor to control the interference from language comprehension process and to help the subjects focus on the emotion processing. The language sounds were then played for a group of 30 students in an age range from 18 to 22 years old. The students then chose one of the five emotions; happiness, sadness, anger, fear, or surprise as the emotion expressed by each setence in the recording. The pre-test result is shown in Table 1. Three sentences with 80% and above of validity were selected to be used as the language sounds.

Table 1 Validity percentages for emotional sounds in the pre-test

Sentences	Emotion	Validity (%)
1	Happiness	70.00
2	Sadness	93.33
3	Anger	100.00
4	Happiness	26.67
5	Sadness	83.33
6	Anger	93.33
7	Happiness	70.00
8	Sadness	46.67
9	Anger	93.33
10	Happiness	36.67
11	Sadness	60.00
12	Anger	90.00
13	Happiness	30.00
14	Sadness	80.00
15	Anger	23.30

2.2 NIRS experiment

Despite its few drawbacks such as poor spatial resolution (Doi et al., 2013), NIRS has been used by many cognitive neuroscientists due to its non-invasive and non-ionizing imaging technique. NIRS provides a therapeutic window which is able to perform the division and quantification of both oxyhemoglobin and deoxyhemoglobin. These allow the system to perform real time studies in human brain (Hall, 2012). The NIRS system comprised an ETG 4000 machine and 33 probes. The machine from Hitachi Medical Corporation has 52 channels used to observe the brain activities. The blue and red probes were attached to the headgear and placed on the prefrontal cortex and left hemisphere of the subject's head as illustrated in Fig. 1. As shown in the figure, the red and blue probes are known respectively as irradiation and detection probes while the green areas represent the channels. Near-infrared rays with wavelength range from 600nm to 900nm were released through the red probes. The rays were then scattered inside the brain before being reflected back to the blue probes. This process allows the concentration of oxygenated hemoglobin and deoxygenated hemoglobin to be measured.

Right-handed Japanese students in their twenties listened to the recording of three sentences with three different emotions selected during the pre-test and the additional three sentences without emotion. The NIRS system ran throughout the listening session and a survey was conducted after the session. The survey asked the subject to choose one of the emotions expressed through the language sounds. A video camera recorded the whole experiment to ensure the measurement of hemoglobin concentration is in sync with the timing of the sound recording.

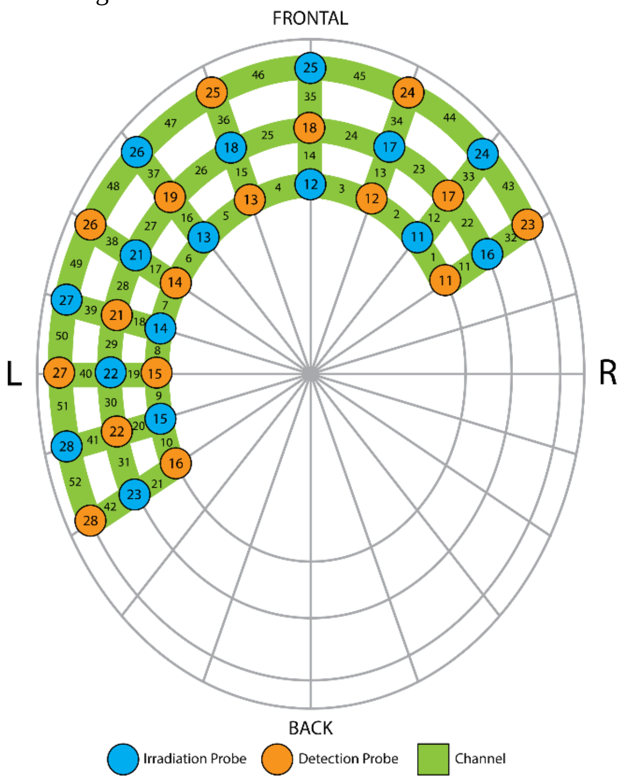

Fig. 1 NIRS probe placement in the experiment

3. RESULT

The NIRS system mapped the changes in oxyhemoglobin concentration onto two-dimensional images of the brain for every 0.1 seconds (Fig. 2). The red region in Fig. 2 indicates the higher concentration of oxyhemoglobin whereas the blue region represents the lower concentration of oxyhemoglobin. The change rates of oxyhemoglobin concentration when the brain receives a stimulus allow us to investigate the brain activities.

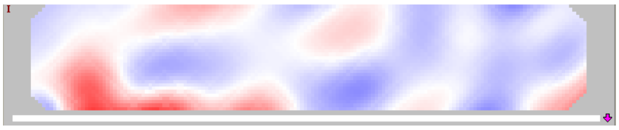

Fig. 2 Relative changes of oxyhemoglobin concentration in the prefrontal cortex and the left hemisphere.

The change rates in oxyhemoglobin concentration for all subjects were averaged for every 0.1 seconds and compared between language sounds expressed with emotion and without emotion. These values are referred as average NIRS values. Figures 3, 4, 5 and 6 show the average NIRS values for Channels 5, 17, 25 and 36 respectively. Channels 5, 17, 25 and 36 are the areas roughly correspond to BA44 and BA 45.

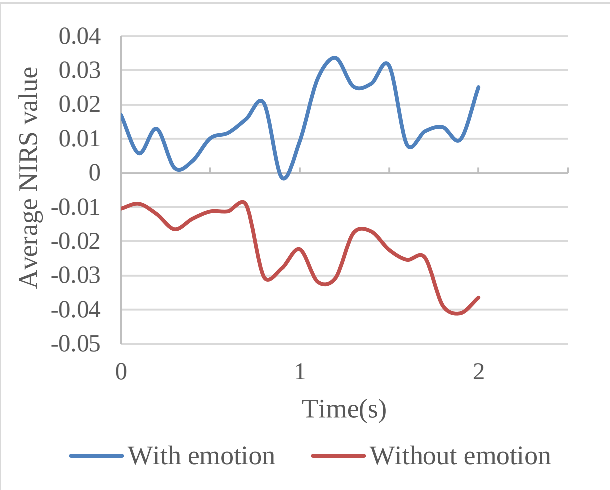

Fig. 3 Plot of average NIRS values for Channel 5

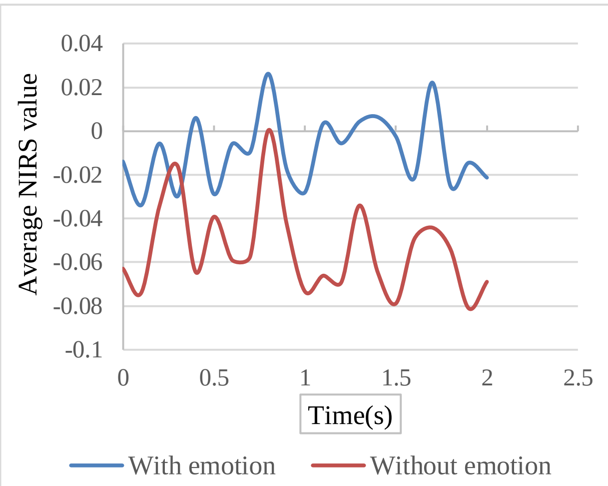

Fig. 4 Plot of average NIRS values for Channel 17

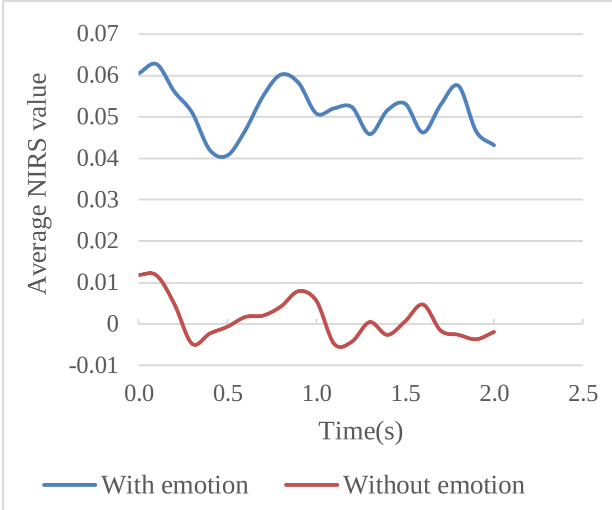

Fig. 5 Plot of average NIRS values for Channel 25

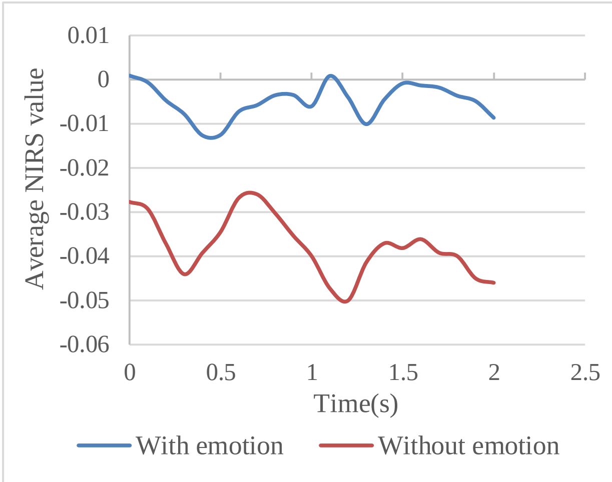

Fig. 6 Plot of average NIRS values for Channel 36

The result of this experiment shows that the average values of the changes in oxyhemoglobin concentration in language areas were higher for language sounds expressed with emotion compared to ones without emotion.

4. DISCUSSION

Only right-handed students with Japanese native speaker were chosen as subjects. The right-handed requirement is important as Broca's area and Wernicke's area are located in different positions according to one's dominant hand. While 95% of right-handed people have Broca's area and Wernicke's area in the left hemisphere, only 70% of left-handed people have them in the same position. Thus, right-handed people are chosen. The Japanese native speakers were chosen as they are easy to recognize that the language sound in the experiment material were prepared in Japanese language.

As shown in Figures 3, 4, 5 and 6, the average NIRS values for language sounds with emotion were higher than for non-emotional sounds. This is true not only for BA44 and BA45, but also for the whole prefrontal cortex and the left hemisphere. Table 2 summarizes the rates of changes for oxyhemoglobin concentration in the prefrontal cortex and left hemisphere of the brain.

Table 2 Average NIRS values for the prefrontal cortex and the left hemisphere.

Sentences	Emotion Presence	Ave. NIRS value
1	With	0.0083
2	Without	-0.0055
3	With	0.0670
4	Without	0.0434
5	With	-0.0024
6	Without	-0.0154

The average NIRS values for sentences with emotion were higher than for sentences without emotion. Although three different emotions; happiness, sadness and anger were used in the language sounds, sentences expressed in happy tones showed a significant difference compared to its non-emotion version. This might be due to the process of preparing the language sounds. The language sounds are first recorded in the normal order of speeches by using these three emotions before reversed. It is due to this particular step that caused the intonation variation used to signal the emotions of the speaker to be altered slightly. The subjects might have noticed the high pitch usually embedded in happiness intonation but failed to recognize the changes of intonation that indicated the sadness and anger emotion.

5. CONCLUSION

Language can be interpreted differently depending on the emotional context infused in it. Thus, emotion plays an important role in the establishment of smooth communication and a good personal relationship (Ihara et al., 2012). In this study, we investigate the effect of emotional context in language sounds to the Broca's area and Wernicke's area of the brain. Six language sounds with two different features, with emotion and without emotion, were prepared for the subjects to listen to while their prefrontal cortex and left hemisphere were measured by a NIRS system. The average values of oxyhemoglobin concentration in BA44 and BA45, which correspond to Broca's area, for 21 right-handed subjects were generally higher when they were listening to language sounds expressed with emotion than without emotion. In other words, the language areas of the brain are more active while a subject is listening to sentences with emotional context. This agrees with results from previous studies that suggested the brain works better with emotional stimuli than non-emotional stimuli (Mazur et al., 2012).

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