EFFECTS OF AMPLIFIED AMPLITUDES OF ENGLISH SPEECHES ON BRAIN FUNCTIONS

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ABSTRACT Some studies have pointed out that high frequency ranges in music or human voices within audible ranges affect the activation of brain function. However, the effects of high frequency ranges to human brain have yet to be completely revealed. In this study the authors conducted an experiment to examine whether English speech with enhanced amplitudes in a certain frequency range can induce a better comprehension of English speech and help learners acquire English. Twenty subjects listened to English sentences whose amplitudes were enhanced in low and high frequency ranges, in random order. By using near-infrared spectroscopy (NIRS), their brain activities were measured while they were listening to English sentences. The result showed that English sentences with enlarged amplitudes in a high frequency range activated brain areas associated with language processing and a portion of left side of the prefrontal cortex more than other areas. This tendency was more obvious among subjects with lower English proficiency.

1. INTRODUCTION

According to an educational method called Tomatis Method and some studies about Mozart Effect, high frequency ranges in music and human voice can play an important role in activation of brain functions in terms of concentration ability (Tonegawa & Watanuki, 2008), (Tomatis, 1991), (Nakamura, 2008), (Arai, 2012). Also, it has been revealed that each language has a preferable certain frequency range as shown in Figure 1 (Tomatis, 1997). For example, Japanese language mainly uses a frequency range from 125Hz to 1500Hz. British English uses a frequency range from 2000Hz to 20000Hz. It has been pointed out that these frequency differences cause Japanese to difficulties in listing and comprehending English sentences.

There are a lot of commercial products that claim to have effects to activate brain functions for English learnings, such as music albums to enhance listening skills, including English learning materials featuring on high frequency ranges. However, those results have not yet to be conducted experiments and proved enough whether the difference frequency ranges in languages relate to the smooth acquisition of other languages. In this study, the authors conducted an experience to examine which amplified amplitudes of English speech in certain range affect the activation of brain function and better understand of English, by using NIRS.

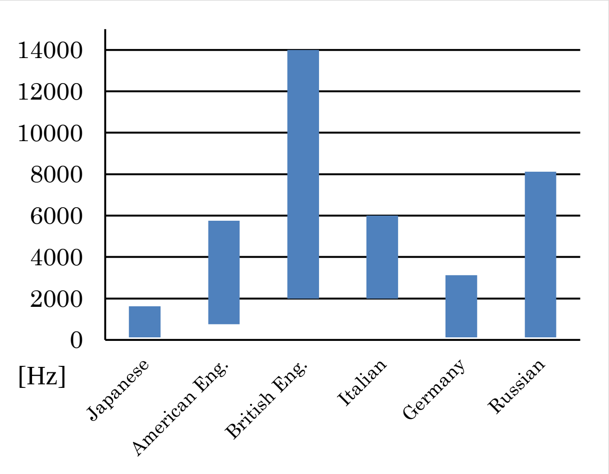

Fig. 1. Frequency ranges for some natural languages

2. EXPERIMENT

In this study, Japanese subjects listened to three types of English speeches: the original speeches, the speeches that were produced by enhancing amplitudes in a high frequency range and a low frequency range of the original ones. While the subjects were listing to these English speeches, we measured changes in hemoglobin concentration rations in their brain by using a NIRS system. After the measurement, the subjects responded to a questioner to evaluate each sound set.

2.1 METHOD OF AMPLIFIIDE AMPLITUDES

We utilized software called Audacity, which is a free multi-track audio editor-recorder, to create English speeches with enhanced amplitudes (Arai, 2012). We used 19 English speeches from learning materials for

English learners at intermediate levels and changed amplitudes of the English sentences by using the software. The amplitudes of the original sentences were enlarged in a low frequency range from 1,000[Hz] to 3,000[Hz], and in a high frequency range from 7,000[Hz] to 10,000[Hz]. Because language vowels mainly consist of sounds in the lower frequency range and native speakers of Japanese preferably use sounds in the frequency range. Therefore, the authors assume that amplitude enhancement in this frequency range can induce a better understanding of English for Japanese learners of English. Also, most English consonants consist of sounds in the higher frequency range and human voice usually does not contain sounds in a frequency range over 10,000[Hz]. Thus, we decided not to take the frequency rages below 1,000[Hz] or over 10,000[Hz] into account. Figure 2 shows the amplitudes of one of the original English speeches.

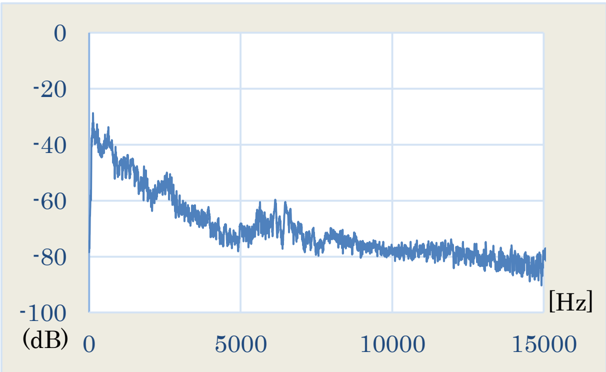

Fig. 2. Amplitudes of one of the original speeches

First, the sound pressure of the English speeches was reduced to each negative 12dB and 3dB. After that, the amplitudes of the English speeches were enhanced to both 18dB in a certain frequency range so that the subjects could tell one speech apart from another clearly by using only their auditory sense. Figures 3 and 4 show the amplitudes of the speeches with enlarged amplitudes in the lower and higher frequency ranges by Equalizer which is on Audacity for the experiment. The red lines in both figures are the amplitudes of the speeches that were different from those of the original speeches.

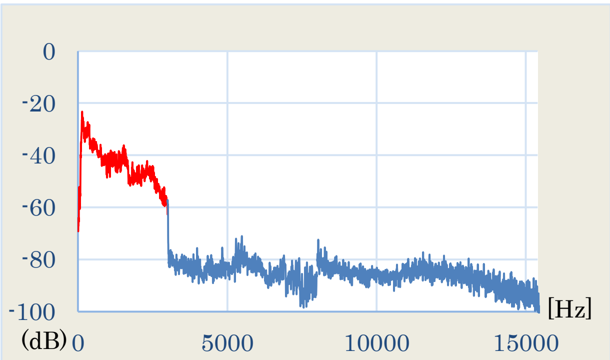

Fig. 3. Amplitudes of the speech created by enhancing the amplitudes of the original one in the low frequency range

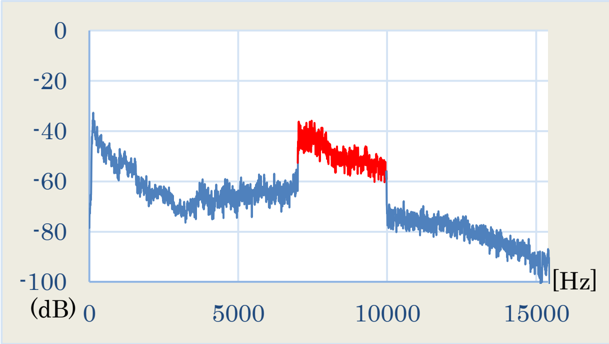

Fig. 4. Amplitudes of the speech created by enhancing the amplitudes of the original one in the high frequency range

2.2 NIRS measurement

In the experiment, we used a NIRS system developed by Hitachi Medical Corporation (EGT 4000, 52 channels) to observe and record hemoglobin concentrations in their brain of every subject. Figure 5 shows one of subjects listening to the English speeches while wearing a headgear for applying NIRS probes to his head. The headgear included 52 optical source-detector channels to monitor relative changes in hemoglobin concentration in subject's brain. The channels covered part of the brain from frontal lobe to the left hemisphere of the brain so that they could cover Broca's Area and Wernicke's Area. The covered areas roughly corresponded to Brodmann Areas (BA) 8,9,10,22, and from BA 40 to BA 46. Figure 6 shows the position of the NIRS probes on subject's head. In order to assess the activation of the brain functions associated with these areas, the blood hemoglobin concentrations of each subject were observed from the beginning of the listening to the end of the English speech, and relative changes in oxy-hemoglobin, deoxy-hemoglobin and total hemoglobin (oxy-Hb, deoxy-Hb and total-Hb) concentrations from 52 channel points which were simultaneously measured and recorded for each subject. Figure 5 shows a photo of a male subjects wearing NIRS proves while listening to English speeches and Figure 6 illustrates the arrangement of NIRS probes.

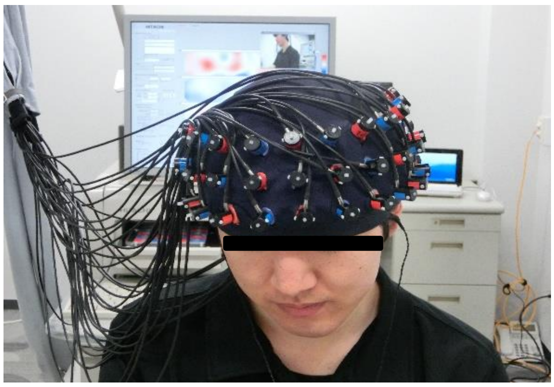

Fig. 5. Photo of one of the subjects listening to the English speeches with optical topography proves applied to his head

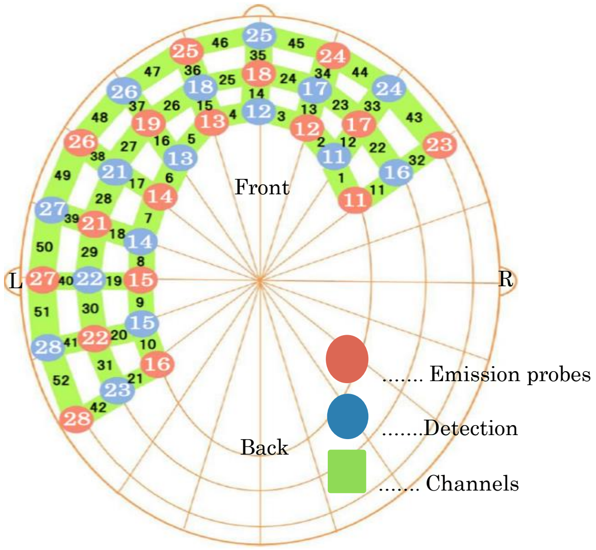

Fig. 6. Arrangement of NIRS probes for the experiment

2.3 Subjects and flow of the experience

Twenty subjects who were Japanese university students participated in the experiment. They are undergraduate students whose ages were from 19 to 25, and their first language was Japanese. Eighteen of them were males and two of them were females, and they were all right-handed. They had taken an English test called TOEIC before the experiment and participated in it regardless of their TOEIC scores. The subjects were given introductions for listening three sets of English sentences. They were not told which set was the one with enhanced amplitudes in high or low frequency ranges or the original speech. Each set consisted of amplified amplitudes in certain high, low frequency ranges and original English sounds. The length of each set with the original, low-frequency enhanced and high-frequency enhanced speeches was about 20 seconds. An interval of 10 seconds was inserted between two sets of speeches. The entire length of a speech test was 1 minute and 30 seconds. The subjects listened to the three sets in a random order. After listening to the three sets, they responded to a questioner to evaluate each sound set in five-scales. They were asked how easy it was for them to recognize English sounds (vowels, consonants and each word) and to comprehend sentences in the speech, by using a five-point grade from 1 (the hardest) to 5 (the easiest).

3. RESULT

The oxy-Hb concentration changes in each subject's brain recorded during the experiment were observed as two- dimensional topographic images. The images were analyzed in relation to the functions of brain regions. The result of NIRS measurement showed that each English sentence activated some brain areas around the front lobe and some regions of the left side of the brain. Moreover, the highest level of oxy-Hb concentration changes was observed in some parts of brain areas, in particular inferior frontal gyrus and superior temporal gyrus (BA 44, 45 and 22), when subjects were listening to speeches with enlarged amplitudes in the high frequency range. Figure 7 shows the average values of oxy-Hb changes from NIRS signals obtained from NIRS channels that covered BA44, 45 and 22.

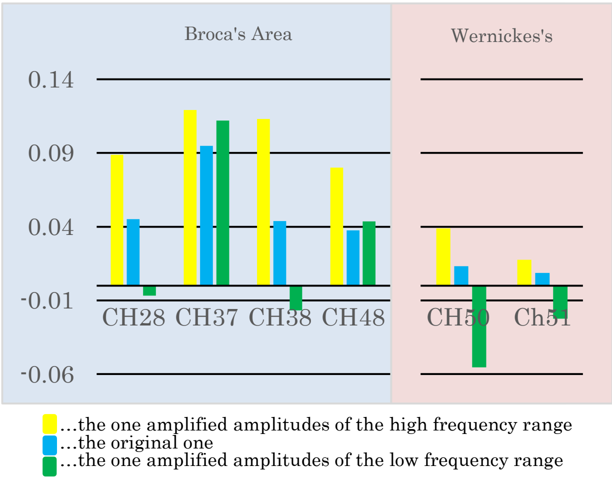

Figure 7. Average values of oxy-Hb changes from channels for BA44, 45 and 22.

The authors divided the subjects into two groups. One had the subjects who had TOEIC score lower than 400. The other had subjects whose TOEIC scores were up to 400. The NIRS observation revealed that the brain functions of the subjects in the former group were slightly more activated than those of the subjects in the latter while they were listening to English speeches in all types. This difference was observed more significantly in the language areas of the brain and while the subjects were listening to English speeches with enlarged amplitudes in the high frequency ranges. Figure 8 shows the average NIRS signal values of concentration changes of oxy-Hb in two language areas for the two groups while they are listening to speeches with the enlarged amplitudes in the high frequency ranges.

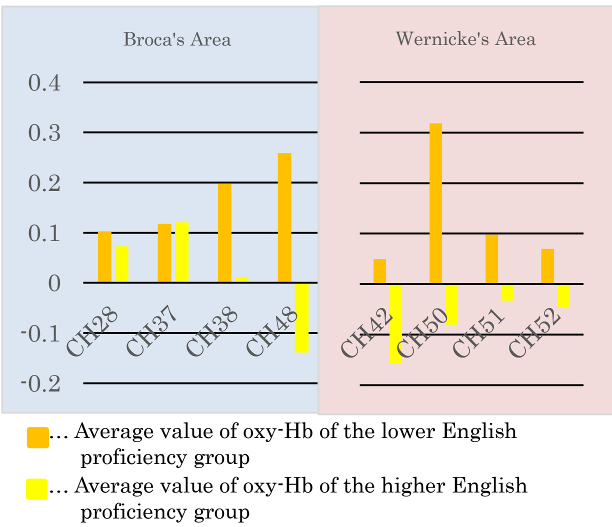

Figure 8. Average values of oxy-Hb changes from channels for BA44, 45 and 22 between two groups.

The NIRS signals indicated that English speeches with enlarged amplitudes in the high frequency range activated subjects' brain activities. However, the result from the questioner indicated that the English sentences and consonants with enlarged amplitudes in the high frequency were not the easiest for the subjects to understand. In addition, the one with enlarged amplitudes in the low frequency did not help the subjects comprehend vowels more easily. The average value of responses to the questionnaire showed that the subjects evaluated all the English speeches as having almost the same difficulty. Those questionnaire results were summarized in Table 1.

Table1. Parentages and average values of questioner results (N=20)

	English Speeches		
	Original	With enlarged amplitudes in	
		High frequencies	Low frequencies
Subjects answered: Easiest to recognize vowels	15%	20%	5%
Subjects answered: Easiest to recognize consonants	25%	15%	5%
How easy to comprehend speeches (Average score)	3.5	3.65	3.45

4. CONCLUSION

In this study, the authors investigated whether English speeches with enlarged amplitudes in a high frequency range can affect brain activities, by measuring the subject's oxy-Hb in the brain and analyzed whether there is difference in oxy-Hb increase among the subjects. The experimental results showed that English speeches with enlarged amplitudes in high frequency ranges raised the amount of oxy-Hb concentration changes in some areas of the subjects' brains, in particular in the brains of the subjects who had low English proficiency. The areas that showed increases in oxy-Hb concentration included Broca's and Wernike's areas, which correspond to language processing areas in human brain. The activation of Broca's area is associated with speaking, grammar processing and understanding of sentences, while Wernike's area is activated during listening to language, phoneme processing and understanding words. (Yamazaki & Eto, 2011), (Kemmerer, 2015) Moreover, the activation of language processing areas is known to be proportional to the levels of language acquisition. In other words, the higher the level is, the lower the areas are activated. Therefore, we assume that the significant difference in oxy-Hb changes between the subjects with lower English proficiency and ones with higher proficiency were observed in this study. This result indicates that speeches with enlarged amplifies can be beneficial for English learners at the initial phase of their learning.

On the other hand, from the result of the questionnaire, we speculate that different preferable frequency ranges in each language do not directly affect the comprehension of other languages very much. Because the subjects evaluated all English speeches as having almost the same difficulty levels and their comprehension ability for both vowels and consonants did not rise, even when they listened to English speeches with enhanced amplitudes in the frequencies ranges that almost all Japanese language sounds have and in the frequency range that Japanese language do not have. However, enough data was not obtained from the experiment in this study to proof this hypothesis. In next study, we need to gather more subjects to obtain data to analyze the effects of enlarged amplitudes in a certain frequency range in more detail. We also plan to modify how to enhance the amplitudes of English sentences to determine exactly which frequency range is the best for brain activation in terms of language learning.

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