The brain activity for chromatic stimuli measured by the near-infrared spectroscopy (NIRS) in the natural viewing condition

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ABSTRACT

Recently mapping of brain activity has become an important method to reveal mechanisms underneath human color perception. Near infrared spectroscopy, NIRS is one of the most advanced tool that could measure the concentration change of oxy- and deoxy- hemoglobin without any subject body restraint, making a practicable natural experimental condition. The final goal of this project is to measure the brain activity during observation of a chromatic stimulus under colored illumination in a natural viewing environment. At this stage, we conducted two preliminary experiments to show that our equipment setting and methodology meet the experimental requirement. We could measure the brain activity to locate the positions of concentration change of hemoglobin corresponding to the stimulus position. And it was confirmed that the concentration of oxy-Hb increased with the increment of luminance contrast of stimulus. These results were agreed with other previous research.

1. INTRODUCTION

The light reflected from an object consists of both illuminant and reflectance components. Nonetheless, in our daily life, we rarely confuse colors of objects under different illuminants. Such color constancy phenomenon was examined by using an actual environment in our previous experiment[1)]. It was shown that the apparent color of an object was strongly influenced by how we recognize the properties of illumination filled in the space such as the color of illumination and its brightness.

The color constancy phenomenon has been also studied in the field of brain mapping. Techniques of functional brain imaging, such as Magnetic Resonance Image (fMRI), magnetoencephalography (MEG) and positron emission tomography (PET) have been used to reveal the brain activities corresponding to the visual perception. However, the subject must be rigidly fixed on a bed in a small cave and no body or head movements are allowed during experiment due to the equipment restriction. Visual stimuli originated from a projector equipped outside the cave must be presented through a small mirror in front of eyes. So it is impossible to measure the brain activity in the context of our daily life by using these methods. Recently, the near-infrared spectroscopy (NIRS) has been recognized as a powerful tool for non-invasive brain imaging system. The NIRS can measure changes in the concentration of oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb), as well as the total hemoglobin by their different specific spectra in the near-infrared range. It has a high temporal resolution (less than 0.5 s) but has a low spatial resolution (about 30 mm). The greatest advantage is that the subject does not need to fix their body and that the equipment can be brought into an experimental booth easily. It has been shown that the optical topographic images of occipital brain agreed with images obtained from fMRI during visual stimulation[2)]. Moreover it was shown that the oxygenation change measured by NIRS corresponds with the signal intensity increment detected by PET[3)].

We set a final goal of this project at measurement of the brain activity when the color of ‘an object’ or ‘an illumination’ is changed in a real environment by using the near-infrared spectroscopy (NIRS). At the first stage, we confirmed that our equipment setting and methodology were in an appropriation by comparing our measurement results with other previous research. In the experiment we test whether the obtained images by NIRS correspond to the activity in the visual cortex where stimuli are presented and whether the different levels of luminance affect the activity in the occipital lobe.

2. METHOD

The oxygenation multichanel monitor, OMM-2000 by SHIMAZU Inc., was used to monitor hemoglobin for three wavelengths 780, 805 and 830 nm. Light in the near infrared region around 800 nm can penetrate human tissue and is mainly absorbed by hemoglobin, Hb. The concentration of Hb can be measured since Hb shows the different spectra according to its oxygenation level in that region. And then the Hb parameters as changes in oxygenated Hb and deoxygenated Hb are calculated.

The subject wore a cap that was equipped with the optical fibers. The position of fibers is shown in Fig.1. There are eight irradiation fibers and eight detection fibers. The topographical image is composed of 24 channels for the occipital lobe and numbers in Fig.1 are corresponding to each channel. A black/white checkerboard was employed as a visual stimulus. It was shown at a left or a right side of a monitor in a dark room as shown in Fig.2. The size of the checkerboard was 8 □ x 8 □. The stimulus was stimulated at 7 Hz. There were three different luminance levels of the black/white checkerboard. The combination of luminance is 7.2 and 127 cd/m^2 for BW1, 0.98 and 134 cd/m^2 for BW2 and 62.2 and 72.7 cd/m^2 for BW3. Averages of the black and white luminance for each condition was at about 67 cd/m^2. A black screen with a fixation dot was employed as a control image.

One trial was composed of four times repeat of presentation for one luminance level. The time sequence of stimulation was shown in Fig.3. One presentation took 80 sec; the first 20 sec for the control image as the rest duration, the next 40 sec for a checkerboard as a task duration and then 20 sec for the control image. The checkerboard was shown at the left side of the fixation point in the first and the third presentation and at the right side in the second and the fourth presentation. Through the trial the subject was asked to fixate at the fixation dot. Three luminance levels of trial had done for eight subjects. The subjects asked to use a chin rest so that the position between face and stimulus were kept constant through the trial.

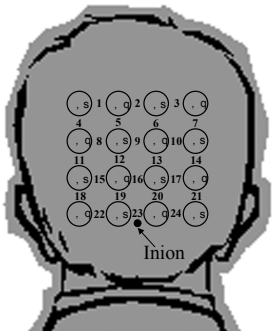

Fig. 1 24 topographical images with 16 optical fibers; T, illumination optical fiber; R, detection optical fiber.

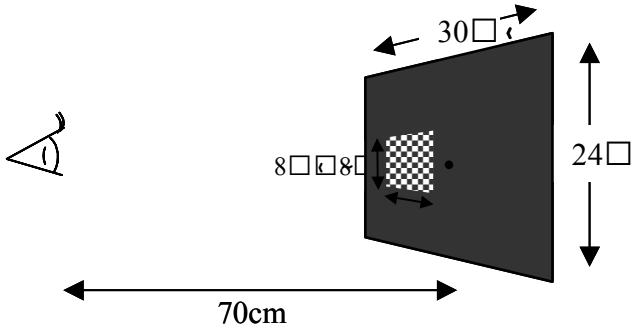

Fig.2 The visual angle of stimulations.

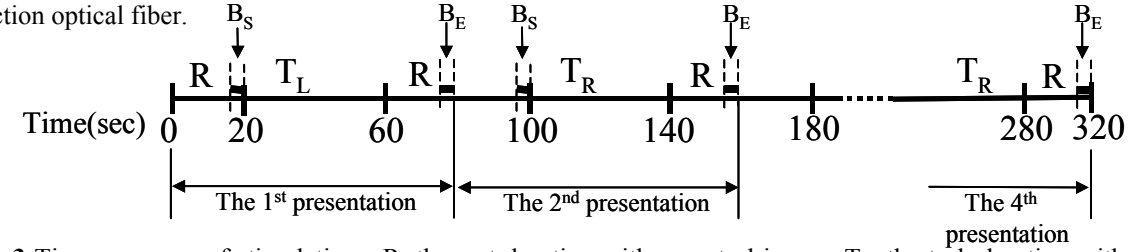

Fig.3 Time sequence of stimulations. R, the rest duration with a control image; T_L, the task duration with the left side checkerboard; T_R, the task duration with the right side checkerboard. B_S, the starting point for the baseline; B_E, the ending point for the baseline.

3. RESULTS

Obtained data set for eight subjects were calculated by following procedure. At first, the data for 320 sec were calculated by the moving average for each 5 data point sequentially. The process was repeated three times. Later the calculated data were averaged for each 1 sec interval. Second, data were normalized to the baseline: the baseline was defined by two data point. The starting point B_S was obtained from the averaged data of the 5 sec interval prior to the onset of stimulation as shown in Fig.3. The ending point B_E was obtained from the averaged data of 5 sec interval prior to the end of each presentation as shown in Fig.3. Third, the first and the third presentation data for the left side

stimulus were averaged and the second and the fourth presentation data for the right side stimulus were averaged.

The results of the concentration change of Hb for the stimulus BW1 from the subject HY are shown in Fig.4. The abscissa indicates the time and the ordinate indicates the difference of the Hb concentration from the baseline in arbitrary units. Figure 4(a), (c) are obtained from the channel 12 which is located at the left side of the occipital area and Fig.4(b), (d) are from the channel 13 which is located at the right side of the occipital area. The results of the left side stimulus are shown in Fig.4(a), (b) and of the right side stimulus are shown in Fig.4(c), (d). Solid line indicates the concentration of oxy-Hb and broken line indicates the concentration of deoxy-Hb. First 40 sec interval is corresponding to the task duration.

The concentration of oxy-Hb tends to increase in Fig.4(b), (c), (d) after 5 or 7 seconds from the onset of stimulation. The activation lasted for 15 seconds as shown in Fig.4(b) and for 20 seconds as shown in Fig.4(c). The increment of Hb concentration change appears clearly as shown in Fig.4(b) however this tendency does not appear in Fig.4(a). This indicates that the left side stimulus evokes the brain activity at the right side of the occipital lobe more than at the left side. On the contrary, the increment of Hb concentration change appears clearly in Fig.4(c) however this tendency does not appear in Fig.4(d). It was shown by previous research[5] that the stimulation at left side of visual field evoked the brain activity at right side of occipital lobe, and vice versa, which is the same as the tendency obtained in this experiment. Therefore we could confirm that an adequacy of the equipment setting and methodology employed here.

In terms of individual difference, four of eight subjects showed the same trend as the subject YH. One subject did not show any tendency for the concentration change of oxy-Hb and deoxy-Hb. All subjects reported that they perceived after image after offset of the stimulation and it faded away during the rest duration with a control image. It is considered that the results during rest duration might be affected by the after image.

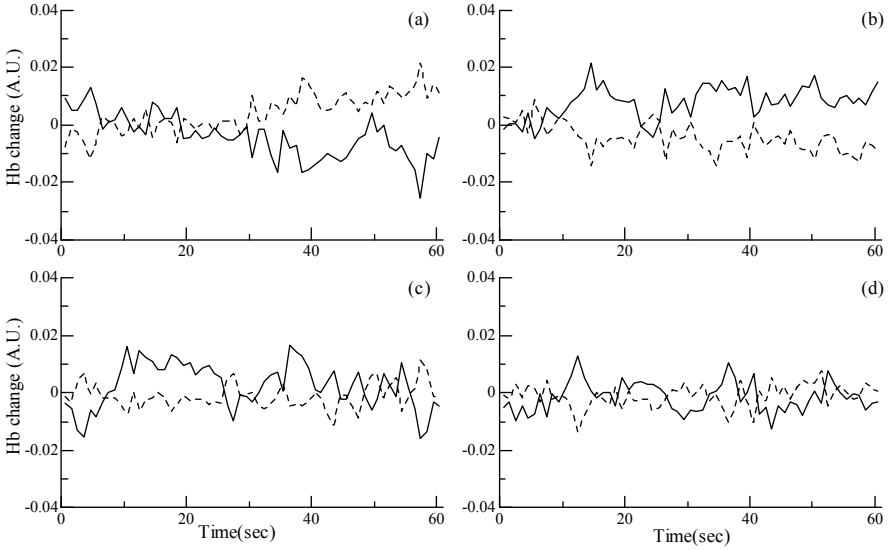

Fig.4 The concentration change of oxy-Hb and deoxy-Hb from the subject YH for the stimulus BW1. Solid line shows the concentration of oxy-Hb and broken line the concentration of deoxy-Hb. (a) and (b) correspond to the left side stimulus and (c) and (d) correspond to the right side stimulus. (a) and (c) are the Hb change at channel 12 and (c) and (d) are the Hb change at channel 13.

The results of three luminance levels of checkerboard are shown in Fig.5. Four graphs correspond to the subject AN, YH, RY and SO. The abscissa indicates the time and the ordinate indicates the difference of the oxy-Hb concentration to the baseline in arbitrary units. Solid line shows the result from the BW1, dotted line shows the result from the BW2 and broken line shows the result from the BW3. Those data are obtained from channel 15 which located at left side of the occipital area. The subject AN and RY show no significant difference of the oxy-Hb concentration among three luminance levels of stimuli. On the contrary, the subject YH and SO show that the concentration of oxy-Hb of the BW3 changed slightly compared to the change at the BW1 and the BW2. It might

indicate that small luminance contrast evoke a small brain activity as other research has shown that an increasing luminance contrast increases the activity of cells in V1 by fMRI[6]. We expected that there is a significant difference in the concentration change in oxy-Hb among BW1, BW2 and BW3. In our results, only four of eight subjects showed the different activity in occipital lobe.

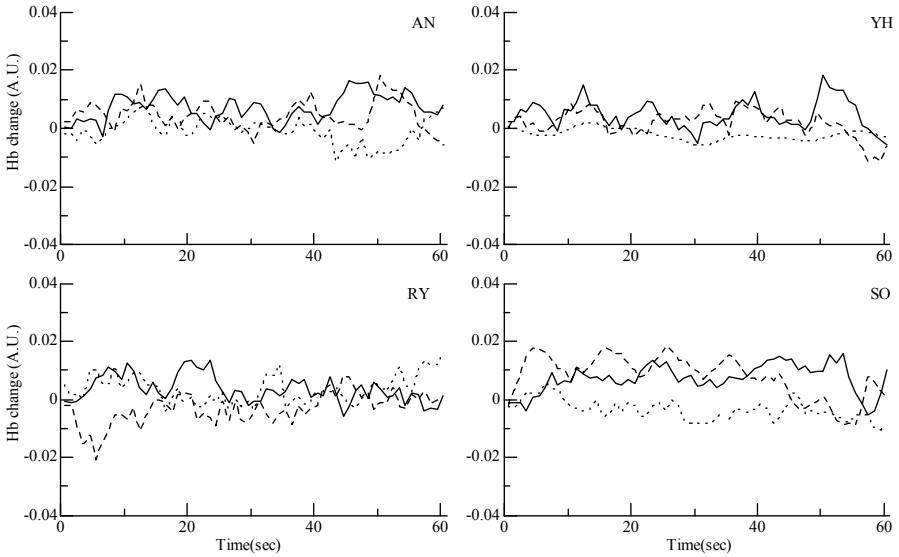

Fig.5 The concentration of oxy-Hb for three luminance levels of stimuli from four subjects. Solid line indicates the result from the BW1, broken line indicates the BW2 and dotted line indicates the BW3.

4. CONCLUSIONS

The brain activity in the occipital lobe was measured by NIRS for the visual stimulation. The brain activity was correctly monitored in relation to the position of visual stimulation in the visual field. Four of eight subjects showed that the different level of luminance affect the concentration of oxy Hb. It is assumed that the equipment setting up and methodology employed here are valid. It was shown that the NIRS is a useful tool to measure how our brain responses when we see objects. It is expected that we could apply this method to monitor our brain activity during observation the color of an object under chromatic illumination in a real environment that will be investigated in the next experiment.

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