Experimental Results on Brain Activation by Color Stimulation

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Abstract

We can perceive information such as colors, shapes, motion, or the depth through our eyes. We feel that we can perceive these stimuli at the moment we watch them, but in fact it took some time to transmit an information from eye to brain, and to process it. In this study we are going to explore what kind of factor influences the image-processing function of our brain. Our experimental results about the dependency of the bloodstream in our brains on the factors such as color (hue, saturation, luminosity), space, and time are reported.

Fundamentals of Visual Perception

Cones are photoreceptor cells in the retina of the eye that are responsible for color vision. Humans normally have three kinds of cones. The first responds the most to light of long wavelengths, peaking at a reddish color, this type is sometimes designated L for long. The second type responds the most to light of medium-wavelength, peaking at a green color, and is abbreviated M for medium. The third type responds the most to light of short wavelength, peaking at a bluish color, and is abbreviated S for short. The three types have peak wavelengths near 564–580 nm, 534–545 nm, and 420–440 nm, respectively, as shown in Fig. 1.

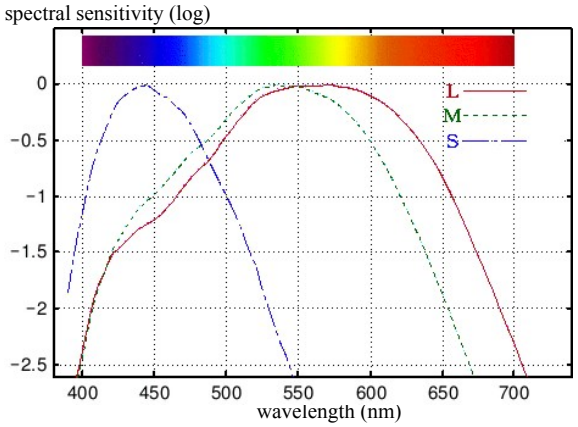


Figure 1. Spectral Sensitivity of cones

Basic function of visual perception is to compare these three signals from cones. Those signal processing is performed at the retina and the result is transmitted to the lateral geniculate body, and then sent to V1, the primary visual cortex, which lies at the back of the cerebral cortex. Among these signals, color information is transmitted through a specified channel. The signals processed in V1 is then transferred through various area in the prestriate visual cortex toward the front of the cerebral cortex. There are two main paths; one leads to the parietal lobe which is related to the processing function of both space and motion, the other one leads to the temporal lobe which is related to the function of object perception. Color information is transferred through the latter path.

Color Perception - Previous Work

Komatsu [1] observed the bloodstream of human brain by using noninvasive methods such as PET, positron emission tomography, and functional magnetic resonance imaging, which visualize the obtained data. He concludes it is a function of cerebral cortex that enables us to perceive colors. He also named the eight fundamental colors for us to perceive, which were “white”, “green”, “yellow”, “orange”, “red”, “pink”, “purple”, and “blue”.

Experiment 1

First we use optical topography system ETG-4000 (Hitachi Medical Co), shown in Fig. 2, to record the amount of bloodstream. Optical topography exploits the different absorption spectra of oxygenated and deoxygenated hemoglobin in the near infrared region. The ETG-4000 allows the simultaneous measurement at multiple brain sites and provides real-time image of change in hemoglobin concentration in the brain.

Figure 2. ETG-4000

A testee puts on a “head band” with several probes on his/her forehead, over the frontal lobe. Fig. 3 shows the positions of head band, where “o” represents a laser irradiation probe and “x” a laser reception probe, and the numbers 1, 2, …, 22 are the positions where the amount of bloodstream was measured.

o	1	x	2	o	3	x	4	o
5		6		7		8		9
x	10	o	11	x	12	o	13	x
14		15		16		17		18
o	19	x	20	o	21	x	22	o

right hemisphere left hemisphere

Figure 3. Illustrated Head Band of ETG-4000

For a testee, eight pieces of colored paper were presented one by one for an constant interval. A testee looks at each colored paper at

the distance of 0.5m. We tried 8 patterns which were different from one another by the order of color and the time of presentation, as shown in Table 1.

Table 1. Experimental Conditions

	Pattern				Time (s) of Presentation	Distance (m)
	A	B	C	D		
1	red	white	yellow	purple	2 or 5 for each	always 0.5
2	pink	purple	red	orange		
3	orange	blue	green	white		
4	yellow	green	blue	pink		
5	green	yellow	pink	blue		
6	blue	orange	white	green		
7	purple	pink	orange	red		
8	white	red	purple	yellow		

Results of Experiment 1

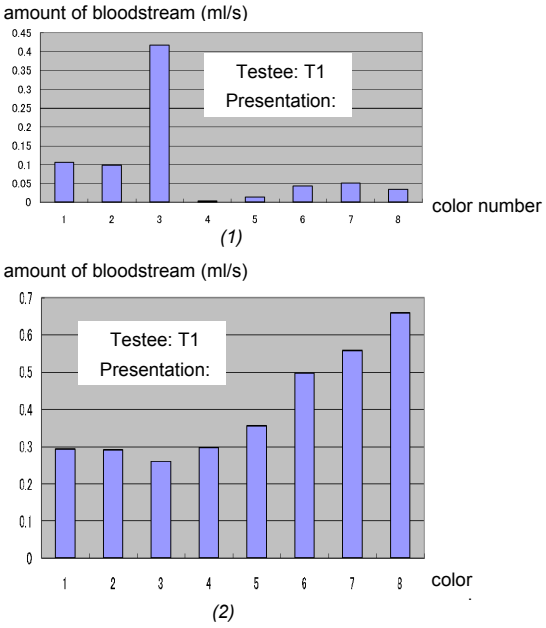
The results of experiment 1 for two testees T1 and T2 are shown in Fig. 4. Each bar represents the average amount of bloodstream changed for the corresponding color. The color numbers are the same as those of Pattern A, i.e, red=1, pink=2, orange=3, … Table 2 shows the total amount of bloodstream changed for each pattern.

Table 2. Average Amount of Bloodstream (ml/s)

Testee	A, 2	B, 2	C, 2	D, 2	A, 5	B, 5	C, 5	D, 5
T1	0.048	-0008	0.160	-0.025	0.402	0.024	0.023	-0.025
T2	-0.126	-0.011	0.008	-0.273	0.040	-0.123	0.007	-0.286

Discussions

The results of experiment 1 for two testees T1 and T2 are shown in Fig. 4. Each bar represents the average amount of bloodstream changed for the corresponding color. The amount of bloodstream increases most when T1 looked the color changed from pink to orange. Another significant change occured when T2 saw blue after looking at green for 5 seconds.



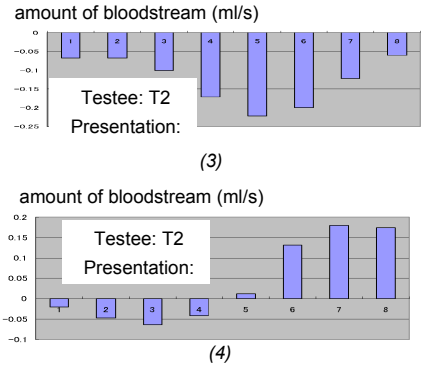


Figure 4. Total amount of bloodstream for each color

We now investigate the correlation between two adjacent channels. Let us define "pair numbers" each of which corresponds to a pair of adjacent channels, as shown in Table 3. Then, Fig. 5 shows the correlation coefficients for each of four observation conditions.

Table 3. Adjacent Channels and Their Pair Numbers

Pair of Channels	Pair No.	Pair of Channels	Pair No.	Pair of Channels	Pair No.	Pair of Channels	Pair No.
1,5	1	10,14	9	1,6	17	10,15	25
2,6	2	11,15	10	2,7	18	11,16	26
3,7	3	12,16	11	3,8	19	12,17	27
4,8	4	13,17	12	4,9	20	13,18	28
6,10	5	15,19	13	5,10	21	14,19	29
7.11	6	16,20	14	6,11	22	15,20	30
8.12	7	17,21	15	7,12	23	16,21	31
9,13	8	18,22	16	8,13	24	17,22	32

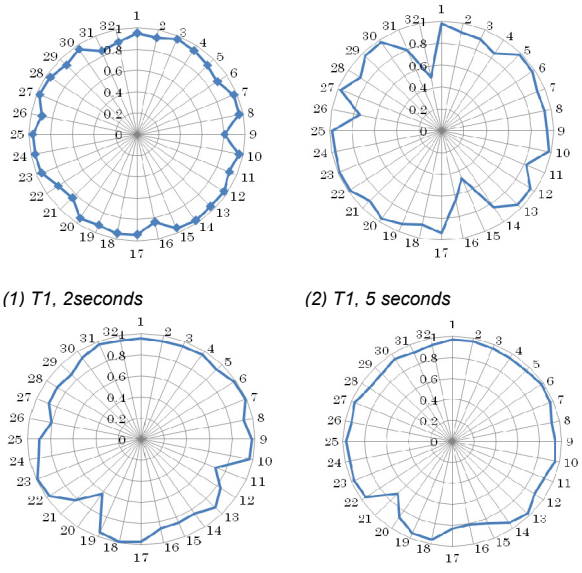


Figure 5. Correlation Coefficients between Adjacent Channels

We need to consider the function of the part of brain where we measured the amount of bloodstream. We know where on the brain

the 22 channels lie by using Brodmann's areas. Fig.6 shows the areas which the head band covers and Table 4 shows the name of area each channel lies on.

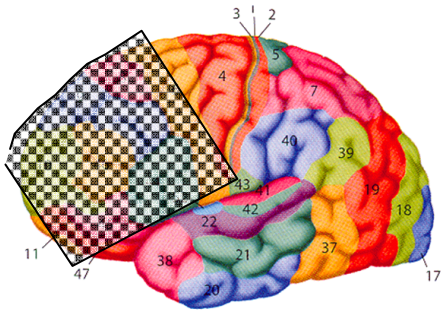


Figure 6. The Area Where the Head Band Covers

Table 4. The Brain Areas our Channels Cover

Channels	Number and Name in Broadmann's Areas
1, 4	11: orbitofrontal
2, 3	10: frontal pole
5, 9	47: infralimbic prefrontal
6, 8, 11, 12, 15, 17	46: dorsolateral prefrontal cortex
7	7: dorsolateral prefrontal cortex
10, 13, 14, 18	45: triangular part of inferior frontal gyrus
16, 20, 21	8: frontal eye field
16, 22	44: opercular part of inferior frontal gyrus

Experiment 2

As the further study we began to use another optical topography system OEG-16 (Spectratech Inc.), shown in Fig. 7. The head band has 16 channels and it also covers the frontal lobe. We are now performing many experiments under almost the same condition as Experiment 1. The obtained data by using this device is the amount of oxygenated and deoxygenated hemoglobin separately, and we can visualize the data as shown in Fig. 8.

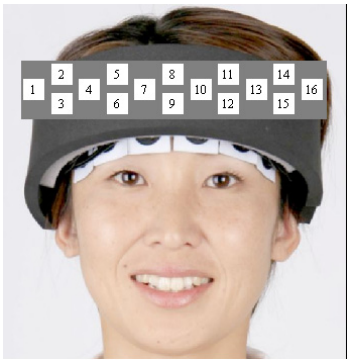


Figure 7. Optical Tomography System OEG-16

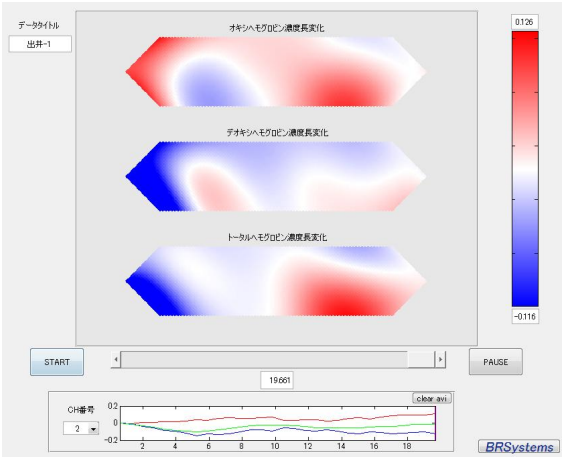


Figure 8. A Distribution Map of Oxygenated (red) and Deoxygenated (blue) Hemoglobin obtained by OEG-16

Summary

In this study we continue the experiments using optical topography systems. By analyzing the output data about the amount of bloodstream on the surface of the brain, we can expect to explore the mechanism of our perception system in terms of activation of the brain.

We can say from our result of experiments that the brain activates when we see a sequence of two colors whose color phases are not far off. We can not find clear effect of presentation time to the brain activity.

References

[1] H. Komatsu, Color Information Processing at Human Brain, O plus E, 22(4): 447-453, (2000).

Author Biography

Kitakubo Shigeru is Assistant Professor of Nippon Institute of Technology. He received his Bs., Ms. and Dr. degrees in Science from Tokyo Institute of Technology in 1986, 1988, and 1992, respectively. He participates in most of NIP conferences since 1995. He is now interested in digital processing theory, especially in halftoning. He is a member of ISJ.